Digital transition in agriculture and public policies. Insights from Latin America

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Preface

Over the past decades, we have seen the different phenomena of digitization, digitalization, and digital transformation gradually unfold in our own lives. It has changed the way we do our jobs, the way we communicate, the way we consume goods and services, the way we date, to name just a few aspects. It has made certain technologies and practices obsolete and has induced new products, services, markets, and societal and planetary dynamics. Virtually no aspect of our lives has remained untouched, and digital technologies have affected our lives in both positive and negative ways, often through trade-offs. Such trade-offs include, for example, efficiency of processes versus digital surveillance and algorithmic governance, unprecedented information access versus digital overload and disinformation, hyperconnectivity versus information bubbles, reduced genuine human contact and polarization, more sustainable production in some fields versus huge energy-slurping data centers being placed on other fields. And perhaps this is just the tip of the iceberg of what awaits us: if we believe the many influencers, prophets, or doomsayers, we are yet to see the full unleashing of a new wave of digital transformation through artificial intelligence.

Digitization, digitalization, and digital transformation have also entered agriculture, and my first modest encounter with this phenomenon was when I did my Master's thesis in Latin America, in 2001, looking at the use of computer-generated land use models in horticulture in Canelon Grande, near Montevideo, Uruguay. In that time period, other forms of digitalization in agriculture, such as precision agriculture, also began to emerge more strongly. Though I found my thesis interesting, I did not continue to work on digitalization for my PhD, but rather on advisory systems and, more broadly, agricultural innovation systems. Digitalization recently entered my career as a professional interest again 15 years later. My second encounter with digitalization was a visit to a Norwegian dairy farm, in 2016. Seeing a milking robot in action and talking to the farmer made me wonder how all the data that robot collected and the information it could generate would influence farm advisors: would human advisors become obsolete? This spurred my interest in studying digitization, digitalization, and digital transformation again, in particular the innovation processes underpinning it and conversely, how it affected innovation process and knowledge and innovation systems. This interest coincided with a next wave of technologies coming to maturation under the banner of Agriculture 4.0 or Digital Agriculture.

Much of the work that started to appear with this next wave of digital transformation, as Le Coq et al. also note in their integrative introduction and synthesis chapter, was on the technical aspects of digitization, digitalization, and digital transformation. However, around 2017 it could be noted that more and more social science analysis of Agriculture 4.0 and Digital Agriculture started to emerge. Some of it was empirical, but a lot of it was also conceptual and speculative, and there was clearly a need for more research into the social and institutional responses to Agriculture 4.0 and Digital Agriculture, given its increased presence. This led to the idea, in 2017, to organize a special issue in NJAS – Wageningen Journal of Life Sciences (now known as NJAS: Impact in Agricultural and Life Sciences) on this topic. The special issue was published in 2019, with 17 articles from different disciplinary angles (sociology, science and technology studies, economics, organization studies)[1]. To make the guest editorial that typically introduces the special issues more than a summary of the articles it contains, the guest editors (Pierre Labarthe, Emma Jakku, and I) decided to do a broader review and try to summarize the state of the art regarding social science and outline a research agenda[2]. While the whole special issue attracted considerable attention, this review article has surpassed all our expectations in terms of its use in the field of social science on Agriculture 4.0 and digital agriculture and is now a frequently cited source.

Particularly in the five years after the publication of the special issue and the review article, it could be noted that there was a surge of work looking at Agriculture 4.0 and Digital Agriculture from different social science disciplines. However, despite this surge, two gaps which we outlined in the research agenda in our review article continued to exist: work on public policies for digitalization has remained relatively scarce, and some geographical regions have remained underrepresented in terms of studies on the processes of digitization and digital transformation — and one of those is Latin America. This leads me to mention a third encounter with digitization, digitalization, and digital transformation in Agriculture 4.0 and Digital Agriculture, which gave me the opportunity to learn how this field had developed in the region to which I moved, in 2022, to work

1 NJAS, Volumes 90–91, December 2019

2 Klerkx, L., Jakku, E., Labarthe, P., 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. NJAS - Wageningen Journal of Life Sciences 90-91, 100315.

at the Universidad de Talca, in Chile. The network for Public Policies and Rural Development in Latin America and the Caribbean (PP-AL) had as a special focus, during 2023 and 2024, the development of studies at the intersection of digital agriculture, public policies, and Latin America, and we were asked to contribute a chapter amongst many other authors across Latin America. This effort has led to an extremely rich collection of studies, collected in a book in Spanish, which was launched in December 2024, in Brasília, the federal capital of Brazil. However, though we live in a time in which automated translation is easily available, the book being in Spanish may still not be found and thus underutilized by those who do not master this language.

Here lies the importance and unique contribution of this book, which presents the translation of several of the chapters of the original publication, as well as an integrative introduction and synthesis chapter. It shows the state of the art of social science on digitization, digitalization, and digital transformation to an English-language audience who might not otherwise have learned about these relevant experiences and insights. It takes into account the diversity and contrasts of Latin America — in terms of its farmers, its innovation ecosystems, its agroecological diversity, its landscapes, its stages of infrastructure development, and its particular cultures of governance. The book also takes into account the diversity of digital innovations, from generic 'everyday' digital innovations to highly specialized and asset-intensive digital innovations. With its dedicated reflection on the implications for public policies to foster an inclusive and just transition towards a digitally transformed agriculture, it is a must-read for academics, policymakers, and digital agricultural practitioners alike. However, the book does not just conclude with presenting lessons and recommendations for policy; it also sets out an important research agenda calling for a better understanding of diversity in digital transformation pathways, a scrutiny of what reconfigurations in innovation systems and public policies only digital transformation engenders, and what are the configurations of digitalization agendas, policies, policy instruments, and their distributional effects. This agenda is not just relevant for Latin America, but has global relevance, so hopefully this book will spur another surge of attention to this important area.

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Sumário

Digital Transition in Agriculture and Public Policies in Latin America[1]

Jean-François Le Coq, Frédéric Goulet, Karina Kato, Jelle Van Loon, Federico Bert, Deissy Martinez Baron

Introduction

Technological innovation has always been a driver of change in agri-food systems over time (Faure et al. 2018) and a point of debate for public policy (Goulet et al., 2019). Since the 1980s, information and communication technologies (ICT) have developed, with advances in computing and internet access. Since 2000, there has been an acceleration and multiplication of digital innovations and an increasing integration of the uses of these technologies in all societal activities. This multidimensional and diffuse process in society, which was emphasized during the COVID 2019 crisis, is now referred to as the digital transition or digital transformation (Gong and Ribiere, 2021) generates new opportunities and challenges in all sectors (health, transport, energy, etc.) and in their policies (Craglia et al., 2020; Ciuriak and Ptashkina, 2021).

Agriculture and agri-food systems do not escape the process of digital transformation. Indeed, the digital transformation has the potential to revolutionize many dimensions of the agri-food system (Khan et al., 2021), such as production practices (Kovács and Husti, 2018), access to and management of the means of production (machinery, financial resources),

1 This chapter is a synthesis of two chapters of the original Spanish version of the book, covering the content of the introductory and the conclusion chapters.

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knowledge and extension in the agricultural sector, management and access to natural or productive resources (water, land), commercialization and marketing of agricultural products. While the digital transformation presents opportunities to solve challenges for agriculture and agri-food systems, such as food and nutrition security or climate change (Bolfe et al., 2020; Gazolla and Aquino, 2022), it also presents new risks and threats for the future of all farmers, particularly family farmers, and the transition towards more sustainable and equitable models of agriculture (Rotz et al., 2019; Cobby Avaria, 2020; González and de Llano, 2020; Gazolla and de Aquino, 2024). In this context, several authors call for the development of policies to promote a digital transformation which mitigates these risks (Ehlers, Huber et al., 2021; Lioutas, et al., 2021; Kukk et al., 2022; MacPherson et al., 2022).

The digital transformation also presents opportunities and risks for policy making and implementation (Craglia et al., 2020; Krutilin et al., 2022). Through digital transformation there is hope to bring more participation of diverse actors in decision-making, to offer more transparency in public management and increased access to public information, e.g. through e-government promotion processes (OECD, CAF et al., 2024), to enable citizens to have more capacities to influence public decisions, or to have better access to public services. However, on the other hand, digital transformation may affect democratic functioning and lead to the manipulation of opinions and the polarization of society, reinforcing authoritarian control, generating challenges related to the regulation of the quality and veracity of information and sovereignty over information (Ávila, 2022).

In Latin America, digital transformation is already underway in agriculture and agri-food systems. Significant use of digital technologies in agriculture (especially GPS guidance systems, mapping tools, mobile applications and remote sensing systems) is revealed in South American countries (Puntel, et al., 2023), as well as the development of digital innovations for farmers and at all stages of agri-food systems (Sotomayor Echenique, et al., 2021; Beanstalk AgTech, 2023). In this scenario, digital transformation constitutes one of the critical factors that affect the future of the region's agriculture and agri-food systems (Patrouilleau et al., 2023).

However, existing literature on digital transformation in agriculture has gaps in two dimensions. The first dimension refers to topics covered by current literature. Klerkx et al. (2019) show from an extensive review of the social science literature that while there is already an important body of international literature on digital transformation and the digitalization of agriculture, covering the practical use of technologies, their consequences on the work of producers and the management and economics of farming systems, and the issues of power in digital transformation processes[2], four issues are still the subject of lesser contributions: 1) digital agriculture socio-cyber-physical-ecological systems; 2) the digital agriculture policy processes; 3) the digitally enabled agricultural transition pathways; and 4) the global geography of digital agriculture development. The second dimension refers to geographical coverage of current literature. While the adoption of digital technologies in agriculture is growing in Latin America (Loukos and Arathoon, 2021), there are still few publications on the process and implications of digital transformation in agriculture in the countries and territories of the region, and even fewer on the implications of these processes on public policies for agriculture and rurality in Latin America[3] (Alcântara, Bert et al., 2022).

In this context, the "Public Policy and Rural Development in Latin America" network (PP-AL Network) created in 2011 by CIRAD and its partners in the region, joined forces with two centers of the Consultative Group on International Agricultural Research (CGIAR), the alliance Bioversity-CIAT and the International Maize and Wheat Improvement Center (CIMMYT), together with the Inter-American Institute for Cooperation on Agriculture (IICA) in order to build a collaborative dynamic of research and reflection to contribute to reducing these thematic and geographic gaps. The product of this collaboration is the present book,

2 Klerkx et al (2019) identify as the most analyzed topics in the academic publications: 1) Adoption, uses and adaptation of digital technologies on farms; 2) Effects of digitalization on farmers' identity, skills and farm work; 3) Power, ownership, privacy and ethics in the digitalization of agricultural production systems and value chains; 4) Digitalization and agricultural knowledge and innovation systems (AKIS); 5) Economics and management of digital agricultural production systems and value chains.

3 According to a search of the Scopus reference database carried out on 23/08/2023 by the authors, using keywords (digital* and agric* and polic*), 694 references were found, of which only 27 dealt with the issue in Latin America, mainly in Brazil and Mexico. However, these references mainly dealt with technical issues and the policy dimension was very marginal in these publications.

which seeks to provide elements of understanding about the dynamics of digital transformation in Latin American agriculture and related policies. In particular, it seeks to clarify the processes of digitalization of agriculture in the region, the dynamics of policies linked to the digitalization of agriculture and the digitalization of the implementation of public policies in the sector.

This chapter will first present the issues and controversies related to digital transformation in agriculture and public policies, then the objective and structure of the book, and, finally, a synthesis of the main transversal findings of the studies presented in this book.

1. Digital Transformation in Agriculture and Controversies

1.1. Digital transformation and agricultural models

With the rapid development of new digital technologies and their increasingly integrated uses in all spheres of society, different terminologies emerged to name the process linked to the development and use of digital technologies. Three main terms are used in the literature: *digitization, digitalization and digital transformation. Sometimes used interchangeably,* these three terms cover different scopes which sometimes are intertwined (Kiron and Unruh, 2017): the first, *digitization,* refers to the process of converting analogue information into digital format (without changing the data, e.g. from information captured in notebooks to data entered into a spreadsheet). *Digitization* allows increased data storage capacity and further processing by computer programs.

The second term, *digitalization*, considers innovations of business models and processes by exploiting the opportunities offered by digital technologies (Kiron and Unruh 2017). Digitalization is a socio-technical process of applying digital innovations, which is comprised of components such as big data, internet of things (IoT), augmented reality, robotics, sensors, 3D printing, system integration, ubiquitous connectivity, artificial intelligence, machine learning, digital twins and blockchain, among others (Klerkx et al., 2019). Thus, digitalization implies a change in socio-technical logic and processes, completely transforming production systems, the rationality of the actors involved and public policies (Rotz et al., 2019; Welby and Tan, 2022). By way of illustration, we can say that filling in a digital form instead of paper is a clear example of *digitization* process, while *digitalization* refers to a comprehensive and automated process of data generation and processing that results in new automated processes without human mediation (Ehlers et al., 2022).

Digital transformation considers a systemic restructuring of economies, institutions and society through the diffusion and integration of digital technologies (Kiron and Unruh, 2017). Digital transformation can be seen as taking place when digitalization processes acquire a global scale, changing the way society and the economy are organized (rules, distribution of power, knowledge and resources). Gong and Ribiere (2021) propose a unified and broad definition of digital transformation as[4]: "A process of fundamental change, enabled by the innovative use of digital technologies accompanied by the strategic leveraging of key resources and capabilities, aimed at radically improving an entity* and redefining its value proposition for its stakeholders (*An entity can be: an organization, a business network, an industry or society)" (Gong and Ribiere, 2021, p 12).

Applied to the agricultural sector and agri-food systems, digitalization thus refers to the socio-technical process of integrating a wide range of digital innovations into production, resource and marketing processes (Klerkx et al., 2019). To describe different forms of digitalization in agriculture, different terms have been used interchangeably in the literature and by actors in the sector (Klerkx et al., 2019). Among the most common: "*digital agriculture*", "*Agriculture 4.0*" (Araújo et al., 2021), *"Smart agriculture";* the latter two are often associated with the more familiar term "*precision agriculture or precision farming*".

Regardless of the term used, digitalization implies that on- and off-farm management tasks (in the value chain and the wider agri-food system) are increasingly relying on the use and processing of different types of data (on location, climate, behavior, phytosanitary status, consumption, energy

4 For a comprehensive review of definitions of digital transit, see Gong, C. and V. Ribiere (2021). "Developing a unified definition of digital transformation." Technovation 102: 102217

use, prices and economic information, etc.) captured by sensors, machines, drones and satellites to monitor animals, soil, water, plants and humans. The data obtained is used to interpret the past and predict the future, to make more timely or accurate decisions through constant monitoring or targeted queries, leveraging big data science (Klerkx, Jakku et al., 2019).

These terminologies have become agricultural reference models, which have been criticized for representing techno-optimistic models, an extension of the green revolution (De Raymond and Goulet, 2020) and its "conventional" intensive practices. Criticisms also arise from the exclusionary nature of these models, the inequalities they generate (Hackfort, 2021) and their bias towards agribusiness actors. Thus, some authors propose to orient digitalization explicitly toward other agricultural models, referring to "digital agroecology" (Wittman et al., 2020; Bellon-Maurel et al., 2022, Sullivan, 2023) and/or a "digitalization oriented towards smallholder farmers" (Gumbi et al., 2023).

For the purposes of this book, we consider the digital transition or transformation in agriculture as a diffuse process that involves a wide range of digital technologies and affects the diversity of production models and producers that characterize Latin American agriculture.

Thus, we consider the integration of various technologies linked to the data-driven digital economy[5], such as data capture technologies (sensors, *Internet of things,* connected objects, drones), data transfer and storage (cloud), data processing (artificial intelligence, *machine learning*, algorithms, *blockchain*) and information visualization and dissemination (e.g. through mobile phones, social networks). We consider that these technologies are mobilized by the actors in the sector in an isolated or integrated manner (as a set of technologies). We will not focus on the digital technologies themselves, but on the digital innovations that are translated into digital tools or services that are mobilized by actors in the agricultural sector and the agri-food system. Thus, we consider the whole range of digital innovations, from the least expensive and accessible to the majority (such as communication tools and services, e.g. social media accessible through smart

5 The digital economy (data-driven economy, or digital economy) centered on the use of data, as opposed to the economy based on labor, capital or other means of production (Ciuriak and Ptashkina,2021).

phones), complex systems that integrate *on-site* data capture, data processing with complex algorithms, data visualization and process automation (such as management platforms, e.g. Climate *FieldView*, developed by Bayer, or *John Deere Operations Center*).

We also consider the diversity of concepts related to digitalization, the diversity of production models (conventional, sustainable, agroecological) and forms and structures of production (small and medium-scale family farming, agribusiness). From these perspectives, the aim is to characterize and explore the diversity of trajectories of integration of digital innovation in agriculture *(digital transformation pathways)* in order to identify the modalities of an inclusive, equitable, fair and sustainable digital transition for Latin American agriculture and agri-food systems.

1.2. Controversies over the digital transition in agriculture and agri-food systems

The digital transformation generates controversies related to all dimensions of agri-food systems (Klerkx et al., 2019; Lioutas et al., 2021; Prause et al., 2021). The literature on the digitalization of agriculture synthetically evidences two main relatively polarized positions (Table 1).

On the one hand, there is the literature in favor of digitalization that is generally optimistic about its prospects and the opportunities it offers in order to meet contemporary challenges. Proponents emphasize opportunities to increase agricultural productivity, facilitate access and efficiency in the management of productive resources, improve the efficiency of farming practices and the management of trade flows. It is also expected that it could facilitate the transition towards more sustainable and equitable production models (Cobby Avaria 2020, Lioutas et al., 2021).

Table 1. Main positions in the literature on the digital switchover in agriculture and agri-food system

Positive positions on the digital transformation in agriculture and agri-food system (opportunities)	**Skeptical or critical positions on the digital transformation in agriculture and agri-food system (risks)**
• Increased agricultural productivity and labor in the agricultural sector • Increased efficiency in crop management and animal production (through precise monitoring of soil and crop needs and climatic conditions) • Increased efficiency in the use of natural resources and means of production (reduction of pollution, efficiency of water use) • Increased efficiency in food chain logistics (optimization of transport, product flows) • Strengthening and diversification of commercialization of agricultural products (through the creation of digital marketing channels that facilitate direct relations between producers and consumers, an increased bargaining power of more informed producers on market prices, better product traceability, etc.). • Creation of economic and employment opportunities outside agricultural production in rural areas (digital service activities) that are attractive for young rural people. • Reduction of harsh working conditions (through automation of repetitive or hazardous tasks)	• Increased competition between types of agricultural models (strengthening of dominant position of agribusiness model) • Loss of knowledge or "commodification" of information and producers' knowledge • Loss of producers' autonomy vis-à-vis large technology companies (Lock-in) • Increased integration of chains by dominant value chain actors and reduction of producers' bargaining power • Deepening corporate power and control in the agri-food system • Reduced demand for agricultural labor force (low-skilled labor) through automation and worsening unemployment in rural area • Unequal appropriation of natural resources according to the capacity to mobilize digital tools • Digital divide and increasing disparities of economic opportunity between urban and rural areas and between connected and unconnected territories

Source: Own elaboration

On the other hand, there is a more skeptical, or even critical, literature that considers that digital transformation will not solve the current challenges facing agriculture, or may even worsen the situation. These authors emphasize the risk that the digital transformation will contribute to worsening existing asymmetries between actors, and thus between forms of agriculture (family farming vs. agribusiness), production models ("conventional" / "intensive" vs. "organic" / "agro-ecological" agriculture), or actors in the value chains, between territories (in particular, rural vs. urban). These authors consider digital transformation as a form of evolution from neoliberal capitalism *to* digital capitalism *in agriculture and agri-food systems* (Prause et al., 2021).

2. Digital Transformation and Public Policy

2.1. Issues related to digital transformation and public policy

The digital transformation affects not only the production, organizational and management processes of agriculture and agri-food systems, but also the policies themselves.

The first dynamic is the **integration of the issue of digitalization of agriculture into policies**. This dynamic is reflected in policy formulation and implementation processes to encourage or regulate digitalization dynamics in the agricultural sector. Indeed, Kukk et al. (2022) identify two main interrelated functions of public policy: 1) to ensure equitable digitalization of the agri-food sector, *i.e. to* protect public interests, the interests of farmers and other actors in the supply chain with little or less organized bargaining power, and 2) to be responsive to the opportunities offered by the development and application of digital technologies and to enable the digital innovation needed for the sector. In other words, the digitalization of agriculture is an emerging issue in policy agendas, particularly in the agricultural agenda. Moreover, digital transformation challenges the boundaries between existing policy sectors, integrating not only agricultural sector policies, but also science and technology or communication policies.

The second dynamic is the **digitalization of the policies themselves**. The digitalization of policies considers the process of using and mobilizing digital technologies in the various stages of policy processes (Craglia, et al., 2020). Indeed, these technologies can affect all stages of the policy cycle – agenda-setting, solution definition, decision-making, monitoring, implementation and evaluation – and political action through public policy instruments.

The digitalization of agricultural policies represents an opportunity to improve policy efficiency, avoid perverse effects and generate desired effects to address agricultural challenges (Ehlers et al., 2021). The digitalization of policies may not consist of only replacing analogue technologies with digital technologies, but also enabling new options for policy design and implementation. These opportunities are, in particular, to capture in real time and in a more accurate or precise way the situation and opinions of actors, to improve spatial prioritization (*spatial targeting),* the prioritization and adjustment of policy instrument to the needs or profiles of producers (*individualization), or even to change the logic of public intervention, such as through performance-based subsidy (Ehlers et al., 2021). However,* the process of digitalization of policies is facing a number of challenges or constraints, such as the quality of data and the institutional interest or capacities of public actors (Ehlers et al., 2021).

2.2. Controversies over the digitalization of public policies

The digitalization of public policies also generates controversy, as it brings opportunities but also risks (Craglia et al., 2020). This literature reveals two main contrasting positions (Table 2).

Authors in favor of digital transition highlight the opportunities presented by the use of digital technologies in State policies and actions. These digital technologies allow for improved public services (Welby and Tan, 2022), including greater access to public information for citizens. This is reflected in e-government initiatives (OECD et al., 2024), which seek to streamline procedures or reduce the administrative cost of public management; and can facilitate a new generation of more efficient instruments thanks to a better spatial or socio-economic prioritization of public interventions, an adjustment of support according to user profiles. Digitalization can generate learning and allow for better responsiveness and adaptation of policies.

On the contrary, more skeptical or even critical authors underline the risks of digitalization of policies. They highlight the potential gaps in the accessibility of digital public services by citizens without digital skills, the risks of disseminating inaccurate or false information in order to influence debates, or the risks of having automated/autonomous policies (*algorithmic governance)* without human democratic control (Gritsenko and Wood, 2022).

While for different reasons, all authors tend to emphasize the challenge of regulating information, property rights, controlling the quality of data and derived information.

Table 2. Main positions in the literature on the digitalization of policies

Positions in favor of the digital transformation in policy processes (opportunities)	**Skeptical and critical positions regarding the digital transformation in policy processes (risks)**
• Increased accessibility of public information for citizens (e- governments) • Increased participation of populations in decision-making • More transparency in public management and increased citizen control (e-government). • Better targeting of policy instruments and intervention ("individualization") • Efficiency in the use of public resources • Policy responsiveness / rapid adaptation of public actions to crises / acceleration of the policy cycle in response to changing situation • Facilitates scaling-up and outreach of public interventions	• Digital divide and exclusion process from administrative processes of less connected populations • Data manipulation and manipulation of public opinions (fake news) • Potential use for coercive control / threat against freedoms • Black box of predictive or decision algorithms (algorithmic governance) • Automation of policy decisions with reduced democratic control and regulation
Challenges of data and information quality regulation / control	

Source: Own elaboration based on literature review

3. Book Objectives and Structure

3.1. Book objectives

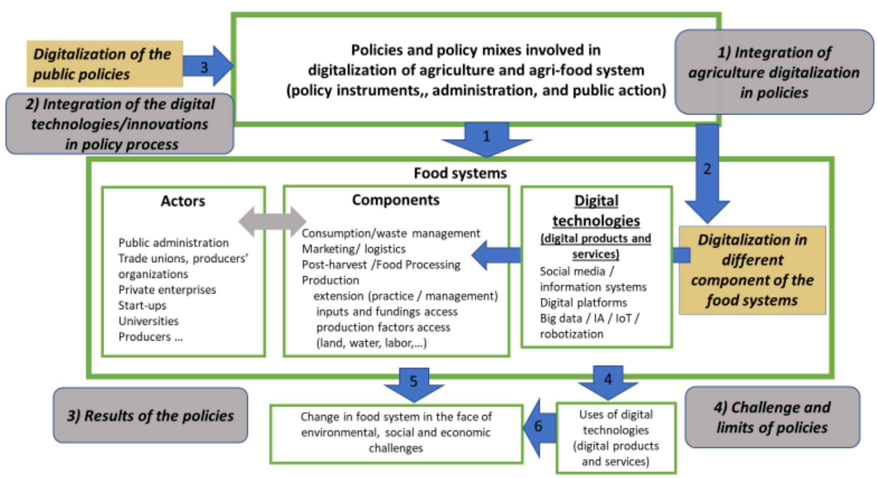
The book aims to provide an overview of the digital transformation processes in agriculture and the related policies in Latin America. It seeks, on one hand, to contribute to the debate and controversies surrounding the process of digitalization in agriculture and inform the process of integration of digital transformation issues into policies, and, on the other hand, to contribute to the debate on the controversies regarding the digitalization process of the policies and their instruments. Hence, the book aims to provide elements to answer the following questions: 1) How is the digitalization of agriculture and agri-food system taken into account and integrated into agricultural, food, rural development and natural resource management policies in Latin America?; 2) How does digital transition affect the processes and scenarios of political decision-making in the agricultural sector and, in particular, the implementation of policy tools?; 3) What preliminary results has the implementation of policies in favor of the digital transition in agriculture and agri-food system had?; and 4) What are the challenges and limiting factors of the current policies involved in digital transformation of agriculture and agri-food system?

For this purpose, an overarching analytical framework was elaborated for the book (Figure 1). This framework specifies the objects of analysis and their linkages. At the center are the agri-food systems, which have country-specific characteristics and can be addressed through territorial or chain approaches. These agri-food systems mobilize a set of actors who interact and make decisions affecting each component of the agri-food system. The starting point for the reflections in this book is the processes of integration of digital technologies in their diversity and the processes of digitalization in the different components of the agri-food system (framed in orange, Figure 1).

Next, we consider the policies or policy *mix* (Flanagan et al., 2011) that affect both the agri-food systems (arrow 1, Figure 1) and the process of digitalization of the agricultural sector itself (arrow 2, Figure 1). This brings us to the first central issue of the book: the integration of the promotion of digital transformation or digitalization of agriculture into the policies (framed in grey, Figure 1, cf. question 1). We also consider (arrow 3, Figure 1) that digital technologies can affect policy processes (digitalization of policies) (framed in orange, Figure 1), and thus change policy instruments affecting the agri-food system (framed in grey, figure 1, cf. question 2).

We therefore question the implications of these processes on agri-food systems in the face of environmental, social and economic challenges, which depend on the evolution of the agri-food system as a whole (arrow 5) and which may depend more specifically on the level of appropriation and use of digital technologies by stakeholders (arrows 4 and 6). In view of these implications, we propose to discuss the results of current policies concerning the agri-food system and digitalization (framed in grey, Figure 1, cf. question 3) and to discuss the current limiting factors of these policies (framed in grey, Figure 1, cf. question 4).

Figure 1. Overall analytical framework of the book



Sources: authors own elaboration

Caption: in orange are the processes to be analyzed, in grey are the themes of the research questions of this book, in the green frames are the components of the system to be analyzed, and the blue arrows indicate the relationships of influence between the different objects of the system.

3.2. Structure and Content

In addition to this chapter, the book contains 13 chapters[6]. These chapters present studies conducted at the Latin American regional level and at the national level in six Latin American countries (Argentina, Brazil, Chile, Costa Rica, Uruguay, Mexico). The book is organized in three parts which together provide answers to the guiding questions of the book[7]. The first part, "Regional analyses of digital transition policies in agriculture", brings together four regional chapters and provides analysis of the dynamics of policies and initiatives in favor of the digital transition in Latin American agriculture. The second part, "Policies for the digital transition in agriculture: national studies", presents studies carried out at the national level on current policies involved in digital transition in agriculture in five countries in the region (Argentina, Chile, Costa Rica, Uruguay, Mexico). The third Part, "Digitalization of policies and implications", presents four analyses of the digitalization of agricultural sector related policies and instruments, and their implications for agricultural dynamics in Brazil and Uruguay.

4. Synthesis of Main Transversal Findings of the Book

In this section, we present a synthesis of the main cross-cutting findings of this book. The first section describes the progress, limiting factors and nuances of digital transformation in Latin American agriculture, as well as the driving forces and drivers of this transformation in the region. We then characterize the current state of the policies and instruments involved in promoting this digital transformation in agriculture. We synthesize the main preliminary lessons regarding policy digitalization processes. Finally, after synthesizing the achievements and limiting factors of the digital transformation processes and the policies involved, we propose

6 The Spanish original version contains a total of 23 chapters. In this English version, 13 chapters are presented integrally, and 10 chapters are presented as abstract.

7 The original Spanish version of this book encompasses 2 other parts: 1) one is related to "Digitalization dynamics in territories and public policies" and presents five studies on digitalization dynamics and policies in territories in five Latin American countries (Brazil, Colombia, Chile, Colombia, Mexico); and 2) the other is related to "Digital services in Latin American agriculture", and presents five experiences of digital services for agricultural producers in several countries (Brazil, Guatemala and Peru).

recommendations to promote a policy environment conducive to an inclusive digital transition in the region.

4.1. Digital divide and diversity of digitalization dynamics in Latin American agriculture

The chapters of this book confirm the digital divides and asymmetries in access to digital technologies and innovations between countries, territories and types of agricultural value chain actors. A great diversity of digital transformation processes that affect the functions of agriculture and different models of agriculture is also discerned.

Connectivity improves, but the digital divide remains

A key factor for the digital transformation in agriculture is connectivity. Rodrigues and Mondaini (chapter 1) confirm the progress in terms of connectivity in the countries of the region. Indeed, household internet access in the countries of the region increased from an average of 20% in 2010 to 67% in 2022 (Observatorio de Desarrollo Digital, 2024). But these authors also highlight the lack of quality internet service coverage and/or the cost of access (sometimes even electricity, which is necessary for the use of digital technology) especially in rural areas, and conclude that connectivity continues to limit the adoption of digital technologies in lagging rural areas and by poorer producers.

The situations regarding connectivity are very contrasting between countries such as Chile, Costa Rica and Uruguay and, to a lesser extent, Brazil, which has higher coverage rates in rural areas, and on the other countries such as Mexico, Colombia or Peru, whose rural connection coverage rates are lower (Chap. 1, Rodrigues and Mondaini). In addition to this contrast between countries and between urban and rural areas in general, there is also a contrast between rural territories within the same countries. Thus, in Argentina, Morales et al (Chap. 5) show differences between the regions of the country. In Mexico, H. Avila (Chap. 9) highlights the difference in connectivity between the southern and northern parts of the country. Finally, the contrast is also expressed between types of producers and their income levels. Rodrigues and Mondaini (Chap. 1) show that internet access depends on the income levels of households in the region.

A second key factor for digital transformation in agriculture is digital literacy, defined as the capacity or ability to use information and communication technologies (ICT). This factor is decisive in determining what internet users do once they have access to the service (Rodrigues and Mondaini, Chap. 1). This digital literacy requires basic conditions, such as low illiteracy and a certain level of education, which are more difficult to achieve among the older population and in certain rural areas. Rodrigues and Mondaini (Chap. 1) show that, as with digital connectivity, there is a wide disparity in terms of digital literacy between rural and urban populations, and that low internet use is directly related to lack of knowledge of its functioning or usefulness, to a level equivalent to restrictions in access to communication infrastructure.

To capture more finely the digital gaps between countries and in rural territories, indicators have been developed which combine information related to connectivity, internet usage, digital literacy, access to equipment and quality of connection indicators. Hence, the ICT Development Index (IDI)[8] confirms the gaps between countries in the region with, on the one hand, countries such as Chile and Uruguay, with a better IDI, contrasting with countries such as Honduras, Nicaragua and Guatemala. In addition, the Index of Significant Rural Connectivity (ICSr), focused on the connectivity of rural areas[9], reveals that 63% of rural dwellers in the countries, where it was estimated[10], do not have access to quality connectivity (Ziegler et al. 2020).

8 Developed by the International Telecommunications Union (ITU), the IDI in 2023 was composed of 11 indicators grouped into three main sub-indices: Access, Usage and Skills. Access is measured through indicators such as fixed and mobile broadband subscriptions. Usage includes metrics such as internet usage and e-commerce activity. Skills are assessed based on indicators related to education and digital literacy. Each indicator is standardized and weighted to ensure a balanced assessment of ICT development (see Rodrigues and Mondaini, Chap. 1).

9 Developed by IICA, IDB and Microsoft, the ICSr is based on the 4 dimensions of meaningful connectivity, which are: (1) regular use of the Internet, (2) having an appropriate device, (3) access to sufficient and permanent data and (4) adequate connection speed. For each of these dimensions, the index combines indicators such as: percentage of the population with daily internet use (dimension 1); average of the percentage of the population with access to smartphones and individuals with access to a personal computer, laptop or tablet (dimension 2); percentage of the population with access to fixed broadband (dimension 3) and percentage of the population with 4G technology coverage (dimension 4) (Chap. 1).

10 The ICSr was estimated directly for seven countries in Latin America: Bolivia, Brazil, Costa Rica, Ecuador, Honduras, Paraguay and Peru (Chap. 1).

Diversity of digital innovations and dynamics of digitalization in agriculture

Although the debate on digital transformation in agriculture tends to emphasize a dichotomy between opposing models (Agriculture 4.0 associated with agribusiness versus family farming totally excluded from this process), looking at the process as a whole confirms that digital transformation is a diffuse and multifaceted process. This results from: 1) the diversity of digital innovations and their characteristics, and 2) the diversity of the conditions of producers and actors, and their production models. Thus, we first note that digital transformation encompasses a wide range of digital innovations that not only target different dimensions of productive activities, but also have the potential to be adopted by various types of actors in the agri-food system with different economic conditions and skills. Second, we observe a diversity of contrasting trajectories of digital transformation (digital transformation pathways) across producers, sector actors and rural territories in Latin America.

Diversity of digital innovations and their characteristics

The literature proposes several classifications in order to characterize the wide diversity of digital technologies and innovations permeating agriculture and agri-food systems (OECD 2019, Prause et al. 2021, CEPAL 2022, Porciello et al. 2022, Moreno et al. 2024)[11]. These classifications have different entry points: the main role of technologies in terms of the data use cycle (OECD 2019), the stages in the agri-food system into which they fit (Prause et al. 2021), or the types of services they provide to actors, such as farm management, market access, financing, rural extension (Porciello et al. 2022), or a more systemic combination of criteria (Moreno et al. 2024).

Considering the existing typologies and the diversity of the digital innovations contemplated in the chapters of this book, the diversity of digital innovations in agriculture can be characterized using the following two criteria: 1) their purpose and design (degree of genericity, degree of complexity and the type of actors designing them) and 2) their accessibility

11 See also adaptation of the OECD 2019 classification, by Rodrigues and Mondaini (Chap. 1).

by the actors in the sector (conditions and form of access, complexity and cost of use, form of appropriation by users). Combining these criteria[12], a global typology of three main categories of digital innovations involved in the digital transformation of agriculture and agri-food systems in Latin America can be discerned (Table 3).

Table 3. Broad categories of types of digital innovations.

Types of innovations	Examples	Chapters specially mentioning them[13]	Purpose	Accessibility
Type 1) "Generic" digital innovations	Social networking applications (WhatsApp, Instagram, YouTube, etc.)	Peru, use of WhatsApp for agricultural extension (see Nakasone et al. 2024) Colombia (see Quintero 2024) Ecuador (see Franco-Crespo and Borja 2024)	Multiple	High
Type 2) easily accessible digital agricultural specific innovations	Specialized information systems (technical, market, geographic, etc.) Specific digital marketing platform	National Livestock Information System (SNIG) (Núñez and Sequeira, Chap. 13, Uruguay) Agro-climatic platform (see Zapata-Caldas et al. 2024, Guatemala) Chile (Sotomayor et al. Chap. 6)	Specific	High to medium
Type 3) Specialized, asset- intensive digital innovations	Specialized decision-support integrated platforms	Climate FieldView - Bayer; John Deere Operation Centre - John Deere, Atfarm - Yara (see Kato et al. 2024, Brazil)	Specific	Medium to low

Source: own elaboration.

The first category consists of "generic" digital innovations (not specifically created for agricultural activities or by agri-food system). These are generally designed outside the region, by multinationals. They are

12 Other criteria are also useful for locating these innovations in agri-food systems, such as their role in chains (production, processing, logistics, marketing, consumption).

13 Including chapter of the Spanish version of the book.

characterized by being relatively easy to access and use, flexible in their uses and purposes, free to use and voluntary. One emblematic case of this type of digital innovation is social networking applications, *e.g. WhatsApp*. In general, they have been developed by international technology companies. They are flexible in the sense that they can be used to exchange information for multiple purposes and multiple functions (technical information, price information, etc.). The user can be proactive, as a low-cost sender of information, their accessibility is high, as they do not require great learning or skills[14], and their usage costs are minimal (mobile telephony and internet access).

The second category is made up of "easily accessible digital agricultural specific innovations" and differs from the first category in that they require specific development in order to fulfil a precise function in the production process or in the agri-food system. Thus, they require a specific investment for their conception and maintenance, which has to be borne by private or public actors or by end-users. However, innovations in this category are still easily accessible in terms of the devices needed to operate them (mobile phone and internet access). But, although they do not require a higher financial investment from their users, they generally require a higher level of skills and a higher learning process than innovations in the first category. Within this category, different levels of complexity of technology development and maintenance can be distinguished. They can also be differentiated according to the provider of the innovation and the associated service, in particular by its public or private nature. In the first case, the cost of developing and maintaining the technology is borne by the public administration, alone or with the support of international cooperation resources. In this category, the technologies may be of a mandatory nature (as in the case of the SNIG in Uruguay, Núñez and Sequeira, Chap. 13) or voluntary (as in the case of agro-climatic platforms and services – Zapata-Caldas et al., 2024). In contrast, digital innovations developed by private actors have to cover their development and maintenance costs, which can lead to different financing models (costs assumed by donations or international cooperation,

14 Certain generic digital innovations may require more learning than others, e.g. market platforms, as Apanio (https://apanio.com/) mentioned in Chap. 6.

costs assumed by users, directly or indirectly). In this case, use is generally voluntary and includes specialized digital information services, specialized exchange or market applications, such as e-commerce platforms for primary products (cf. cases in Chile, Sotomayor et al., Chap. 6). In this category, there are different degrees of flexibility and proactivity of users, who may or may not supply the system with their information inputs.

The third category, made up of "specialized and asset-intensive digital innovations", differs from the second by having an even higher level of complexity in its design, and an accessibility conditioned by a higher level of investment in assets for the end user. In this category, innovations generally combine different digital technologies for data storage (*Cloud) and processing (AI, Big Data algorithms)*, information representation and dissemination (GIS, graphic interfaces), and also for specific and *in situ* information capture processes (via GPS, drones, sensors, *IoT*) that are costly to acquire and maintain. These innovations can take on one or several functions in production or chain activities in a specific or integrated way. Thus, their main characteristic is the cost of development, maintenance and thus their accessibility for users, who need both investment capacity (to acquire the necessary materials) and competences/skills to use and mobilize these innovations. Access to and use of these innovations are linked to other specialized agricultural equipment (spraying drones, tractors and connected sensors, etc.) in a logic of automation and robotization. These digital innovations are generally of private design and development, driven by large companies or Ag-Tech start-ups. The most emblematic cases are the platforms for decision support in farm management, developed by large agribusiness or agricultural machinery companies *(e.g. Bayer's Climate FieldView or John Deere Operations Center* – Kato et al. 2024). These innovations are generally associated with the concept of "precision farming" and aimed at large-scale agriculture. However, it is worth mentioning that a variety of digital innovations of this type are being developed which may require more limited levels of investment, compatible with medium-scale operationalization.

It is worth noting that, for the same technical or management issue, there is a range of digital innovation options available that derive from these different categories. For example, in the face of climate uncertainty and the need to manage climate risk, there are different digital innovations in different categories that target different audiences. Thus, Zapata-Caldas et al. (2024) present a category 2 digital innovation, the agroclimatic platform developed by the Bioversity-CIAT alliance in conjunction with Guatemalan actors and institutions, aimed at helping small-scale family and indigenous producers to make decisions in a context of climate variability. In contrast, Kato et al. (2024) present category 3 innovations in the case of Brazil: the platforms developed by large commercial precision agriculture application groups, targeting an audience of large agribusinesses, which enable climate risk management.

In addition, the coexistence of different dynamics in the design and development of digital innovations stands out. Alongside the dynamics driven by large multinational companies in the technology sector through their generic applications (category 1), and/or agribusiness companies in technologies linked to precision agriculture (category 3), there is an increasing development of a wide range of experiences of specific digital innovations in category 2, driven by AgTech entrepreneurs and/or research centers, with the specific objective of being accessible to producers with fewer resources and skills, in line with the concept of responsible digital innovation (Cf. Gardeazabal, Chap. 4).

Finally, this diversity of innovations with different characteristics leads to the adoption of barriers of different kinds (e.g. in Ecuador, cf. Franco-Crespo and Borja 2024). Identifying these barriers is essential to create the right conditions for scaling access to and use of these different categories of digital innovations.

Diversity of the dynamics of digitalization of agriculture and agri-food systems

Along with the diversity of digital innovations, contrasting dynamics of digitalization can be observed between types of producers, value chain actors and territories.

Contrasts between producers. The chapters of the book show the differences in digital transformation according to the types of producers. Thus, family or small-scale producers tend to mobilize more digital communication tools, such as social networks (WhatsApp, Instagram, ...), for dissemination, exchange and access to technical or market information. These innovations can be mobilized by individual producers or their organizations (cf. Quintero 2024, Colombia). Agro-industrial actors tend to mobilize more complex digital technologies, including systems that integrate complex information capturing and processing, which are combined with processes of automation and robotization that reduce the demand for agricultural labor. Thus, two main dynamics of digital transformation can be observed in the agricultural sector: a "low cost" digital transformation that takes advantage of digital innovations not specific to agriculture, and generally developed by international companies or start-ups in the ICT sector, and a more "asset and knowledge intensive" digital transformation based on more specialized and expensive technologies (applications) and equipment (drones, sensors, machinery), developed by international companies, sometimes in collaboration with local companies. The latter is reflected or described in the literature as a foundation of precision agriculture or agriculture 4.0, while the former is much more diffuse, little studied, and its potential little analyzed or exploited yet. Between these two contrasting dynamics, the chapters also show the initiation of alternative trajectories where family farmers and/or their organizations start to mobilize digital innovations with low access costs (limited to mobile phones) and with applications dedicated to specific functions and at the service of family farming (see Ávila et al. 2014).

Contrast between actors in value chains and agri-food systems. Contrasted digital transformation can also be observed among value chain actors. As illustrated by Akaki et al. (2024) in the case of coffee and mezcal chains in Mexico, actors in production, processing and marketing take advantage of opportunities to use digital innovations in different ways. Thus, producers, mostly family farmers, tend to mobilize communication technologies (social networks). Processing actors and cooperatives mobilize different digital innovations in order to promote the sale of their products (online sales platforms, social networks). Multinational actors in the marketing and export of products (e.g. Nestlé in the case of coffee) mobilize innovations and advanced digital technologies (AI, big data) to improve their strategies for selling to consumers (personalization of the offer, e-auction). This example illustrates how pre-existing asymmetries of capabilities and power in the value chains are reinforced by asymmetric digital transition between actors.

We can also note the dynamism of the digital transformation in the marketing and consumption functions of agri-food systems contrasting with the limited digital transition observed in the production function. Sotomayor et al. (Chap. 7) show the proliferation of marketplace-type consumer-oriented platforms to sell agricultural products, but also to avoid waste and encourage recycling[15] or to distribute food to vulnerable populations (food banks[16]) or guide consumers towards healthy eating[17].

Contrast between territories. Finally, at the cross-road between the territorial characteristics in terms of productive models and inequalities in connectivity and digital skills, authors reveal differentiated dynamics of digitalization between territories in many countries of the region. Thus, as exemplified by the case of Mexico (Avila, Chap. 9) and the work of Vargas-Canales (2023), there is a contrast between: 1) the northern region states bordering the United States, characterized by dominating agro-exports agriculture led by large companies, where capital-intensive digitization is carried out, and 2) the central and southern Mexico states where family agriculture prevails, with fewer digital capabilities and a low level of connectivity and where digitalization transformation is limited to the use of cell phones and generic apps. Territorial differences are also observed in Brazil and are illustrated in two ways. First, in the mobilization and different use of a digitalized policy instrument, the rural environmental register (CAR), and its differentiated use according to territories and key actors (Kato et al., Chap. 11). Second, in the differential spatial distribution among Brazilian territories of innovations adopted by family producer organizations (Tartaruga et al. 2024).

15 Such as the digital platforms Good Meal, Maifud, Olio Chile, Cáscara Foods or Co-food (Chap. 6).

16 Such as the Chilean food bank networks: Red de Alimentos, Banco de Alimentos Biobío Solidario and Banco de Alimentos Lo Valledor (Chap. 6).

17 Such as the Cheaf application, created in 2020 in Mexico, and present in Chile since 2023, which helps to rescue food (with 50% discounts on the original value of the food), in agreement with supermarkets (Chap. 6).

This territorial differentiation leads to envision territorialized interventions, as illustrated by the lessons learned from the South-South cooperation project *Digital Transformation and Innovation in Agriculture*, implemented by FAO at the request of the Community of Latin American and Caribbean States in 12 countries in the region (see González et al., Chap. 3).

Driving forces and actors in the digitalization of agriculture

The chapters of the book identify the driving forces of digital transformation on the supply side of digital innovations and on the demand side.

Supply-side drivers of digital transformation

The digital transformation of agriculture is accompanied by the arrival of new actors in the agricultural sector and new configurations of actors in agricultural innovation systems. Below, we present the main actors involved in the dynamics of the supply of digital innovations in the region.

Technological Multinationals. Digital innovations are developed and promoted at the international level by large multinational companies in the technology sector, particularly from the United States (such as Google, Microsoft, Meta). This evidence at the international level (Birner et al. 2021) can also be observed in Latin America and its agricultural sector, where these companies are present in two ways. First, they are present directly through the applications they have developed and manage (e.g. WhatsApp, etc.), which are used by all actors in the value chains and by all types of producers and actors in the sector. The second modality is through collaborations and direct investments in projects to develop specific technological innovations for agriculture, where they forge alliances with different types of actors: large agribusiness and agribusiness companies and a network of small local AgTech start-ups, universities or ministries (cf. Costa Rica, Chap. 7).

Large agribusiness companies. A second major player in the development of the supply of digital innovation for agriculture are the large multinationals present on the continent. They develop specific digital innovations (sometimes in collaboration with big Tech firms) with the aim to consolidate their relationships with their (mainly agribusiness) customers and to build customer loyalty by offering not only the sale of products and machinery, but also services and business connections in the form of platforms for decision making on field operations.

Although these categories of actors are the most visible and studied when addressing digital transformation in agriculture at the international level (Birner, et al. 2021), the presence of other driving forces and actors in Latin America is evident.

Universities and national or international research centers. These actors develop innovations for different functions of agriculture and different types of actors. **International research centers** develop innovations for all kinds of audiences, and have a particular focus on smallholder farmers with the aim of bridging the digital divide by adapting solutions to the conditions of these categories of producers. Several examples of these dynamics and processes are illustrated in this book: the development of agro-climatic services in Guatemala by the Bioversity-CIAT alliance (Zapata-Caldas et al. 2024), the mobilization of WhatsApp groups for agricultural extension in support of small potato farmers by CIP (Nakasone et al. 2024), or the development of responsible and inclusive innovations by CIMMYT (Gardeazabal, Chap. 4). These innovations are developed in conjunction with public administrations (ministries, state services), national research centers, civil society actors or representatives of producer organizations. **National research centers** are also important players in the development of digital innovations. The role of Embrapa in Brazil, INTA in Argentina and Costa Rica, and INIA in Chile and Uruguay is particularly noteworthy. These institutes have developed research and development programs for digital technologies and innovations. They also collaborate in the framework of international networks such as the Ibero-American Network for the Digitalization of Agriculture and Livestock (RIDAG).

The role of **Latin American universities,** through their agricultural and/or technological faculties, is also highlighted. They are involved in the production of digital innovations for various types of actors and address different problems. These universities have various modes of action. They can develop innovations "alone" through their own specific projects, as illustrated by the case of Cegafi, at the University of Brasília, where a center creates a specific structure that develops different applications for family farming (Ávila et al. 2024). They can participate in more comprehensive collaborative structures, in the form of territorial innovation clusters in collaboration with large private companies - as for example in the state of Guanajuato in Mexico (cf. Ávila, Chap. 9,) - and/or start-ups, or in innovation systems on a local scale, made up of producers, extensionists, universities and private companies, as illustrated by the case of the digital innovation system of Maule, in Chile (Castrillón et al. 2024).

In addition, there are the **small AgTech starts-ups**. The growth of small (and sometimes medium-sized) tech companies has a fast and diffuse dynamic. This category of start-ups is particularly developed in Brazil, where more than 759 AgTech companies were identified in 2023 (Dias et al. 2023). It also exists in Argentina, where an estimated 165 AgTech companies were expected in 2022 (Endeavor and Bain & Company 2022); in Chile, where more than 100 AgTech companies are estimated to be linked to the digital sector (Sotomayor et al., Chap. 6); in Uruguay (Bianco and Sierra, Chap. 8) and in the Andean region countries (Bert 2023). These companies develop independently or in closer collaboration with large companies (in the tech or agricultural sector) and with universities. They are beginning to structure themselves into organizations or associations that represent their interests, such as AgTech Chile (Sotomayor et al., Chap. 6). The creation of innovation hubs and AgTech incubators is noticeable in most Latin American countries. These companies are very dynamic in the generation of digital innovations, and constitute innovation ecosystems where research actors (universities, research centers, universities of applied sciences, etc.), private companies of the sector and funders interact and collaborate.

Finally, the role of **international and regional cooperation organizations** can also be seen, such as ECLAC, which has created an observatory of digital dynamics in Latin America (Rodrigues and Mondaini, Chap. 1); FAO, which promotes support programs for digital transformation in rural territories, such as the FAO-China-CELAC South-South Cooperation Project (González et al., Chap. 3); or IICA, which promotes projects aimed at promoting digitalization in the region (Alcântara and Bert, Chap. 2,).

New networks and the reconfiguration of innovation systems

In all countries, it is revealed that digital transformation is leading to a reconfiguration of the landscape of actors involved in innovation in the agricultural sector with the integration of new private actors from the Tech sector, as well as research institutes and faculties from outside the sector.

This leads to the creation of diffuse networks of companies in the countries, with regional and international linkages, which are difficult to address. Digital ecosystems are also generated around a specific issue. For example, Cegafi (mentioned above) is an example of a digital ecosystem managed from a university around the issue of monitoring family farming (Ávila et al. 2024). Another example is the creation of a digital ecosystem to operate the *Cédula de Produtos Rurais* (CPR) in Brazil (Desconsi et al., Chap. 12).

New multi-actor networks are also generated at regional or international level, such as the digital hubs organized by chain (e.g. in Mexico, Ávila, Chap. 9) or by territory (e.g. in Chile, Castrillón et al. 2024), or the international network RIDAG mentioned above.

Thus, the digital transformation is accompanied by the increasing involvement of actors who were outside the agricultural sector and by the generation of new relationships or alliances between actors in the agricultural and technological sectors. The digital transformation is also supported by new public-private partnerships, as well as new interfaces of multidisciplinary work between communities that do not share the same interests, the same referential or languages (e.g. in the case of SNIG, Núñez and Sequeira, Chap. 13), and new funding mechanisms.

Demand-side drivers of digital transformation

Several demand-side drivers have been identified in the chapters of this book, according to types of actors: producers, actors of value chain, and public administration.

Diversity of producers' needs. The needs addressed by digital technologies and innovations are multiple and wide-ranging. However, patterns can be identified according to types of producers. For family farmers and their social organizations, who mainly use generic digital innovations for communication purposes, a first motive is access to comprehensive information (technical, market, etc.) in an agile and direct way. This motive was exacerbated by the mobility restrictions that occurred during COVID-19 and continues to grow by the need to respond to different disturbances to which agriculture is exposed, such as natural disasters resulting from climate change, variations in market prices, etc. An example of this motive can be found in the mobilization of agro-climatic information by peasant and indigenous users in Guatemala (Zapata-Caldas et al. 2024) or technical advice on pest management problems in Peru (Nakasone et al. 2024). A second reason is the desire to be known or recognized, to promote their activities (as information providers), as in the case of social organizations in peasant territories in Colombia (Quintero, 2024). This communication responds to the desire to generate or reinforce social links, but also to be recognized by society and made visible for their role in food supply and conservation. Finally, the motive is to maintain or generate new opportunities to their products to chain actors or consumers (Niederle et al. 2021).

For agribusiness companies there are additional reasons for the adoption and use of digital innovations, such as increased productivity and reduced production or labor costs (Kato et al. 2024), or access to financing by private companies or banks (Desconsi et al., Chap. 12,). There is also evidence of the motive of accompanying market demands and, in particular, their international requirements, such as the traceability and animal health demands of the international meat market, as shown in the case of Uruguay's SNIG (Núñez and Sequeira, Chap. 13).

For chain actors. Whether by simple means (communication via WhatsApp) or more complex and integrated systems, intermediary actors seek to better manage product flows in the agricultural product value chain. In a context of competition between actors for marketing, they also seek to increase their knowledge of consumer demand thanks to digital technologies, as for example in the case of international actors in the coffee chain (Akaki et al., 2024).

For public administration. The digital transformation of public policies responds to different motives of public administration. The first is the management of information, as accurate as possible, to be able to define policies and monitor agricultural dynamics. The example of the Integrated State System for Family Farming (SEIAF MT) in the state of Mato Grosso, in Brazil (Ávila et al., Chap. 10) illustrates this motive. Given the difficulty of acquiring reliable and systematic information on the dynamics of family farming, the State Secretariat for Family Farming in Mato Grosso promoted a digitalized system for capturing information. The second reason is to increase the efficiency of the public service, reducing the costs of acquiring and processing information in systems with limited public financial resources.

4.2. Policies for digital transformation in agriculture

Unlike other issues such as food security (Le Coq et al. 2021), digital transformation in agriculture is an emerging issue and identifying digital transformation policies for agriculture is a complex task. Indeed, the policy elements for digital transformation in agriculture are scattered across a variety of documents[18] (Patiño et al. 2021). However, based on the regional and national studies presented in the book, we can provide an overview of policies related to digital transformation in agriculture and identify the elements of policies and instruments in place in the countries of the region, the institutional constructions around this issue and the orientations of these policies.

Digital switchover policies in general: digital agenda and e-governments

The vast majority of countries in the region have already adopted policies for digital transition[19]. These policies focus mainly on the development of communication infrastructures, connectivity issues, the creation of

18 According to Patiño and Rovira (2021), the instruments that guide policies to drive digital transformation are mainly divided into four types: (i) chapters or sections within national development plans that address the digital domain; (ii) national digital agendas or ICT strategies, which establish strategic objectives in the digital domain; (iii) sectoral plans, which define actions to promote the adoption of digital technologies in specific sectors, including agriculture; and (iv) digital plans driven by sub-national governments.

19 In addition to national digital agendas, there are digital agendas at the Latin American sub-regional level, such as, in particular, in the Andean region with its Andean digital agenda (Alcântara and Bert, Chap. 2).

enabling environments and data regulation, as well as digital governance initiatives (Rodrigues and Mondaini, Chap. 1). Although they are not specific to the agricultural sector, they contribute to digital transformation in the agricultural sector and, in particular, to the issues of connectivity and bridging the digital divide, especially affecting rural areas. Thus, different policies can be highlighted in the countries analyzed in this book. In Argentina, a series of policies for the universalization of connectivity have been developed since 1998, culminating in the comprehensive plan for productive rural connectivity and 4.0 technologies of 2023 (Morales et al., Chap. 5,). Similarly, since 1999, Chile, through its planning "Chile: Towards the Information Society", has a policy trajectory and digital agenda that culminates in the "Digital Agenda 2020", which sets the guidelines and measures to enable universal access to the internet at low cost (Sotomayor et al., Chap. 6,). These policies aim to develop infrastructures for connectivity in rural areas through: 1) the strengthening investment in fiber optics (such as the federal fiber optic network in Argentina, or the Austral, national or cross-border complexes "Fibra Opticas" projects in Chile; and 2) the development of satellite technology for wireless coverage (ARSAT 1 and 2 satellites in Argentina, Starlink network in Chile). They also add local service provision structures in order to facilitate access to more remote areas, such as local provider hubs in Argentina or regional "last mile" projects in Chile. Similarly, Mexico has recently seen a federal roll-out called *"Internet para el Bienestar"*, which offers access to unlimited social media services with nationwide coverage at very affordable prices.

Sectoral policies for the digitalization of agriculture

The integration of digital transformation issues into agricultural sector policies is still very limited in the countries of the region, as shown in Rodrigues y Mondaini (Chap. 1) and confirmed by several chapters with a national focus. National digital agendas generally operate independently of the specific issues of digitalization of agriculture, and where sectoral digital agendas exist, they are totally marginal compared to agricultural regulations and policies and, in turn, are very partial with respect to the diversity of digital transformation processes. This contrasts with the situation in the European Union and the case of Spain (Caal et al. 2024).

The regional studies (Chapters 1 and 2) and the country chapters presented in this book reveal that policies in favor of the digitalization of agriculture are very recent and uneven among the countries of the region. According to the Digital Development Observatory (2024), see Chapter 1, only four countries in the region (Brazil, Costa Rica, Panama and Cuba) include in their digital agenda actions aimed at the digital transformation of agriculture. In addition, considering the inclusion of digitalization issues in agricultural sector policies in the region, the analysis of the FAOLex database (2024) presented by Rodrigues and Mondaini (Chap. 1) reveals that only 4.2% of agricultural policy documents refer to digital agriculture. Within this percentage, a minority (23.5%) contemplate specific implementation plans for digital agriculture. The rest provide general guidelines, mentioning digitalization as a concept to be considered, but without implementation details (43.9%), or mention digitalization as a secondary component within documents dedicated to other purposes (32.7%).

Three main levels of progress can be identified regarding the integration of the issue of digitalization of agriculture in the countries of the region: 1) countries with a general digital agenda, without explicit mention of agriculture, 2) countries with a general digital agenda that integrates some guidelines for the agricultural sector, together with initiatives scattered across several institutions, 3) countries that have a sectoral policy for the digitalization of agriculture promoted by the Ministry of Agriculture.

In the first category are countries such as Ecuador, Guatemala, Peru and Argentina, which have a digital agenda promoted by the Ministry of Telecommunications, but without references or framework documents and specific public programs for digital transformation in agriculture. Thus, Ecuador has a global digital agenda through its policy for the digital transformation of Ecuador (2022-2025), formulated by the Ministry of Telecommunications and the Information Society, in 2022, but makes no mention of the agricultural sector (Ministry of Telecommunications and the Information Society 2022). Guatemala has a Digital Nation Agenda 2016-2032, outlined by the Economic Commission for Latin America and the Caribbean (ECLAC) in 2018, and a National Open Data Policy

(MINGOB, 2018), but no agricultural sector agenda (Zapata-Caldas et al., 2024). The government of Peru has a National Digital Transformation Policy, approved in July 2023 (Alcântara and Bert, Chap. 2,), but no specific policy for agriculture. Argentina has a digital inclusion policy with a dedicated item on rural divides, but no specific sectoral digital agenda (Morales et al, Chap. 5).

In the second category are countries such as Costa Rica, Chile and Mexico. Costa Rica has a digital agenda, particularly through its National Telecommunications Development Plan 2015-2021, under which a National Strategy for the digitalization of the agricultural sector was formulated. However, this policy document developed by the Ministry of Science, Technology and Telecommunications (MICITT) did not receive much follow-up after the change of government in 2022, and finally lacks a comprehensive guiding framework for the agricultural sector built by the Ministry of Agriculture (Sáenz et al., Chap. 7). Chile has a digital agenda, with specific guidelines for rural areas through its National Rural Digital Connectivity Plan, and the creation of a Rural Digital Connectivity Roundtable, under the responsibility of MINAGRI and the Sub-Secretariat of Telecommunications. It also has digital extension service and marketing initiatives from the Institute for Agricultural Development (INDAP), but it does not have a unified agricultural sectoral digital agenda[20] (Sotomayor et al., Chap. 6). In Mexico, the Sectoral Program for Agriculture and Rural Development 2020-2024 includes guidelines for the promotion and adoption of 5G technology and artificial intelligence in the primary sectors, and some innovation initiatives, but there is no sectoral agenda (Ávila, Chap. 9).

In the third category are countries such as Brazil, which in addition to having programs for connectivity (such as the *Connected Rural Communities Program)*, has policies for the promotion of digital agriculture (Agro 4.0 Program), as well as programs to support digital innovation for the agricultural sector, such as the *TechStart Agro Digital* Program or MAPA *conecta* (Alcântara and Bert, Chap. 2). Uruguay has e-government plans

20 In Chile, some sectoral agenda initiatives have been proposed by the International Telecommunications Union (ITU) in 2020 and by MINAGRI, with the National Program for the Promotion of Agriculture 4.0 in 2021, but they were not implemented (Chap. 6)

that have allowed the consolidation of several digital information services in agriculture, such as the *AgroTic* program, which seeks to contribute to a more equitable digitalization, facilitating access to digital technologies for family farmers. It also has a specific policy focused on the promotion of digital technologies in the agricultural sector, the *AgTech Challenge program (2020)* managed by the National Innovation Research Agency (ANII), whose direct promoters are the Ministry of Agriculture, Livestock and Fisheries (MGAP) and the National Development Agency (Bianco and Sierra, Chap. 8). Finally, the case of Colombia, which has not only specific policies and programs to bridge the digital divide in rural areas, such as the National Rural Connectivity Plan and the National Project for Universal Access to Information and Communication Technologies in Rural or Remote Areas, but also an Action Plan to accelerate the digitalization of the agricultural sector (Alcântara and Bert, Chap. 2).

Set of policies and instruments for the digital transformation of agriculture

While there are few sectoral policies for the digital transition in agriculture, there are definitely *policy and instruments mixes (*Rogge and Reichardt 2016) that affect the digital transformation of agriculture. These policy mixes comprise several policies designed from different sectors leading to de facto complex policy instruments mixes (Ossenbrink et al. 2019).

Policies involved in the digital transformation of agriculture are found in different sectors or policy fields. First, they are mainly found in telecommunication policies, which aim to increase internet connectivity and regulate telecommunication services. In these policies, the main tools are guidelines for investment in telecommunications infrastructure, regulation of telecommunications markets and protection of data rights. They also include training programs in the use of digital technologies. Secondly, they are to be found in science and technology policies[21] aimed at the development and dissemination of digital innovations. These policies mobilize funding instruments for research and for companies such as

21 In some countries, the telecommunications sector is under the same ministry as science and technology, as in the case of Costa Rica

start-ups in general, and possibly AgTech, and instruments for capacity-building for professionals and companies. These instruments aim at strengthening regional innovation (*e.g.* in Brazil) and creating digital hubs (*e.g.* in Chile). Then, there are policies and programs related to the agricultural sector and rural development. While few countries have a sectoral political framework dedicated to digital transformation, we identified instruments which contribute to digital transformation in different agricultural and rural development sub sectors, such as chapters or sections in the rural development plans (*e.g.* Mexico, Avila, Chap. 9), programs promoted by agricultural research institutes (e.g. Chile, Sotomayor et al., Chap. 6), or in environmental policies, such as those on climate change (*e.g.* Guatemala, Zapata-Caldas et al. 2024).

In terms of instrument mixes, four types of instruments relevant for the digital transformation in agriculture can be observed. The first type of instruments are **regulatory instruments**, in particular linked to data rights. The second type are **financial and investment instruments,** applied for various purposes: development of telecommunication infrastructures, investments to support companies that design digital innovations for the agricultural sector (such as the Smart Field program in Chile, Chap. 6, or the program *desafio AgTech in Urugay, Bianco* and Sierra, Chap 8), research and/or experimentation project, or assistance for access to technology projects, such as the AgroTics program in Uruguay aimed at family farmers (Bianco and Sierra, Chap. 8); microcredit programs with an emphasis on the implementation of technologies, such as in dairy production systems, foreseen in the "small and medium enterprises Digitalization Plan" in Costa Rica (Saenz et al., Chap. 7) or the Digital Kit Program in Chile (Sotomayor et al., Chap. 6). The third type of instruments are those oriented to the training of actors. These instruments can be aimed at agricultural producers and/or professionals in the sector, such as the diploma courses in digital agriculture or digital school in Chile (Sotomayor et al., Chap. 6), the permanent training programs for FIRA professionals in Mexico (Ávila, Chap. 9) or the program to strengthen entrepreneurial capacities for start-ups in management, marketing and the search for financing (Sotomayor et al., Chap. 6). The fourth type of **instrument is of an organizational and institutional strengthening nature**, such as the creation of commissions, councils or roundtables in order to coordinate and define actions among stakeholders. The case of Brazil is noteworthy, for example, where the Ministry of Agriculture, Livestock and Supply (MAPA) promoted spaces such as the Agro 4.0 Chamber, the *Câmara de Inovação Agro-Digital* and the *Comissão Brasileira de Agricultura de Precisão e Digital* (Alcântara and Bert, Chap. 2). Mention can also be made of the *Mesa Conectividad Digital Rural*, run by MINAGRI and the Subsecretaría de Telecomunicaciones (SUBTEL) in Chile, with the participation of several institutions from the agricultural and tourism sector (Sotomayor et al., Chap. 6).

These instrument mixes are very disparate across countries in the region, giving more priority to one type of instrument or another, but they fit the policy roles for digital transition in agri-food systems identified by Kukk et al. (2022): 1) bridging digital divides and favoring more inclusive digitalization, and 2) favoring or accelerating digital innovation in line with the demands of agribusiness. However, the dispersed nature of the instrument implemented in the framework of various policies, by various ministries and administrations, leads to coordination challenges between entities in order to have a coherent and efficient public action for an inclusive digital transition in the agricultural sector.

Concepts and policy orientation and instruments: from the concept of agriculture 4.0 to an inclusive transition

In the policy mixes related to the digital transformation in agriculture, there is a diversity of guiding concepts and targeting of types of farmers. The policies of the digital agendas driven by the telecommunications sector mobilize concepts of the digital divide and inclusiveness of connectivity. This inclusiveness can take the form of a recognized constitutional right (as in Mexico) or be underlying policies and strategic frameworks. In terms of policies and initiatives more directly linked to the agricultural sector, various terminologies are used, such as Digital Agriculture and Agriculture 4.0. In the most prominent sectoral policy frameworks, as in the case of Brazil, there is a clear orientation towards models of Agriculture 4.0 and Precision Agriculture, a focus on the agribusiness sector (De Souza and

Bidarra 2022), in line with the criticisms mentioned in the international literature (see Section 1 and 2).

However, it is worth noting that programs have already been developed in many countries in the region with an inclusive digital transformation approach targeting family or small producers, or lagging rural territories. This can be exemplified by initiatives such as: i) AgTic in Uruguay (Bianco and Sierra, Chap. 8), ii) several projects promoted by INTA in Argentina, with a focus on small producers (Morales et al., Chap. 5), such as the "Supply, commercialization and consumption of goods and services products of Indigenous Peasant Family Farming" project, or, iii) the support programs for Small and Medium Entreprises (SME) or cooperatives, such as "Digitalize your SME" or "digital kit", in Chile (Sotomayor et al, Chap. 6).

4.3. Digital transformation of the State and digitalization of policy instruments

Digital transformation is not only a new issue for public policy, but also affects public policy itself through the process of using and mobilizing digital technologies in the various stages of policy processes (Craglia et al. 2020). This process of digitalization of public policies is observed in all countries of the region, with varying degrees of progress and forms. In fact, in most countries of the region, this process is framed in digital government, open government or e-government strategies (OECD et al. 2024). These strategies propose digitalizing administrative processes and facilitating access to public data in a logic of transparency (Ávila 2022). Although these strategies are not specific to the agricultural sector, they already affect the administrations of this sector.

As far as agricultural sector policies are concerned, the studies presented in this book, and in particular in part 2, provide evidence of general trends.

The digitalization of policy tools concerning the agricultural sector in the region is taking place in line with a process of digitization that began in the 1990s with the availability of computers, and is materializing in the information tools, in particular the information and monitoring systems established by the administrations of the Ministries of Agriculture and their institutions. Thus, in all the countries of the region, the studies reveal a wide range of agricultural information systems, production and market statistics (cf. in particular the cases of Chile, Chap. 6, Uruguay, Chap. 8, and Mexico, Chap. 9). These systems provide generic information freely accessible to all agricultural producers and actors.

There are also instruments with more specific purposes that allow the integration of information generated by producers and actors, and/or provide information profiled according to the users. A first example is veterinary monitoring systems, such as the National Livestock Information System (SNIG) in Uruguay (Núñez and Sequeira, Chap. 13). This digitalized system allows accurate, real-time monitoring of livestock throughout the production and processing chain. Thus, it improves animal traceability and serves to maintain the competitiveness of the sector, while complying with international sanitary standards. Another example is weather or climate information systems, such as the agro-climatic information system in Guatemala (Zapata-Caldas et al., 2024). This system combines climate information with expert knowledge in order to provide information and recommendations according to identified user profiles and their specificities. Another example is the State Information System on Family Farming of Mato Grosso (SEIAF) Brazil (Ávila et al., Chap. 9). This tool, as part of the policy to promote family farming, seeks to collect primary information on family farming for decision-making in the management of support for family farming and its monitoring.

Digitization is not only seen in information systems but also affects the very operationalization of pre-existing sectoral policy instruments, drastically changing their scopes. In this book, this process is observed in two examples of policy instruments, the first one concerning agricultural marketing and finance policy (Desconsi et al, Chap. 12) and the second one concerning environmental regulation policy (Kato et al., Chap. 11). Thus, the new *Cédula de Produto Rural (CPR) in Brazil is an* example of a tool initially created to facilitate contractual relations in commodity trade, and which evolved as a tool facilitating agricultural financing. The CPR is a document that attests to an obligation to deliver rural products, which makes it possible to constitute a financial guarantee to obtain credit for producers. The digitalization of the CPR - initially physical - together with its standardization, has streamlined its use, broadened its scope and opened up the possibility of raising funds on the market. The rural environmental registry (CAR) is a public electronic registry that collects environmental information on rural properties and land holdings for monitoring, environmental and economic planning and deforestation control purposes. It is mandatory and based on a self-declaration process by the landowner. Digital technologies (digital maps, GPS, Geographic Information System) allow the operationalization of this register. Initially created for environmental regulation purposes, this instrument is increasingly used for land tenure regularization processes.

The studies presented in Part 2 reveal insights into what digitalization of policy instrument enables, in line with the literature on this topic (Ehlers et al. 2021). In particular, they show that digitalization allows for greater efficiency in data collection (thanks to digital capture devices and, in general, self-reporting by the actors themselves) and continuous updating of information (thanks to the digital integration of systems). Moreover, in cases such as SNIG (Núñez and Sequeira, Chap. 13) or SEIAF (Ávila et al., Chap. 10), it shows that digitalization allows the integration of multiple data sources, which provides a more complete view of the agricultural or chain reality and contributes to a more informed and, possibly, more effective public management. The digitalization of policy tools also implies spill-over effects. In the case of the SNIG, initially oriented towards animal health issues, digitalization has facilitated its use as proof of safety for access to international trade and for strategic chain management. In the case of the CPR, digitalization has facilitated access to financing for producers and has generated a network of companies that have developed digital innovations that provide digital services necessary for the management of CPRs. In the case of the CAR, which was initially created to meet environmental objectives, digitalization has facilitated its conversion into a tool that facilitates the land regularization. Also, recently, the potential of this tool to access markets has also been observed as an "environmental and territorial seal" in the face of the environmental and social demands of international markets (the European Union's zero deforestation policy).

Finally, new problems, limiting factors and challenges generated by the digitalization of policy tools are also emerging. A first problem is the **validity of the data**. In fact, in all the information system tools analyzed in this book (except for agro-climatic systems – Zapata-Caldas et al 2024), the information collected is self-declared by the users. Self-declaration in digital format makes it possible to have accurate and reactive information systems, but generates a problem of validity and control of the data, as users can make erroneous declarations. If this problem of validity was not highlighted in the SNIG, SEIAF or CPR studies, it is noticeable in the case of CAR (Kato et al., Chap. 11) where self-declarations lead to several problems, such as the declaration of overlapping properties, and ownership conflicts. A second problem stems from **digital divide**, i.e. lack of connectivity and/or digital skills. This problem is mentioned in the studies on SNIG in Uruguay and SEIAF and CAR in Brazil. While it limits the information available (as in the case of SEIAF), it is particularly problematic in the case of SNIG, where the declaration is mandatory in order to sell livestock, or in the case of CAR, it may result in differentiated access to land tenure and possible land grabbing, aggravating structural inequality in the countryside. In relation to the collection of data through these tools, it is worth highlighting the need to mobilize other tools to encourage actors to provide information, as in the case of SEIAF, where a part of the transfer of the Tax on the Circulation of Goods and Services (ICMS) was conditioned to the municipalities, which implement the information system on family farming. There are also problems of **privacy and data protection management** (e.g. SEIAF case, Avila et al, Chap 10**), limitation of the capacities of professionals and civil servants** to handle the complexity of digital technologies (e.g. SNIG and SEIAF case) or the **lack of investment in storage and processing infrastructures** to handle large amounts of data (SEIAF case).

4.4. Achievements, constraints and recommendations

The analyses presented in this book allow for the identification of achievements, key factors and recommendations for the promotion of an influential digital transition in the agricultural sector in Latin American countries and territories.

Achievements

Three main achievements in terms of the digital transformation in agriculture and accompanying policies were identified.

The first achievement is the improvement in connectivity to internet services in the countries of the region over the last decade. Although the situation varies greatly from country to country (cf. Chap. 1), progress is particularly notable in countries such as Chile (Sotomayor et al., Chap. 6) and Uruguay (Bianco and Sierra, Chap. 8). Thus, there is a trend towards a progressive closing of the digital divide in the countries of the region.

A second achievement is the increase and diversification of the supply of digital innovations available. These digital innovations come from actors outside the region, but are also developed by a network of local actors. We observe the development and strengthening of digital innovation ecosystems that are constituted in the form of hubs or national or sub-national networks (as in Chile, Castrillón et al., 2024). There is also a dynamic development of a network of AgTech start-ups in countries in the region, which in some cases are structured in associations (e.g. AgroTech in Chile). The development of digital innovations covers a wide range of innovations for various types of producers. Alongside this process, local capacities and professionals trained in the use of these technologies are gradually being developed.

A third achievement is the existence of sets of public policies and instruments that address the issue of digital switchover in the region. The main policies are aimed at reducing the digital divide through the development of telecommunication infrastructures and developing the digital skills of lagging populations. But there are also some policies to promote digital innovation and facilitate access to digital innovations. Although most of these policies are recent and do not yet constitute a specific policy field (and are addressed in a diffuse manner by different institutions), there is a trend in certain countries towards the creation of more integrated policies, as in Chile[22].

22 In Chile, it is proposed to move from the "Chile connected without gaps" pillar (focused on coverage, access, use) to the "Digitalized Chile" pillar (digitalization of processes and activities), which proposes progress in seven strategic areas: (i) Enabling digital infrastructure; (ii) Development of digital skills; (iii) Digital rights; (iv) Digitalization of the economy; (v) Digitalization of the state; (vi) Cybersecurity, and; (vii) Governance (Sotomayor et al., Chap. 6).

Finally, systematized information on digitalization processes and policies in the region is beginning to become available thanks, among others, to the digital development observatory[23] led by ECLAC.

Limiting factors

While achievements were evident, at the same time, many limiting factors and obstacles to an inclusive digital transition in the agricultural sector were highlighted. Two categories of limiting factors can be distinguished: those affecting the digital transition in general and those affecting the policies that promote it.

Limiting factors and obstacles to an inclusive digital transition

Turning to elements of the controversies present in the literature of the digitalization of agriculture, the studies presented in this book provide some answers. In particular, in line with Klerkx and Rose (2020), several studies suggest that digital transformation exacerbates inequalities between producers, but also between rural territories (e.g. Mexico, Avila, Chap. 9) and between chain actors (e.g. Mexico, Akaki et al., 2024).

In terms of obstacles, despite improvements in connectivity, rural connectivity continues to limit access to digital innovations for producers, in particular due to the cost of telephone services and the cost of access to equipment (mobile telephony, computers) for poorer households. The limited digital skills of producers are also evident, particularly in the context of the generation gap, as the limited digital capacities of agricultural officials and technicians.

Limiting factors of current policies for digital transition in the agricultural sector

It was also possible to identify some limiting factors of policies or sets of policies for the digital transition in the agricultural sector.

23 Information on ECLAC's digital development observatory process: https://ciapem. org/cepal-lanzo-observatorio-de-desarrollo-digital-para-contribuir-a-la-transformacion-digital-de-america-latina-y-el-caribe/.

- **Data regulation:** Despite developing policies and regulations on data rights in the region, certain countries (e.g. Mexico, Avila, Chap. 9) still lack regulations to govern the use of data generated by apps, drones, sensors and satellite imagery.

- **Resources, action plan, and coordination:** Strategies and policies lack clarity on the implementation plan and available resources (*e.g.* Costa Rica, Saenz et al, Chap. 7). Thus, there is a certain disconnect between the objectives contained in policy documents or policy frameworks, on the one hand, and the actual capacity of the State to implement these policies, on the other. This problem is compounded, in certain cases (*e.g.* Argentina, Morales et al, Chap. 5), by the low efficiency of public administration due to excessive administrative procedures that generate long execution times and thus limit policy implementation. In addition, due to the fragmented nature of the policy mix regarding the digital transformation in agriculture and in the absence of sectoral policies on digital transformation, coordination between policies and the disarticulation between State bureaucracies is a limiting factor of current policies in several countries such as Argentina (Morales et al., Chap. 5) and Costa Rica (Saenz et al., Chap. 7).

- **Continuity between the administrations of different governments and "project" logic:** The promotion of a digital transformation faces a "classic" problem in all policy agendas in the region: the lack of continuity due to changes of government, as illustrated by the cases of Argentina (Morales et al., Chap. 5), Mexico (Ávila, Chap. 9) and Chile (Sotomayor et al., Chap 6). Added to this problem is the fact that, in many countries, government initiatives for digital transformation are linked to project resources dependent on external funding from regional or international cooperation. This "project" logic in policy implementation aggravates the continuity of public action and coordination problems.

Policy recommendations

These cross-cutting findings allow for the formulation of recommendations to foster a public policy environment favorable to an inclusive digital transformation of agricultural in Latin America.

- **Prioritize the improvement of communication infrastructure and digital literacy in lagging rural territories.** With a persistent digital divide between rural territories and populations, there is a need to continue prioritizing the improvement of basic telecommunication infrastructure, as well as digital literacy for rural population, particularly in isolated rural territories.

- **Strengthen the curricula of professionals in the management of digital technology for the agricultural sector.** Academic and vocational training is key to the development and management of digital innovations for the agricultural sector. Many professionals in the sector are still poorly trained in these emerging technologies. The development of specialized courses and curricula is recommended. Digital skills should be promoted in countries' vocational and academic training institutions.

- **Conceptualize digitalization as part of a broader approach to rural development.** The conceptualization of the digital transformation in agriculture is still very much associated with the agriculture 4.0 model and precision agriculture in Latin America. However, digital transformation underway in the sector is multiple and multifaceted. The conceptualizations of public policies to accompany the digital transition in agriculture must therefore take into account this diversity of processes. This conceptualization should include principles of responsible innovations (Gardeazabal, Chap. 4), consider the development of sustainable and scalable "territorial digital ecosystems" (González et al., Chap. 3) and pay attention to the needs and constraints of different categories of farmers.

- **Strengthen regulation and data exchange regulations.** In many countries there is still a lack of legal clarity on data ownership rights. In addition, there is a lack of regulations on the capture, dissemination and transparency of data management, as well as on the use of digital equipment. This leads to the definition of national or even regional frameworks to regulate activities around data and to facilitate data exchanges in an efficient and ethical way.

- **Develop national agendas for the agricultural sector focused on digitalization.** Policies affecting digital transition processes are multiple and developed in various policy fields, but there is no integration of digitization in the form of sectoral policies that clarify objectives and provide means to move towards an inclusive digital transition. The formulation (and implementation) of such sectoral policy frameworks would allow for the integration of different aspects, such as connectivity infrastructure, digital capacity building or support for digital innovations in the sector. These sectoral agendas could facilitate more effective coordination between government entities, ensuring coherent and successful implementation of policy instruments affecting the digital transformation in agriculture and livestock sector. In the absence of such an integrated agenda and policies at the sectoral level, multi-sectoral coordination mechanisms or multi-stakeholder interfaces would be necessary in order to improve coordination between initiatives of different administrations.

Conclusion

The digital transformation in Latin America's agricultural sector has accelerated since the COVID-19 crisis. It has the potential to revolutionize many aspects of agri-food systems, such as production practices, access to and management of productive resources, agricultural extension and product marketing. Digital transformation also has the potential to transform the way agricultural policies are designed and implemented. But while digital transformation offers many opportunities to address the challenges facing agriculture in Latin America, it also presents various risks, particularly in terms of widening the gap between family farmers and agribusiness.

This book provides an overview of the dynamics of digital transformation in the Latin American agricultural sector and reveals the current advances and limitations of digitalization in this sector, as well as the policies involved in this digital transformation in several countries in the region.

Although digital divides are narrowing, asymmetries in access to digital technologies between countries, territories and producers remain. Thus, the lack of quality internet service coverage and/or the cost of access continues to limit the adoption of digital solutions in rural areas and by producers in lagging areas. Where the internet does reach, there are contrasting dynamics between types of agriculture. Family or small-scale producers tend to mobilize more digital communication tools, such as social networks, for dissemination and exchange of technical or market information. Agribusiness players tend to mobilize more complex digital solutions that include systems that integrate sensor technology, complex information processing, in line with agriculture 4.0 and precision farming models. These systems are combined with automation and robotization processes with the aim of increasing productivity, but reducing the demand for farm labor.

It is clear that the driving forces of digitalization continue to be mainly driven by private, international or national companies, as well as international or national research centers and universities in the region. These local digital innovation ecosystems generate digital innovations for the sector's players. However, the degree of development of these ecosystems is very uneven across countries of Latin America.

Authors also identify the existence of public policies in the countries of the region involved in digital transformation of agriculture, particularly with the aim of improving rural connectivity. Although these policies have improved the connectivity, they have not succeeded in eradicating digital divides in the countries, which would also require training programs or facilitating access to communication infrastructure and equipment in more remote areas. In general, policies and public initiatives are still scarce or lack resources. Thus, situations prevail with a set of public initiatives that are developed without a general guiding and specific framework for the agricultural sector that may facilitate sufficient effective coordination mechanisms.

Beyond some digital government initiatives, based on facilitating access to public data and relations between citizens and public administrations, the digital transformation of policies is mostly observed as processes of digitalization of policy instruments. Noticeable are the cases of digitalization of monitoring tools, which make it possible to improve information for decision-making by actors in the sector (producers, and other actors of value chains) or the traceability of agricultural products, and the process of digitalization of financial or environmental policy instruments. However, this process tends to affect the equity of opportunities among actors and is potentially aggravating structural inequalities.

It is worth highlighting some of the limitations of this book. The first is the scant literature available on the issue of digitalization of agriculture in Latin America. Although this situation motivated the publication of this book, it also limits the references available to discuss the results and the sources of secondary information that can be mobilized to analyze the processes and dynamics underway. The second limitation stems from the recent nature of digital transformation and especially from the policies related to it. This situation creates methodological challenges and limits the ability to conclude on a rapidly evolving process, in particular, on the real impact of this transformation at the level of producers and the impact of the current policies and instruments.

Despite the authors' desire to be as comprehensive and all-encompassing as possible, there are some issues that could not be covered, and this offers some initial ideas for strengthening future research agendas. Despite our willingness to consider the different functions of the agri-food system, the specific topic of digital innovations for marketing and market access, which is nevertheless an important area, particularly for family farmers (Niederle et al. 2021), was not explored in any depth. We also did not delve into the development of digital financial services (with the exception of chapter 12, by Desconsi), which would deserve more attention because of the great potential observed in other regions of the world (Cao and Wang 2024). While we were able to cover the challenges related to the implementation of the digitalization of policy instruments aimed at the agricultural sector, we did not manage to integrate studies that consider the implications of digital transformation in all the different phases of the policy cycle, and in particular agenda-setting, formulation and decision-making. In this sense, it would be interesting to analyze: 1) the role of digital innovations in the representation of interests and their appropriation by social movements in the agricultural sector; 2) the role of the digital transformation in agenda setting and identification of public problems where digital innovations are mobilized to generate citizen information and research.

Finally, the findings presented in this book open up new avenues for research. First, given the diversity of digital transformation dynamics observed, there is a need for a more systematic and thorough characterization of the various *digital transformations*' pathways for Latin American agriculture. Second, there is a need for more systematic analyses of the reconfigurations of actor networks, both in agricultural innovation systems and in the construction and implementation of policies in a context where large tech companies are entering the agricultural sector (Birner et al. 2021). In the face of these re-configurations, new alliances and collaborations in innovation ecosystems and new investment flows would need to be further analyzed. A third theme, which is partially addressed in this book but deserves to be strengthened, concerns the distributional effects of digital transformation, characterizing who wins and who loses in digital transformation processes, conducting territorial and producers' sensitive approach. A fourth theme is the analysis of the policy processes, looking at the interplay of actors and coalitions in the construction of digital agendas concerning the agricultural sector, and a research theme concerns the in-depth analysis of the existing combinations of instruments in the countries, their interactions and their coherence and effectiveness. Therefore, more studies are needed to understand the effects of digitalization on the capacities of Latin American States, on the capacity of digitalization to foster participatory and adaptive governance and to change the relations between governments and citizens (Vesnic-Alujevic 2021).

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1 Digitalization of the Agricultural Sector in Latin America and the Caribbean: Gaps and Public Policies

Monica Rodrigues, Andrés Mondaini

1. Introduction

Digital agriculture is a powerful force for achieving positive change in food systems in Latin America and the Caribbean (LAC) as well as globally. Digital technologies are reshaping traditional agricultural practices and fostering sustainability in food production, with impacts across the 2030 Agenda for Sustainable Development. Indeed:

- The integration of digital tools such as Artificial Intelligence (AI), the Internet of Things (IoT) and big data analytics into agricultural operations, especially when these technologies are combined, opens up new possibilities for improving efficiency, productivity and environmental management in food systems.

- Through real-time data collection and analysis, farmers can make informed decisions on crop management, irrigation and pest control, resulting in optimized use of resources and higher yields. For example, precision irrigation (optimized in time and space based on soil moisture sensors, weather forecasts and mathematical models) allows for savings of up to 60% of water use in different production systems (ECLAC, FAO and IICA, 2021).

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- Precision agriculture facilitates the targeted application of inputs such as fertilizers and pesticides, minimizing waste and environmental contamination. In Argentina, for instance, targeted herbicide sprays based on optical sensors, actuators and software enabled savings of up to 80% in the use of herbicides on wheat and soybean crops (ECLAC, FAO and IICA, 2021).

- Food systems are currently facing major challenges, not least of which is the need to increase productivity to meet the growing demand for food, while responding effectively to the climate crisis. Food production must also adapt to geopolitical shifts that increase price volatility, constrain input availability, and raise production costs. Data-driven knowledge can play a central role in addressing these challenges:

- By harnessing vast amounts of data generated from sensors, drones and satellite imagery, farmers can gain valuable information on crop health, soil conditions and weather patterns, enabling proactive decision-making and risk mitigation.

- Predictive analytics enable farmers to anticipate market trends, optimize supply chains, and adapt to changes in global supply chains and consumer preferences.

- Although this scenario is promising, it is important to recognize that several barriers hinder the widespread adoption of digital technologies in food systems: limited access to technology, low levels of digital literacy, and concerns over privacy and data security continue to pose major challenges. In the case of access, we highlight the high initial investment cost and a long payback period in many cases, especially for rural households dependent on small-scale agriculture. In the case of selective spraying technologies, the payback period significantly decreases as the cultivated area increases (Bilbao et al., 2022).

- Disparities in infrastructure and connectivity exacerbate existing inequalities, particularly in territories lagging before others. Studies and indicators reveal widening technological gaps between high-income commercial producers and smallholder farmers (Cortés et al., 2020; León and Meza, 2020 and Cruz Moreno and Aedo, 2021, among others). In this scenario, there is a risk for family farming, and for the most vulnerable sectors, such as rural women, of being left behind or even excluded from the adoption of new technologies.

Although the region has seen dynamic technological development in agriculture, evidenced by the creation of thousands of Agtech[1] startups in recent years (Dias, Jardim, and Sakuda, 2019), policies and incentives for the creation and adoption of these technologies among the most vulnerable segments remain scattered and insufficient (Buainain, Cavalcante, and Consoline, 2021). This compromises not only the development of the region's productive potential but also the possibilities of generating a fairer economy and a more equitable society.

Levels of access to and use of digital technologies in agriculture in countries of the region remain low. Between 2020 and 2022, among eight countries with available data, only one reported that computer access in farming households exceeded 50%, and in three of them it was below 20%. These values are even lower when analyzing the use of computers (Digital Agriculture Observatory, 2024).

Improving access to and use of digital technologies in agriculture requires strengthening basic infrastructure - e.g. electricity and internet services, which are still lacking in a large proportion of farm households in some countries (see Section 2 of this chapter) - and in training in order to reduce second-level gaps, which refer to digital literacy (Van Deursen and Van Dijk, 2014).

Public policies are essential to ensure that the benefits of digital agriculture are accessible to all stakeholders, including family farmers and marginalized communities. In this context, this chapter aims to contribute to the discussion by analyzing the main gaps that limit inclusive digital

1 The term Agtech comes from the fusion of the words agriculture and technology and refers to the sector that provides knowledge-based services or technologies based on the digitalization of the various links in the agri-food chain. The spectrum of services and technologies included in this sector is broad. Examples include field management software, weather sensors and food trading on online platforms, among others.

development in agriculture, as well as current policies aimed at reducing these gaps.

The chapter is structured as follows: section 1 provides a brief overview and classification of digital technologies for agriculture; section 2 updates the information on the main gaps that limit the development of digital agriculture in LAC; and section 3 analyzes the state of digitalization policies for the agricultural sector in the region.

2. Digital technologies for agriculture

Digitalization is reshaping economies and societies both regionally and globally. While sectors such as financial services and information and communication technologies (ICT) are among the most advanced, others –such as agriculture – lag behind in this transformation. Despite this, digitalization provides opportunities for cross-sectoral integration and fosters technological progress even in less developed sectors. In LAC, in addition to intersectoral disparities, there are also significant inequalities in the adoption of digital technologies within sectors, depending on the size of production units. Adoption levels are notably lower among micro and small-scale units compared to larger ones.

The transition toward a digitalized economy involves value creation through digitalization, both within and across sectors. Firms are integrating digital technologies throughout their operations, giving rise to new products and business models, such as e-commerce. Key actors in the digital ecosystem include firms that facilitate digitalization across sectors, such as providers of software and telecommunications, as well as technology-based companies and digital platforms, which have emerged because of the increased presence of digital technologies in societies.

In food systems, digital technologies are significantly enhancing productivity and sustainability by improving data collection, analysis and automation (ECLAC, 2021 and Startups Latam, 2022). Recent advances in the use of digital data in agriculture and across food systems are aligned with current global challenges, particularly the need to improve productivity and sustainability of food production in a context of limited resources.

Moreover, these advances have significantly improved the accessibility, speed of generation and cost-efficiency of data relevant to agricultural policies. The generation and use of digital data for agricultural policy design, piloting and monitoring represent a high potential area for development in LAC.

The Council on Digital Government Strategies of the Organization for Economic Co-operation and Development (OECD) defines digital technologies as a range of information and communications technologies (ICTs), internet, mobile technology and data analytics (OECD, 2019). In agriculture, the OECD identifies various emerging technologies that are transforming production models, patterns of the interaction of stakeholders, and approaches to innovation and public policy implementation. One possible classification of these technologies – relevant for analyzing digitalization policies – is presented in Table 1.

Table 1. Digital technologies for food and agriculture

Purpose of the technology	Category	Subcategory
Data collection technologies	Remote sensors	• Satellite data acquisition or monitoring systems
		• Drone-mounted monitoring or data acquisition systems
		• Systems for data tracking/acquisition from manned aircraft
	On-site detection	• Water volume measurement devices
		• Water quality sensors; air quality sensors
		• On-site weather sensors
		• In situ soil monitors
		• *In situ* biodiversity, invasive species, or pest monitoring
		• Crop monitors
		• Livestock monitors
		• Precision agriculture machinery data
	Data collection through collective collaboration (crowdsourcing)	• Serious games for collecting agri-environmental data
		• Citizen science
	Online surveys/ censuses	• Data collection portals (e.g., online census)
	Financial and market data collection	• Retail scanner data
		• Business software for recording financial or market information (e.g., database entry systems)

Purpose of the technology	**Category**	**Subcategory**
Technologies for data analysis	GIS and sensor-based analytical tools	• Digital elevation modelling
		• Land use and land cover mapping
		• Watershed modelling
		• Soil mapping
		• Landscape modelling
		• Software (programs, applications) for translating sensors and other agricultural data into actionable information
		• Software for automating agricultural machinery that uses sensors or other agricultural data as input.
		• Software for measuring and classifying agricultural production (e.g, channel classification software)
	Crowdsourcing data	• Crowdsourcing applications for data classification/ labelling
	Artificial intelligence	• Data cleaning algorithms
		• Big data analytics algorithms
		• Machine learning
		• Predictive analytics
Data storage technologies	Secure and accessible data storage	• Cloud storage
		• Confidential Computing
		• Virtual data centers
Data management technologies	Data management technologies	• Distributed ledger technologies (e.g., blockchain)
		• Interoperability programs and applications
Technologies for data transfer and exchange	Technologies for digital communication	• Digital data visualization technologies.
		• Social media
		• Web-based videoconferencing
		• Machine-assisted communication (e.g., chatbots, natural language generation algorithms)
	Online platforms	• Online registries of property rights and permits
		• Online trading platforms
		• Platform-based crowdfunding for agriculture and agroecosystem services
		• Online payment platforms
		• Service delivery platforms

Source: Adapted from OECD (2019).

3. Gaps in access to and use of digital technologies

The digitalization of food systems is an evolving phenomenon in LAC, marked by substantial growth in household internet access across the region. From an average of 20% in 2010, internet penetration reached 67% in 2022, revealing a significant increase in digital connectivity. However, these regional figures hide considerable disparities between countries, ranging from a high of 95% of households with internet access in Chile to a low 33% in El Salvador in the most recent year recorded (Digital Development Observatory, 2024).

This regional growth has been driven primarily by the expansion of high-speed mobile internet, which increased from 50% to 96% over a twelve-year period. Although high-speed fixed internet more than doubled its reach (from 6.6% to 17.2% in the same period), it remains accessible to relatively few households.

In both cases, there remains a gap of around 20 percentage points compared to penetration rates in the European Union (Digital Development Observatory, 2024). The predominance of mobile internet in the region has implications for productive development, as mobile connections are often limited in their use for production-related tasks. This is particularly true in a sector such as agriculture, which is developed in large, isolated areas and with considerable limitations in the quality of the connection.

The digitalization of households and society has led to a partially spontaneous digital transformation of food systems. This, however, carries the risk of amplifying pre-existing gaps in income and access to public resources, as discussed below.

Electricity

Reliable electricity is a basic intermediate resource for the use of digital technology. In some LAC countries, such as Guatemala and large areas of Brazil, limited access to electricity can pose a significant barrier to the digitalization of agriculture, an issue that is much less prominent in countries like Uruguay and Chile (Sotomayor et al., 2021).

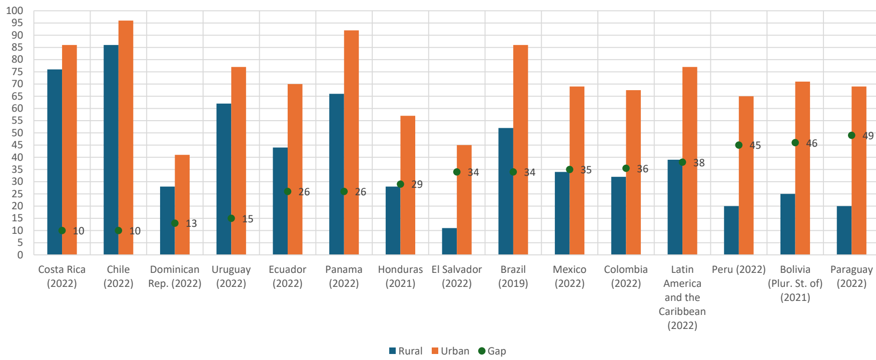
Electricity supply also varies by type of rural producer and geographic location. In Guatemala, 88.1% of households have access to the electricity grid; however, the indicator drops to 75.7% when focusing only on households whose main activity is agriculture. The department of Alta Verapaz has the lowest electrification rate among agricultural households, at only 33.6%. In Brazil, nearly 84% of farms had electricity according to the 2017 agricultural census. Among family farmers, access to electricity drops to 70.3% in the North of the country but rises to 92.2% in the South (Sotomayor et al., 2021).

Internet access

Internet access – along with service cost and quality, particularly the differences between urban and rural areas and among income levels – is one of the key indicators for measuring the barriers to digital technology adoption in the agricultural sector. According to the Economic Commission for Latin America and the Caribbean (ECLAC), in 2022 around 77% of LAC households had internet connection, but in rural areas only 39% had connectivity. In some countries (Bolivia, El Salvador, Paraguay and Peru), fewer than 25% of rural households had internet access (Digital Development Observatory, 2024).

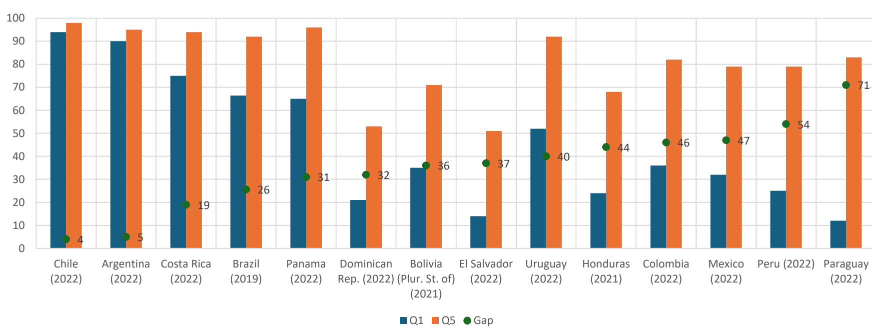
The gap in internet access between urban and rural households can reach almost 50 percent in some countries (Figure 1). Even in countries with high national averages, such as Chile, Costa Rica and Uruguay, disparities in internet access between urban and rural areas persist. The gap becomes even more pronounced when comparing internet access across income quintiles, reaching alarming differences of up to 71 percentage points in Paraguay, 54 percentage points in Peru and 46 percentage points in Mexico (Figure 2). These inequities are strongly linked to the high cost of digital connectivity in LAC, which excludes a significant part of the population from the benefits of the digital age (see next section).

Figure 1. Latin America and the Caribbean (14 countries): Households with Internet access, urban and rural areas (%) and gap (percentage points)



Source: Own elaboration based on ECLAC, Digital Development Observatory (https://desarrollodigital.cepal.org/en).

Figure 2. Latin America and the Caribbean (14 countries): Households with Internet access by income quintiles (%) and gap (percentage points)

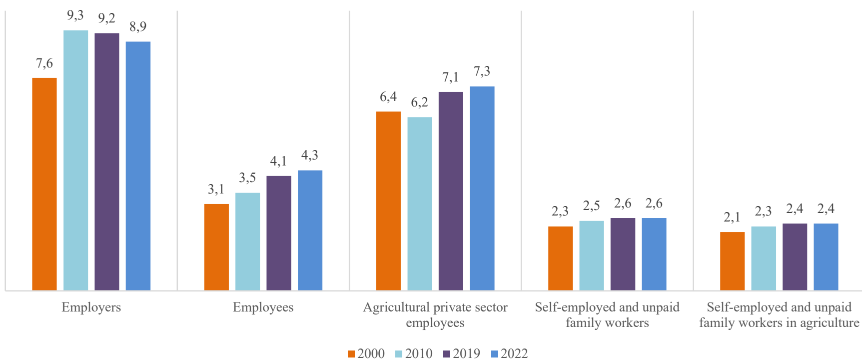


Source: Own elaboration based on ECLAC, Digital Development Observatory (https://desarrollodigital.cepal.org/en).

Rural areas are not homogeneous entities, they have their own internal disparities, which are also reflected in the digitalization process of the agricultural sector. Family farmers, for example, face specific challenges due to their incomes being approximately 30% lower than those of the overall employed population in rural areas of LAC (Figure 3). This trend is also reflected in lower internet access among family farming households:

households headed by family farmers show even lower levels of connectivity compared to rural areas (Figure 4).

Figure 3. Latin America and the Caribbean (14 countries): Average income of employed people in rural areas, in multiples of the poverty line



Source: Own elaboration based on data from CEPALSTAT.

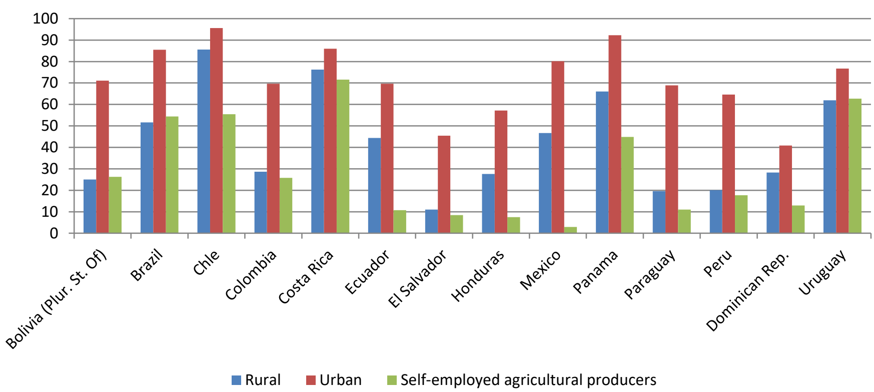
Some countries have specific information – derived from agricultural censuses or surveys – on access to and use of the internet on farms. These data reveal significant disparities within the agricultural sector of each country. In Brazil, Argentina and Mexico, there are substantial gaps in the use of the internet on farms (Figure 5).

For example, although the national average in Argentina shows that 34% of agricultural holdings use the internet, in the province of Santa Cruz that figure rises to 68%, while in Jujuy it drops to just 5.6% (Sotomayor et al., 2021). The location of farms matters as it is closely linked to connectivity infrastructure and the economic opportunities available to the agricultural sector. Location is closely linked to factors such as household income, connectivity infrastructure, access to digital devices, and levels of digital literacy.

Regarding the type of connection, what distinguishes farms is their predominant reliance on mobile connectivity. This holds true at different levels of the development of the infrastructure of telecommunications (Digital Development Observatory, 2024).

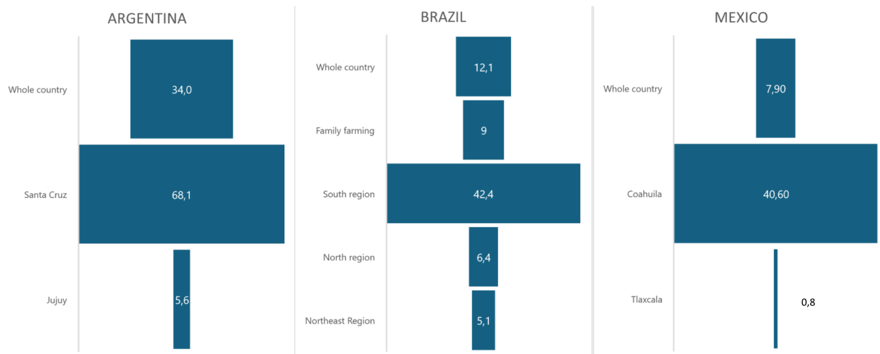
A promising tool to address the existing gaps in internet access and use is the digital basket (CBD, by its Spanish acronym), a set of information and communication technologies designed to guarantee and universalize digital connectivity. It can serve as a central tool in demand-side subsidy policies to improve effective connectivity. The CBD comprises a laptop, a smartphone and a tablet, along with fixed and mobile broadband services, as an alternative to provide effective connectivity to households that cannot otherwise access these services, as well as digital literacy components. In ECLAC's proposal, in addition to addressing access barriers, the CBD also considers digital literacy, including content aimed at developing users' basic digital skills (Digital Development Observatory, 2023). This initiative underscores the need for integrated approaches that combine infrastructure development with measures that promote the effective and equitable use of digital technologies in rural areas.

Figure 4. Latin America and the Caribbean (14 countries): Households with internet access, by geographical area and main activity. Year 2022 or latest available year



Source: Own elaboration based on ECLAC, Digital Agriculture Observatory (https://agriculturadigital.cepal.org/en). Economic Commission for Latin America and the Caribbean. (2022). A digital path for the sustainable development of Latin America and the Caribbean. Santiago: Economic Commission for Latin America and the Caribbean (ECLAC).

Figure 5. Internet use on farms in Argentina, Brazil and Mexico (2021)



Source: Own elaboration based on Sotomayor et al. 2021.

Cost of internet services

Regarding the cost of internet access, the reference threshold recommended by the Broadband Commission for Sustainable Development to classify the service as affordable is less than 2% of gross monthly per capita income (ITU, 2018). According to ECLAC data (2021), in LAC countries, the average cost remains quite high, at 12% and 14% (for mobile and fixed broadband, respectively) of the income of the population in quintile I. In no country in the region are these costs below the recommended threshold for income quintile I, and only in Uruguay does the cost of mobile broadband represent less than 2% of the income of the population in quintile II. Chile and Costa Rica follow as the countries with the lowest costs of broadband access as a percentage of income.

Digital literacy

While increased internet coverage is directly related to GDP growth (Patiño and Rovira, 2021), higher connectivity levels do not automatically translate into a contribution to national growth and development. This would require the development of specific digital skills in the population to take advantage of these technologies.

Digital literacy – defined as the ability to use information and communication technologies (ICTs), is a key factor that determines how users engage with the internet once they gain access. This type of literacy requires basic conditions such as low levels of functional illiteracy and a certain minimum level of education, which are more difficult to find among the older population and in rural areas.

Low internet use is directly linked to a lack of knowledge about how to use it or its perceived usefulness, sometimes at a level equivalent to infrastructure restrictions. In Mexico, for example, 14.8 % of rural households reported the lack of providers or infrastructure in their area as the reason for not using the internet, while 13.1 % pointed to a lack of interest or perceived need, and 12% stated their lack of knowledge on how to use it as their reason for not having internet. Consistent with this, among the main reasons why individuals in Mexico did not use the internet in 2018, the following were reported: 1) lack of knowledge on how to use it (60.7%); 2) the perception that it was not needed (14.4%); and (3) other reasons (24.9%). These data highlight the need to expand digital literacy services, particularly among the adult population (Cruz and Aedo, 2021).

Within-country inequalities in basic and general ICT skills are closely related to historical patterns of economic inequality. The rural-urban socio-economic divide in the countries of the region tends to be mirrored in terms of the digital skills of the population. For this reason, it is important not only to include rural areas in digital literacy and training programs, but also to address specific limitations faced by rural populations, such as isolation, higher incidence of poverty and lower levels of education.

Composite indices: ICT Development Index (IDI) and Rural Significant Connectivity Index (RSCI)

To enable cross-country comparison, several indicators have been developed that combine connectivity with aspects such as internet usage, digital literacy and skills, access to devices and quality of connection.

One such indicator is the International Telecommunication Union's (ITU) ICT Development Index (IDI), which serves as a global benchmark for assessing the state of ICTs across countries. In its 2023 version, IDI comprises 11 indicators grouped into three main sub-indices: access, usage and skills. Access is measured through indicators such as fixed and mobile broadband subscriptions, while usage includes metrics such as internet usage and e-commerce activity. Skills are assessed based on indicators related to education and digital literacy. Each indicator is normalized and weighted to ensure a balanced assessment of ICT development (ITU, 2023).

In general, while some LAC countries such as the Bahamas, Chile, and Uruguay perform well in the IDI, disparities persist across the region. Thus, while these three countries rank 32nd, 40th, and 49th, respectively, out of 169 economies on the IDI, Honduras, Nicaragua, Cuba and Guatemala rank between 133rd and 136th in the global index. The average IDI score for the 30 LAC countries with available data is 73.7, compared to a level of 96.6 in the United States and 88.4 on average in Europe. Among the IDI components, LAC has performed better in the significant connectivity pillar – which includes indicators related to the speed and quality connections and their cost – than in the universal connectivity pillar, which includes indicators more closely linked to service coverage (ITU, 2023).

Another relevant indicator – particularly because it focuses on rural areas – is the Rural Significant Connectivity Index (RSCI), developed by IICA, the IDB, and Microsoft (2020). The RSCI is based on the four dimensions of significant connectivity, which are: (1) regular internet use; (2) access to an appropriate device; (3) sufficient and consistent data availability, and (4) adequate connection speed. For each of these dimensions, the index incorporates specific indicators such as: percentage of the population with daily internet use (dimension 1); average percentage of the population with access to smartphones and individuals with access to a personal computer, laptop or tablet (dimension 2); percentage of the population with access to fixed broadband (dimension 3); and percentage of the population with 4G technology coverage (dimension 4) (Ziegler, Arias Segura, Bosio, and Camacho, 2020).

The RSCI was directly estimated for seven countries in the region (Bolivia, Brazil, Costa Rica, Ecuador, Honduras, Paraguay and Peru) and reveals that an alarming percentage – 63%, or 75% if Brazil is excluded – of the rural population in these countries lack access to quality connectivity. When this percentage is extrapolated to the rural population of the entire LAC region, it amounts to more than 77 million people without access to quality connectivity services. The main reasons for the low score of the RSCI in countries of the region are the low frequency of use and the limited penetration of broadband services (Ziegler, Arias Segura, Bosio, and Camacho, 2020).

4. Policies for the Digitalization of Agriculture

The differences in infrastructure and access to connectivity discussed in the previous section, as well as the disparities in terms of digital literacy, pose significant challenges to the effective adoption and productive use of digital technologies in the agricultural sector of LAC.

Against this backdrop, it is crucial to design and implement policies and actions that recognize and address these disparities and promote the digitalization of food systems in an equitable and inclusive way. Such policies must proactively tackle existing gaps, preventing territorial and income inequalities from being perpetuated in the digital realm. Furthermore, it is crucial to coordinate efforts among different stakeholders and sectors in order to maximize the impact of these initiatives.

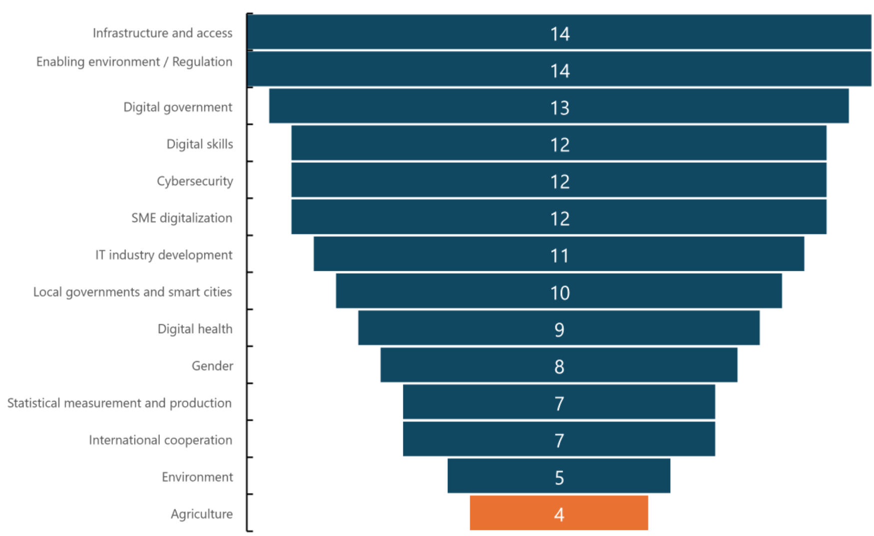
In this sense, digital agendas play a crucial role, although they currently have limited scope in promoting agricultural digitalization in LAC. Fewer than half of LAC countries have an implemented and operational national digital agenda (ECLAC, 2022 and Digital Development Observatory, 2024) and only Brazil currently has a digital agenda dedicated to the agricultural sector. It is essential that regional governments expand efforts in this area, recognizing the strategic importance of agriculture and its potential to drive not only digital transformation, but also sustainable development and economic prosperity across the region.

The instruments that guide policies to drive digital transformation are mainly divided into four types (Patiño and Rovira, 2021): (i) chapters or sections within national development plans that address the digital domain; (ii) national digital agendas or ICT strategies, which establish strategic objectives in the digital domain; (iii) sectoral plans, which define actions to promote the adoption of digital technologies in specific sectors, including agriculture; and (iv) digital plans driven by sub-national governments. The following section analyzes the role of digital agendas and other initiatives for the digitalization of agriculture in LAC countries.

Digital agendas

In the region, 14 countries have been identified as currently having a national digital agenda (Digital Development Observatory, 2024). These instruments typically address areas such as infrastructure, digital skills and regulation. However, they pay less attention to issues such as the gender gap, environmental protection and the adoption of digital technologies in specific sectors. Only four countries in the region (Brazil, Costa Rica, Panama and Cuba) have actions aimed at the digital transformation of agriculture in their digital agendas (Figure 6). Among them, only Brazil has a specific agenda for the agricultural sector.

Figure 6. Latin America and the Caribbean (13 countries): Policy measures by topic included in national digital agendas (number of countries)



Source: Patiño and Rovira (2021).

Despite the existence of strategic frameworks, most digital agendas lack concrete roadmaps, clearly assigned responsibilities, and defined budgets. This limits the effectiveness of these instruments in driving real change in the digital domain, particularly in a complex sector such as agriculture. Moreover, there is a significant lack of development in critical areas such as education and the adoption of emerging technologies, highlighting insufficient attention to these fundamental aspects. Considering the previously identified digital divides in rural areas and in the agricultural sector, as well as the challenges facing regional food systems - including the need to increase productivity and respond effectively to the climate crisis – these shortcomings must be addressed through targeted actions within digital agendas.

Although there are agricultural digitalization efforts that operate independently of national digital agendas, it is imperative to integrate them into these agendas because of the importance of the so-called enablers: connectivity infrastructure, data governance, and regulatory framework. To maximize the value of digital technologies in the agricultural sector, it is essential to ensure adequate access to these enablers. In addition, a wide range of services is required for data collection, storage and analysis, such as sensors, cloud platforms and data processing software, as well as a regulatory environment that encourages innovation and adoption of technologies in agriculture.

The development and implementation of these elements often fall under the responsibility of public institutions beyond ministries of agriculture. Therefore, the need for effective coordination among various government entities becomes evident in order to ensure the coherent and successful integration of agricultural digitalization initiatives within national digital agendas.

Digitalization Policies in the Agricultural Sector

To analyze policies for the digitalization of agriculture not necessarily linked to digital agendas, a review and classification exercise was carried out using the FAOLEX (2024) database for LAC countries covering 2018 to 2023. FAOLEX is a legislative and policy database that provides access to national laws, regulations and policies related to food, agriculture and natural resource management from countries around the world.

FAOLEX has registered 3,662 agricultural laws, policies and regulations for LAC countries during the analyzed period. Of these, 4.2% refer to digital agriculture. Within this percentage, only 23.5% (equivalent to 0.98% of the total) contemplate specific implementation plans for digital agriculture and 43.88% (or 1.8% of the total) provide general guidelines, mentioning digitalization as a concept to be considered, but without implementation details. Finally, the remaining 32.7% (1.37% of total agricultural policies) is divided between auxiliary technology, where agricultural digitalization is a secondary component, and referential mentions, where digitalization is cited in relation to other documents (Figure 7).

To analyze the main topics addressed by the policies, cases classified as referential mentions were excluded, since they lack direct impact on policy implementation as they do not exert a direct influence. This left a total of 139 policies that were then thematically classified. The policies were grouped into 6 categories according to their area of action, as described below.

- Advanced Agricultural Technologies and Digital Innovations: agriculture 4.0; precision agriculture; agricultural automation; big data; blockchain; cloud computing; Internet of Things (IoT); machine learning; artificial intelligence.

- Digital Services and Support: online technical assistance; digital technical assistance; online extension; digital extension; parametric insurance.

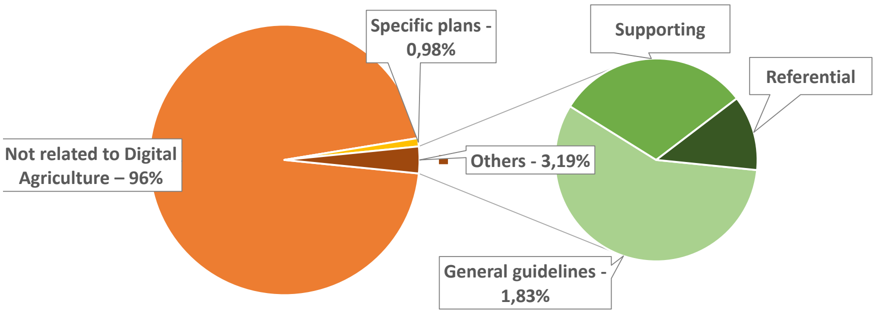
- Platforms and applications: digital platforms; mobile platforms; mobile applications and other applications.

- Monitoring tools: agricultural sensors; remote sensors; drones.

- Climate-smart agriculture.

- Irrigation: precision irrigation; irrigation sensors; smart irrigation; automated irrigation.

Figure 7. Latin America and the Caribbean: Agricultural laws, policies and regulations by type (percentages) 3,662 agricultural laws, policies and regulations in LAC from 2018 to 2023

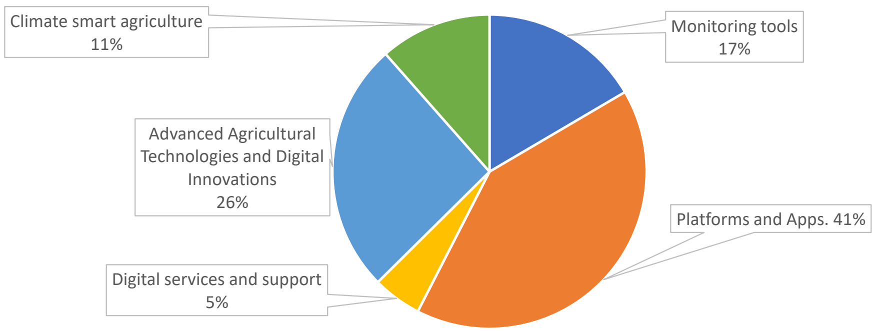


Source: Own elaboration based on ECLAC, Digital Agriculture Observatory, https://agriculturadigital.cepal.org/en/politicas-y-normativa.

Figure 8 presents digitalization policies for agriculture in LAC classified into the six categories described above, providing an overview of the region's prioritized areas. Digital platforms and applications appear as the most common policy focus area, while digital services and support, as well as digital innovations, have a smaller share. In the case of irrigation, no policies were found once those with merely referential mentions of the technology were excluded.

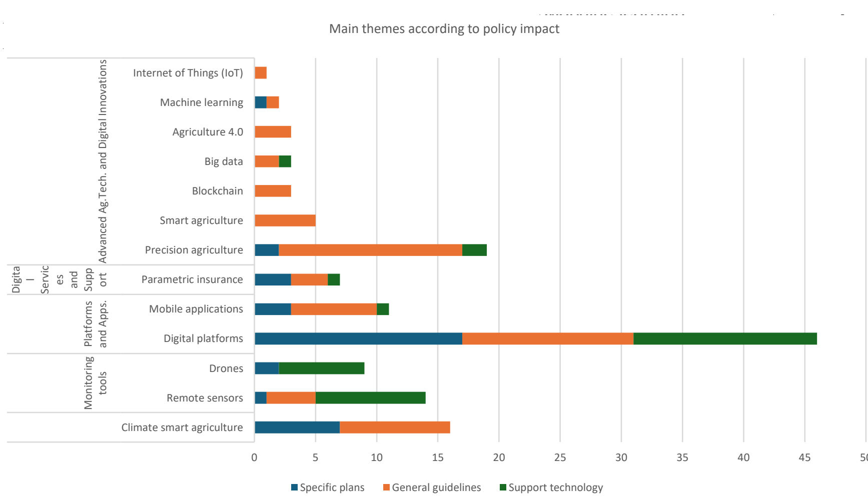
Figure 9 presents the six categories of digitalization policies broken down by subtopics and classified according to the different types of measures. A total of 139 policies are considered, excluding referential mentions and secondary topics, in order to focus on initiatives with greater practical impact. Figure 10 highlights digital platforms and climate-smart agriculture as the areas with the highest number of measures featuring concrete practical applications, whereas drones and remote sensors appear more prominently in measures where digital technology is considered an additional support.

Figure 8. Latin America and the Caribbean: Agricultural digitalization policies by specific topics



Source: Own elaboration based on ECLAC, Digital Agriculture Observatory, https://agriculturadigital.cepal.org/en/politicas-y-normativa.

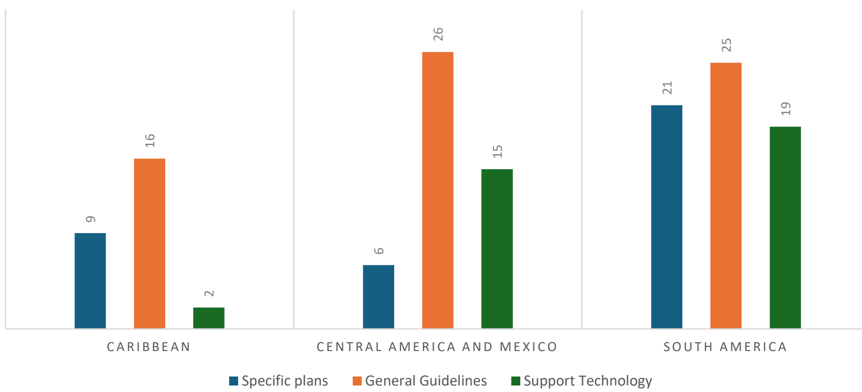
Figure 9. Latin America and the Caribbean: Agricultural digitalization policies by topic and type of measures



Source: Own elaboration based on ECLAC, Digital Agriculture Observatory, https://agriculturadigital.cepal.org/en/politicas-y-normativa

By presenting policies by type of measures and sub-region (Figure 10), it is possible to advance in the understanding of how each sub-region works on digitalization policies. For example, in South America, approximately one-third of the policies are specific, indicating a more targeted and detailed approach. In contrast, Central America and Mexico show a tendency to include digitalization policies within more general plans, with only 13% of specific policies. This difference highlights variations in policy and strategic focus among sub-regions, which is crucial for understanding regional priorities and the depth of digitalization implementation in agriculture.

Figure 10. Latin America and the Caribbean: Agricultural digitalization policies by sub-region



Source: Own elaboration based on ECLAC, Digital Agriculture Observatory, https://agriculturadigital.cepal.org/en/politicas-y-normativa

In summary, the analysis of agricultural digitalization policies in LAC presented in this section offers an initial approximation of government responses to the gaps and challenges outlined in the previous sections. It shows that agricultural digitalization still occupies a minor fraction of the total spectrum of agricultural policies, and the proportion of policies with clearly defined objectives and instruments is even more limited.

By thematic category, current agricultural digitalization policies in the region tend to concentrate on "soft" areas, with a strong focus on digital applications and platforms, while more advanced technologies and technical assistance occupy more marginal positions. This has implications for productive development policies that could be linked to these digitalization initiatives, given that advanced technologies and technical assistance are, in many cases, essential for achieving outcomes such as increased productivity and effective climate action in the agricultural sector.

At the subregional level, there are differences in the scope of policies. While South America has a higher proportion of specific policies, Central America, Mexico and the Caribbean remain at the level of rather general guidelines. Across the region as a whole, the share of policies with clearly defined objectives and activities is limited, highlighting an opportunity for the development of more detailed and concrete policies and instruments in the future.

5. Conclusions

The digitalization of agriculture represents a key transformative force for improving food systems in LAC, as well as globally. This progress not only boosts agricultural productivity but also promotes sustainability in production. However, in most countries of the region, access to and use of digital technologies in agriculture continues to lag behind urban areas and other economic sectors. This lag is attributed to significant limitations and inequalities in infrastructure development, internet connectivity and digital literacy.

Policy makers in the region must prioritize improvements in basic infrastructure and digital literacy to promote access to and adoption of digital technologies in the agricultural sector. While enhancing basic infrastructure is essential for enabling access, it does not necessarily ensure effective use. To achieve this, policies must promote the development of targeted digital competencies among the population. In some cases, lack of knowledge about how to use these technologies – and their potential benefits – represents a barrier as significant as infrastructure limitations. This study identified a lack of coordinated and long-term policies in the region to enable inclusive and effective digitalization of the agricultural sector. Digital agriculture policies currently represent only a small fraction of the broader agricultural policy landscape, and most remain general in nature, lacking specific implementation plans. These gaps hinder efforts to tackle critical challenges, including productivity enhancement, climate resilience, and global competitiveness in agriculture.

Moreover, only a small number of countries in the region have a dedicated digital agenda for the agricultural sector. The existence of such agendas would make it possible to jointly address dissimilar aspects of the digitalization process, such as infrastructure, digital skills and regulation of access to and use of digital technologies in the agricultural sector. It would also improve coordination among various government entities, ensuring the coherent and successful integration of agricultural digitalization initiatives into the public policy framework.

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2 Public Policies as Instruments for a Dynamic and Responsible Digital Transformation of Agriculture in LAC: What Actions Are Countries in the Region Taking?

Alice Alcântara, Federico Bert

1. Introduction

Digital technologies will likely be the most impactful factor in shaping and operating agri-food systems in the coming years. The effects of the advancement of digital technologies are already observable in different areas of life, and agriculture is no exception. As seen in other industries, the introduction of digital technologies generates major positive impacts, but also some adverse effects — a phenomenon that will likely be observed in agriculture as well. This raises the need for strategic interventions in order to accelerate the realization of the many benefits digitalization can offer, while at the same time minimizing the risks of negative impacts. Digital technologies are a highly promising tool for addressing the major challenges of agri-food systems (more production, efficiency, resilience, sustainability, inclusion, etc.). In a context where the progress of digitalization seems inevitable, it is important to intervene in order to ensure that this process does not become a factor that widens gaps, triggers exclusion, and generates conflict. The challenges are diverse — lack of infrastructure and

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connectivity in rural areas (Ziegler, Arias, 2022), digital illiteracy (Ziegler, 2021), asymmetrical access to technology between large and small farmers, lack of financing, among others (Sotomayor, Ramírez & Martínez, 2021). However, public policies can address these challenges through strategies that encourage and organize the conditions for the development and use of digital technologies in agriculture, aiming to achieve their benefits while avoiding the unintended consequences of digitalization.

The public sector, through public policy, has a major responsibility in creating conditions that facilitate and stimulate digitalization while minimizing its potential negative impacts. Thus, it is essential to establish policies that define priority areas of action, interventions in order to implement, and the resources needed to chart a path toward digital transformation in the agricultural sector. In this regard — and given the growing importance of the topic — in Latin America and the Caribbean (LAC), an increasing number of countries are beginning to propose policies to promote the development, access, and use of digital technologies. For example, in 2019 a study in Colombia outlined the state of digitalization in the country's agricultural sector, which led to the creation of an Action Plan to accelerate the process, with proposals for implementation from both the public and private sectors (Alcântara et al., 2019).

Digitalization is a complex process involving multiple actors, both public and private. A public-private partnership is necessary to ensure the success of digitalization. Currently, private actors are at the center of technology generation (Klerkx and Villalobos, 2024; Birner et al., 2021; Arias, Rodríguez and Beduschi, 2021), playing a decisive role in the digitalization process. In many countries, the progress of digitalization is driven primarily by private actors, especially small agri-entrepreneurs or AgTech startups and the network of organizations that emerge around them (incubators, accelerators, investment funds, etc.). However, the complexity of the process calls for measures to stimulate and organize these efforts to support the activities of different actors and foster collaboration among them, highlighting the role of the State in coordinating actions designed to meet the specific needs and demands of the sector.

Given the State's non-delegable role in promoting digitalization (Arias, Rodríguez, Beduschi, 2021), this chapter aims to present the results of a review of public policies that various countries or regions are implementing in order to promote the digitalization of their agri-food systems at both regional and national levels. The goal is to gather insights and highlight experiences that can inspire the development of a new generation of public policies. These should help countries design new institutional frameworks and policy initiatives that enable a dynamic and responsible digital transformation of their agri-food systems.

2. Methodology

This chapter presents a review of measures or initiatives aimed at promoting the digitalization of agriculture driven by public institutions related to agriculture in various countries. The mapping was conducted at both regional and national levels, including the European Union, the Andean Community, Spain, and six countries from Latin America and the Caribbean: The Bahamas, Brazil, Colombia, Costa Rica, Guyana, and Uruguay. The information was gathered through open-source searches of publicly available materials, including government reports and studies, official websites, documents from international organizations, and academic and journalistic publications. Whenever possible, interviews were conducted with individuals knowledgeable about and connected to the identified initiatives to verify findings, explore further details, and, where applicable, assess the impacts of the actions implemented.

The identified initiatives were classified by type of intervention and characterized according to their dimensions, based on the criteria established by the Public Policy Observatory for Agri-food Systems (OPSAA[1]) of the Inter-American Institute for Cooperation on Agriculture (IICA). The classification of initiatives is divided into: (1) policy frameworks, understood as the legal foundation for state action to promote agricultural digitalization, expressed through agendas, policy guidelines, strategies, regulations, plans, or agreements at various levels — international, regional, national, and subnational; and (2) policy initiatives, which in this study take the form of programs and projects. These have more specific objectives, detail the

1 https://opsaa.iica.int/

instruments used to achieve expected outcomes, and have allocated resources (public or private) (IICA, 2023).

The characterization of the initiatives includes the following dimensions: (1) geographical (referring to whether the initiative is regional or national in scope); (2) targeted population (referring to the intended beneficiaries of the initiative); (3) financing (referring to the source and amount of resources allocated for the initiative); (4) sectors (referring to the agricultural sector); (5) stakeholders (referring to the institutions involved in the initiative); and (6) contexts (referring to the political framework within which the policy initiative — programs and projects — is embedded) (IICA, 2023). The results are presented in a structured manner for each region or country. A list of the mapped initiatives is available on Table 1.

The mapping was conducted throughout 2022 (Brazil, Colombia, Uruguay, Costa Rica, The Bahamas, and Guyana) and 2023 (European Union, Andean Community, and Spain). Therefore, new initiatives launched during or after the analysis may not be included here, and some initiatives analyzed may have changed or become obsolete due to changes in leadership, government, or for any other reasons. Thus, the mapping is not intended to be an exhaustive summary of everything the selected countries and regions are doing in terms of digitalization policies, but rather a selection of the most relevant findings and impressions drawn from the exploratory process.

In the analysis of the initiative descriptions, it was observed that the concepts of "digitalization" and "digital transformation" are often not specified, or they are used interchangeably or synonymously without clarifying any distinctions. In this chapter, to avoid confusion, we understand and use the term *digitalization* as the use of digital technologies to adapt the way a process is carried out within a value chain (in this case, agricultural), and *digital transformation* as the integration of digital technologies as the foundation for renewing the entire model of a value chain (Arias, Rodríguez, Beduschi, 2021).

3. Policy Initiatives at Regional and National Levels

The digitalization of agriculture is a broad process that encompasses various stages and procedures and involves multiple actors. As such, policy initiatives aimed at promoting digitalization can vary greatly in terms of their objectives, proposed mechanisms and actions, stakeholders involved and more. The mapping carried out in this study — which covered two regions and seven different countries — demonstrates the wide range and diversity of policy initiatives that can be used to drive the digitalization of agriculture. In this regard, more than 50 highly diverse initiatives were identified (in terms of their objectives, instruments used, levels of specificity in the measures implemented, etc.), including sectoral policies, agendas, strategic plans, financing programs, projects and others (see Table 1).

Significant differences were observed among countries regarding the number and characteristics of the initiatives being implemented. Some countries had well-structured agendas with clearly defined priorities and themes, supported by initiatives that complemented and collaborated with one another. Conversely, in other cases, although ongoing initiatives were identified, it was difficult to detect a relatively solid institutional framework to structure and support them (in some cases, it was difficult to verify the actual level of implementation or progress beyond the initial announcement that revealed the initiative). As will be discussed later, this undermines the effectiveness, the progress of implementation, and especially the sustainability and long-term impact of the launched actions.

Table 1. List of initiatives mapped by country/region.

Country/ Region	Initiative	Web page
European Union	Digital Agenda for Europe (2010–2020)	https://www.europarl.europa.eu/factsheets/es/sheet/64/digital-agenda-for-europe
	Horizon Europe Program	http://data.europa.eu/eli/reg/2021/695/oj
	Digital Europe Program	https://eur-lex.europa.eu/eli/reg/2021/694/oj
	Common Agricultural Policy – CAP (2023–2027)	https://eur-lex.europa.eu/legal-content/ES/TXT/?uri=CELEX%3A32021R2115&qid=1693937841698
	AgriDataSpace	https://agridataspace-csa.eu/
	AgrifoodTEF	https://www.agrifoodtef.eu/#our-mission
	ScaleAgData	https://remotesensing.vito.be/new-horizon-europe-project-scaleagdata
	CrackSense	https://cracksense.eu/
	AgriData Value	https://agridatavalue.eu/
	Divino	https://divine-project.eu/
Andean Community	Andean Digital Agenda	https://www.comunidadandina.org/agenda-digital-andina/
	Andean Agricultural Agenda	https://www.comunidadandina.org/wp-content/uploads/2022/11/AAA-Version2_FINAL.pdf
	Community Interoperability – INTERCOM	https://www.comunidadandina.org/wp-content/uploads/2023/12/Dimension-2023-SGCAN.pdf
	Regional Center for Phytosanitary Intelligence of the Andean Community	
	Strengthening and accelerating competitiveness and growth of international trade in the agri-food system in the Andean Region	http://www.iica-ecuador.org/agenda-agropecuaria-andina/
	Capacity-building to close technological gaps in sustainable, commercial, and business-oriented production processes in family farming in the Andean Community	http://www.iica-ecuador.org/agenda-agropecuaria-andina/

Country/ Region	Initiative	Web page
Spain	Strategy for the Digitalization of the Agri-food, Forestry and Rural Environment Sectors	https://www.mapa.gob.es/es/ministerio/planes-estrategias/estrategia-digitalizacion-sector-agroalimentario/default.aspx
	Strategic Program for Recovery and Economic Transformation	https://planderecuperacion.gob.es/como-acceder-a-los-fondos/pertes/perte-agroalimentario
	Strategic Plan for the Common Agricultural Policy (CAP)	https://www.mapa.gob.es/es/pac/pac-2023-2027/plan-estrategico-pac.aspx
	La Vega Innova	https://lavegainnova.es/
	Línea Agroinnpulso	https://www.enisa.es/es/financia-tu-empresa/lineas-de-financiacion/d/agroinnpulso
	Observatory of Agri-food Sector Digitalization	https://www.mapa.gob.es/es/desarrollo-rural/temas/innovacion-medio-rural/estudio_3def_tcm30-655779.pdf
	Digital Competence Center	https://centrocompetencias.mapa.es/
	AKIS Advisory Platform	https://akisplataforma.es/
	Advisory Service (7202)	https://www.mapa.gob.es/es/desarrollo-rural/temas/innovacion-medio-rural/ayudas-asesoramiento-digitalizacion/
Brazil	Agro 4.0 Chamber	https://www.gov.br/mcti/pt-br/acompanhe-o-mcti/transformacaodigital/camara-agro
	Brazilian Commission for Precision and Digital Agriculture (CBAPD)	https://www.gov.br/agricultura/pt-br/assuntos/inovacao/agrohub-brasil/iniciativas/comissao-brasileira-de-agricultura-de-precisao-e-digital-cbapd
	Agro Digital Innovation Chamber	https://www.gov.br/agricultura/pt-br/assuntos/camaras-setoriais-tematicas/camaras-tematicas-1/inovacao-agrodigital
	Agro 4.0 Program	https://agro40.abdi.com.br/
	TechStart Agro Digital Program	https://venturehub.se/techstart-agro-digital/
	MAPA Conecta Program	https://conexaoagro.com.br/tag/mapa-conecta/
	Connected Rural Communities Program	https://www.gov.br/agricultura/pt-br/assuntos/inovacao/agrohub-brasil/produtores-rurais/internet-no-campo-1/internet-no-campo#:~:text=Programa%20Comunidades%20Rurais%20Conectadas&text=O%20acesso%20a%20tecnologias%20digitais,assist%C3%AAncia%20t%C3%A9cnica%20e%20extens%C3%A3o%20rural.
	ATER Digital Program	https://www.embrapa.br/busca-de-noticias/-/noticia/85620345/ater-digital-e-seus-beneficios
	AgroHub Brazil	https://www.gov.br/agricultura/pt-br/assuntos/inovacao/agrohub-brasil

Country/ Region	**Initiative**	**Web page**
Colombia	Action Plan to Accelerate the Digitalization of the Agricultural Sector	https://bibliotecadigital.ccb.org.co/handle/11520/24326
	National Rural Connectivity Plan	https://mintic.gov.co/portal/715/articles-126217_recurso_1.pdf
	Rural E-Commerce Plan	https://colaboracion.dnp.gov.co/CDT/Conpes/Econ%C3%B3micos/4012.pdf
	Artificial Intelligence for Agriculture Project	https://mintic.gov.co/portal/inicio/Sala-de-prensa/MinTIC-en-los-medios/100832:El-proyecto-de-inteligencia-artificial-que-busca-ayudar-al-campo-colombiano
	National Unified System of Rural and Agricultural Information (SNUIRA)	https://www.upra.gov.co/sistema-nacional-unificado-para-la-informacion-rural-agropecuaria
	National Project for Universal Access to ICT in Rural or Remote Areas	https://micrositios.mintic.gov.co/centros_digitales/
	Public Agricultural Extension Service using the Digital Methodology	https://www.adr.gov.co/150-mil-campesinos-del-pais-recibiran-el-servicio-publico-de-extension-agropecuaria-con-metodologia-digital-gracias-a-la-adr/
	Agro 4.0	https://c4ir.co/uso-y-apropiacion-de-tecnologias-4-0/
Uruguay	*Agtech Challenge*	https://desafioagtech.uy/
	AGROTIC: Digital Solutions for Family Farming	https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/publicaciones/bases-convocatoria-agrotic/bases-convocatoria-agrotic
	Pilot Program for Inclusion and Development of Digital Skills for Rural Women and the Agricultural Sector	https://www.gub.uy/ministerio-ganaderia-agricultura-pesca/comunicacion/noticias/mujeres-rurales-se-capacitaran-alfabetizacion-digital-desarrollo-empresarial
	Program for the Adoption of Digital Technologies in Uruguay's Agricultural Sector	https://www.iadb.org/es/project/UR-L1185
Guyana	*The ICT Access and E-Services for Hinterland, Poor and Remote Communities Project*	https://open.undp.org/projects/00094518
	FarmersMarket.GY App	https://guyanachronicle.com/2019/07/10/farmers-market-app-to-transform-guyana/
Costa Rica	*Agrinnovación 4.0*	https://revistas.tec.ac.cr/index.php/tec_marcha/article/view/6059
	Leveraging technologies to support the Government of Costa Rica with the development of a climate-smart greenhouse	https://ktf.bcie.org/portafolio/proyecto/apalancamiento-de-las-tecnologias-para-apoyar-al-gobierno-de-costa-rica-con-el-desarrollo-de-invernaderos-climaticamente-inteligentes
The Bahamas	*Digital Territorial Villages*	https://www.fao.org/jamaica-bahamas-and-belize/news/detail-events/es/c/1631336/

Source: Prepared by the authors.

3.1. Regional-Level Initiatives

The mapping identified several initiatives aimed at promoting digitalization at the regional level. This study focused on two cases: (1) the European Union, as a region that has long worked on this topic and has a robust institutional framework that can serve as an example and source of learning for LAC countries, and (2) the Andean Community, as a pioneering case within the region. In both cases, digitalization is promoted in a general sense as a result of regional political consensus within the framework of their respective institutions. These initiatives include or reference efforts specifically targeting agriculture. Despite the many differences between these regions, both have outlined regional guidelines and objectives that serve as frameworks and provide tools for designing and implementing national-level initiatives within their member countries.

The European Union has been fostering an institutional environment that promotes digitalization for over a decade. Since 2010, when the first comprehensive strategy, named the Digital Agenda for Europe, was launched, various measures have been implemented. The Digital Agenda for the 2010–2020[2] decade set the guidelines and objectives for early digital transformation efforts. However, priorities have shifted over time. Initially, the focus was on reducing electronic communication tariffs, improving internet connectivity across the EU, creating a digital single market, and digitizing public services (Comisión Europea, 2010). In the second phase of the Digital Agenda (2020–2030[3]), the scope of digital transformation was broadened to address changes brought by emerging technologies and to stimulate digital innovation across sectors.

This shift in the EU's Digital Agenda priorities eventually encompassed the agricultural sector, especially after the COVID-19 pandemic. Although agriculture was not mentioned during the first phase

2 Digital Agenda for Europe (2010-2020): https://eufordigital.eu/wp-content/uploads/2019/10/COMMUNICATION-FROM-THE-COMMISSION-TO-THE-EUROPEAN-PARLIAMENT.pdf

3 The Digital Agenda (2020–2030) was created using the following documents as references, namely: (1) Shaping Europe's digital future: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0067 and (2) 2030 Digital Compass: the European way for the Digital Decade: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0118

(2010–2020), in the second phase (2020–2030) the importance of digital technologies for improving the efficiency and sustainability of the sector is emphasized, with the belief that these technologies enable more competitive and eco-friendly agricultural processes (Comisión Europea, 2021).

Specific progress in agricultural digitalization in the EU includes the incorporation into the Common Agricultural Policy (CAP) of a cross-cutting objective to "modernize agricultural and rural areas by fostering and sharing knowledge, innovation, and digitalization, and promoting their adoption by farmers" (Parlamento Europeo, 2021). For the first time, the new CAP for the 2023–2027 period includes regional measures to promote digitalization and the adoption of digital technologies, providing guidelines for national-level actions. The CAP regulation for 2023–2027[4] requires each member country to translate the policy's objectives and measures into a national strategic plan (Parlamento Europeo, 2021). The next section will present Spain as a case study showing how regional policy can stimulate national initiatives, specifically illustrating how CAP guidelines on innovation and digitalization are reflected in the country's own initiatives.

In the case of the Andean Community (CAN), efforts to promote digital transformation are more recent. The crisis triggered by the COVID-19 pandemic was the main driver for advancing digitalization policies. In this context, the CAN became the first subregional institution in the Americas to develop a strategy on this topic. In 2022, the Andean Digital Agenda[5] was launched, offering a roadmap to guide member countries in addressing the challenges of digital transformation (Comunidad Andina, 2022).

The CAN's Digital Agenda is a pioneering case in the region. Although it does not directly mention agriculture, it targets all sectors in a general way. The agenda supports regional projects for digitalizing state services and procedures that directly (e.g., through a digital platform for phytosanitary process management) and indirectly (e.g., through digital infrastructure to facilitate the exchange of foreign trade customs data) benefit the agricultural sector (Secretaría General de la Comunidad Andina, 2022; Comunidad Andina, 2023).

4 Regulation of the Common Agricultural Policy (CAP) for the 2023–2027 period: https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1693937841698&uri=CELEX%3A32021R2115

5 Andean Digital Agenda: https://www.comunidadandina.org/agenda-digital-andina/

3.2. Country-level Initiatives

While regional initiatives can serve as a framework and guide, their absence does not prevent countries from moving forward with their own domestic initiatives. The national-level mapping identified a range of initiatives which, although diverse in their objectives, share a common effort to promote agricultural digitalization, either directly or indirectly. The cases of Brazil, Colombia, Uruguay, The Bahamas, Costa Rica, Guyana and Spain were studied, and in each of them, at least one relevant initiative was identified. These diverse initiatives suggest that promoting digitalization is seen as a tool to address broader challenges in the agricultural sector of these countries.

In Spain, significant progress has been made in public policy, with initiatives encouraging debate, the generation of studies, and the identification of challenges, as well as the definition of priority investment areas. Many initiatives have clear objectives, allocated budgets, managing institutions, and pre-defined lines of action. A similar trend is observed in some Latin American countries. In Brazil, institutional spaces have been consolidated with reference networks to discuss and propose support for the development of policies, programs and projects focused on agricultural digitalization. Advances in the digitalization of public services, for example, led to the creation of *AgroHub Brasil,* a virtual platform that provides access to information about the country's entire agri-innovation ecosystem (Ministério da Agricultura, Pecuária e Abastecimento, 2022). In Colombia, institutional efforts include nationwide plans prioritizing the expansion of the infrastructure of connectivity in rural areas and the digitalization of agricultural data. However, political dynamics have limited the implementation and continuity of these initiatives.

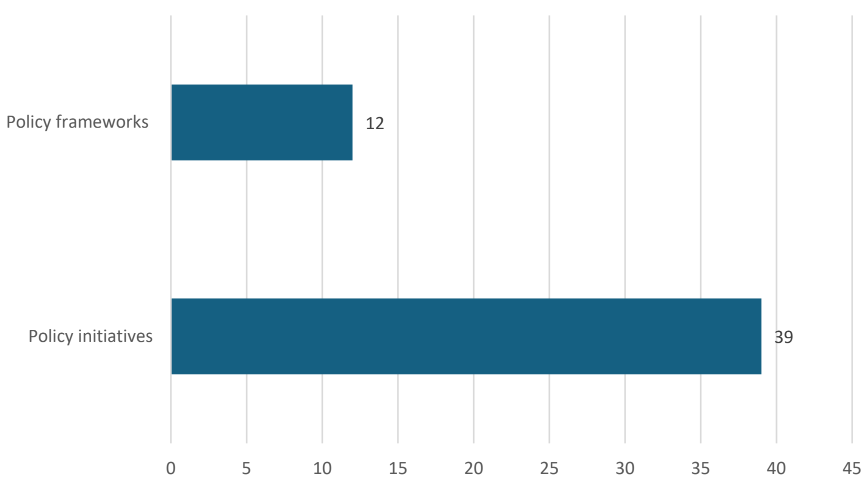
Many of the initiatives mapped out in various countries involve the private sector and/or establish partnerships with it — for developing digital technologies, providing financing, or building the infrastructure of connectivity. Another key aspect observed was the partnerships with international organizations. In some countries, progress in this area has been partially made possible by technical and financial support from such organizations. In The Bahamas, the Food and Agriculture Organization

(FAO) supports the *Digital Village Initiative*, which aims to promote the digital ecosystem in rural communities (FAO, 2023). In Guyana, the United Nations Development Programme (UNDP) supported the *ICT Access and E-Services for Hinterland, Poor and Remote Communities Project* (PNUD, 2023). In Uruguay, the Inter-American Development Bank (IDB) supports the *Program for the Adoption of Digital Technologies in the Uruguayan Agricultural Sector*, which promotes the digitalization of agricultural ministry services and the practices of family farmers and rural women (BID, 2022). In Costa Rica, the Central American Bank for Economic Integration (CABEI) supported a pilot project with the title *Leveraging Technology to Support the Government of Costa Rica with the Development of Climate-Smart Greenhouses*, aimed at research and development and providing evidence-based recommendations (BCIE, 2021).

3.3. Types of Initiatives

Across the regions and countries analyzed, a total of 51 initiatives were identified. Although the mapping was not exhaustive, a wide variety of interventions were found to promote the digital transformation of agriculture. These were categorized into policy frameworks and policy initiatives (see Figure 1).

Figure 1. Types of intervention among the identified initiatives.



Source: Prepared by the authors.

a. Policy Frameworks:

At the regional level, **three agendas** have been formalized: one from the European Union (Digital Agenda for Europe) and two from the Andean Community (Andean Digital Agenda and Andean Agricultural Agenda). These agendas outline the needs and priorities of each region in the context of digital transformation, proposing a roadmap to ensure implementation and detailing the objectives to be achieved through the promotion of digitalization. As previously mentioned, in the European Union, **one policy** was also identified — the Common Agricultural Policy (CAP) — the longest-standing policy supporting agriculture and rural development, which in its most recent reformulation promotes digitalization as one of its core objectives.

At the national level, Brazil has made progress by consolidating **three initiatives** linked to the Ministry of Agriculture, Livestock and Supply to support the creation of public policies in this area: *Agro 4.0 Chamber*[6], *Agro Digital Innovation Chamber*[7], *and the Brazilian Commission for Precision and Digital Agriculture*[8]. These initiatives bring together experts from various organizations and sectors related to agriculture to discuss and propose lines of action and recommendations to policymakers. The *Agro 4.0 Chamber* was the first institutionalized initiative focused on digital solutions for agriculture and created an Action Plan for the 2021–2024 period. However, following the expiration of the technical cooperation agreement that established the initiative[9], the *Agro Digital Innovation Chamber* came into effect in 2022 to continue the work (Rodrigues, Nunes, Sotomayor, 2023).

Strategic plans proved to be a common type of intervention. A **total of five** were identified: two in Spain and three in Colombia. One of Spain's strategic plans (*Strategy for the Digitalization of the Agri-food*

6 Ministério da Agricultura, Pecuária e Abastecimento de Brasil, 2019.

7 Ministério da Agricultura, Pecuária e Abastecimento de Brasil, 2024.

8 Ministério da Agricultura, Pecuária e Abastecimento de Brasil, 2022a.

9 The Agro 4.0 Chamber was formalized in 2019 through a Technical Cooperation Agreement between Brazil's Ministry of Agriculture, Livestock, and Supply (MAPA) and the Ministry of Science, Technology, Innovations, and Communications (MCTIC) (Ministério da Ciência, Tecnologia, Inovações e Comunicações do Brasil, 2022).

and Forestry Sector and Rural Areas[10]) is exclusively focused on promoting digitalization in agriculture and rural areas. The other (*Strategic Plan for the Common Agricultural Policy - CAP*[11]) proposes mechanisms to promote digitalization as one of its thematic axes across different economic sectors. In Colombia, initiatives were identified to accelerate digitalization (*Action Plan to Accelerate Digitalization of the Agricultural Sector*[12]) and strengthen the enabling conditions for digital transformation — that is, to address infrastructure deficiencies that hinder the introduction of digital solutions (*National Rural Connectivity Plan*[13] and the *Rural E-Commerce Plan*[14]).

b. Policy Initiatives:

It is observed that most efforts and resources are directed towards **policy initiatives (a total of 36),** including many pilot projects with specific short or medium-term objectives (see Figure 2). These efforts involve collaboration among multiple actors, such as private companies, academic institutions, and international organizations. Generally, these initiatives are more flexible and adaptable to the specific needs and contexts of each country, with a budget allocated from public agencies and, in some cases, contributions from other stakeholders.

In Uruguay, for instance, the *Program for the Adoption of Digital Technologies in the Uruguayan Agricultural Sector* is being implemented by the Ministry of Livestock, Agriculture, and Fisheries (MGAP), with support from the Inter-American Development Bank (IDB) through a US$6,500,000 loan, in addition to a US$500,000 contribution from the national government (BID, 2023). The program aims to improve the sector's competitiveness by promoting the digitalization of MGAP's services and activities, encouraging the adoption of digital technologies by family farmers and rural women, and developing the country's AgTech network (BID, 2023).

10 Ministerio de Agricultura, Pesca y Alimentación de España, 2019.

11 Ministerio de Agricultura, Pesca y Alimentación de España, 2022.

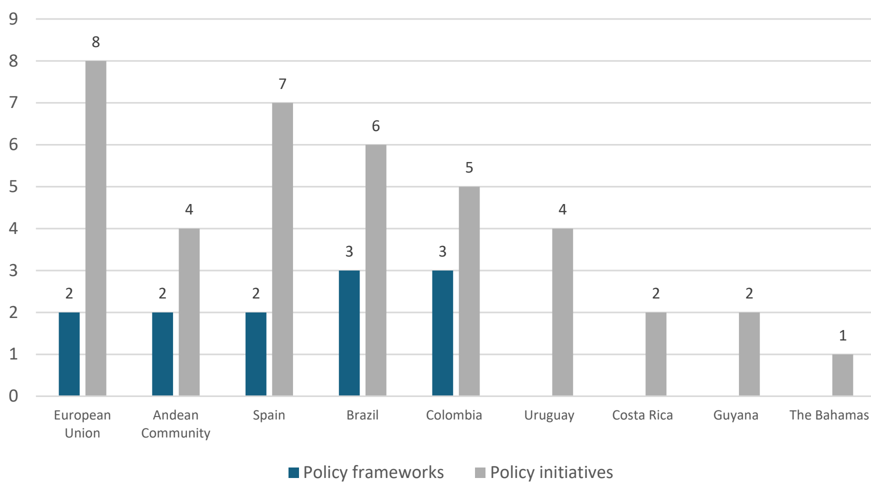
12 Cámara de Comercio de Bogotá, 2019.

13 Ministerio de Tecnologías de la Información y las Comunicaciones de Colombia, 2019.

14 Ministerio de Agricultura y Desarrollo Rural de Colombia, 2021.

All the countries analyzed have at least one policy initiative aimed at promoting agricultural digitalization. Figure 2 reveals an interesting trend: countries and regions that adopt a policy framework tend to have more policy initiatives, suggesting a higher level of public activity around the guidelines and objectives defined by those frameworks.

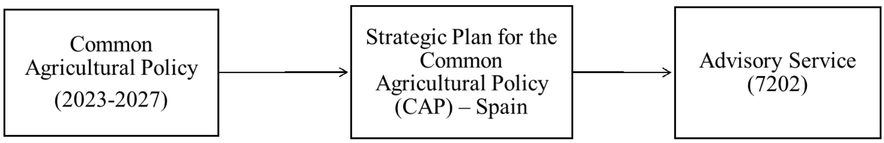
Figure 2. Distribution of public interventions by region and country.



Source: Prepared by the authors.

In the European Union and Spain, due to a more developed institutional context, there is an observable organizational structure that frames and connects public interventions both with each other and across different levels, something not necessarily seen in the countries of Latin America and the Caribbean. In other words, projects are conducted in alignment with the guidelines and directives established in the policy frameworks developed by the institution (EU) or country. Within the framework of the Common Agricultural Policy (CAP), for example, Spain has created the Strategic Plan for the Common Agricultural Policy (CAP) – Spain, which proposes measures to promote the digitalization of agriculture in the country. One such measure is implemented through the project *"Advisory Service 7202"*, which includes actions to support the use of advisory services for the digitalization of businesses in the agricultural and forestry sectors, as well as young professionals in agriculture (Table 1) (Ministerio de Agricultura, Pesca y Alimentación de España, s.f.).

Table 1. Examples of initiatives connected at regional and national levels



Source: Prepared by the authors.

3.4. Main Focus Areas of the Initiatives

The initiatives analyzed cover a broad range of objectives and, therefore, differ in terms of the actions or interventions involved. As such, initiatives can be identified that focus on different components or specific areas of the agri-food digitalization process (Figure 3). This reflects variations in the needs and priorities of each country or region regarding the promotion of digitalization.

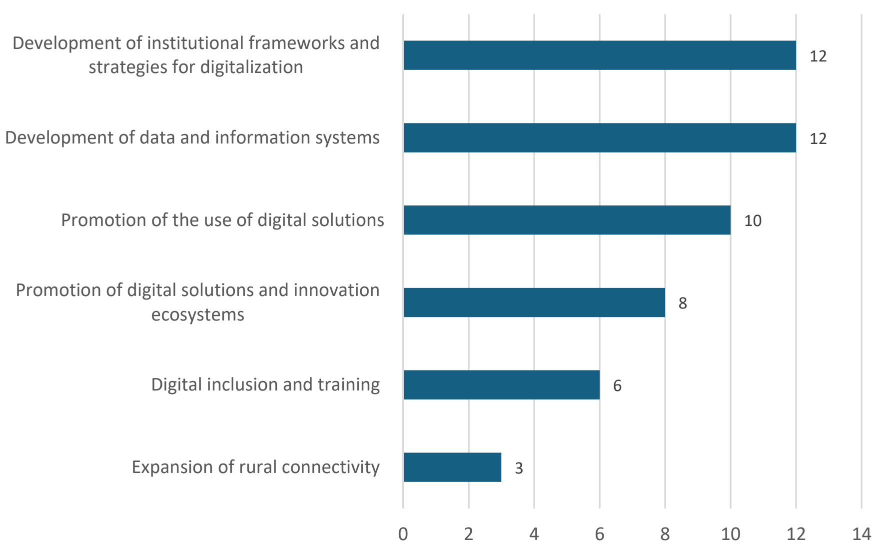
Among the diverse initiatives mapped out, at least six different focus areas can be arbitrarily distinguished: **(1)** development of institutional frameworks and digitalization strategies, **(2)** development of data and information systems, **(3)** promotion of the use of digital solutions, **(4)** promotion of the development of digital solutions and innovation ecosystems, **(5)** digital inclusion and training, and **(6)** expansion of rural connectivity (see Figure 3).

In the European Union, Andean Community, Spain, Brazil and Colombia, initiatives were identified that focus on the **development of institutional frameworks and strategies for digitalization,** making these one of the two most common focus areas observed. In some cases, these initiatives were based on previous studies conducted in order to analyze and diagnose the challenges involved in the digitalization process.

In the Andean Community, the study "Analysis and Diagnosis of the Digital Ecosystem of the Andean Community for Telecommunications and ICTs" (Castro & García, 2022) laid the foundation for the creation of the *Andean Digital Agenda*, by including recommendations to promote community-level policies or regulations (Comunidad Andina, 2022). On the other hand, in Spain, the study "Focus Group on Digitalization and Big Data in the Agri-Food, Forestry, and Rural Sector: Ideas for a Strategic Approach to Digitalization" (Aparicio, 2019) explored the challenges and opportunities linked to the digitalization of the agri-food, forestry, and rural sectors and served as the foundation for the creation of the *Digitalization Strategy for the Agri-Food, Forestry, and Rural Sector* by the country's Ministry of Agriculture, Fisheries and Food.

In other cases, the development of an institutional structure was the initial step to promote analytical and diagnostic studies, which in turn formed the basis for the design of policy initiatives. For instance, in Brazil, the consolidation of the *Agro 4.0 Chamber* led to the study "Potential and Challenges of Agro 4.0" (Ministério da Agricultura, Pecuária e Abastecimento do Brasil, 2022, which aims to support public policy decision-making by analyzing the challenges faced by production chains and highlighting the potential of digital technologies in this context.

Figure 3. Main focus areas of the mapped initiatives.



Source: Prepared by the authors.

In addition to institutional progress, there was a clear predominance of initiatives aimed at **promoting the use of digital solutions**, with a total of 10 initiatives. Five out of six Latin American and Caribbean countries analyzed have at least one initiative in this area: Brazil, Colombia, Uruguay, Guyana and The Bahamas. It was observed that promoting the use of digital solutions generally prioritizes facilitating the digital marketing of agricultural products, improving government services — including rural extension services — and training farmers in the use of these tools.

Another noteworthy focus is the **development of data and information systems**, with a total of 12 initiatives. These aim to establish data systems and generate information for various purposes (e.g., to facilitate foreign trade, manage phytosanitary measures, inform policy and strategy, etc.). In this regard, some European Union initiatives serve as valuable examples for LAC countries. All four of the mapped projects funded under the *Horizon Europe Program*, the EU's main research and innovation funding program (Parlamento Europeo, 2021a), specifically adopt this focus. This indicates that the EU is employing a targeted strategy when designing initiatives, concentrating on specific areas of the digitalization process.

Initiatives aimed at **promoting the development of digital solutions and the innovation ecosystem** (8 in total) have two particularly important characteristics for the digital transformation of agriculture: (1) the promotion and acceleration of AgTechs, i.e., startups based on innovative digital technologies for delivering agricultural services (Bert, Lachman, Del Río, 2023), and (2) public–private partnerships. Generally, these initiatives use AgTech public calls in collaboration with private companies and investors as a means to promote (and sometimes finance) the development of digital technologies. One example is the *TechStart Agro Digital Program*, created by Embrapa (Brazilian Agricultural Research Corporation) and the venture capital firm Venture Hub. The program supports innovation and the acceleration of AgTechs by offering business and technological training (Venture Hub, 2023). Similarly, Uruguay's *AgTech Challenge 2022* was created to select AgTechs capable of developing digital solutions to address various challenges in the country's agricultural sector (MGAP, 2023).

Lastly, there were initiatives focused on **digital inclusion and training** (6 in total), with a strong emphasis on including family farming and rural women, as well as on **expanding rural connectivity** (3 in total). In Uruguay, for example, the *Pilot Program for Inclusion and Development of Digital Skills for Rural Women and the Agricultural Sector* offered digital training to improve basic computer literacy, along with the provision of internet-connected devices for participants who needed them (MGAP, 2022). In Brazil, the *Connected Rural Communities Program*, and in Colombia, the *National Project for Universal Access to ICT in Rural or Remote Areas*, were created to expand internet access infrastructure in rural regions. These initiatives address the foundational challenges of digital transformation, strengthening the environment through digital literacy and connectivity infrastructure, which are especially important in Latin America and the Caribbean.

4. Progress and Remaining Challenges

All countries have taken some action to promote digitalization in the agri-food sector, reflecting a recognized need to act on this front. In this scenario, the significant differences found between countries stand out, with some being notable for the number and diversity of initiatives they present. While some countries have made substantial progress by establishing policy frameworks, agendas, plans, or formal policies, others have only a few isolated initiatives in the early stages of implementation, often without institutional frameworks or regulations to guide or facilitate execution.

4.1. The Case of the EU And Spain as a Reference

At the regional level, the **European Union** shows clear institutional progress in this area, reflected in key initiatives such as the Common Agricultural Policy (CAP 2023–2027), which, for the first time, includes measures to promote digitalization within its regulations, as well as programs like Horizon Europe and Digital Europe, which direct resources and financial support towards the digitalization of agriculture. The CAP is particularly noteworthy as it proposes indicators to measure the policy's implementation performance in member States. One of these outcome indicators relates to agricultural digitalization, measuring the percentage of farms benefiting from financial aid to incorporate digital technologies through the CAP (Parlamento Europeo, 2021).

Through national strategic plans, member States can use these indicators to meet the CAP's goals, including the cross-cutting objective of modernization and promotion of innovation and digitalization (Parlamento Europeo, 2021). The EU example illustrates how different instruments can be used to promote interaction between initiatives across different areas. When analyzing Spain's initiatives (Table 1) in this context, it becomes evident how regional policy guidelines help steer national-level actions.

4.2. Ongoing Progress in Latin America and the Caribbean

In Latin America and the Caribbean, the same level of institutionalization of the topic in regional political agendas is not generally observed as in the EU. However, the Andean Community stands out for developing a subregional strategy through the Andean Digital Agenda (Comunidad Andina, 2022). This agenda is part of the work plan of the Andean Committee of Telecommunications Authorities (CAATEL) and was developed based on official mandates from the Heads of State of member countries — Bolivia, Colombia, Ecuador and Peru. The agenda's goal is to guide members in addressing the challenges of digital transformation by fostering an environment that catalyzes digitalization opportunities across sectors, without focusing on any single one.

While the agenda does not explicitly mention agricultural digitalization, it includes a line of action to "design strategies for adopting 4.0 technologies in MSMEs and entrepreneurship in different sectors" (Comunidad Andina, 2022). Nonetheless, efforts are already underway to digitize certain agricultural processes as part of the Andean Digital Agenda, including the *Regional Center for Phytosanitary Intelligence* project. In its early implementation phase, the project aims to develop a digital platform for managing phytosanitary processes using digital technologies to strengthen pest prevention and control (Comunidad Andina, 2023).

At the national level, the Andean Digital Agenda is implemented by each member State's competent authorities, allowing flexibility to adapt proposed actions based on the specific needs of each country (Comunidad

Andina, 2022). Unlike the EU's CAP implementation plan, the Andean Digital Agenda's roadmap does not include performance indicators to monitor the digitalization progress or deadlines for submitting strategies, nor does it establish a commission to analyze or approve member actions. Nonetheless, some progress can already be seen within the framework of the Agenda: for example, Peru's government has incorporated the agenda's commitments into its National Digital Transformation Policy, approved in July 2023 (Plataforma Digital Única del Gobierno Peruano, 2024). On the other hand, none of the initiatives mapped out in Colombia — one of the CAN member countries analyzed in this study—were found to reflect the guidelines of the Andean Digital Agenda at the national level, since the data collection in that country was carried out prior to the creation of the Agenda.

Alongside regional initiatives, which can serve as a guide for national efforts, countries are also organizing and implementing local initiatives, as described in sections 3.3 and 3.4. In Brazil and Colombia, more structured initiatives with institutional backing have been identified. However, the initiatives mapped out in Costa Rica, Uruguay, Guyana and the Bahamas are more isolated and only directly or indirectly related to some aspect of digitalization, without actions being clearly aligned with an overarching strategy.

Furthermore, the initiatives are seen to focus on a variety of approaches, although those promoting the development of data and information systems, as well as the development and use of digital technologies, stand out. It is reasonable to find several initiatives with these focuses, since they provide a foundation for making informed decisions and integrating information into other digital solutions (e.g., soil data integrated into applications). Many of these efforts are directed towards family farming and small producers, groups traditionally underserved by public policies supporting technology adoption. Many of these initiatives are aimed at family farming and small-scale producers — groups that have traditionally been more affected by the lack of public policies promoting the adoption of digital technologies. The high number of initiatives mapped out to promote the use of digital technologies (see Figure 3) suggests that the technology is already present, although for various reasons, its dissemination and use remain very limited.

The digitization of government processes and services — particularly those led by ministries of agriculture and rural technical assistance — is also a strong component of the initiatives. In addition to these objectives, there are also initiatives focused on expanding connectivity in rural areas. This is a priority given the significant limitations of connectivity and gaps in Latin America and the Caribbean (Ziegler, Arias, 2022). Finally, it is important to highlight that several initiatives involve the private sector and/or establish partnerships with it. Whether individually or through organized efforts, many initiatives have been implemented to promote the development and use of digital solutions in collaboration with the private sector (see Section 3.4).

4.3. Considerations for States

In general, the initiatives in Latin America and the Caribbean are recent, many are still in their early stages of development and implementation. These findings reflect a very incipient interest from the public sector in the subject, highlighting a long way ahead in the promotion of public policies. In this regard, a common characteristic was identified in how countries manage public policy coordination. Limitations were observed in mobilizing mechanisms that foster strategic and sustainable initiatives, both in the short and long term. In more than one country, promising initiatives were discontinued due to changes in political leadership, which makes it even more difficult to draw conclusive insights on the effectiveness and impact of public policies in terms of fostering dynamic and inclusive digital transformation in agriculture.

A crucial turning point in building an institutional environment that fosters public policy is the promotion of studies in order to identify key barriers and challenges. This is evident in examples such as the Andean Community, which developed the Andean Digital Agenda based on a diagnostic study of the region's digital ecosystem, and Spain, which created the Strategy for the Digitalization of the Agri-food, Forestry, and Rural Environment sectors based on reports from a focus group on digitalization and big data in the country (see Section 3.4). Similarly, in Brazil, thematic chambers and bodies were established to bring together multiple stakeholders from the agricultural sector to discuss action lines and recommendations for promoting digitalization to the relevant authorities.

Public policy design requires understanding obstacles and capitalizing on lessons learned. Proposing the creation of technical cooperation working groups to explore the initiatives and experiences of countries leading the way towards digital transformation is key to advancing concrete and effective actions. In addition, it is recommended to propose metrics for evaluating and monitoring the implementation and progress of these initiatives.

Furthermore, the involvement and coordination between the public and private sectors are essential in order to address such a broad and complex issue, in which the private sector plays a highly relevant role. This requires the State to promote initiatives that organize interactions among the multiple actors involved in the digitalization process, fostering collaboration around the challenges facing agriculture. This is especially important considering that, based on the objectives of the mapped initiatives, digitalization does not appear as an end in itself, but rather as a tool to address broader challenges of agri-food systems (e.g., low competitiveness and productivity, inclusion of small-scale producers, adaptation to climate change, etc.)

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3 Processes of Digital Transformation in Rural Territories: Challenges of Implementation and Social Learning in Latin America and the Caribbean

Juan Felipe González, Katalina Moyano, Luiz Beduschi

1. Introduction

The dizzying advance of technology in recent decades has established an environment of continuous transformation that impacts all aspects of society. This rapid progress has facilitated global access to the internet and digital tools, revolutionizing production processes in various economic sectors. In this context, Industry 4.0 (big data, artificial intelligence, robotics, nanotechnology, augmented reality, the internet of things and cloud services) has emerged as a horizon that redefines production through the adoption of advanced technologies focused on interconnectivity, automation and real-time data analysis.

Although digital technologies are usually associated predominantly with urban industry, their application has begun to permeate agricultural production processes, establishing the conceptual basis for the so-called Agriculture 4.0. According to Santos Valle and Kienzle (2021), Agriculture 4.0 refers to an *"agriculture that integrates a series of innovations to produce agricultural products. These innovations encompass precision agriculture, the Internet of Things (IoT) and big data analytics to achieve greater production"*.

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This digital transformation, which is in its early stages, faces numerous challenges in order to replace the predominant conventional agriculture. The full adoption of Agriculture 4.0 requires infrastructural and technological conditions that are still far from being massively accessible in rural areas of Latin America and the Caribbean.

To address this complex transition, this text is based on the analysis of recent experiences implemented in the framework of a project of the Food and Agriculture Organization of the United Nations (FAO) entitled *Digital Transformation and Innovation in Agriculture*. This project originated from a request from the Community of Latin American and Caribbean States (CELAC), within the framework of the FAO-China South-South cooperation program and is part of the FAO's global initiative "One Thousand Digital Villages"[1]. Considering the experience accumulated in this project will make it possible to explore the digital transformation efforts, policies and programs adopted by various countries in the region, supported by FAO, as these actions play a crucial role as an intermediary in public discussion and in the design and implementation of policies related to the digitization of agrifood systems and rural territories.

In this sense, the FAO-CELAC project stands out as a representation of how international cooperation can boost the integration of advanced technologies in rural agriculture. By analyzing the strategies adopted and the results obtained in this initiative, it is possible to identify the necessary conditions for the effective adoption of Agriculture 4.0. This project is expected to contribute to a deeper understanding of the dynamics of digital transformation in agriculture, highlighting the challenges and opportunities present in rural areas of Latin America and the Caribbean.

This chapter examines the digital context of rural areas in Latin America and the Caribbean, focusing on the considerable connectivity gap between rural and urban sectors. The analysis explores the variables that influence digital inequality and assesses the conditions of access and use of technology in rural areas. The chapter also reviews public policies and programs aimed at digital transformation in these regions, highlighting the opportunities and potential benefits of digital tools to improve the living conditions of vulnerable rural populations. It considers the efforts

1 https://www.fao.org/americas/regional-initiatives/digital-villages/en

of organizations such as CELAC and FAO, with a specific focus on the Digital Transformation in Agriculture project, aimed at strengthening the capacities of actors in the region's rural territories.

2. Digital Transformation In The FAO's Strategic Framework 2022-2031[2]

The *Digital Transformation and Innovation in Agriculture* project arose in the context of the COVID-19 pandemic, which severely affected the rural economies of Latin America and the Caribbean. This health crisis exacerbated problems such as malnutrition, hunger and structural inequalities, further deteriorating the quality of life in rural territories. In response to these challenges, the project aims to mitigate the negative effects of the pandemic and improve living conditions in vulnerable rural sectors, in line with the United Nations Sustainable Development Goals (SDGs), in particular SDG 1 (End Poverty), SDG 2 (Zero Hunger), SDG 5 (Gender Equality) and SDG 10 (Reducing Inequalities).

This project also fits within FAO's Strategic Framework 2022-2031, specifically within the Program Priority Areas (PPAs) of "Better Production 5: Digital Agriculture" and "Better Life 2: Inclusive Rural Transformation". These areas guide the integration of advanced and digital technologies for more efficient and resilient agriculture as well as rural transformation in which are included the most disadvantaged communities.

The purpose of the project is clear: to *improve living conditions in vulnerable rural sectors in Latin America and the Caribbean through the implementation of digital technologies as tools for transformation*. The experiences and results obtained from this initiative are essential to provide data and information to support the adoption of policies and programs aimed at digital transformation in the region.

Although significant initial steps have been taken, the debate on digital transformation and its real impact on rural sectors is still developing. This is because the potential benefits and outcomes of implementing digital tools in vulnerable rural areas are still in the process of maturing.

2 https://www.fao.org/strategic-framework/es

To analyze the FAO initiative, it is essential to consider the regional context in which it is implemented, especially in relation to public policy. The state of digitalization in Latin America and the Caribbean should be examined, exploring the debate on the relevance of digital transformation and the efforts, policies and programs that countries in the region are implementing in this area. It is also crucial to investigate the variables that affect the access of vulnerable rural sectors to digital tools. This analysis of the environment will allow a better understanding of the challenges and opportunities in the digitization of agriculture in the region, providing a solid basis for assessing the impact of FAO's initiative and guiding future public policies and initiatives in this field.

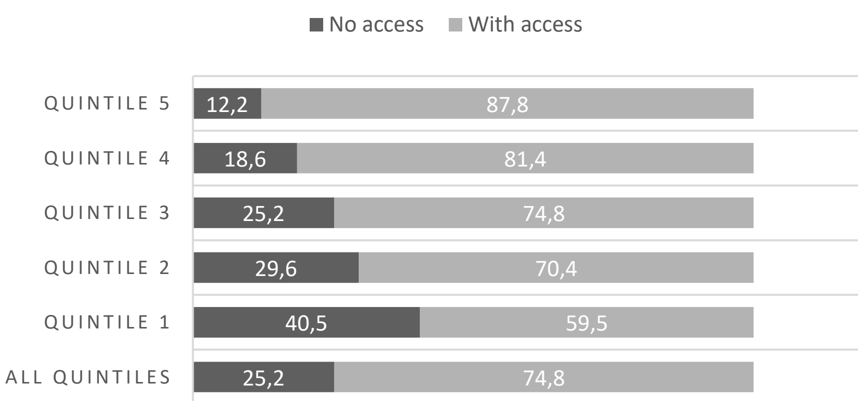
3. Poverty, Vulnerability and Digital Inequality

The imperative of digital transformation and innovation in agriculture has manifested itself in a context where the effects of the COVID-19 pandemic have exacerbated pre-existing problems. According to a study commissioned by FAO, the pandemic increased severe or moderate food insecurity in Latin America and the Caribbean from 31.9% in 2019 to 40.9% in 2020 (Clausen, 2022).

In terms of poverty and extreme poverty, the percentages in Latin America also increased during the pandemic, from 41.5% in 2019 to 46 per cent in 2020 (ECLAC, 2023). Although there was a decrease in poverty rates, reaching 39.2% in 2022 (ECLAC, 2023), rural sectors remain markedly more vulnerable compared to urban areas. In 2022, poverty and extreme poverty in urban areas in Latin America stood at 35.5%, while in rural areas it reached 60.5% (ECLAC, 2023). This relationship between poverty levels and internet access in the region reveals a significant correlation between socio-economic status and the ability to connect to the internet, which poses a considerable challenge for states in terms of inequality and connectivity. For example, the United Nations General Assembly has recognized internet access as a human right, highlighting its crucial role in advancing sustainable development and achieving the Sustainable Development Goals, with a commitment to "leave no one behind" (UN, 2021).

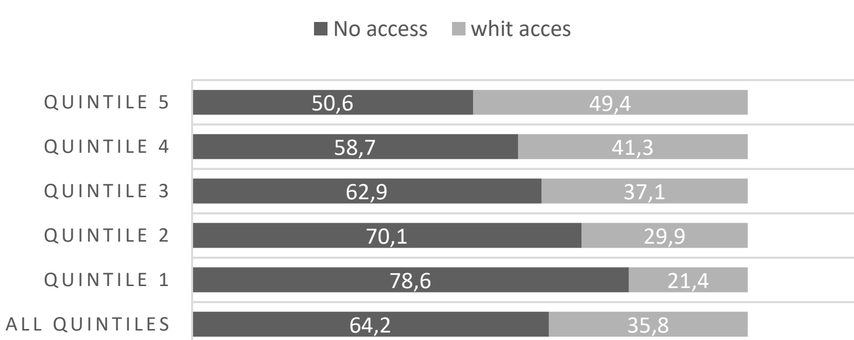
Despite the clear correlation between socio-economic status and connectivity, this relationship is even more affected by the urban-rural variable. Inequality in internet access is particularly acute in rural areas, where 64.2% of the population lacks access, compared to 25.2% in urban areas (CEPALSTAT, 2023). This data underscores the significant digital divide affecting rural communities and the urgency of addressing these disparities. Detailed information is given in Figures 1 and 2.

Figure 1. People with internet access in Latin American urban areas by per capita income quintiles.



Source: Economic Commission for Latin America and the Caribbean (ECLAC), CEPALSTAT, based on Household Survey Data Bank (BADEHOG), 2023.

Figure 2. People with Internet access in rural Latin America according to per capita income quintiles.



Source: Economic Commission for Latin America and the Caribbean (ECLAC), CEPALSTAT, based on Household Survey Data Bank (BADEHOG), 2023.

On the other hand, based on the discussion of the Human Rights Council of the United Nations General Assembly, it is possible to point out that inequality in access to digital tools is not only linked to economic and sectoral variables (rural/urban), but also to gender. This is expressed in the resolution approved by the Human Rights Council of the United Nations General Assembly on July 13, 2021, which notes with concern that almost half of the world's population, especially women and girls, do not have access to the internet, and states that the COVID-19 pandemic has exacerbated pre-existing inequalities due to digital divides (UN, 2021).

In this context, it is crucial to recognize that in rural Latin America and the Caribbean, digital inequality is a significant problem. Unlike the "digital divide", which refers primarily to disparity in access to the internet, "digital inequality" encompasses a lack of access that is multidimensional. This inequality includes not only a lack of connectivity, but also a lack of knowledge, skills for development and the minimum conditions necessary for digital progress.

Rodrigo Ramirez, Director of Public Policy on Digital Development at FLACSO-Chile, argues that the concept of digital inequality transcends the simple categorization of those who have access versus those who do not[3]. Ramírez argues that this concept encompasses a more dynamic and multidimensional framework that goes beyond internet penetration and access differences and addresses the capabilities and opportunities necessary for full participation in the digital sphere.

Public policies must address this digital inequality through a comprehensive approach that looks not only at expanding internet access, but also at developing digital skills and creating the conditions for true digital inclusion. This includes:

- **Infrastructure development**: Invest in the necessary technological infrastructure in rural areas in order to reduce the connectivity gap.

- **Digital training and education**: Implement training programs that improve digital skills, especially among women and vulnerable groups.

3 https://flacsochile.org/desigualdad-digital-nueva-constitucion-y-la-urgencia-de-infraestructura-que-hacemos/

- **Gender equity policies**: Design policies that address gender barriers to internet and technology access.

- **Local development initiatives**: Promote initiatives that use technology for economic and social development in rural communities, adapted to their specific needs.

By adopting a public policy approach that addresses these dimensions, governments in Latin America and the Caribbean can move towards greater digital equity, fostering an environment where all citizens have the opportunity to fully participate in the digital economy.

4. Potential Benefits of Digital Transformation in Rural Territories

According to a report commissioned by FAO, the potential benefits of digital transformation in agriculture include efficiency gains, reduction of labor-intensive work and improvements in agricultural production. These benefits translate into higher yields and sustainability, allowing the time saved to be spent on other productive activities, such as poultry farming or gardening, thus expanding income opportunities within the value chain (Santos Valle, Kienzle, 2021, p. 16).

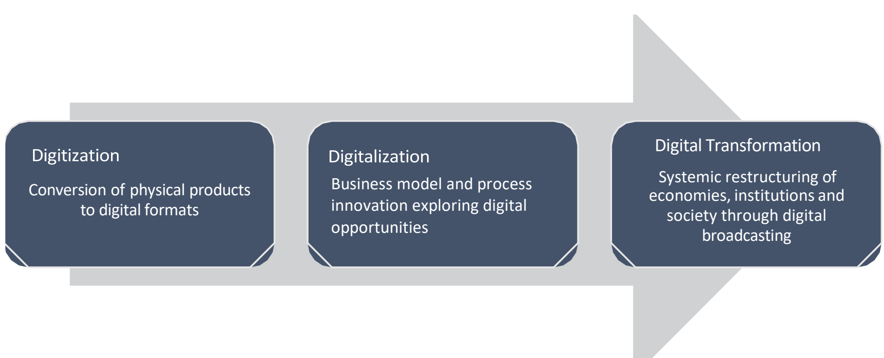
To fully explore the potential benefits of digital transformation in vulnerable rural areas in Latin America and the Caribbean, it is essential to distinguish between the concepts of digital transformation and digitalization. These terms are often used interchangeably, but they have different implications and scopes that affect the formulation of public policies and programs.

Digital transformation implies a profound reconfiguration that goes beyond the mere adoption of digital technologies. It encompasses fundamental changes in economic, cultural, social and political structures, embedding digitalization into the very fabric of society. It is a phenomenon that transcends simple process digitization, which refers to the application of digital technologies to optimize and improve specific processes within a business model. In contrast, digitalization, although related, has a more limited scope and is mainly oriented towards innovation and improvement of specific processes and business models. The distinction between the two concepts is crucial, as digital transformation implies an integral evolution that can restructure various spheres of society, while digitization focuses on the implementation of digital tools to improve operational efficiency.

Recognizing the difference between digitization and digital transformation enables policymakers to address digital inequality more effectively. Public policies that foster a holistic view of digital transformation can ensure that the implementation of technologies not only improves specific processes, but also enhances the quality and efficiency of the that also contributes to inclusive and sustainable development across the region. This is especially relevant in rural areas, where the adoption of digital technologies must be integrated with a holistic approach in order to maximize their positive impact on the living conditions of the population.

In advancing the digital transformation, it is crucial that public policies are designed to harness the potential benefits of this technological integration, addressing existing inequalities and promoting equitable development. This requires an approach that views digitization not as an end in itself, but as a tool to achieve a broader and deeper transformation in the socio-economic structures of Latin America and the Caribbean.

Figure 3. Concept of digitization and digital transformation.



Source: Kiron and Unruh, 2017.

5. Digital Transformation and Innovation in Agriculture in Latin America and the Caribbean

Digital transformation in agriculture in Latin America and the Caribbean has emerged as a strategic approach to address inequality and improve living conditions in vulnerable rural sectors. Analyzing the implementation of the project "Digital transformation and innovation in agriculture"[4], led by FAO and CELAC, reveals the interplay of public policies, specific programs and the diversity of contexts in which it is deployed. The project is implemented in twelve countries: Chile, Argentina, Uruguay, Guyana, Suriname, Trinidad and Tobago, Barbados, Panama, Costa Rica, Jamaica, Cuba and Mexico.

The implementation of the project covers territories with significant political, institutional, economic and cultural disparities, all of which pose unique challenges. To address these challenges, the project is articulated around three main components:

- **Exchange of experiences**

The goal is to facilitate collaboration between participating countries, promoting collective learning about institutional, cultural and economic differences. This exchange has been reinforced by cooperation with China, which allowed the participation of Chinese experts in various activities and visits to participating countries. For example, in May 2024, a delegation visited China to interact with leading e-commerce companies, such as Pinduoduo and Alibaba, exploring digital marketing and *e-commerce* applied to rural sectors.[5]

- **Implementation of digital technologies**

This refers to the implementation of advanced technologies such as the Internet of Things (IoT), drones and artificial intelligence in agriculture. These digital tools have been implemented in countries such as Argentina, Barbados, Guyana, Mexico, Suriname and Trinidad and Tobago to improve agricultural efficiency and sustainability. In Mexico, for example, a digital

4 https://www.fao.org/in-action/south-south-digital-transformation-innovation/en

5 https://www.fao.org/in-action/south-south-digital-transformation-innovation/news/news-detail/fao-and-five-celac-countries-participate-in-rural-digitalization-exchange-in-china/en

system for monitoring and evaluating data from sensors and information systems has been developed to improve water and fertilizer use, covering more than 12,946 hectares in Michoacán.

- **Connectivity**

This focuses on improving infrastructure in order to facilitate internet access in rural communities. Countries such as Chile, Costa Rica, Cuba, Jamaica, Panama and Uruguay have implemented technologies such as Starlink antennas for connecting farmers and rural communities. In Uruguay, the creation of connectivity centers has enabled women in the community to meet and use the internet for various activities, supporting community cohesion and digital literacy.

5.1. Implementation process

The implementation of these three components in various national contexts reflects the need for an adaptive and contextualized approach. Different levels of institutional and cultural development in each country require specific strategies to maximize the benefits of digital transformation. The adoption of a *path dependence* approach, where initial policies create a positive feedback effect, underlines the importance of tailoring digital transformation strategies to the particular characteristics of each country (Sánchez, 2003).

The experience-sharing component not only addresses disparities but also fosters the creation of knowledge networks that enrich the technical and strategic capacity of participating countries. The implementation of digital technologies points to the transition to "agriculture 4.0", in which the integration of IoT and artificial intelligence optimizes agricultural processes and improves the resilience and sustainability of rural communities. The focus on connectivity ensures that rural communities are not left behind in the digital age, providing the necessary access to engage in online educational, commercial and social activities. However, connectivity alone is not enough; digital literacy is crucial in ensuring that communities can effectively use digital resources, transforming internet access into a real tool for community development.

5.2. Public policies and sustainability

FAO's capacity to act as a link between various institutions facilitates the creation of deliberative spaces where actors from the public, private and civil society sectors converge. These spaces are essential for the formulation and sustainability of public policies that promote digital transformation and innovation in agriculture. Examples of these collaborations include the cases of Chile, Costa Rica and Uruguay, where cooperation between different sectors has allowed local projects to expand and sustain themselves over time.

Digital transformation in agriculture, as promoted in this project, seeks not only to improve efficiency and productivity, but also to build resilient agri-food systems that benefit rural communities as a whole. Public policies must therefore integrate digitalization as part of a broader approach to rural development, ensuring that technological innovations effectively contribute to the socio-economic well-being of rural regions in Latin America and the Caribbean.

6. Digital Transformation in Rural Sectors and Public Policies

After analyzing the outputs of the FAO project, it is crucial to examine how the Digital Transformation and Innovation in Agriculture initiative acts as a tool for states in the region to strengthen, design and implement policies and programs that facilitate the transformation of vulnerable rural communities. The project uses the idea of implementing what are known as "*Living Labs*", which according to the *European Network of Living Labs*, are "*open innovation ecosystems in real-life environments that use iterative feedback processes along an innovation lifecycle approach to create sustainable impact*" (European Network of Living Labs, 2022). In simple terms, they are small-scale experiments designed to analyze, study and learn about the impact of certain experiences.

The importance of these laboratories lies in their ability to identify best practices in policy design at regional or national levels through small-scale projects. Small-scale implementation makes it easier to obtain direct feedback from the beneficiary communities, allowing for policies and programs to be developed according to a bottom-up approach.

However, unlike in a conventional laboratory where it is possible to isolate and control most of the external factors, in this specific approach used by the project, what is of interest is to set up these workshops in real conditions, where the interests of the actors, the institutional framework, the spaces of interaction in which they move and the difficulties they face are those of everyday life. It is not a matter of setting up a social experiment in "optimal" conditions, but of accompanying the actors – the state, social organizations, companies, etc. – in the concrete implementation of solutions to the problems and challenges they themselves identify. This change of approach contributes to building experiences closer to the dilemmas of implementation that rural territories face when trying to promote a digital transformation process, which provides a much broader and more complex learning repertoire that can feed a more complete discussion on the paths of transformation.

The 12 countries where this approach has been implemented are serving as starting points for states to design and deploy policies and programs based on digital transformation for the development of vulnerable rural sectors. The basic idea is that it should not be implemented in isolation but should be embedded in existing policies and programs.

The experiences of Chile, Costa Rica, Mexico and Panama are used to briefly illustrate this approach. This review will provide a deeper insight into how states have approached digital transformation and how the FAO project has been aligned with existing policies.

- **CHILE**

In the case of Chile, the FAO project is part of the **National Rural Digital Connectivity Plan**[6], which seeks to reduce the barriers and gaps in access, coverage, use, affordability, competencies and skills that are most prevalent in rural areas. This National Connectivity Plan aims to advance towards universality, inclusion, equity and access to digital connectivity with a

6 https://www.indap.gob.cl/noticias/gobierno-anuncia-plan-interministerial-que-se-enfocara-en-combatir-la-brecha-digital-en-el

minimal basis that enables citizens' digital well-being and meaningful connectivity.

In addition to the above, the FAO's Digital Transformation project also ties in with the government's **Zero Digital Divide** plan[7], which aims to ensure that everyone in the country has access to connectivity regardless of where they live or their economic conditions.

It is through the aforementioned plans that it has been possible to take a long-term view of connectivity, which has allowed different public institutions to come together to participate in the coordination of the FAO initiative through a *digital working group for the rural sector*, The Ministry of Agriculture, the Agricultural Development Institute (INDAP), the Office of Agricultural Studies and Policies (ODEPA), the Undersecretariat of Telecommunications (Subtel) and the Undersecretariat of Tourism (Subturismo).

The FAO initiative has been carried out in four localities in the region; 1) Batuco, Ránquil commune; 2) Buenos Aires, Portezuelo commune; 3) Pullay, Cobquecura commune; and 4) Antiquereo, Trehuaco commune, which have acquired priority at central and regional levels due to the proportion of young people and women in relation to the number of people in the locality, the potential for productivity, the level of organization and possibility of generating activities that allow for the sustainability and scalability of the project.

In order to ensure that the participating population had the minimum conditions for optimal use of the internet connection, a basic digital literacy skills course at user level, focusing on computer programs and mobile applications, was held through the National Training and Employment Service (SENCE). The workshop was aimed at 58 small producers and members of Neighborhood Councils, who received tablets to facilitate the use of the internet in their localities. In addition to the SENCE training, FAO offered digital literacy training in four neighborhood associations.

7 https://www.gob.cl/noticias/lanzamos-el-plan-brecha-digital-cero-para-que-todas-y-todos-tengan-acceso-conectividad-independiente-del-lugar-en-que-viven/

The project also focused on the use of the Google Account, digital marketing and social media[8].

It is worth noting that the cross-cutting coordination table set for the implementation of the FAO-CELAC initiative has remained active throughout the course of the project, thus enabling the sustainability and potential increased connectivity in the Ñuble region[9]. This instance will have a relevant role in future connectivity plans and policies, given that the experience acquired by the different institutions can be highly relevant when developing new digital initiatives in the region or throughout the country. The closing seminar of Phase I of the project, which was attended by representatives of the Ministry of Agriculture, INDAP, ODEPA, Subtel, Subturismo, municipalities, the Embassy of the People's Republic of China, among other institutions, corroborated the willingness of the different actors to continue deepening the process of digital transformation in the territories.

- **COSTA RICA**

The digital agriculture and agro-climatic information project in the canton of Guatuso, Costa Rica, is an initiative led by FAO and implemented by the Cooperative of Rural Electrification of San Carlos (COOPE-LESCA R. L.L) in collaboration with various entities, including the Ministry of Agriculture and Livestock (MAG), the Rural Development Institute (INDER), Central American Indigenous and Community Agroforestry Coordinating Association (ACICAFOC) and the Municipality of Guatuso. This project is aligned with the "**National Plan for the Improvement of Productivity and Sustainability of the Agricultural Sector**" Gomez, Guillén, et.al, 2022), known as AGRINNOVA-CION 4.0, which seeks to boost economic recovery and employment generation, especially after the COVID-19 pandemic, through the implementation of digital tools.

The objective of the project is to implement a sustainable and scalable "territorial digital ecosystem" that allows for the extension of digital innovation by connecting at least fifty families in the Guatuso

8 https://www.fao.org/in-action/south-south-digital-transformation-innovation/news/news-detail/la-fao-y-el-gobierno-de-chile-promueven-el-fortalecimiento-de-habilidades-digitales-en-sectores--rurales/es

9 https://x.com/FAOChile/status/1760364264957583403

Farmers' Settlements with precision agriculture systems and more efficient, friendly and sustainable production technologies[10]. The digital ecosystem established allows for agro-climatic information and traceability of harvested products (through the data generated by the measurements), in addition to generating data on the state and health of the pastures, which is very valuable information given that 90% of the farming families have dual-purpose pasture on their plots.

The project was developed in eight of the thirty-one rural settlements of Guatuso and benefited, in this first stage, twelve farming families that produce grass for dual-purpose cattle (milk and meat), cassava and cocoa, among other products. The implementation rationale was by "cascade" or extrapolation of data from the placement of four units of equipment (weather stations, dendrometers, nitrate and potassium sensors and humidity and suction probes) on three farms in the canton selected on the basis of technical criteria with the guidance of a specialized MAG staff. This group became known as the "SMART" families.

Likewise, work was carried out with nine more families called "ADVANCED", which were equipped with sensors for measuring soil humidity and temperature and detecting nitrates and potassium, which, together with the "SMART", generated data that can be applied to 320 hectares around them. This makes it possible to reach about 50 families (known as "BASIC" families), who with the accompaniment of MAG technical staff will be able to have data in order to make decisions for the management of their farms.

It should be noted that the experience of digital agriculture developed in the canton of Guatuso allows for the establishment of the foundations of a socio-economic cooperation model based on public-private partnerships (PPP), where public institutions such as ministries and municipalities can work together with entities such as COOPELESCA R.L., which is governed by private law. This model allows small and medium sized farmers to have a sustainable and inclusive system of technical assistance and production, while facilitating the scalability of the experience to other cantons in the Northern North Territory (NTN).

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10 https://x.com/FAOCostaRica/status/1717965463626383434

The capacity that exists because of the formation of inter- institutional coordination, accompanied by public-private partnerships, allows the government's National Development Plan to be sustained and scaled up to other territories in Costa Rica. This facilitates the constitution of future public policies with the participation of actors and the experience acquired through the FAO project[11].

- **MEXICO**

Mexico is facing a severe water crisis due to a prolonged period of drought. According to the National Water Commission (CONAGUA), more than 65% of the national territory suffers some degree of drought. It is because of this problem that the FAO initiative seeks to support the efficient use of resources and is part of the Sectoral Program for Agriculture and Rural Development 2020-2024, derived from the National Development Plan (PND). This established program "contributes to guaranteeing the right to nutritious, sufficient and quality food and to making progress in ending hunger, achieving food security and improved nutrition and promoting sustainable agriculture, goals contemplated in Sustainable Development Goal 2 of the 2030 Agenda approved by the United Nations" (Programa Sectorial de Agricultura y Desarrollo Rural, 2019, 6).

The Ministry of Agriculture and Rural Development (AGRICULTURA) stood out as the main counterpart of the project, showing interest and openness to its adoption. Its intervention in the territory was carried out through the coordination of the **Inter-Institutional Working Groups (**MTI), which bring together more than 40 federal and state governmental entities, as well as 33 representatives of municipal councils, academia, research centers and members of civil society, in a joint effort to address the challenges of the area.

The Mexican Institute of Water Technology (IMTA), as the executing agency, provided its specialized technical component. This is because IMTA focuses on water management through research and technological development, for which it has more than 300 specialists. Its specific capabilities give it a competitive advantage and enable it to implement

11 https://www.fao.org/in-action/south-south-digital-transformation-innovation/news/news-detail/fao-coordina-trabajo-con-grupo-intersectorial-encargado-de-instalar-piloto-digital-en-costa-rica/es

projects aimed at water resource efficiency, as well as to provide training for products and organizations involved in such projects[12].

The FAO initiative in Mexico took the name "Design and implementation of a digital monitoring and evaluation system" in 12,946 hectares of Modules III, IV and V of the Irrigation District 020 Morelia-Queréndaro, Michoacán, which represent a significant part of the total 20,397.16 hectares. Through sensors and geographic information systems, data are obtained to optimize the use of water and fertilizers, benefiting water user associations and farmers.

The producers of the Irrigation District 020 Morelia-Queréndaro-Modules II, IV and V, were key subjects of the intervention and benefited directly from the recommendations on the optimal use of water and fertilizers on their crops, as well as from the technology transfer. Their participation has been crucial for the effective implementation of sustainable practices and for ensuring that innovations reach and are applied on the ground, thus ensuring the sustainability and scalability of the project.

The combination of governmental perspective, international experience and local voices has generated a holistic approach that not only promotes technical efficiency but also fosters inclusive participation and a deep understanding of local needs and contexts. This allows for the future design and implementation of programs born with cross-cutting visions of what are the best solutions to the water problems affecting Mexico and several countries in Latin America and the Caribbean.

- **PANAMA**

In the case of Panama, the FAO initiative is part of the **Program for Sustainable and Inclusive Agricultural Innovation (PIASI)[13],** which is implemented through a loan requested from the Inter-American Development Bank (IDB). This resource has been used to accompany the country's commitment to the recovery and sustainable transformation of the agricultural sector, which, although it emerged before the pandemic, focuses its actions on family farmers and includes innovation and digitalization among its components.

12 https://x.com/FAOMexico/status/1724570420345799157

13 https://proyectos.idiap.gob.pa/proyectos/

The initiative has been carried out in the Ngäbe Bugle Comarca, focusing on indigenous women[14]. The project has been implemented in the Districts of Nole Duima and Muna, the districts of Hato Chamí and Chichica, and in the communities of Boca del Monte, Cerro Tula, Alto Cedro and Cerro Gavilán. These communities present problems of high poverty rates, as a result of poor income distribution; marginalization and social exclusion; lack of opportunities for income and employment generation; and unequal coverage of basic services and infrastructure. These problems are addressed by the Integral Development Plan for Indigenous Peoples of Panama (2013).

The institutions that participated in the FAO initiative in Panama were the Fundación Nuestra Señora del Camino (FNSC), a non-governmental organization whose mission since 2005 has been to strengthen the capacities of vulnerable groups in the Ngäbe Bugle Comarca, as well as their socio-economic integration, development with equity and access to opportunities; the Institute for Agricultural Innovation of Panama (IDIAP), a governmental institution whose main function is research to generate, adapt, validate and disseminate agricultural knowledge and technologies, framed within the policies, strategies and guidelines of the agricultural sector; and the Ministry of Agricultural Development of Panama (MIDA).

The project carried out a process of **digital literacy** through training sessions lasting 100 hours, which aimed to increase competence in the use of office software; improve efficiency in internet navigation; reinforce hardware and software security; encourage participation in the training sessions and promote the practical application of knowledge in agricultural and artisanal activities.

It should be noted that, in addition to training, the FAO initiative aims to enable community connectivity to internet access. This is why *Starlink* antennas have been installed, enabling communities to use the network for the first time. In order to promote the sustainability of the initiative, each organization within the community is responsible for the equipment provided by the project and allows people to make optimal use

14 https://www.fao.org/in-action/south-south-digital-transformation-innovation/news/news-detail/fao-construye-capacidades-digitales-en-comunidades-rurales

of the internet based on the availability of the equipment and the knowledge acquired in the training sessions.[15]

Regarding sustainability, and with the objective of guaranteeing it, MIDA, through the Directorate of Rural Development and IDIAP, is responsible for following up with the communities, providing the required technical assistance and extension. In addition, these governmental institutions are in charge of considering the communities participating in the initiative for programs and projects generated within the area.

While we have been able to illustrate in some detail the FAO initiatives in four countries, as well as the existing policies and programs on digital transformation, we still need to present the policies and experiences in the other countries participating in the project. This information is provided in a summary table that shows the existing policies and programs in the 12 CELAC countries participating in the FAO project (Table 1). The table also allows us to see the institutions involved in each initiative, considering the cross-cutting commitment that the countries of the region have with the development of digital transformation.

15 https://twitter.com/FAOMesoamerica/status/1780345009113362674

Table 1. Summary of experiences, policies and programs in 12 countries in Latin America and the Caribbean.

	Characteristics of the experience	Key actors	Territorial associations	Territory	
Argentina	Training for groups of producers with IGDO seals (Geographical Indications and Designations of Origin). The objective is that, through digital marketing and the use of different digital tools, they can give greater added value to the seals of origin.	Secretariat of Agriculture, Livestock and Fisheries (SAGYP), Argentine Chamber of the Small and Medium Food and Beverage Industry (CAPYMA), Integral Assistance Service for Agri-Food SMEs (SAIPA), Argentine Agency for International Trade Investments (AAICI).	Asparagus from Médano de Oro de San Juan, Platense Artichokes, Mesa de Fortalecimiento Institucional IGDO	Médano de Oro, San Juan; La Plata, Buenos Aires	Federal Management Improvement Plan for Food and Beverage Companies
Barbados	Training and funding for technified irrigation. FAO supports with training in technified agriculture, drone management and data reading for their proper use.	Ministry of Agriculture and Food Security (MAFS), Barbados Agricultural Development and Marketing Corporation (BADMC), Guyana Rice Development Board (GRDB), Barbados Agricultural Society (BAS)	Barbados Agricultural Society (BAS)	River Plantation, Greenland, Lears plantation	Farmers' Empowerment and Enfranchisement Drive (FEED)
Chile	Delivery of computer equipment,Starlink antennas and video conferencing equipment. In addition, the following have carried out digital literacy training. All this through the INDAP-PRODESAL platform. It should be noted that this FAO-MINAGRI coordination SUBTEL-SUBTURISMO was promoted by the rural digitization table, which is a technical policy space that coordinates digital transformation projects in the region and the country.	Ministry of Agriculture (MINAGRI); Institute for Agricultural Development (INDAP) Oficina de Estudios y Políticas Agrarias (ODEPA), Subsecretaría of Telecommunications (SUBTEL) Subsecretaria de Turismo (SUBTURISMO), Rural Connectivity Roundtable, Qualitas Rural Development Foundation	Junta de vecinos de Pullay, Junta de vecinos de Batuco, Junta de Vecinos de Buenos Aires, Junta de vecinos de Antiquireo	Pullay, Cobquecura, Batuco, Ranquil, Buenos Aires, Portezuelo, Antiquireo, Treguaco	National Rural Digital Connectivity Plan

	Characteristics of the experience	Key actors	Territorial associations	Territory	
Costa Rica	Training for technical specialists and farmers in the use of meteorological tools, irrigation sensors and fertilization. These instances are at boosting input savings (fertilizers and water) and, in turn, reduce the uncertainties and risks of family production.	Municipality of Guatuso, Ministry of Agriculture and Livestock (MAG), National Institute for Innovation and Transfer of Agricultural Technology (INTA), Rural Development Institute (INDER), San Carlos Rural Electrification Cooperative R.L. (COOPELESCA), Asociación Coordinadora Indígena y Campesina de Agroforestería Comunitaria Centroamericana (ACICAFOC)	Association of Agroenvironmental Cocoa Producers of Guatuso (ASOPAC)	Canton of Guatuso	National Plan for the Improvement of Productivity and Competitiveness Sustainability of the Agricultural Sector (AGRIN-NOVATION 4.0)
Cuba	Creation of a digital ecosystem in the communities of Finca Vista Hermosa, in order to attract new agricultural producers, improve investment and tourism.	Ministry of Agriculture (MINAG), Ministry of Tourism (MINTUR), Ministry of Foreign Trade and Foreign Investment (MINCEX), Grupo Empresarial Flora y Fauna (GEFF), Fundación Universitaria de Innovación y Desarrollo (FUNDACIÓN UH)	Colectivo Vista her-mosa, Grupo de De-sarrollo del Municipio de Guanabacoa	Vista Hermosa Farm	Local Development Programme for Livestock and Agriculture in the municipality itself
Guyana	Improved rice production and reduced losses caused by the lack of monitoring. Drones have been delivered to facilitate the monitoring of the fields and the technical team has been trained in the appropriate use of the information collected by drones.	Ministry of Agriculture (MINAG-RIGY), Guyana Rice Development Board (BRBD)	Rice Producers Association	Pomeroon-Supenaam, Essequibo Island-West demerara, East Berbice- Corentyne	Agriculture Development Strategy-2021-2025

	Characteristics of the experience	Key actors	Territorial associations	Territory	
Jamaica	Creation of a platform that can be used on different devices (tablets, mobile phones, computers) with the aim of improving the flow of information from the entire production chain, including different types of crops and livestock, as well as weather information and upcoming events. This platform allows farmers to receive information from markets and to be able to make informed decisions.	Ministry of Agriculture and Fisheries (MOAF), Rural Agricultural Develop- ment Authority (RADA)	Mile Gully Youth Farmers Group, Mile Gully Progressive Farmers Group	Mile Gully	Jamaica's Vision 2030
Mexico	The experience is based on two main points: 1) technical support for state monitoring and evaluation through equipment provided by the government and 2) generation of strategic primary information for the agricultural, livestock and fisheries sector at the national level. These points have the objective of increasing sustainable development practices.	Secretaria de Agricultura y Desarrollo Rural (SADER), Comisión Nacional del Agua (CONAGUA), Instituto Mexicano de Tecnología y Agua (IMTA), Dirección General de Políticas, Prospección y Cambio Climático (DGPPyCC), Mesa de Trabajo Interinstitucional	Asociación de Productores del Valle Álvaro Obregón y Tarímbaro A.C., Asociaciación de Usuarios del Canal Zacapendo A.C., Asociación de Usuarios de la Presa Malpaís A.C.	Queréndaro	Agriculture and Rural Development Sectoral
Panama	Delivery of computer equipment and starlink antennas and digital literacy training in 4 indigenous communities. The objective has been to improve connectivity in areas that are lagging behind.	Ministerio de Desarrollo Agropecu- ario (MIDA), Instituto de Innovación Agropecuaria de Panamá (IDIAP), Fundación Nuestra Señora del Camino (FNSC)	Community of Cerro Gavilán, Community of Alto Cedro, Municipality of Boca del Monte, Community of Cerro Tula	Cerro Gavilán, Alto Cedro, Boca del Monte, Cerro Tula	Programme for Sustainable and Inclusive Agricultural Innovation (PIASI)

	Characteristics of the experience	**Key actors**	**Territorial associations**	**Territory**	
Suriname	Development of a digital framework for collection, storage, analysis, distribution and reporting of plant production data.	Ministry of Agriculture, Animal Husbandry and Fisheries (LVV)	To be confirmed.	Saramacca, Paramaribo Wanica, Para, Commewijne and Marowijne	Animal Traceability Scheme (Animal Traceability Solutions ATS)
Trinidad and Tobago	Training on traceability, which enables farmers to access better markets.	Ministry of Agriculture, Land and Fisheries (MALF), Natural Agricultural Marketing and Development Corporation (NAMDEVCO), Supermarket Association of Trinidad and Tobago (SATT), Farmers and Farmers Associations		St. George, Caroni, Mayaro, St. Partick, St. Andrew, Victoria, Nariva	Digital transformation strategy
Uruguay	Delivery of computer equipment and videoconferencing equipment. In addition, digital literacy training has been provided in order to contribute to the development of community centers. It should be noted that an alliance was made with a public internet company that brought connection to the communities.	Directorate-General for Rural Development, Mesa de Desarrollo rural basalto superficial and its member organizations, National Commission for Rural Development, National Administration Telecommunications, Local Organizations	Sociedades de Fomento Rural Basalto Ruta 31, Sociedades de Fomento Rural colonia Lavalleja, Asociación de fomento rural Valentín, sociedad de Fomento rural Vera y cañas, Sociedad de rural Mataojo Grande, Asociación Rural Guaviyú de Arapey	Paso Cementerio, Carumbé, Pueblo Lavalleja, Puntas de Valentín, Puntas de Valentín, Cerros de Vera, Pueblo Fernández, Sarandí de Arapey, Colonia Artigas, Sexta sección, Pueblo Biazini	Rural Productive Development Programme II (RPRDP II)

It should be noted that each digital initiative has been defined through different processes according to the institutional characteristics of each country. However, there are common elements that allow the definition process to be summarized in the following steps, which are not consecutive, but can be interchangeable according to the reality of each country:

1. Analysis of public policies, programs and/or projects related to digital transformation in rural sectors of the country.

2. Agreements with national and local institutions on priorities in terms of territories and participants.

3. Call for discussions with institutions and organizations from civil society and the private sector in order to generate cross-cutting coordination instances that facilitate sustaining and scaling up initiatives in the future.

4. Workshops and field visits with the participation of small and medium-sized farmers, women, young people and indigenous people, depending on the composition of the territory's inhabitants.

5. Definition of local strategic partners for implementation.

6. Collective definition of the design of the intervention model and implementation of digital transformation tools in rural territories.

7. Summary and Conclusion

Throughout this chapter it has been emphasized that the high rates of poverty and extreme poverty in rural areas are closely linked to digital inequality. This disparity prevents vulnerable rural communities from accessing the multiple benefits of digital transformation, limiting their ability to move towards more efficient and sustainable agriculture and to take advantage of the benefits of Agriculture 4.0.

This represents a significant challenge for states in the region, which have begun to deploy efforts to promote digital transformation in these sectors.

The cases of Chile, Costa Rica, Mexico and Panama, briefly reviewed in this chapter, as well as the experiences of other countries listed in Box 1, demonstrate that Latin American and Caribbean states have initiated the formulation of plans that seek to implement digital transformation in rural areas.

What we are corroborating with the *Digital Transformation and Innovation in Agriculture* project is that it is necessary to create minimum essential conditions for the success of these initiatives, which include:

- Cross-sectoral participation and commitment of public and private institutions;
- Integration of initiatives into existing policies, programs or projects;
- Active participation of the subjects of policies/programs/projects;
- Digital literacy programs.

These conditions, present in the cases reported, have facilitated the implementation of the initiatives. Community participation has allowed for constant feedback, while intersectionality has offered a broad vision and commitment, which can create the circumstances for the future scalability and sustainability of the projects.

In addition, digital literacy has equipped the population with the necessary skills to use digital tools in an optimal way, facilitating progress towards a more robust process of digital transformation in rural areas.

FAO's support through the *Digital Transformation and Innovation in Agriculture* project has been fundamental in establishing solid foundations in the various countries, which facilitates the future design of public policies and programs that can sustain and scale up the positive results of current experiences.

For these experiences to be scaled up into effective policies and programs in the region, it is essential to reach consensus and cross-cutting will that recognizes digital transformation as an essential element for the development of family farming and the improvement of living conditions in vulnerable rural sectors. *Cross-cutting coordination roundtables*, comprising civil society organizations, state institutions and the private sector, as seen in countries such as Chile and Costa Rica, are crucial in order to ensure that local experiences translate into tangible improvements for these communities.

These cross-cutting spaces facilitate the participation of civil society and other relevant actors in the design, implementation and evaluation of policies, reinforcing a *bottom-up* approach, ensuring that public policies better reflect local realities and thus increase their quality and effectiveness.

As more digital inclusion policies and programs are implemented in vulnerable rural areas in the region, states will face the challenge of developing a robust institutional framework to monitor and evaluate the effectiveness of these efforts.

Although Latin America and the Caribbean still have a considerable way to go, regional efforts and the growing consensus on the benefits of digital transformation to improve living conditions in vulnerable rural areas suggest that the region is moving towards a deeper discussion on the institutionalization of this issue. FAO's initiative with CELAC, therefore, contributes by providing countries with lessons to be further examined as more concrete results are obtained, offering valuable experiences and learning for the development of the digital transformation in the region and, consequently, for the progress of family farming and rural communities in Latin America and the Caribbean.

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4 Responsible Digital Innovation and Data Governance in Smallholder Agriculture: Navigating in the Digital Age With Ethics and Equity

Andrea Gardeazabal Monsalve

1. Introduction

Digital innovation and effective data management represent transformative opportunities to improve the productivity, sustainability and resilience of smallholder farmers (Basso and Antle 2020). The design and adoption of responsible digital solutions, coupled with appropriate data governance, have the potential to empower farmers by providing them with access to relevant information, decision-making tools and advanced agricultural services. This can contribute significantly to improving their livelihoods and the economic development of their communities (Klerkx et al. 2019; Lajoie-O'Malley et al. 2020).

Specifically, the implementation of technologies such as sensors, drones, geographic information systems and big data analysis can optimize input use, improve crop management or guide optimal management dates in order to increase yields (Lindblom et al. 2017). Precision agriculture can also contribute to sustainability by reducing the use of water, fertilizers and pesticides (Clapp and Ruder 2020). In addition, digital platforms can better connect farmers to markets, giving them access to information on prices, demand and logistics (Abate et al. 2023).

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However, smallholder farmers in Latin America face a number of challenges due to the restrictive and exclusionary conditions of the rural context (Zaballos and Rodriguez 2017). These challenges include lack of access to connectivity and technological infrastructure, the digital divide, high costs of digital technologies, lack of technical skills and support, and concerns around privacy and data security (Agüero et al. 2020; Selva and Rosa 2015; Zaballos and Rodriguez 2017). Additionally, existing digital systems are designed for a specific group of users, leaving out already excluded or vulnerable populations and, when these systems include other groups, they allow the more powerful to take advantage of the work or resources of the less advantaged, thus increasing inequality (Heeks 2022).

This requires coordinated regional efforts in terms of capacity building, financing and public policy, as well as a comprehensive approach to the management of innovations that addresses technical as well as socio-economic and cultural barriers. It is essential to ensure that all farmers, regardless of their location or available resources, can fully benefit from the opportunities offered by digitalization in agriculture (Eastwood et al. 2019). Data privacy, ownership and equitable access to information are priority concerns that need to be carefully considered in the design and implementation of digital solutions for small-scale agri-food systems (Kaur et al. 2022). It is therefore crucial to address the ethical and legal implications related to the collection, storage and use of agricultural data (van der Burget al. 2019).

This chapter aims to provide an approach to the concept of Responsible Digital Innovation, specifically related to smallholder farmers, connecting the various facets that comprise it, from ethics and sustainability to social inclusion and transparency. In addition, three cases in Latin America will be analyzed to illustrate how digital innovation, when implemented responsibly, has the potential to transform smallholder agriculture, empower farmers and contribute to the sustainable development of their communities. Finally, the chapter considers two key elements of the ecosystem, public policy and governance frameworks, as enablers of the transformation process.

2. Fundamental Principles of Responsible Digital Innovation

Responsible Digital Innovation is an approach that seeks to harmonize technological development with ethical values, social needs and environmental considerations from the earliest stages (Bastidas et al. 2023). In the context of smallholder agriculture, this concept becomes crucially relevant due to the direct impact these innovations have on producers' livelihoods, food security and environmental sustainability (van der Burg et al. 2019).

Recent studies on Responsible Digital Innovation in agri-food systems (van der Burg et al. 2019; Eastwood et al. 2019; Klerkx and Rose 2020; Rijswijk et al. 2021; Rose and Chilvers 2018) suggest cyber-socio-technical analysis frameworks (Metta et al. 2022) that allow insights into the complexity of digital ecosystems and their consequences. For example, the Responsible Research and Innovation (RRI) framework (Eastwood et al. 2019) integrates key principles such as anticipation, inclusiveness, reflexivity and responsiveness to guide innovation in a socially and ethically acceptable direction. This approach is designed to ensure that technological advances, while pursuing economic and efficiency gains, also address potential social, ethical and environmental impacts. It encourages stakeholders to think about the consequences of innovations from the outset and to engage in an ongoing dialogue to align the innovation process with societal values and needs. The cyber-socio-technical approach provides a holistic view of the interactions between the social, cyber and physical domains within agri-food systems and helps to understand how digital technologies integrate and transform traditional production practices. It also emphasizes the interconnectedness of technological, social and environmental factors and helps to identify the systemic impacts of digital transformation (Rijswijk et al. 2021). The main concepts of these responsible digital innovation approaches are presented below:

Anticipation: This means identifying potential negative consequences of innovations before they occur through methods such as scenario planning, risk assessment and foresight analysis. Anticipation helps to prepare for future challenges and mitigate risks associated with new technologies (Rose and Chilvers 2018).

Example: Before implementing an automated irrigation system, a risk assessment can be carried out to identify possible system failures and their impacts on water supply and crop health. If a technical failure could leave crops without water during a critical period, back-up mechanisms and early warnings should be designed in order to avoid significant losses. Also, prospective analysis can anticipate how climate change might affect water availability, adjusting the system to be more resilient to such changes.

Reflexivity: Requires actors to analyze their own roles, positions and potential biases in the innovation process. It involves questioning the norms and values underlying technological development and considering how these may influence social outcomes. Reflexivity helps make the innovation process more transparent and aligned with public interests (Eastwood et al. 2019).

Example: When designing a crop monitoring application, developers may find that their perception of "efficient practices" differs from local traditions that are also sustainable. By reflecting on this with farmers at the local level, they can adjust the application to respect and support these traditional practices.

Inclusion: This refers to involving a variety of stakeholders, including marginalized and under-represented groups, in the innovation process through participatory approaches such as workshops, public consultations and collaborative research projects. Inclusion ensures that the perspectives and expertise of all relevant stakeholders are considered, which can lead to more robust and widely accepted results. In any case, digital innovation involves designing and delivering solutions to a particular group. Establishing with clarity and awareness which groups are excluded from the service makes it possible to avoid or foresee unexpected consequences and mitigate their impact (Heeks 2022).

Example: In designing a seed exchange app for a rural community, women farmers and youth are involved in the process. This results in an interface that uses local symbols and allows voice recordings to overcome literacy barriers.

Responsiveness: This involves the ability of the innovation process to change direction or adapt based on stakeholder feedback and emerging issues. This dynamic aspect of RRI allows for adjustments as new information becomes available or as societal values evolve. Responsiveness ensures that innovations remain relevant and beneficial over time (Eastwood et al. 2023).

Example: An NGO adjusts its digital training programme for small-scale livestock keepers after receiving feedback on the difficulty of using smartphones. They implement a simpler text messaging-based system to share animal health information.

Equity: This refers to ensuring that the benefits of digital technologies are distributed fairly and equitably, without discriminating against the most vulnerable producers on the basis of gender, race, geographic location or socio-economic status (Klerkx and Rose 2020; Rotz et al. 2019). Furthermore, ensuring the availability and affordability of technologies, guaranteeing that benefits are distributed equitably and that no group is disproportionately disadvantaged by new innovations (Klerkx et al. 2019; Shepherd et al. 2020).

Example: A digital marketing platform for smallholder farmers in disadvantaged regions can offer reduced fees or subsidies for the use of the technology to low-income farmers and provide customised technical assistance to help them become familiar with the tool.

Responsible design: This includes creating technologies that are not only functional, but also socially and environmentally responsible, including safety, ethical and sustainability considerations, from the early stages of development (Rijswijk et al. 2021).

Example: Development of a pest diagnosis app for small farmers that works offline and consumes little battery power, considering connectivity and energy limitations in rural areas.

System Complexity: Refers to the intricate interactions and dependencies within agri-food systems. Understanding this complexity is essential for managing the risks associated with digital transformation and for designing systems that are resilient and adaptive (McCampbell, Schumann, and Klerkx 2022).

Example: A farmer cooperative purchases a set of basic soil moisture sensors and weather stations that are installed on representative plots in the region. The data collected is shared among all members through a common access platform, which can be as simple as a WhatsApp group or an online forum. This approach recognizes the complexity of the farming system by considering not only technological data, but also local knowledge and farmers' traditional practices.

Ethics: Ethical considerations in digital agriculture involve ensuring that technological advances respect social values and norms, and do not lead to adverse social, environmental or economic outcomes (Ryan 2023). Ethical design of technologies must consider the impacts on all stakeholders, including farmers, consumers and the wider community. This includes addressing issues such as animal welfare, environmental sustainability and social equity (van der Burg et al. 2019). The RRI approach emphasizes the need for reflexivity, where innovators must critically assess their own assumptions and the ethical implications of their work (Eastwood et al. 2023).

Example: A micro-credit initiative based on artificial intelligence for small farmers is designed with a local ethics committee that oversees the approval algorithms, ensuring that they are fair and culturally appropriate.

Privacy: Privacy concerns in digital agriculture relate mainly to the collection, storage and use of data. With the increasing use of digital technologies such as mobile phone devices, the IoT - a network of connected objects and devices that transmit and receive data - and big data analytics, a significant amount of data is generated that can include sensitive information on farming practices, crop yields and livestock health. Ensuring the privacy and security of this data is very important (Kaur et al. 2022). The cyber-socio-technical framework highlights the urgency of designing digital systems that respect user privacy and include robust data protection measures. Issues of data ownership and control are also critical, as they relate to who has access to data and for what purpose it is used. Ensuring transparency in the use of data and providing farmers with control over their own data are very relevant aspects when it comes to addressing privacy in digital agriculture (Rijswijk et al. 2021).

Example: A livestock monitoring project for nomadic pastoralists uses GPS collars, implementing a system where data is owned by the community and stored locally, with strict protocols for sharing information with outsiders.

Sustainability: This involves ensuring that digital innovations contribute to sustainable development by minimizing negative environmental impacts and promoting resilient and environmentally friendly farming practices (Bronson and Knezevic 2016; van der Burg et al. 2019).

Example: A crop management app for smallholder farmers integrates traditional knowledge on crop rotation and pest management and promotes agro-ecological practices adapted to the local context.

Having established the fundamental principles of responsible digital innovation, it is essential to explore how these are integrated with effective governance frameworks and data management, key enablers to ensure that digitalization in smallholder agriculture is equitable, sustainable and beneficial to all stakeholders.

3. Governance and Data Management for Smallholder Agriculture

Effective governance and management of agricultural data is a fundamental component that enables responsible digital innovation and facilitates the empowerment of small-scale farmers. For these small-scale producers, ownership over their data is not only a matter of control, but a crucial tool to improve their decision-making capacity, protect their interests and even rely on their data as a form of capital (Forney and Epiney 2022). Data governance and management involves establishing policies, rules and mechanisms that govern in an ethical, transparent and collaborative manner the collection, use, sharing, protection and exploitation of agricultural data (Benfeldt et al. 2020). It is especially critical for smallholder farmers due to their economic and social vulnerability, unequal access to information, and the importance of local context in their operations. Data ownership enables smallholders to better negotiate, protect their rights and avoid exploitation in digital markets. It also provides them with a tool to level the playing field by making more informed decisions and improving their competitiveness.

On the basis of the principle of informational self-determination, which recognized the right of individuals to exercise control over their personal information (Forney and Epiney 2022), smallholder farmers should have the ability to decide how their agricultural data is collected, used and shared. Aligned with the principle of privacy by design, which advocates incorporating privacy safeguards from the earliest stages of technological development (McCampbell et al. 2022), robust measures such as data encryption, strict access controls and regular risk assessments should be implemented in order to protect producers' information against unauthorized access, misuse and cyber-attacks (Kaur et al. 2022).

Furthermore, it is very important to adopt open standards and promote interoperability between different data systems and platforms in order to facilitate information sharing and data integration from different sources (Kaschel et al. 2022). Interoperability applies the principle of modular design, which enables connection and communication between different components of a system (Calvet et al. 2022) and is instrumental in unlocking the potential of data by integrating disparate datasets in the agricultural value chain. Open data standards and sharing protocols allow IoT data to be combined, such as sensors and drones, with remote sensing, climate, soil, market and other related data (Misra et al. 2022). These integrated data feed into analyses and decision-support tools that benefit smallholder farmers. However, ensuring semantic and technical interoperability between heterogeneous data sources is a significant challenge that requires robust governance frameworks with common metadata specifications, dataset documentation and ontological alignment (Wolfert et al. 2017).

Data governance involves a variety of actors, each with specific roles and responsibilities. On the one hand, the public sector plays a key role in establishing regulatory frameworks and policies that protect the privacy and informational self-determination rights of farmers, especially smallholders, over their data. It should also promote transparency and open access to public agricultural data, invest in digital infrastructure and capacity building programmes to bridge the digital divide in rural areas, facilitate collaboration and data sharing between different actors in the agri-food chain, and ensure compliance with data management standards and protocols (Ingram et al. 2022).

On the other hand, agribusiness companies have a responsibility to adopt ethical and transparent practices in the collection and use of farmers' data, respect the privacy and data control rights of producers, establish fair agreements for the sharing and monetization of agricultural data, invest in data management solutions that benefit smallholders, and promote interoperability and secure data sharing along the value chain.

Digital technology companies in the sector play a crucial role in developing data management tools and platforms that are accessible, affordable and tailored to local needs. They should incorporate privacy by design and data security principles from the earliest stages, facilitate the integration and analysis of data from multiple sources in order to provide valuable information to farmers, collaborate with local communities in the co-design of user-centered solutions, promote the adoption of open standards and interoperability between systems (Somers and Stapleton 2020).

Producer organizations are tasked with representing farmers' interests and needs in data governance, educating and empowering farmers about their rights and the value of their data, negotiating fair agreements with companies and data platforms on behalf of farmers, facilitating the active participation of farmers in the design and implementation of data management solutions, and promoting the exchange of knowledge and best practices among farming communities.

Effective implementation of data governance in smallholder agriculture requires collaboration between the public, private, academic and civil society sectors, fostering inclusive partnerships and dialogue. A prominent example in this area is the Global Open Data Partnership for Agriculture and Nutrition (GODAN), which brings together diverse actors to promote the openness and responsible use of agricultural data (Maru et al., 2018). These multi-sectoral collaborations allow the knowledge and resources of different stakeholders to be harnessed, generating more holistic and sustainable solutions.

In addition, appropriate financing and investment mechanisms are needed to support the development and adoption of responsive digital technologies in agriculture. This can be achieved through public-private partnerships, impact investment funds or innovative financing programmes, such as the World Bank's "Growing Solutions" programme, which supports digital solutions for sustainable agriculture (World Bank, 2022).

4. Case Studies in Latin America

In Latin America, there are several cases that illustrate the challenges and opportunities for responsible digital innovation and data governance in agriculture. Three cases are presented below that have been selected because of their direct relationship with the security and privacy of data, the equity that is lacking in many agri-food contexts in the region, and the need for low-cost, interoperable systems to strengthen data governance and management.

4.1. IDENTI - Boosting Digital Identity

Identi[1] is a non-profit association based in Lima, Peru, that has developed an innovative protocol for inclusive, decentralized and sovereign digital identity. Its pioneering solution stems from the need to make visible and empower people, objects and organizations working with vulnerable communities, particularly in rural areas.

A digital identity is a virtual or online representation of a person or entity, consisting of a set of information and data that describe and define who that person or entity is in the digital world (Liu et al. 2020). It includes personal information such as name, date of birth and contact information; credentials such as username, passwords and ID numbers; biometric data such as fingerprints, facial recognition and voice patterns; digital footprints such as web browsing history, social media activity and geolocation data; financial information such as credit/debit card numbers, bank accounts and purchase history; and professional information such as CVs, certifications and affiliations. Digital identity allows individuals to authenticate and interact online securely in a variety of contexts and facilitates personalization of digital services and experiences, but its proper management is crucial to protect privacy and prevent identity theft or online fraud (Masiero and Bailur 2021). During its research and pilot testing phase, Identi verified that there was a crucial challenge: the existence of multiple interventions made by different actors in the same vulnerable communities. Each of these actors, whether companies, non-governmental organizations or government

1 https://identi.digital/

entities, only collected isolated fragments of information about their work with these populations. Consolidating the information into a single, decentralized and secure database became a fundamental requirement in order to create a comprehensive and reliable digital representation of each beneficiary.

To address this challenge, Identi developed a certificate-based digital identity protocol on the Blockchain network, which allows organizations to generate "economic and employment profiles" of the populations they work with. These profiles are built with the evidence and interactions that organizations have with their beneficiaries, and the resulting information is digitalized and remains under the sovereign control of each beneficiary, who may choose to share it with third parties in the future. By resolving the challenge of silos or clusters of data that were separated or isolated, making it difficult to extract and use, Identi facilitated reliable verification of identities, effective monitoring of impact, and efficient delivery of projects and donations to target populations.

The impact of Identi's solution has been significant. More than 36,000 Digital Identities have been created and supported on the Inter- American Development Bank's (IDB) blockchain network, known as "LACCHAIN". More than 20 successful projects have been implemented in various sectors, including agriculture, textile-camelids, energy, development and social inclusion. In addition, the solution facilitated the reliable identification of beneficiaries, the validation of identities, the carrying out of remote voting and consultations, mass surveys and the construction of customized incentive programmes. With validated digital identities, beneficiaries can now be easily linked to other complementary initiatives, such as women's empowerment programmes, government projects, telemedicine services and virtual education.

Along the way, Identi has learned some lessons. Research and pilot testing revealed the crucial need to bring together fragmented information from different actors. On the other hand, the incorporation of technologies such as voice biometrics and voice recognition has been instrumental in the inclusion of people without access to internet or smart devices.

Identi's success has been driven by a number of strategic collaborations. In collaboration with the Peruvian Ministry of Production and the

IDB, it succeeded in creating digital wallets for alpaca breeders in the south of the country, one of the most disconnected production chains with incomes of less than USD 5 per day. This wallet, operated by voice in Quechua, allowed breeders to record shearing and artisanal processing activities, facilitating their connection to the growing tourism market in Cusco, as well as access to medical advisory services. Subsequently, this initiative was expanded to include the commercial visibility of avocado producers in the inter-Andean valleys with plots of less than one hectare, as a result of strengthening programmes of the Ministry of Production, making connections with buyers at trade fairs. In addition, more than four thousand wallets have been created in the cocoa chain in Peru and Colombia, facilitating verification of compliance with EU regulations and receiving forest conservation incentives by connecting with decentralized financing services (EthicHub, Spain) and financing for irrigation systems (Netafim, Israel). Support on Lacchain, the IDB's Blockchain network, has been instrumental in ensuring sovereign and decentralized digital identity standards.

Identi is a good example of inclusive innovation by developing a digital identity solution that seeks to empower and raise the visibility of vulnerable communities, particularly in rural areas. It demonstrates a participatory approach by involving different actors (businesses, NGOs, government entities) working with vulnerable communities in the collection of information to build the digital profiles. This suggests that local needs and perspectives were considered in the design of the solution.

On the other hand, the Identi case demonstrates a strong approach to data governance and management by developing a decentralized, Blockchain-based digital identity protocol that allows beneficiaries to have control over their data and decide with whom to share it. This aligns with the principles of informational self-determination and data ownership. It also addresses interoperability by consolidating information from different actors in a decentralized and secure database, facilitating data sharing and integration of multiple sources.

Overall, Identi demonstrates a promising approach to responsible digital innovation and data management, with strengths in stakeholder participation and inclusion, beneficiary ownership and control of data, and interoperability of systems. However, more information is needed on some aspects such as ethics, transparency, sustainability and local community participation in the design and governance of data systems.

4.2. e-Agrology: Interoperability for Low-Cost Rural Contexts

e-Agrology[2] is an agricultural data management platform led by the International Maize and Wheat Improvement Center (CIMMYT) since 2010 and co-developed with local stakeholders. It emerged to standardize agronomic data collection among organizations in Mexico and evolved from a digital logbook, called "Bitácora Única MasAgro BEM", to a comprehensive open-source platform that today operates in multiple countries and projects, with more than 100 local partners in Mexico, Colombia, Honduras, Guatemala, East African countries and India.

The objective of e-Agrology is to facilitate the standardization of agronomic and socio-economic data for large volumes of experimental and observational data. Its online/offline functionality addresses rural connectivity issues, while the integration of satellite and climate data responds to integrated agricultural management needs, eliminating silos and enabling second use of data. The development of e-Agrology has been a collaborative and adaptive process reflecting a deep and continuous learning process over a decade, where co-development with local actors has been crucial to adjust the tool to the real needs of users.

The e-Agrology data collection process follows a meticulous approach that ensures the quality and accuracy of the information. During growing season, a data validation process is implemented, where outliers or unusual values are automatically flagged and verified by the field teams. This feedback loop ensures that anomalous data points are corrected in a timely manner, maintaining the integrity of the dataset. At the end of each season, a thorough review of the data is conducted, where remaining inconsistencies are analyzed and validated in collaboration with regional teams of agricultural advisors, technical coordinators and operational center managers.

After completing the data collection process for each cycle in each project, the platform allows for the execution of automated cleaning processes by variable and the feeding of control panels to monitor sustainable

2 http://cimmyt-analytics-idp.cimmyt.org/

production indicators, such as efficient water use, carbon sequestration, efficient nitrogen use, profitability per hectare and optimal management dates.

e-Agrology stands out as an example of responsible digital innovation, incorporating ethical and sustainable design principles. Its open source philosophy fosters transparency and accessibility, while its multi-level analytics tools offer descriptive, diagnostic, predictive and prescriptive capabilities without charging licensing fees to its users. In addition, the platform addresses critical ethical considerations, such as data privacy, through robust security protocols, and drives agricultural sustainability by supporting informed decisions that promote sustainable practices. e-Agrology has a digital identity based on Blockchain technology, which allows each producer to have a unique identification number and securely store their data.

In Latin America, the platform has had a significant impact, collaborating with more than 100 partners, collecting data from 289,643 farmers on 317,343 plots, generating more than 24 million data points. In addition, e-Agrology has promoted digital inclusion by providing customized training to vulnerable groups, such as women, indigenous peoples and low-income producers.

The e-Agrology platform faces ongoing challenges, such as the need for more producer-centric interfaces, as so far, most functionalities have been developed for use by extension workers and other local actors. It also requires improved access in remote areas and the development of specific analytical solutions for regional agricultural problems. The next phase of e-Agrology envisages interactive interfaces for data analysis and direct connection to Agro-tutor, which is a generative artificial intelligence-based chatbot that is being fed with the historical data collected so far.

e-Agrology is a transformative digital tool that has revolutionized the way agronomic information is collected, managed and used in Latin America, especially in rural contexts where connectivity and resources are limited. Its importance lies in several key aspects that have had a profound impact on small-scale agriculture and the sustainability of agricultural systems in the region.

First, e-Agrology has democratized access to agricultural information by enabling hundreds of thousands of smallholder farmers to record and access crucial data on their crops. This has not only given them greater visibility and control over their operations, but has also facilitated informed decision making. Farmers can now base their practices on accurate data, helping them to optimize yields, reduce costs and adopt more sustainable farming practices.

In addition, e-Agrology has had a significant impact on agricultural policy planning and implementation. By providing high, consolidated data, e-Agrology has enabled governments and non-governmental organizations to design and implement more effective policies and programmes. Data generated through e-Agrology has been used to map vulnerable areas, identify specific needs and assess the impact of agricultural interventions, resulting in more efficient allocation of resources and greater effectiveness of public policies.

Another fundamental aspect of e-Agrology is its focus on data security and privacy. In a context where data is crucial, especially for vulnerable communities, e-Agrology has implemented robust protocols in order to ensure farmers' data is protected. This has fostered user trust in the platform, and in turn has increased participation and the amount of data collected, creating a virtuous circle of continuous improvement in the quality and usefulness of the information.

Finally, e-Agrology has not only impacted agriculture at the technical level, but has also had a positive effect on the empowerment of rural communities. By providing farmers with the tools and information they need to improve their practices and results, e-Agrology has contributed to raising living standards, reducing rural poverty and strengthening local economies.

4.3. Tech - Agrifintech Transforming Access to Formal Finance for Smallholder Farmers

IncluirTech[3], a Colombian AgFintech established in 2018, has pledged to address the challenge of providing access to formal finance to Latin America's 123 million rural inhabitants, 75% of whom lack this possibility. This commitment comes in response to the alarming reality that only 6% of the portfolio of financial institutions in the region is allocated to agricultural credit, leaving small producers with limited financing options.

3 https://incluirtec.co/

In addition, smallholders have limited access to finance due to a lack of traditional collateral, such as land titles, and little or no formal credit history. Conventional *credit scoring* systems often do not adequately capture the economic reality of these farmers, which is characterized by seasonal and informal incomes. Traditional financial institutions perceive this sector as high risk, resulting in high interest rates or outright refusal of credit. However, there is an emerging trend towards alternative assessment models that consider factors such as production patterns, agricultural knowledge and community networks. Some initiatives are incorporating agro-climatic data, crop history and adoption of agricultural technologies into their *scoring* models. Furthermore, microfinance and fintech companies are developing financial products more tailored to the specific needs of smallholder farmers, such as seasonal loans with repayments adjusted to harvest cycles.

In this context, IncluirTech has developed an innovative algorithm that assesses the credit risk of producers in an alternative way. This algorithm combines qualitative variables, such as socio-economic characteristics, with quantitative variables, such as income and productive capacity, allowing financial institutions to offer formal loans tailored to the needs and profiles of each producer. IncluirTech's digital platform enables financial advisors to perform these assessments 100% digitally in the field, thus simplifying the agricultural credit approval process.

In addition to addressing low credit coverage, IncluirTech also faces the challenge that financial institutions lack specialized technologies and methodologies to adequately serve the high-risk agricultural sector. Furthermore, recognizing the crucial role that Latin America plays in global food security, where it provides 13% of the world's food and 38% of its land is devoted to agricultural activities, IncluirTech has positioned itself to directly address this problem.

As of the third quarter of 2023, IncluirTech processed more than 2,500 loans in Colombia, benefiting 2,557 small producers (1,597 men and 960 women). The average loan amount is $15.2 million Colombian pesos and the average approval time is 5 days, well below the traditional average of 25 days.

This case exemplifies the importance of adapting technological solutions to the local realities of the agricultural sector, involving small producers from the beginning, both in the design and in the validation and implementation phases. It also highlights the power of technology to drive financial inclusion, equity in access to finance and improved livelihoods for the most vulnerable rural communities.

In order to ensure accountability and fairness in its use of data, IncluirTech conducts regular audits of its algorithm and training data to identify and mitigate potential discriminatory bias. In addition, the platform uses encryption schemes to protect data, and producers agree to a Data Processing and Use form when applying for a loan, which limits access only to the financial institution granting the loan.

The platform also has a tracking module that allows tracking the use and destination of resources, as well as the impact on production. However, it would be advisable for IncluirTech to implement consultative strategies with representatives from different regions and producer groups (such as indigenous people, women and youth) to channel their input and feedback into the development of products and services.

In addition, IncluirTech could improve the accessibility of its platform through digital interfaces in several languages, including, for example, local dialects, intuitive and adapted to different levels of digital literacy. Furthermore, offering training and assistance tailored to the needs of vulnerable groups, such as women, indigenous people and low-income producers, would further strengthen their commitment to inclusion and equity in access to formal agricultural finance.

The cases of Identi, e-Agrology and IncluirTech in Latin America demonstrate that responsible digital innovation in agriculture is not only possible, but essential for creating inclusive, sustainable and equitable agrifood systems. Each addresses challenges faced by smallholder farmers and rural communities in the region and demonstrates that the principles of responsible innovation can be applied in practice. The development of e-Agrology over a decade shows foresight in addressing issues of rural connectivity and the need to standardize agronomic data collection. In addition, the evolution from a digital logbook to a comprehensive platform demonstrates adaptability to user needs and emerging challenges. IncluirTech's alternative credit assessment algorithm reflects a critical examination of the shortcomings of traditional financial systems in serving small producers from an equity perspective.

All three cases prioritise inclusivity, with Identi focusing on data ownership for vulnerable communities, e-Agrology providing training to under-represented groups and IncluirTech adapting financial services for smallholder farmers. Also, all three cases implement robust data protection measures and IncluirTech even conducts regular audits to mitigate bias and protect user information. Taken together, they highlight the importance of participatory approaches and co-development with local actors in creating technologies that truly meet user needs.

However, there is also evidence of the need for more user-centric interfaces, especially for direct use by small producers. They underline the need for robust and ethical data governance framed by the importance of public policies that encourage and guarantee these processes. Privacy protection, transparency in the use of data and mitigation of possible biases are aspects of data governance. The need to ensure that these innovations do not perpetuate existing inequalities or introduce new risks for vulnerable communities is critical.

5. Public Policies on Responsible Digital Innovation in Latin America and the World

As mentioned above, collaboration between the public sector, private sector, academia and civil society is essential in order to develop policies and technological solutions that respect the rights of smallholders and promote sustainability and equity. Latin America has lagged behind in the implementation of comprehensive public policies that promote responsible digital innovation in agriculture, compared to regions such as Africa, Asia and Europe. While there are some isolated initiatives and programmes, the region lacks a strategic and coordinated approach at the regional level.

Brazil, in particular, stands out for its significant progress in this area. In 2018 it launched its Digital Transformation Strategy (Government of Brazil, 2018), prioritizing agriculture as one of the key sectors to drive change. It also instituted the Legal Framework for Science, Technology and

Innovation, the General Law on Data Protection (Law n.º 13.709/2018), the National Plan for the Internet of Things and the Co-Mission for Precision and Digital Agriculture. This was done together with the work of EMBRAPA, the Chamber of Agro 4.0, the Ater Digital Programme and the Agro 4.0 Programme, actions that seek to stimulate the development and adoption of digital technologies in the agricultural sector. However, additional strategies are needed to include rural producers and workers (Souza and Bidarra 2022).

In Africa, there are good examples of policies and frameworks focused on data sovereignty and digital inclusion of smallholder farmers. The African Union, for example, launched in 2020 the Digital Transformation Strategy for Africa 2020-2030 (African Union, 2020), establishing Digital Agriculture as a critical sector. Kenya passed the Data Protection Act (Act No. 24 of 2019) in 2019 to safeguard citizens' privacy and rights over their data. It drove initiatives such as AgriWallet, which allows smallholder farmers to securely manage and monetize their data. In addition, the M-Pesa mobile money system, a pioneer in the region, has been instrumental in the financial inclusion of these farmers in the digital ecosystem (Njenga et al., 2021). Rwanda also launched its Agricultural Transformation Strategy (PSTA IV) in 2016 (Rwanda Ministry of Agriculture, 2018), including a component on digitalization and responsible use of agricultural data through the National Agricultural Data Management System (NAMIS).

In Asia, India has been one of the leaders in developing agricultural digital innovation policies. In 2022, the Indian government launched its National Digital Agriculture Policy, which sets out a comprehensive framework for driving the digital transformation of the agricultural sector in a sustainable and responsible manner. Key aspects of this policy include the creation of digital infrastructure (deployment of broadband networks, agricultural data centers and integrated national and state-level digital platforms); the promotion of precision agriculture; digital skills training; and data governance with the establishment of standards, protocols and governance mechanisms to ensure the privacy, security and sovereignty of agricultural data. Moreover, India has implemented concrete initiatives such as Digital Agri-Stack, a unified digital platform that integrates data from different government and private sources to provide digital services to farmers, such as personalized advice, access to credit and insurance, and connection to markets.

China, on the other hand, has taken a more centralized, hands-on top-down approach in its General Plan for Building a Digital China, driven by an ambitious modernization plan including the agricultural sector. The plan includes deployment of IoT sensor networks and remote monitoring systems in large-scale farms and agricultural fields (Li et al. 2023); development of big data and analytics platforms to process and extract insights from the huge volumes of data collected (Dai et al. 2023); implementation of food supply chain traceability and monitoring systems using technologies such as blockchain and QR codes (Zhai et al. 2023); and investment in research and development of emerging technologies such as artificial intelligence, robotics and vertical farming in order to increase interoperability, productivity and efficiency.

However, policies and actions in China have focused more on increasing productivity and efficiency, with less emphasis on aspects such as data privacy, farmer sovereignty and smallholder inclusion (Guo & Lyu, 2024). Other Asian countries, such as Japan, South Korea and Singapore, have also made significant progress in adopting digital technologies in agriculture, such as automated vertical farming, drone and sensor-based crop monitoring systems, and e-commerce platforms for agricultural products.

Overall, Asia has been one of the leading regions in implementing policies and actions to drive digital innovation in agriculture, albeit with different approaches and levels of priority in terms of aspects such as data governance, privacy and inclusion of smallholders.

In this context of the global South, in Latin America there are still major challenges to boosting responsible digital innovation in agri-food systems. The region lacks a coherent regional vision and strategy to harmonize national efforts and faces a digital infrastructure gap that hinders connectivity and access to technologies in rural areas and for small producers. There is also a lack of strong regulatory frameworks to promote data governance, privacy protection and sovereignty over smallholder agricultural data, according to an ECLAC report (2022).

Conclusion

Digital innovation in smallholder agriculture represents a promising horizon for transforming food systems and improving the livelihoods of millions of people in Latin America. The cases of Identi, e-Agrology and IncluirTech demonstrate the transformative potential of these technologies when implemented responsibly and ethically. However, to maximise their impact and ensure that they benefit small-scale producers in particular, an integrated approach is needed that combines public policies, strategic investments and the creation of collaborative innovation ecosystems. Based on reflections on the concept of Responsible Digital Innovation and lessons learned from these cases, the following recommendations are made:

- Develop legislation that protects farmers' privacy and data sovereignty, inspired by Identi's decentralized digital identity model, and establish data mechanisms that involve local communities in decision-making on the use of their agricultural data.

- Promote the adoption of open standards for agricultural data collection and management, following the example of e-Agrology, and encourage the creation of open-source platforms that facilitate collaboration and knowledge sharing between different actors in the sector.

- Promote policies that encourage the adoption of innovative credit assessment models, such as the one developed by IncluirTech, to increase access to financing, and promote collaboration between financial institutions and agricultural technology companies to develop financial products tailored to the needs of smallholders.

- Implement digital training programmes specifically targeted at small producers, rural women and indigenous communities and encourage the creation of farmer-to-farmer support networks and mentoring to facilitate the adoption of digital technologies.

- Prioritize the expansion of connectivity in rural areas through public-private partnerships and the use of innovative technologies, and develop solutions that work offline or with limited connectivity, such as those implemented by e-Agrology.

- Enable co-creation spaces and innovation labs involving farmers, technology developers, researchers and other actors, and establish innovation funds specific to technological solutions that address the challenges of small-scale producers.

- Develop ethical guidelines and impact assessment frameworks for digital innovations in agriculture, and encourage the adoption of user--centered design practices and the inclusion of ethical considerations from the earliest stages of technology development.

To make progress in this area, it is essential that the countries of the region work together to develop a regional strategy that establishes guiding principles, guidelines and coordination mechanisms that promote the harmonization of national policies and regulations, ensuring the protection of the rights of small producers and the ethical and sustainable use of agricultural data. In addition, significant investments in connectivity infrastructure are needed, especially in rural areas, to bridge the digital divide and facilitate access to digital technologies for farmers. This should be complemented by digital literacy and training programmes that empower farmers to use these tools.

Another key aspect is the promotion of open innovation ecosystems that involve diverse actors, including the private sector, academia, civil society organizations and, above all, the farmers themselves and their communities. These ecosystems should promote the development of digital technology solutions adapted to local needs and realities, ensuring the inclusion and active participation of small producers throughout the process.

Finally, it is crucial that countries in the region establish sound legal and regulatory frameworks that protect farmers' rights to privacy and data sovereignty, while encouraging responsible innovation. These frameworks should be based on ethical and human rights principles, including data governance mechanisms that involve local communities and ensure the transparent and accountable use of agricultural data.

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5 Connectivity as a Condition for the Digital Transition of Family Farming in Argentina. Current Gaps, Public Policies and Perspectives

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1. Introduction

In Argentina, research on the digital transition in agriculture and the policies that support this transition is very recent. There are some surveys and studies linked to policy planning processes and analyses promoted by agricultural innovation agencies at the international level (Lachman, et al, 2022; Sotomayor, et al 2021). Specifically in the family, peasant and indigenous farming sector, more than in others, a central issue that arises in addressing the digital transition is the problem of connectivity[1]. This sector especially combines its means of work with its livelihood. For this reason, connectivity is not only a condition for productive transformation, but also enables basic issues of access to services and participation in the framework of current communications and technologies. The research includes analyses of the access situations of family farming. The report also discusses connectivity, its role in reversing the constant uprooting of rural families and the construction of rurality as a place to live and develop. To

1 By "connectivity" we mean the condition of a technological connection to the global network of information and communication technologies, made possible by certain infrastructure and equipment (Duarte and Pires, 2011)

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a lesser extent, the possibilities for this sector to access the technological advances of digitalization are addressed.

Connectivity is a condition for access to new digital technologies, but also, especially for this sector, it is a necessary condition for strengthening the self-recognition of communities, for generating spaces for public dialogue and participating in the communication fabric from the local level, as well as to accessing production of information and entertainment that is produced at different scales. In this sense, we find research on youth (Bontempo et al, 2017, Centeno, 2021), rural education (Chachagua, 2021) or digital rights (Bizberge and Segura, 2021). Thus, connectivity becomes a condition of the possibility for multiple practices that articulate sociability and daily life, together with the exercise of freedom of expression and participation in collective dynamics. It is important to bear in mind that not just any access to the internet implies connectivity, but rather a broadband service, with adequate speed, together with the devices that make it possible (Kessler, 2021).

Connectivity and its flipside, disconnection, constitute a gap which has been problematized for decades. In the context of the COVID19 pandemic, this fundamental resource was included even more on the agenda for various reasons, from accessing to substantial information to facing the health situation and to the very possibility of providing continuity in access to issues such as education, work, state contingency plans for vulnerable populations, the commercialization of different products and activities, the acquisition of goods and services, the provision of medical consultations, the activity of procedures with state offices, among other issues. The technological fabric constitutes a condition of possibility for the development of a multiplicity of practices and a condition for inclusion, which is articulated in differential ways with the community fabric and the dynamics of local economic development.

In Argentina, the inequalities between urban and rural populations became evident in this context. The structural deficiencies in access to basic services became apparent, and the sense of a lack of access to basic services deepened in rural areas (Alcoba, et al, 2021: 23). In contexts where digitalization is accelerating, the family, peasant and indigenous farming sector, as well as rural workers, are even more isolated in the face of the centrality of technical mediation of social, political and cultural life.

At the same time, the information produced by different local public bodies on access to connectivity is scattered and tends to be based on the parameters of large urban conglomerates (Zaballos et al, 2019; Ziegler et al, 2022; Monje et al, 2021). Thus, the particularities of rurality and of the different places and settlements are diluted in the framework of information linked to other social dynamics, losing sight of the conditions of access to connectivity for these actors.

Research on the link between the family farming sector and the processes of digitalization in production is still less developed. The conditions for the possibility of this relationship are still being discussed, and data and lines of understanding are still being constructed around access to connectivity in rural areas. In view of this, the concentrated sectors of rural Argentina have greater conditions of resolution for access to technologies and connectivity, without the need for a public policy agenda to accompany them, even when, due to their political status, they benefit from public policies as a whole[2]. In this sector, access to devices and the deployment of capacities for digitalization can be resolved autonomously from state policies. However, as recognized by Lachman et al. (2022, p. 5), the socio-economic impact of the new technological paradigm in the productive sector will depend not only on the capacity of agricultural actors to adopt new technologies, but also on the role that the country can play in the development of these new technologies.

This chapter seeks to make contributions in several respects: firstly, it aims to understand the starting point for the digitization processes linked to heterogeneity and social and regional inequalities in the agricultural sector and in rural Argentina, taking into account the primary and secondary data on the different conditions of access to connectivity. Secondly, it seeks to identify and analyze the main policies that have sought to narrow the gaps in this inequality from 1998 to date, providing infrastructure, regulations and funding in order to promote access to services and equipment in rural

2 Authors such as Wahren (et al, 2023) mention: subsidies, tax exemptions, promotion regulations, deregulation and/or little control of their social, health and environmental impacts.

areas[3]. Third, with the support of a qualitative survey of actors linked to rural telecommunications and their experience with public policies, some critical points are identified through interviews that serve as a kind of qualitative evaluation of the implementation processes. Finally, the chapter gathers elements on the current agenda for digitalization being pursued by different actors in the innovation system.

The study was based on a series of surveys, the analysis of antecedents and interviews with actors linked to telecommunications in rural areas and key sources related to the policies analyzed. Two surveys were used: *Survey on connectivity and communication in rural areas of Argentina and Survey on internet service providers in rural areas of Argentina,* both carried out since 2019 by INTA, the National Communications Agency (ENACOM) and the CEA - UNC Program of Studies on Communication and Citizenship (VV. AA, 2021). Partial results were taken from the former, which systematized the information on 311 rural areas[4]. From the second, the identification of the critical knots in the development of policies for rurality was taken. The empirical approach was complemented with interviews with key figures in the implementation of policies[5]. A chronology was also carried out of the policies implemented from the late 1990s to 2023 (see Table 1 in Annex). With regard to digitalization initiatives, some of the existing initiatives were surveyed.

3 For reasons of space and length, the paper does not focus on policies that promote digital literacy.

4 The survey addressed the following dimensions and variables: characterization of the population (socio-productive actors and types of production in the sites, with special attention to the presence of indigenous peoples), organizational forms of the communities (recognition, characterization, formality and connectivity status of the institutions and organizations present in the sites), access to connectivity (number and types of providers, evaluation of service quality), identification of communication and information technologies (number and types of providers and evaluation service quality) and community communication infrastructure.

5 Between the second survey and the ad hoc interviews for this study, 17 interviews were conducted with: 5 officials from ENACOM, 2 officials from the Secretariat of Public Innovation of the Chief of Cabinet of Ministers, an official from the Secretariat of Development Planning and Federal Competitiveness (SECPLAN, Ministry of Economy), an official from ARSAT and an official from the Ministry of Economy of INTA. The rest were from representatives of different sectors linked to the provision of connectivity (SMEs, public service cooperatives, social organizations).

2. Agricultural Development Models and Persistent Gaps. Inequality in Access to Connectivity.

Rurality in Argentina is marked by inequality and the heterogeneity of its subjects and development models within the framework of certain historical continuities that define persistent gaps (Wahren et al, 2023; Balsa, 2013; Azcuy Ameghino, 2016; Gras and Hernández, 2009). These continuities can be characterized in terms of the concentration of land and land management, the advance over historical forms and cultures of rural life, the prevalence of extractive forms of production, and the disparate support of public policies for the different subjects of the rural fabric since the colonial origins of the country.

In the last four decades, the different models of agrarian development have oscillated between two main types, depending on the ideological, economic and social matrixes promoted by the governmental projects that have followed one after the other. Each of them is based on a different concept of the role of the state and public policies; broadly speaking, one conceives of the need for minimal intervention and the other for broader public policy intervention in order to achieve desirable development (Balsa, 2013).

However, a line of continuity can be identified that gives rise to extensive export production, characterized by the concentration of land and its management, which promotes the advance on land rich in natural resources and family production by private companies for the production of monocultures, and the prominence of technological packages designed by agribusiness (Wahren et al., 2023). Towards the end of the last century, the technological development of the prevailing model went hand in hand with the *soybean* phenomenon *(Gras and Hernandez, 2009).* The successive *neo-developmentalist governments*[6] did not question the structure of this matrix, although some included new actors in the agenda and as targets of public policies. Thus, a growth model based on agricultural *commodities* (soya, sunflower and maize) was combined with the capture and redistribution

6 We rely on Wainer's (2019) definition of neo-developmentalist governments, with a focus on state intervention in industrial policy but with limited and difficult to sustain impacts over time in macroeconomic terms.

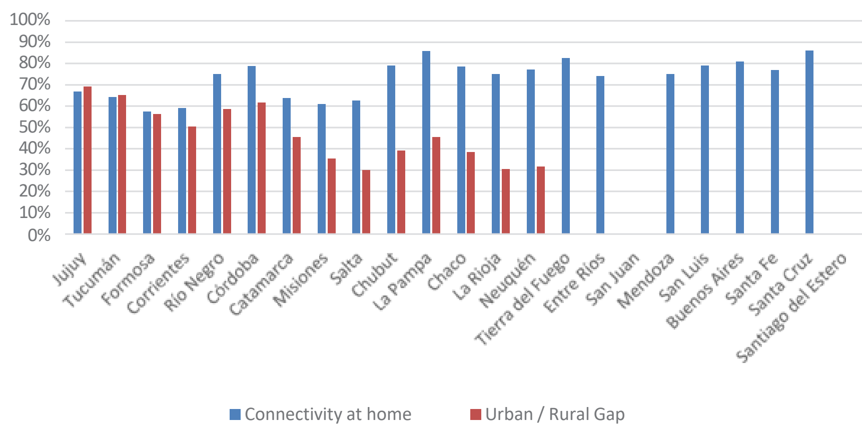
of part of the agrarian income and a process of state institutionalization of the family, peasant and indigenous farming sector. This sector of rurality was recognized as a productive actor, although state structures and public policies maintained inflexibilities in the treatment of problems from sectoral rather than comprehensive perspectives (Patrouilleau et al., 2018). Thus, the effectiveness of policies was challenged by the oscillating political logic, the lack of broader discussions and the resistance of sectoral institutional arrangements.

Data from the National Agricultural Census (CNA) are conclusive about this continuity between models. Between 1960 and 2002 the number of farms in Argentina fell from 472,000 to 297,000, with 175,000 units eliminated (Azcuy Ameghino, 2016: 13). If this variable is analyzed from 2002 to 2018 (the next intercensal period), the trend of decreasing units continued. Of the 333,533 units counted in 2002, 249,663 remained in 2018, showing a decrease of 25.1%. The stratum most affected by the disappearance of production units was that of units with less than 200 hectares. This sector declined by 27.5% in the last intercensal period (2002-2018) (Wahren et al, 2023: 215). Authors such as Azcuy Ameghino claim that these processes are promoting the rural exodus and the advance of the green desert (2016:18), turning the agrarian social crisis into a structural one. However, it is important to highlight the impact of new inequalities on this agrarian social structure based on unequal access to connectivity services.

In terms of access to connectivity, the situation in Argentina does not differ from the general reality in the region, where 67% of urban households are connected to the Internet, while in rural areas only 23% of households are connected to the Internet (ECLAC, 2020). In Argentina, according to data from the Inter-American Institute for Cooperation on Agriculture (IICA, 2022), based on data from the 2022 National Census, the average connectivity gap between urban and rural areas at the national level is 40%, with wide regional differences.

Figure 1 shows the differences and inequalities in access to connectivity and urban-rural gaps by province[7]. Household internet penetration is very heterogeneous by province and region. While the Patagonian provinces have high levels of connectivity, the provinces of the northwest and northeast have the lowest percentages of access to connectivity in households, as well as the highest connectivity gaps. Other provinces with high connectivity averages also show a high urban-rural gap, such as Córdoba and Río Negro. There are socio-economic, geographic, demographic, infrastructure and rural development particularities that explain these situations.

Figure 1. Household Connectivity and Urban-Rural Gap by Province



Source: IICA (2022). For the Province of Santiago del Estero there is only connectivity data.

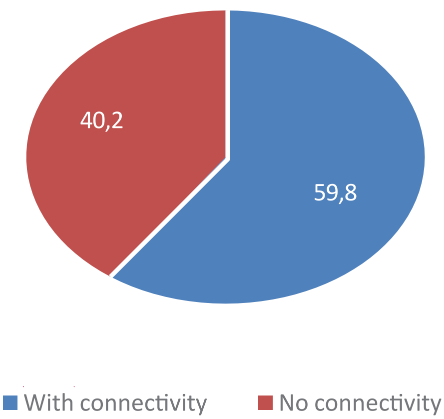
Just as we can observe these types of indicators in terms of the political and territorial distribution of access to connectivity in Argentina, it is possible to delve deeper into the complexity linked to rurality in the country with data that cross-reference the level of access with the different agrarian social types in the territory.

The INTA-ENACOM-CEA-UNC survey (VV. AA, 2021) shows that in 40.2% of the 311 villages surveyed the population does not have Internet connectivity (Graph 2). It may be that in these places there is an access

7 Data from the Autonomous City of Buenos Aires are not considered, as it does not have a rural population. For a review of the methodology used, see Ziegler, et al, 2022.

point linked to a school or another institution, but not in a way that is open to the population. If we consider only those places where there is an indigenous population, the lack of connectivity is even greater: 60%.

Figure 2. Connectivity in the surveyed rural areas



Source: Survey on connectivity and communication in rural areas of Argentina (VV. AA, 2021).

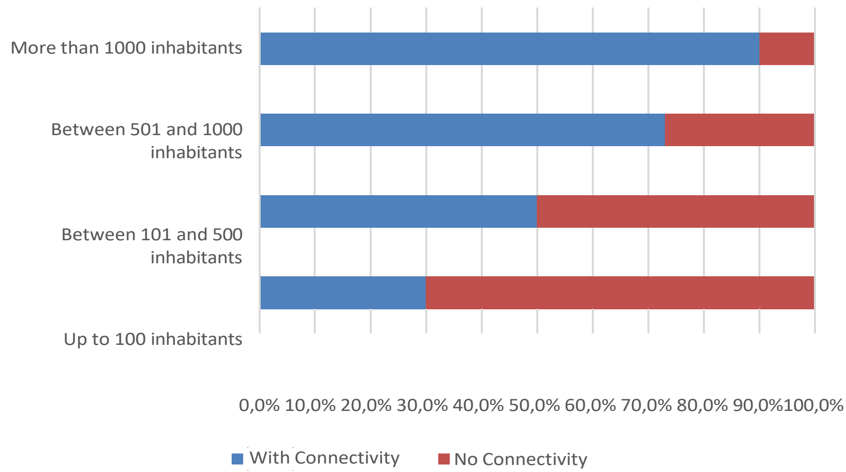
Among the villages where the population does not have access to the Internet, the percentage rises to 80% when including those with poor or regular connectivity (VV. AA, 2021).

In order to better understand the universe of subjects affected by these conditions, the same survey analyzed the presence of family farming in rural areas: in 75% of the areas, family farming is the exclusive or main type of production[8]. This sector is therefore the most affected by the lack of access to connectivity.

As the number of inhabitants decreases, so does their access to connectivity. Only 31% of the villages with the fewest inhabitants have access to the internet.

8 For further characterization of the productive subjects, see https://repositorio.inta.gob.ar/xmlui/ handle/20.500.12123/17784?show=full

Figure 3. Connectivity of the sites according to their number of inhabitants (%)

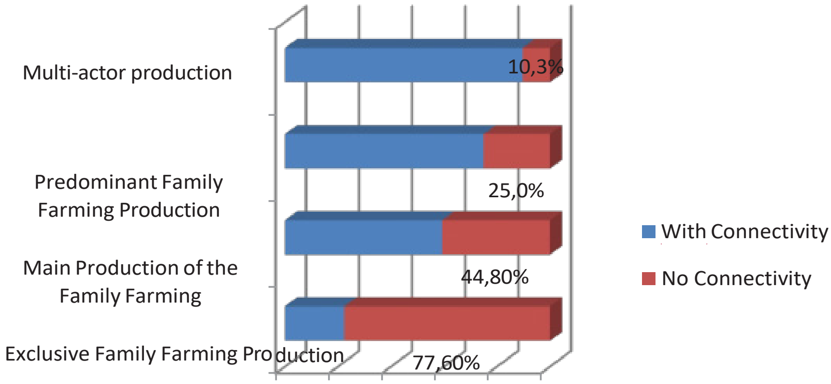


Source: Survey on connectivity and communication in rural areas of Argentina (VV. AA, 2021).

If we consider the sites without connectivity, 85.6% have less than 500 inhabitants.

As the number of inhabitants increases, so does the presence of multi- stakeholders: among those with up to 100 inhabitants, only 10% are multi-stakeholders. Among those with more than 1,000 inhabitants, on the other hand, 46.2% are multi-stakeholders, including more capitalized types of production (Graph 4).

Graph 4. Connectivity according to the productive type of the sites



Source: Survey on connectivity and communication in rural areas of Argentina (VV. AA, 2021).

With this data, we were interested in highlighting the relationship between productive types and access to connectivity. The information analyzed allows us to raise the fundamental problem of the possibilities of digitalization in a diverse subject, with a territorial presence in different regions and a general lack of access to connectivity. At the same time, policies for the digital transition cannot ignore this sector if the aim is to halt the widening of existing socio-productive gaps. For this reason, an important part of the policies analyzed in this paper have to do with those that seek to universalize access to connectivity services.

3. Policies for Access to Connectivity in Family Farming. Strong Enunciation, Weak Deployment

Since shortly before the year 2000, policies aimed at promoting and guaranteeing connectivity in universal terms were deployed in Argentina, with different impulses depending on the government. These policies included actions to include vast social sectors that, because they did not target urban areas, were left behind in terms of the deployment of services by the main business actors (see Table 1 in the Annex for a chronology of the policies analyzed).

This first took place in the framework of the deregulation of the telecommunications system in the 1990s, with specific promotion programs towards the end of the period. Later, within the framework of the neo-developmentalist model, a strengthening of state participation in the development of basic connectivity infrastructure and the development of regulations for access were proposed. The milestones of this public policy model were the National Telecommunications Plan Argentina Conectada, in 2010, and the Argentina Digital Program, in 2014, which included the state's promotion of the development of satellite technology.

The *Argentina Conectada* Program included the development of infrastructure and public goods[9] and Argentina Digital[10] proposed a set of regulations that guided the meaning and integration of connectivity policies from a rights-based perspective. These actions provided the framework for the deployment of a series of actions for promotion and equipment at the federal level. In another area, the issue of connectivity for family farming also entered the agenda with the passing of the Law for the Historical Reparation of Family Farming (Law 27.118/2014)[11]. Although this law was partially regulated, the chapter on infrastructure that mentioned connectivity was excluded from the regulation.

In the 2015-2019 governmental period, the scaffolding of the public system linked to the issue was reconfigured, although infrastructure extension and licensing policies continued.

Then, in the context of the COVID19 pandemic, and taking up the sense of the Argentina Digital Program, a series of regulations and programs

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9 It included the deployment of the Federal Fiber Optic Network (ReFeFo), in coordination with the state-owned satellite technology company ARSAT and the *Conectar Igualdad* (Connect Equality) program to provide devices to secondary school students throughout the country. In 2012, the Plan was awarded by the International Telecommunications Union as the best international telecommunications plan (Maule, 2019).

10 The law that framed the Argentina Digital program was promptly amended by the new government in 2015, with Decree 267/2015.

11 In Section VII, Article 30, paragraph d, it states that "communications, whether traditional or new Information and Communication Technologies (ICTs), will be at the service of the social, educational-cultural and productive needs of each area; and therefore the Ministry (of Agriculture, Livestock and Fisheries of the Nation) will implement a permanent plan in coordination with the competent structures, so that no area or family is isolated, the digital divide is overcome and the best service that the country or the province can provide in each historical period is available according to the requirements of farmers and family farmers in each territory" (Law 27.118/2014).

were enacted to guarantee access to connectivity in this situation, including specific programmes aimed at rural areas from different government bodies. ENACOM promoted the Web Tax Program, the Program for Access to ICT Services for populations in adverse areas, Roberto Arias Program for the Promotion of Community Internet Networks, the Program for the development of internet infrastructure in small rural localities and indigenous communities, comprehensive ICT cabinets and the Program for the development of internet infrastructure in public institutions in rural areas. Other policies were promoted by the Office of the Chief of Cabinet of Ministers, in coordination with the Secretariat of Public Innovation and ARSAT: the Punto Digital and *Mi pueblo Conectado*[12] programs.

On the other hand, in the Ministry of Economy of the Nation, from the Secretariat for Development Planning and Federal Competitiveness, the *Rural Productive Connectivity Plan* was designed and began to be implemented in coordination with different provinces. Tecnologías 4.0, which proposed through its actions to contribute to the competitiveness of "small and medium agricultural producers and family farming, through more and better internet connectivity, better agricultural and productive information, training and links with various actors linked to rurality"[13.]

As can be seen, most of the more specific initiatives aimed at rural areas were developed during the government of Alberto Fernández (2019-2023), which meant that they had very little time to be defined, deployed and evaluated. Moreover, they were subject to a set of restrictions linked to the general economic situation of the country. This is the framework that explains, at least in part, the limited impact on counteracting the disconnection in rural areas.

At present, Argentina is undergoing a new governmental administration that proposes that any kind of response to the problem of connectivity lies in the market. In Title XII of the Decree of Necessity and Urgency (DNU 70/2023)13 called "Bases for the reconstruction of the Argentine economy"[14] , measures to deregulate the communications

12 For a full characterization of these programs, see Meirovich and Culasso (2024).

13 https://www.argentina.gob.ar/normativa/nacional/decreto-70-2023-395521/texto

14 As this article is being written, the presidential decree "Bases for the reconstruction of the Argentine economy" becomes law with the approval of the bill, including amendments by the legislative chambers.

sector are presented, including internet services, “to allow competition from foreign companies”[15], according to President Javier Milei at a press conference to present the DNU, where he specifically mentions “Starlink”. Elon Musk’s company offers a service that works through a constellation of mobile and low-orbit satellites and has been operating since 2024, although it has been authorized to do so since 2021.

The low latency service is stable in remote or difficult to access regions, such as rural areas, and without the need for large infrastructures such as those required for fiber optic connection, with only a technology kit that can be purchased in stores. Today, the cost in Argentina is USD 530 for the installation kit and a monthly service fee of USD 63.

In some Latin American countries, such as Brazil, where the company has been operating since 2019, there are some risks (Barbosa and Duchiare, 2023), such as the consolidation of a monopolistic process and the use of sensitive data in the hands of a single actor, such as information on geolocation and frequency of use in countries like Brazil or Argentina, with abundant natural resources and where, moreover, no digital literacy strategy is implemented.

4. Analysis of Critical Nodes for Policy Deployment

A question that arises from the identification of policies is what the critical points for their deployment were. In the qualitative survey carried out by INTA ENACOM and CEA-UNC, we worked with the actors involved in these processes. In the task of “illuminating” rural areas, the question quickly emerges that it is not the traditional actors in the communications sector (the large “telcos”) who appear as protagonists, because connecting rural areas is not profitable for the large companies that provide internet. In this framework, “the expansion of internet service in rural areas implies

15 This statement was accompanied by the national government’s Resolution 13/2024, which freed the companies that provide internet, mobile phone and cable TV services to set their tariffs without state intervention and which responds to the Necessity and Urgency Decree (DNU) 302/2024 that annulled the previous DNU 690/2020 that had declared ICT (Information and Communication Technologies) services as “essential and strategic public services”, granting the Argentine state the power to regulate their tariffs.

the confluence and articulation of diverse actors for the deployment of infrastructure and the development of the necessary services, which participate from different perspectives, with different interests, under diverse and unequal conditions and modalities (and, at times, in dispute)" (Meirovich and Culasso, 2024: 84).

As Monje et al. argue (Monje et al., 2018), analyses processes linked to the info-communication sector tend to focus on the big players and suggest the need to analyze the peripheries of the system, which are subalternized by both the market and public policies. And also, they focus on the peripheral sector: cooperatives, SMEs and social organizations that have been covering the infrastructure deficit with successful results in terms of inclusion, coverage, social participation and high-quality services.

The qualitative survey inquired about the perspectives of these actors who carry out connectivity projects, especially about their experience with public policies: small businesses, cooperatives and social organizations that deploy community connectivity networks[16].

From this crossroads of views emerges a set of critical knots that limit the penetration of connectivity policies and reveal an ambivalent role of the National State in the policies, which on the one hand, proposes a strong enunciation of the problem through the design and presentation of concrete plans and the promotion of different initiatives, presenting itself at certain times as the actor capable of defining the rules and conditions. However, the logic of the state itself, with its different levels and bureaucratic sectors, the macroeconomic framework and the lack of continuity of policies, questions this enunciation. We develop some of these issues as critical nodes in the deployment of policies:

a. The ambivalence of the state as a regulatory arbiter

Ambivalence arises when considering the role of control bodies such as ENACOM, which generates policies whose main regulations do not address the constitutive differences of an expanded sector although specific programs and projects targeted at the smallest rural actors are then proposed.

16 There is one more type of actor that could not be accessed because of its very nature: clandestine providers, small companies that provide connectivity services in areas where legal companies do not reach or because existing regulation makes it de facto impossible for them to exist.

The SME and cooperative sectors raise the issue of the lack of recognition of their specificity as providers since the rules of the game create unequal conditions that favor concentrated players in the provision of connectivity. This has a direct impact on the possibilities for growth and investment in infrastructure and technology, as the large companies' lack of access to specific subsidies or financing leaves them out of the market. Community actors feel that they do not have the technical and economic resources and the necessary links to implement the different existing policies. Bureaucratic procedures, the time required to implement projects and the type of requirements requested are the main issues identified as limiting.

The relationship with the state-owned satellite company ARSAT is another example of ambivalence. While some value the deployment of fiber optic infrastructure and the fact that ARSAT sites have enabled improved and efficient connections, as well as connectivity for more than 3,000 rural schools, other actors find it impossible to lease fiber and resolve other technical problems that prevent them from connecting.

b. Disarticulation between state bureaucracies

The different state actors involved in the provision of connectivity are fragmented and disjointed, working with different logics, even within the same level of government, and even more so when it is necessary to combine actions between levels. Depending on the institutional configurations of each moment (which are also very changeable), the agencies present different dynamics, institutional structures and management models, which in many cases contradict each other. This panorama becomes more complex when the international level comes into play in terms of funding sources. Internationally funded programs pose other bureaucratic requirements and evaluations that are often not adapted to local realities.

c. Lack of continuity between the administrations of different governments

Disarticulation also occurs at the longitudinal level between the successive government administrations that take office after each election, since, as we have seen, each new government brings with it particular conceptions of the role of the state in the realization of citizens' rights and, consequently, different orientations and definitions when planning and executing policies. The lack of continuity in the orientation of policies aimed at the sector and the consequent short cycles linked to changes of government do not make it possible to establish public policies that are sustained over time, to maintain the developed articulations or to build the necessary basic infrastructure.

Again, ARSAT can be interpreted as key evidence of the different policies and projections of successive administrations, oscillating between being conceived by different governments as a price regulator or even an enabler for the creation of a cooperative *carrier*, to establishing a strictly commercial link like any other supplier company.

d. Centralization of agencies and lack of federalization of policies

The characterization of a "distant state" concentrated in the Federal Capital at the level of bureaucracy and resource distribution is a condition that generates inequality for the set of peripheral actors that develop connectivity infrastructure. Along with this, there is the perception of inequalities in relation to the state on the part of different actors, who consider that they do not have the technical and economic resources or the necessary links to implement the different existing policies.

e. Macroeconomic weakness (exchange rate and inflation)

In terms of economic policy, the most critical issue is the fact that the sector is totally dollarized, both in terms of infrastructure and equipment, as well as internet service. This is combined with the limitation on the purchase of products and the contracting of services from abroad, which often slows down processes, requires new quotations and budgets, and generates uncertainty, which makes many projects almost impracticable, since any delay means a devaluation of the amounts previously considered.

f. Inefficiency in policy implementation

This leads to inefficiency in the implementation of policies: excessive bureaucracy in the requirements, procedures and deadlines, both for the application and the execution of funds, the apparent mismatch between what is demanded by the state and the state's fulfilment of its obligations and commitments, especially in the phase of contracts and payments (for example, delays of up to six months in the payment of invoices for the provision of services), undermines the sustainability of the initiative.

g. The projectivity logic and voluntarism to sustain policies

In logic, public policy has been praiseworthy in the deployment of articulations with different social actors, such as cooperatives, community organizations and small businesses, with a territorial deployment capable of reaching the different rural areas of the country. However, many of these actors recognize that there is a dynamic in which social and community organizations are the ones who must make the effort in order to guarantee rights, presenting them with a demand to sustain initiatives that go beyond their conditions and possibilities.

5. Initiatives for the Digital Transition in Family Farming From the Innovation System

As has been remarked, addressing the processes of digital transition for the family farming sector implies recognizing both the inequalities in access and the heterogeneities of rural life itself. With regard to the experiences of digital transition, once again, in general, what has been addressed most often has to do with capitalized agriculture. In this field, we find a series of actors involved, some of whom are traditional actors who are incorporating and transforming the rest of the ecosystem based on these tools, and others who are new actors emerging from the processes. A wide diversity can be found among the users themselves, who are producers or also contractors, input suppliers, the public sector (production and information, seals, certifications and other processes) or another set of companies that are facilitators, incubators and accelerators of the processes, as well as investment funds (Lachman et al., 2020). In the field of family farming, other actors come into play. Here, networks, social organizations and public policies that support the production of information for use in production, the development of applications and experiences in the adoption of digital technologies from rural extension or from the innovation system in general, take center stage.

In the field of public policies, different capacities are created linked to the agricultural innovation system and focused on the generation of information and developments on the use of digital tools and applications. From the scientific-technological system and even from public-private initiatives, *software and hardware*, proofs of concept, artificial intelligence and satellite technology are developed, specific human resources are trained in this field, and open data are generated for simulations and forecasts. The National Meteorological Service (SMN), INTA, the Sadosky Foundation, the National Atomic Energy Commission (CNEA) and the National Commission for Space Activities (CNAE) are some of the key organizations in the development of digital capabilities.

Specifically for the family farming sector, INTA's digitalization agenda is in its infancy, with a few scattered initiatives. On the one hand, an area of this organization developed a survey on the use of apps and/ or digital platforms for data management in agriculture (Scaramuzza et al, 2022), aimed at recognizing the development of precision agriculture[17]. The survey was conducted with producers and technicians (94%), with a low participation of operators and workers. Among the former, 65% use web platforms and digital tools. The main needs identified were linked to the integration between apps and platforms, automatic synchronization in data uploading, prediction in the detection of anomalies and traceability in agricultural production.

INTA has also developed a set of applications that allow the systematization of processes[18] linked to different agricultural practices. Many of them have been downloaded more than ten thousand times, which implies certain levels of appropriation by producers. Other extension experiences include support for the training of family farming organizations in digital

17 The report does not have a technical sheet that would allow us to recognize the representativeness of the study, as well as the type of rural respondent. The information is concentrated in the Pampean area, linked to agricultural establishments dedicated exclusively to extensive crop production; while a similar proportion (36%) would be establishments dedicated to mixed production systems, where agriculture coexists with livestock, meat or milk. This report highlights the potential of digitalization processes for the production of real-time data.

18 These include analyses of dairy farms, operating parameters of seed drills and harvesters, different types of spraying parameters, calibration of fertilizer spreaders and estimation of yields of different crops, among others. These can be consulted at: https://www.argentina.gob.ar/ inta/aplicaciones-inta

marketing[19], the design of marketing platforms[20], development of apps to collect data on goat and pig production indicators[21] and some initiatives being promoted by the project "Innovation ecosystem, digital integration and adoption of AgTech to bridge the technology gap" and researchers from INTA's Centre for Research and Technological Development for Family Farming (CIPAF). In this center, a team is working, for example, on the development of a digital application for a milk bagging machine for family farmers that can be used online or offline. The development makes it possible to process, pasteurize and sell safe milk in local markets. The associated application allows for product traceability.

An INTA Ideas Competition was recently launched to contribute to the development and/or achievement of technologies related to climate-smart and inclusive agroclimatic systems. Among the proposals submitted, only one was aimed at the family farming sector. It is an application developed by students from the National Technological University that gathers key information (climate, irrigation, crop diseases, etc.) for the sector when planning tasks and managing crops.

From the point of view of the researchers who accompany these processes, it is necessary to work with family farming organizations in order to incorporate the issue of digitalization into the sector's agenda, since it is not an agenda that is generally prioritized by the organizations, which have

19 An interesting work in this sense was carried out by the "Supply, commercialization and consumption of goods and service products of the Indigenous Peasant Family Farming" project of INTA and the Chasqui consumption community, which is accompanied by the National University of Quilmes. https:// tiendaschasqui.ar/

20 One concrete experience is the "Voy de Feria" platform, an initiative promoted by family farming organizations, agro-ecological fairs and consumers in Cordoba, which was supported by the local project "Development of a system of collaborative networks for the commercialization of family farming in the northwest and center of Cordoba", the creative agency for family farming Majada and funding from the Special Projects for Rural Community Communication line of the ProHuerta program. https://www.voydeferia.com/

21 The computer application CaprinApp (https://play.google.com/ store/apps/details?id=ar.gob.inta.cabrinapp&hl=en_US), designed by INTA, is in operation in Las Breñas, Chaco; from where other tools are being developed, such as PorcinApp and an app for the detection of goat diseases, in conjunction with the Institute for Research and Technological Development for Family Farming, NOA Region, INTA.

other priorities and are sometimes unaware of the potential benefits of this type of technology[22].

6. Perspectives of the Digital Transition for Agriculture, by Way of Conclusion

Access to connectivity and the advantages of ICTs and digitalization is a pending issue for a large part of Argentina's rural populations. This situation particularly affects the sector that guarantees the production of food consumed by the majority of Argentines. The relevance of this also lies in the question of rights and development processes and rooting in rural areas. Without effective connectivity policies, it is impossible to think of reversing the trend towards depopulation of rural areas. There are a series of promising conditions for developing effective policies in this sense, which require a rethinking in the field of public policies in order to be extended and strengthened.

Infrastructure is in place for connectivity in rural areas. Since 2010, the Federal Fiber Optic Network (REFEFO) has been implemented, which has increased the quality and extension of broadband throughout the country. It currently has 34,500 kilometers deployed with its corresponding technological support, in 700 provincial nodes, crossing more than 1,000 localities. This is a basic infrastructure with which local providers can carry out the work for the last-mile service. The creation of state-owned telecommunications companies in different provinces of the country is no less important.

Satellite technology to provide internet outside the area of terrestrial wireless coverage is offered by ARSAT, through the ARSAT 1 and 2 satellites. Argentina is one of the few countries in the world that not only designs and builds satellites, but also operates them. It also has a third satellite whose objective is to reduce the digital divide in rural areas.

22 Edurne Battista of IPAF Pampeano (CIPAF-INTA) is gratefully acknowledged for her contributions to these ideas.

There are researchers and, for the time being, there is technical capacity to make progress on the above-mentioned objective. The issue needs to be prioritized in research agendas.

There is a nucleus of local providers, identified as cooperatives, SMEs and community-based, willing to work on last-mile services in rural areas. These providers are demanding specific rules for the development of the sector, but have built a dialogue channel with state programs linked to telecommunications.

There is information on the situation of connectivity in the rural areas, based on different surveys and censuses that need to be integrated.

There are public policies for internet access in rural areas, which have multiplied after the pandemic as part of the process of digitalization developed by the national state and which have a Trust Fund[23] of the Universal Service[24] for the implementation of their programmes, projects and activities.

There is one sector that particularly interests us – that of family, peasant and indigenous agriculture – which has been incorporated as a subject of policies and has included the problem of access to connectivity on its agenda in discursive terms. The Family Farming Historical Reparation Law recognized this problem, but no progress was made in the regulation or in the design of specific plans.

In this state of affairs, a way out of the crisis in Argentina's rural areas, visible in the sustained process of uprooting of its rural areas, that allows for the promotion of a desirable development model, a rurality that is habitable, with decent work, enlightened and with access to technologies and innovations, could begin to be built from the recognition of current weaknesses on the part of different political and institutional actors and from the consolidation of public policies and State actions that re-know the different actors as productive actors and/or of centrality in the productive process. This could be done by facilitating access to initiatives that enable

23 It is made up of the contribution of one percent of the revenues of the licensees of telecommunications services, earned from the provision of ICT services.

24 According to Argentina's National Telecommunications Agency, Universal Service is the set of information and communications technology (ICT) services that must be provided to all users, guaranteeing their access under quality conditions and at fair prices regardless of their geographic location.

technological adaptation for production, accompanying associative forms in this sense; and stimulating agreements between the diverse range of subjects through incentives and/or opportunities for access to public banks. Multiple and coordinated actions are needed from different actors in order to influence and turn rural connectivity into a public problem. This is because, as we have seen, beyond specific initiatives, the effectiveness of policies depends on the functioning, comprehensiveness and articulation of the institutional system as a whole, and on the possibility of forging a more solid consensus on policy direction in order to make policies effective in the future.

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Annex

Table 1. Chronology of major policies for universalizing access to connectivity

Year	Policy	Driving Agency	Policy focus
1998	Decree 1018/1998 Program argentin@ Internet.todos	Secretariat for Communications and the International Telecommunication Union (ITU)	Dissemination and promotion of Internet access. Community enterprises with interactive and multimedia applications: Community Technology Centers (CTC).
2000	Decree 764/2000 Deregulation of Telecommunications Services	Communications Secretariat	Deregulation of telecommunications services, creation of the Universal Service Trust Fund (FFSU) Article 10).
2000	National Program for the Information Society	Communications Secretariat	Programs and projects to disseminate information and knowledge through IT procedures.
2006	Law 26.092/2006 Creation of ARSAT	National government and legislature	Design and development of geostationary telecommunications satellites for the occupation of orbital positions, as part of a telecommunications sovereignty policy
2010	National Telecommunications Plan "Argentina Conectada".	Ministry of Federal Planning, Public Investment and Services	Infrastructure and public goods (deployment of the Federal Optical Fibre Network -ReFeFo- and ARSAT company) for universal access and digital inclusion. Network of Access to Knowledge Nuclei (NAC).
2010	Conectar Igualdad Programme	Ministry of Federal Planning, Public Investment and Services	Equipment and connectivity for students and schools

Year	Policy	Driving Agency	Policy focus
2014	Law 27.078 Argentina Digital. Modifies- The decision was adopted in 2015 with the 267/2015.	National Executive Power, the Federal Authority of Information Technologies and Tele- communications (AFTIC), then through the National Communications Entity (ENACOM).	Organization and integration of the telecommunications sector, with a view to universal access.
2014	Law 27.118 on the Historical Repa- ration of Family Farming for the Construction of a New Rurality in Argentina.	National Government and Ministry of Agriculture	General framework for the development of rural development policies and attention to the family, peasant and indigenous agriculture sector.
2015	Decree 267/2015	Ministry of Communications	Creation of the National Communications Entity (ENACOM) as the regulatory body for the sector.
2016	National Plan for the Development of Competitiveness and Quality Conditions Mobile Communications Services	Ministry of Communications	Efficiency in the mobile communications market with regulatory alignment and incentives
2016	Resolution 3597/2016, within the Federal Internet Plan (*Connectivity Program*).	ENACOM	Financing of projects for the provision of wholesale and/or retail services on areas with unmet needs
2017	Connectivity Plan for rural schools	ARSAT	Connectivity to more than 2,232 rural schools throughout the country through ARSAT' installation of V-SAT antennas that allow access to the Internet and the television signal of public digital content.
2018	Satellite Internet Access Programme in small towns and villages	ENACOM, ARSAT	Satellite Internet for small towns

Year	Policy	Driving Agency	Policy focus
2018	Decree 996/2018 Argentine Digital Agenda	Office of the Chief of Cabinet of Ministers, Secretariat of Digital Government and Technological Innovation	Digital literacy
2020	Necessity and Urgency Decree 69, ENACOM Regulation 721/2020 and other regulations.	National Executive Branch, ENACOM	Ensuring access to digital services in a pandemic context
2020	Tasa Web Program. Banco Nación loans for SMEs in the process of digital transformation.	ENACOM and Banco de la Nación Argentina	Loans at subsidized rates through the Ban- co Nación for the purchase of equipment for micro, small and medium-sized enterprises and cooperatives, to operate infrastructure networks for connectivity
2020	Resolution 721 General Regulation on Universal Service	ENACOM	Investment contributions that are obtained through the Universal Service Trust Fund.
2020	Resolution ENA- COM 727/2020 Access to ICT services to populations in disadvantaged and underserved areas Program	ENACOM	Projects to provide access to connectivity in totally or partially underserved areas, which, due to their geographic, demographic or other characteristics, are very difficult for the deployment of infrastructure.
2020	Resolution 1490/2020 Non-Refundable Contributions Program for Small Licensees	ENACOM	Projects to improve and/or enable the provision of Fixed Broadband Internet Access Service and/or, fundamentally, the replacement of existing power lines fiber optic cables.
2021	Community Internet Networks Program Roberto Arias	ENACOM	Connectivity for rural and indigenous communities, promoting self- management through the figure of Community Networks. Financed with funds from the Universal Trust Fund.

Year	Policy	Driving Agency	Policy focus
2022	Digital Dot Program	Secretariat of Public Innovation of the Office of the Chief of Cabinet of Ministers and ARSAT	*Puesta en Valor* through which 52 Digital Points (former Knowledge Access Centers have already been fully or partially renovated. (NAC) in 16 provinces.
2022	Resolution 1352 ENACOM Program for the development of Internet infrastructure in small rural localities. and indigenous communities	ENACOM	Access to ICTs and communications through the delivery of integrated cabinets ICTs to target communities that do not have the knowledge and technological know-how to meet network maintenance requirements.
2023	Resolution ENA- COM 64/2023 Program for the Development of Internet Infrastructure in Public Institutions in Rural Areas	ENACOM	Universal Service Trust Fund financing program for rural areas
2023	My Connected Village Program	Secretariat for Public Innovation of the Office of the Chief of Cabinet of Ministers and ARSAT	Access to satellite connectivity and digital resources in more than 370 Argentinean localities with little or no internet connection.
2023	Integral Plan for Productive Rural Connectivity and Technology 4.0	Secretariat for Development Planning and Federal Competitiveness of the Economy	Investment projects in the different provinces to strengthen connectivity infrastructure, with IDB funds. It included actions in coordination with IN-TA-ARSAT and ENA-COM for the development of 4.0 technologies in agriculture

Source: own elaboration based on regulations and interviews.

6

Evolution of Public Policies Applied in the Area of Digital Agriculture in Chile

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1. Introduction

Since the late 1990s, Chile has promoted a national digital development policy as part of its strategy to boost economic growth and promote social inclusion. In 1999, the approach "Chile: Towards the Information Society" was developed, which was later replaced by the "Digital Agenda Chile 2004-2006", the "Strategy for the Digital Development of Chile 2007-2012", the "Digital Agenda Imagine Chile 2013-2020" and the "Digital Agenda 2020".

All these policies share a common approach: the idea of developing an advanced, competitive, market-based regulatory framework that allows universal internet access at very low costs, and they have been implemented at a high technical level that has been able to go beyond political cycles. This task is the responsibility of the Subsecretaria de Comunicaciones (SUBTEL) (https://www.subtel.gob.cl/), of the Ministry of Transport and Telecommunications, with the collaboration of other government agencies. Substantial contributions have also been made by private companies, grouped in the Chilean Association of Information Technology Companies A.G. (ACTI) (https://acti.cl/), the Chilean Society of Software and Services A.G. (Sociedad Chilena de Software y Servicios A.G.), CHILETEC (CHILETEC) (https://acti.cl/). CHILETEC (https://chiletec.org/) and

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the Chilean Chamber of Commerce and Industry of Digital Infrastructure (https://lainfraestructuradigital.com/), as well as private non-profit institutions, such as the Fundación País Digital and its Plan "Un País Digital 2021" (https://paisdigital.org/).

In this way, the Internet has become a service that is now present in almost every household in the country. According to a recent survey commissioned by SUBTEL, 94.3% of Chileans reported having their own paid Internet access in their homes, a figure that drops slightly to 89.5% in rural households (SUBTEL-CADEM, 2023). These figures are the result of the application of public policies aimed at closing the gaps in access to this technology based on considerations in bidding processes for companies, such as mandatory coverage in isolated locations, free *wifi* in rural sectors or connectivity in schools. These policies have also considered the development of large infrastructure projects, such as fiber optic networks, to reduce the lack of connections in the extreme sectors of the country.

These advances can also be explained by the massification of other complementary technologies, such as mobile telephony (99.1% with a mobile phone or smartphone in urban and rural areas, according to the SUBTEL-CADEM survey), and within this, 5G telephony. The latter has been in the process of implementation since August 2020, when 5G concessions were allocated to telecommunications companies. The SUBTEL-CADEM survey reveals that 35.1% of mobile broadband or mobile internet connections had this technology, a figure that reached 22.3% in rural areas. The implementation of 5G in Chile has been progressively implemented by multiple operators offering this technology in various regions of the country. This survey concludes that while fixed internet access is increasing, mobile internet has an important role to play in bridging gaps, especially in rural areas.

This digitalization process has enabled the construction of a more productive, secure and efficient environment. However, the digital transformation of companies is still a pending challenge. According to the latest figures from the Virtus Digital Maturity Index (IMDV), available for 2021, only 55% of large companies and 53.7% of SMEs in Chile had initiated a digital transformation process (IMDV, 2021). This means that there is still a considerable percentage of companies that have not yet started a digital transformation process, the small and medium-sized farms, especially family farms. This challenge - to digitalize the economy of agricultural chains, of territories and of the rural world in general - is the guide that we have used to carry out this study.

Chile must move to another stage, shifting the emphasis on connectivity to the focus of public policy. While there are still many access gaps to be addressed in this area - in rural areas, at lower-middle and lower socio-economic levels, in households with elderly people and female heads of households - new policies should aim to increase the use of this technology, favoring digital literacy and the development of new digital capacities and skills, as well as the development of applications and digital solutions that contribute to improving the productivity of economic activities. In the terms of a recent study conducted by ECLAC and the Transport and Telecommunications Commission of the Chilean Senate, it is necessary to move from the "Chile connected without gaps" pillar (coverage, access, use) to the "Digitalized Chile" pillar (digitalization of processes and activities) (Órdenes et al., 2023). To this end, these authors propose progress in seven strategic areas: (i) Enablement of digital infrastructure; (ii) Development of digital skills; (iii) Digital rights; (iv) Digitalization of the economy; (v) Digitalization of the state; (vi) Cybersecurity, and (vii) Governance.

This chapter analyzes the progress and pending challenges in the Chilean agri-food sector. This is done by analyzing the institutional framework and the policies on access to infrastructure, and then by analyzing all the relevant sectoral initiatives. The aim is to provide an overview that allows a consistent series of public policy recommendations to be visualized. In order to carry out the analysis, secondary sources have been consulted and interviews have been conducted with some authorities, producers and specialized professionals.

2. The Institutional Framework

The digital transformation in Chile has been based on policies that seek to promote economic growth and social inclusion through digital development. Since the 1990s, Chile has recognized the importance of promoting a national digital development policy. Initially, strategies such as "Chile: Towards the Information Society" and the "Chile Digital Agenda 2004-2006" were developed. Subsequently, the "Strategy for the Digital Development of Chile 2007-2012" and the "Digital Agenda 2020" were implemented. These policies have focused on strengthening digital infrastructures, improving the quality of life through e-government and advancing in the digital transformation of the State to offer more efficient services to citizens.

Law 21.180 on the digital transformation of the State, approved on November 11, 2019, has been an important milestone in this process, as it determines that the Chilean State must move towards digitalization in all sectors, establishing deadlines and promoting various improvements: digitalization of administrative procedures, validation of electronic official communications, incentives for citizens' requests and carrying out procedures electronically, electronic files for document management and transparency, and application of the principle of interoperability between institutions, seeking greater integration and efficiency in administrative processes. In addition, this legal body defines an institution responsible for digital government (SUBTEL) with a clear mandate and powers to promote systemic change in public administration.

Other pending developments relate to legislation on digitalization as a public service. In April 2024, a law was passed in the Senate (unanimously) that enshrines the Internet as a public telecommunications service (https://www.senado.cl/acceso-a-internet-como-un-servicio- publico-de-telecomunicacione-ad). This law has been under discussion in Parliament for six years and is close to final approval. Its importance lies in the fact that, for the purposes of Chilean law, internet connection is not yet a public service, as telephony is. This law promotes the internet as a public telecommunications service, allowing the state to subsidize the service to people who, having the technical feasibility to contract it, cannot afford it. This law will also allow users to organize themselves into communities to provide Internet services in the most isolated places, which are currently not reached by the Internet, using a figure that is similar to the Rural Drinking Water Committees. In addition, this new regulation requires the creation of a National Digital Plan that considers various policies on connectivity, investment, cybersecurity, quality of services, accessibility and universality, among others (El Mercurio, 2024a). All these factors will have a strong impact on Internet massification in rural areas.

2.1. The Telecommunications Development Fund

The Telecommunications Development Fund (FDT) is a financial instrument operated by SUBTEL that aims to promote the increase in the coverage of telecommunications services in low-income rural or urban areas with low or no availability of these services due to the economic unfeasibility of being served by the national telecommunications industry.

FDT is a tool that seeks to increase inclusion and cohesion, both geographically and socially. Its objective is to enable citizens who are isolated, due to geographical or technological conditions, to access telecommunications services at the same price and quality conditions as the regional capitals, thus helping to reduce the digital divide. The FDT does not directly implement the projects it designs, but awards them through public tenders to companies and institutions that meet the established conditions and obligations.

The beginnings of FDT date back to 1994, when many geographically isolated localities were completely lacking telecommunications services that would allow them to connect to the rest of the country and the world, further increasing their sense of isolation. This lack was mainly due to the fact that its provision was not economically sustainable for private companies, because of high investment costs in infrastructure and operation, coupled with insufficient demand.

The structure of operation and reception of requirements that can be tendered by the FDT operates on the basis of requests for telecommunications services that are received at SUBTEL's Office of Information, Complaints and Suggestions (OIRS). These requests or demands for connectivity are made by telecommunications service concessionaires, municipalities, neighborhood councils and other social and community organizations or third parties. From there, a portfolio of projects is prepared, which is technically and socially evaluated by SUBTEL, and then submitted for consideration by the Development Council (CDT). If approved, they become part of the subsidisable projects, which will be called for public tender during the following year. The Telecommunications Development Council is in charge of approving the portfolios of projects to be developed, as well as the calls for tenders to be carried out by the Fund through the FDT's Management Division, and the subsequent award of the projects to the selected legal entities.

Table 1. TDF projects.

PROJECT/ COMPETITION	AMOUNT OF THE SUBSIDY (US$ Millions)	NATIONAL BENEFIT	STATE OF PROGRESS
Connectivity for Education	14, 7	16 regions (716 educational establishments)	Very advanced
Telecommunication Services for Wi-fi Zones 2.0	3,6	8 regions (508 Chile-Gob wi-fi hotspots)	In operation
Southern Fibre Optic Project	66,7	3 regions	In operation
National Fibre Optics	78,7	13 regions (202 communes)	Very advanced
Optical Fibre Border Complexes	4,1	South, North and Central Macrozone	In operation
Enabling Tarapacá Fibre Optics	6,1	15 locations	Early stage (20%)
Last-Mile Regional Projects	s.i.	16 regions	Newly awarded
Last-Mile Project in the Lake District	6	Lakes Region	Newly awarded
Last-Mile Project in the Region of Ñuble	5,4	Ñuble Region	Newly awarded
Implementation of Digital Television Broadcasting Systems	1,6	16 regions	Newly awarded
Fiber Optic Project for Villa O'Higgins	7, 5	Commune Villa O'Higgins	In the process of drawing up the bases
Project to Increase Fixed Internet Service coverage for Homes	98,8	16 regions	In technical design and economic evaluation stage
TOTAL	293,2		

Source: SUBTEL, 2024. Note: Dollar value: 954 pesos.

2.2. Fiber optic projects

The Fibra Óptica Austral (FOA) project seeks to deploy the necessary infrastructure for the implementation of the Optical Infrastructure Trunk Lines in the regions of Los Lagos, Aysén and Magallanes. This infrastructure corresponds to a submarine and three terrestrial fiber optic cable trunk lines, with Optical Telecommunications Infrastructure Operation and Interconnection Points (POIIT) that open a non- discriminatory access to this infrastructure in the southernmost area of the country. These trunks will support all existing telecommunications services in the area and incorporate new high-capacity services, access and applications for end users.

The project called Fibra Óptica Nacional (FON) will make it possible to establish a terrestrial fiber optic connection between the country's communal capitals and their respective regional capitals, which will enable the non-discriminatory use of infrastructure and the digital support necessary to promote socio-productive development, improve the quality of life of the population and face the challenges brought about by the technological revolution. The deployment of regional infrastructure networks will be integrated with the current national networks (private and FOA) to create a national network that includes a large part of the communes nationwide, allowing more equitable access to state-of-the-art technologies in urban and rural areas.

The FON will deploy a fiber optic network in different communes of the country, through the FDT public tender, allowing potential public telecommunications service concessionaires to access this fiber optic transport network, with an open and non-discriminatory offer in order to generate greater dynamism in the market and promote access and digital integration for the social and productive development of communes and localities in the country. In addition, it is expected that this network will have a significant impact on the resilience of the country's infrastructure, by providing fiber optic routes on different routes from the current ones in order to better face possible emergencies and critical events.

The purpose of the Fiber Optics in Border Complexes project is to install, operate and exploit optical telecommunications infrastructure in order to improve the coverage of telecommunications services in strategic transit centers within the country and thus enable the Border Complexes and Land Border Crossings, as well as the localities situated along the route corresponding to the planned optical fiber routes, to access physical tele-communications infrastructure networks.

2.3. Last-Mile" regional projects

These are initiatives designed and implemented jointly with the Regional Governments (GORES) with the aim of establishing needs and priorities to be considered during the study of technical and economic feasibility. These projects survey and prioritize the localities to be served, then provide a tele-communications solution, with services that can be transported via fiber optics, such as telephony and mobile data transmission services to end users in the municipalities and/or localities of each region. These initiatives are financed through regional government resources and amount to US$ 189 million.

2.4. Satellite Internet services

This service is offered by the company Starlink, which provides high- speed, low-latency Internet access worldwide through a constellation of satellites. In Chile, this service has gained popularity by offering an alternative Internet connection in rural and remote areas where traditional options are limited. By the end of 2023, it had a total of 40.9 thousand customers who, in general, have been able to access a good quality service (EMOL, 2024). In terms of pricing, Starlink's Standard Satellite Internet Kit is available in Chilean retail for US$ 450, while the monthly fee is US$ 49. There are other alternatives that offer wireless connections, such as Hughesnet and Viasat.

2.5. National Policy on Artificial Intelligence (AI)

AI is a general-purpose technology with a cross-cutting impact on productivity. The Chilean government has been working in this area for many years, seeking to promote the development and ethical and responsible use of AI so that this technology can play a promoting role in the country's new development and growth model. This has materialized in multiple initiatives, including the National Artificial Intelligence Policy, approved in

September, 2021 (Ministerio de Ciencia, Tecnología, Conocimiento e Innovación, 2021).

This Policy was developed in a participatory manner and is based on four principles: (i) AI with a focus on people's well-being, respecting human rights and security; (ii) AI for sustainable development; (iii) inclusive AI, and; (iv) globalized and evolving AI. This policy considers strategic guidelines for the next ten years and was structured along three axes: (i) Enabling factors; (ii) Development and adoption, and; (iii) Ethics; legal and regulatory aspects and socio-economic impacts. Since then, significant progress has been made in this area: the creation of the National Centre for Artificial Intelligence (CENIA), the implementation of the Millennium Nucleus research project "Futures of Artificial Intelligence Research" (FAIR), the focus on AI in PhD scholarships (ANID), the implementation of 5G networks, the first PhD in AI in Chile and Latin America and the implementation of the Ethical Algorithms Project, among other measures[1]. This has placed Chile in first place in the region in the Latin American AI Index (https://indicelatam.cl/).

During 2023, the accelerated progress of generative AI prompted an update of this Policy, especially Axis 3 (Governance and Ethics), which was carried out with the participation of various public bodies and civil society (Ministry of Science, Technology, Knowledge and Innovation, 2024). In addition, a new Action Plan was elaborated and new draft laws are being prepared to regulate this matter (El Mercurio, 2024b). This Policy includes ethical aspects, AI pre-school education, AI research funds, infrastructure for everyone to have Internet, cybersecurity and specific AI applications for SMEs, among many specific subjects.

2.6. Other government initiatives

- **Chile *Atiende* Programme**: This is a multi-service network of the State that seeks to make people's lives easier through its various channels of attention and guidance. This initiative provides clear and simple information on how and where to carry out procedures, the

1 https://www.minciencia.gob.cl/areas/inteligencia-artificial/politica-nacional-de-inteligencia-artificial/

necessary requirements, as well as the services and benefits of the State. Chile Atiende has 200 branches to carry out procedures and obtain guidance, in addition to offering telephone assistance through the 101 number (https://www.chileatiende.gob.cl/).

- **Digitalize your SME Programme:** This program is promoted by the Ministry of Economy, together with the Development Corporation (CORFO) and the Technical Cooperation Service (SERCOTEC), in alliance with public and private institutions. It promotes the digitalization of smaller enterprises. It offers training, tools and a digital check-up to assess the level of digital maturity of SMEs and facilitate their digital transformation. (https://www.digitalizatupyme.cl/)

- ***Red de Asistencia Digital Fortalece Pyme – Proyecto Red*:** This is aimed at business networks and allows access to up to 80% co- financing of the total cost of the project (with a ceiling of US$ 210,000) to help SMEs increase their income and/or improve their productivity levels through the adoption of digital technologies in their business processes (production, management and/or commercial) (https://www.corfo.cl/sites/cpp/inf/fortalece-pyme).

- **Digital Kit Program:** This is a fund administered by SERCOTEC that promotes the digitalization of micro and small enterprises and co-operatives through a subsidy to acquire technological tools and a catalogue of free courses on the subject. The program grants US$ 1,250 to finance a work plan that includes the acquisition of goods needed to improve the operational and financial management of businesses, their production or service commercialization process and their degree of innovation. (https://www.sercotec.cl/ ruta-digital)

3. The Conceptual Framework: Food System Approach

3.1. Levels of analysis

In order to analyze the progress of the digitalization process in the Chilean food system, we consider the national level as the main unit of analysis, as this is where the digital ecosystem is fully deployed. However, within this ecosystem, specific units or subsystems are considered, such as production chains, territories, thematic jurisdictions (health, irrigation, financing, etc.) or operational units (public and private), which fulfill specific functions and cover the entire production cycle, from food production to consumption (HLPE, 2018).

- For simplification purposes, we will analyze the process of digitalization of such an ecosystem by considering five levels[2]:

- The first one concerns **agricultural holdings**. This process involves soft technologies (business management) and hard technologies (robotization, automation, sensorization, etc.), which are mainly promoted by the National Agricultural Research Institute (INIA) and universities. At this level are also the agro-industrial companies or service companies that operate in the food system throughout the industrial chain, from collection and preparation to industrial processing, marketing and waste management.

- The second level covers **production chains**. Digitalization goes beyond the boundaries of an enterprise (a farm, agribusiness or a service enterprise) and mainly encompasses innovation networks, agricultural extension systems, marketing and value-adding strategies, and financial services. This is the area of cooperatives, NGOs and public extension and production promotion programs. It is also the area of input companies, which have an increasing influence on producers'

2 This analysis builds on previous work, which, for reasons of simplification, distinguished only three levels: enterprises, extension systems and territorial coordination hubs (Barrera et al., 2023; Aedo et al., 2023). In this paper, two new levels (consumption and recycling) are added to account for the entire Chilean food system.

technical decisions. At this level there are also local fairs, the HORECA channel (hotels, restaurants and cafeterias), supermarket networks, Internet sales and other marketing spaces.

- The third level is that of **household consumption**: problems of access to food, in the most vulnerable segments of the population, but also problems of obesity, diets and consumption patterns. Many public health and food programs have benefited from digital, and the same is true at the level of individual consumption: there are now many applications that can be used to monitor food consumption, help consumers to find their way around the market and eat healthier.

- The fourth level deals with **recycling systems for by-products and inputs**. It involves studying food waste processing systems and the role that digital can play. The most relevant case concerns the management of Food Banks, which allow the reuse of food products that are still useful for human consumption. The management of these programs, which requires a high level of coordination of actors, has been optimized with the help of digital applications.

Finally, there is the challenge of **coordinating actors at the level of production chains and territories**. This area encompasses the use of digital hubs as tools for governance of the development process, including mechanisms for social participation and decision-making through face-to-face and digital means. It also includes the integration of extension and marketing networks with other applications that are part of the digital ecosystem.

3.2. The sectoral coordination model

MINAGRI has a tradition of coordinating public-private agendas, using National Commissions by Regions, Committees, Councils and Working Groups, many of which are coordinated by the Office of Agricultural Studies and Policy (ODEPA). These bodies include producer and agribusiness associations, as well as public bodies, universities and other sectoral actors. The specific management of these coordination bodies is highly variable, as it depends on the political and economic situation, as well as the style of each ministerial administration.

In the digital case, MINAGRI has not defined a single national agenda that frames the work of all ecosystem actors, as is the case in Brazil (MAPA, 2021). MINAGRI has opted for a model based on various working commissions, which operate as driving centers that fill in spaces on their own initiative[3].

- A relevant milestone was the creation, in 2022, of a Working Group dedicated to defining a National Rural Digital Connectivity Plan, which responds to the challenge of closing the digital divide by the end of the current government (March, 2026). In this model, there are several institutional agendas that are connected to each other, establishing multi- actor coordination in a network, but each one of them works in its own field. In this way, it operates various working groups:

- Rural Digital Connectivity Roundtable, led by MINAGRI and the Undersecretariat of Telecommunications (SUBTEL), with the participation of the Undersecretariat of Tourism, the Natural Resources Information Centre, the Institute for Agricultural Development (INDAP), the Foundation for Agrarian Innovation (FIA) and ODEPA.

- Regional Commission on Digital Agriculture in the Ñuble Region, which implements a pilot project in the Itata Valley, with the support of the CELAC/FAO Project. The Regional Government, INDAP, the National Training and Employment Service (SENCE) and SUBTEL participate in this roundtable. A similar roundtable has recently been set up in the Araucanía Region.

3 There is a sectoral digital agenda approach proposed by a consultant of the International Telecommunications Union (ITU) to the Chilean government in 2020, which was not implemented, leaving only a reference document. See: Martínez, 2019. The National Program for the Promotion of Agriculture 4.0, launched by MINAGRI in June 2021, with the support of the Foundation for Agrarian Innovation (FIA) and the Technological Extension Centre, Thinkagro, is another example of a sectoral agenda that has not materialized. At the territorial level, the Regional Directorate of Corfo Maule launched in April 2023 an initiative called “Industry 4.0 for the agri-food sector in the Maule region” https://www.corfo.cl/sites/cpp/sala_de_prensa/regional/21_04_2023_maule_agroalimentario.

- Regulatory Commission, in charge of adjusting regulations to rural conditions. SUBTEL, the Undersecretariat of Regional Development (SUBDERE), ODEPA and INDAP participate.

- Rural Tourism Roundtable, with the participation of the Undersecretariat of Tourism, ODEPA and INDAP, to analyze the implementation of a specific strategy for this economic and social sector.

- Public-Private Roundtable, made up of private companies collaborating with the ministerial strategy, such as Hughesnet, Claro VTR, Mundo Pacifico and ENTEL. For the government, SUBTEL, ODEPA and INDAP participate.

Innovation Commission, led by FIA, which has commissioned the development of a directory of digital solutions for the agro-livestock sector to the Centre for Public Systems of the University of Chile, which is expected to be completed by mid-2024.

This National Rural Digital Connectivity Plan was launched in September, 2023 (Subsecretaría de Turismo, 2023) and has been in the implementation phase since then. It is an open, non-prescriptive coordination model, where the State exercises its regulatory role, appealing to *loosely coupled* schemes, which allow for deviations in the face of possible contingencies (Sotomayor et al., 2023). Each institution has its own digital agenda and advances separately, making its own contributions. As important projects emerge that set the tone, the framework becomes more complex, leading to the *de facto* implementation of a national agenda. The model is flexible, but sometimes leads to lack of coordination, duplication or gaps that are not filled by anyone; in other words, progress is made, but synergies are lost that could be used to accelerate the digitalization process.

4. Sectoral Initiatives

4.1. Established institutional information programs

All MINAGRI institutions have experienced progress in the area of digitalization. This occurs in the area of internal institutional management (digitalization of the State), where they have implemented projects to improve their internal systems, including issues such as *online* procedures, electronic signature, "dematerialization", human resources management, inventory management and other administrative areas. Digitalization has also advanced in the area of information management for external users, as well as in project management with producers and their associations.

4.1.1. ODEPA data systems

ODEPA has been improving its digital capabilities for information management for many years. It maintains freely accessible databases on the evolution of agricultural prices (fruit and vegetable wholesalers, flower wholesalers, international prices, consumer prices, producer prices, inputs and forestry products) and on many other subjects: foreign trade, national and regional cost sheets, fruit cadasters, production statistics, economic statistics, agricultural employment and territorial information. ODEPA also maintains a line of studies and publications that are available to the public on its web page and monitors the dynamics of the production chains through bulletins and meetings of 12 National Commissions of Items and two Comities, two Councils and six Working Groups, where the public and private sectors are coordinated. In addition, ODEPA organizes seminars, workshops and other events, provides advice to the ministerial cabinet and is in charge of international cooperation and international trade negotiations for food and forestry products (https://www.odepa. gob.cl/#).

4.1.2. CIREN data systems

The Natural Resources Information Centre (CIREN) is an institution with legal personality and private law that, for more than 30 years, has provided information on the country's natural and productive resources through the use of geospatial technologies and applications. The result of this work has allowed the construction of the most important database related to georeferenced information on soils, water resources, climate, fruit and forestry information in Chile, as a complete cadaster of rural property.

CIREN works to ensure quality in the provision of public goods and the generation of new high-value products and services that contribute to planning and design of policy for productive development and land-use planning. In addition, the institution provides updated information on the territory and its resources in order to mitigate possible risks, including natural disasters and climate change. To this end, CIREN coordinates the following projects.

- The **Institutional Observatory** (https://observatorio.ciren.cl/) is CIREN's heritage information base. It allows searching, comparing and analyzing productive and geographical data on species and natural resources in the country, providing a broad overview of Chile's agriculture and natural resources.

- **The Monitoring System of Native Forest Ecosystems in Chile. (**https://simef.minagri.gob.cl/) is a digital platform implemented by CIREN, INFOR and CONAF that provides updated information on the status and situation of native forest ecosystems.

- The **Rural Territorial Information System (SIT Rural)** (https://www.sitrural.cl/) provides free descriptive and cartographic data at the communal level, through "Communal Reports" and a "Map Viewer" that support territorial planning and management.

CIREN also works with specific applications, such as APP Agropredial, created in 2018. This mobile application provides information on the productive aptitude of different fruit and vegetable species in a given territorial location, helping the farmer to plan his crop (https://apps.apple.com/cl/app/agropredial/id1544020566).

4.1.3. Integrated data management

In data management, there is a committee made up of all MINAGRI institutions, which has been in operation since 2010 and seeks to standardize the data of the different institutions. This committee manages:

- The **Spatial Data Infrastructure** Project of the Ministry of Agriculture (IDE MINAGRI) (https://ide.minagri.gob.cl/geoweb/), an online and interoperable technological platform that allows access to all the material generated by the services of this portfolio. IDE MINAGRI allows access to the material generated by institutions such as CIREN, INFOR, INIA, ODEPA, SAG and SIGMINAGRI.

  This platform seeks to provide a unified system that allows professionals to access a common and standardized base of geographic information, avoiding redundancy and ensuring the integration of information for planning, monitoring and evaluation of public policies. This Platform is managed from the Natural Resources Information Centre, CIREN, the Spatial Data Infrastructure of the Ministry of Agriculture (IDE MINAGRI) and makes available to users multiple layers of geospatial information linked to the rural world, configured as the spatial expression of intervention of the Ministry of Agriculture at the level of policies, plans and programs in the country, through the timely delivery of georeferenced data and territorial information, arranged in a practical and easy to understand way, ideal for any type of user linked to Chilean agriculture.

- **SIGMINAGRI** is a geographic information system (GIS) developed by the Ministry of Agriculture of Chile. It is based on QGIS, a project of the Open Geospatial Software Foundation (OSGeo). The system is designed to provide a common and standardized basis of geographic information to professionals in the sector, avoiding redundancy and ensuring the integration of information for planning, monitoring and evaluation of public policies. The system is part of the Unified Information System of the Ministry of Agriculture, which includes the Cadasters and Systematization of the Ministry's Administrative Records. It has been developed in accordance with

Chilean geographic information standards, including the ISO 19115 standard for metadata, and has been observed by the Geographic Institute Agustín Codazzi (IGAC) of Colombia and the Geological Mining Service (SERNAGEOMIN) as well as the Ministry of Agriculture and the Natural Resources Information Centre (CIREN) in Chile. The system is used to manage the geographic information of the different services that make up the Ministry of Agriculture, such as CNR, CONAF, FIA, INDAP, INFOR, INIA, ODEPA, SAG, SIGMINAGRI and CIREN.

4.1.4. The FIA project system

The *Fundación para la Innovación Agraria* (FIA) is an agency of the Ministry of Agriculture that aims to promote innovation in the Chilean agricultural sector. FIA's mission is to contribute to solving agricultural challenges through innovation. The agency has four strategic programs to support innovation in the agricultural sector, a focus on women and rural youth, to turn them into leading actors in their territories and local ecosystems. FIA's work is based on four pillars: promoting innovation, developing capacities, disseminating technology and fostering networking. FIA has also promoted the dissemination of information related to innovation in the agricultural sector, creating the OPIA platform, the first agricultural innovation observatory in Latin America (https://opia.fia.cl/601/w3-article-58862.html).

The Observatory for Agricultural Innovation (OPIA) is a platform developed by the Foundation for Agricultural Innovation (FIA) to centralize, channel and process the vast amount of information useful for people involved in the agricultural sector. The platform is designed to promote innovation in agriculture, agribusiness and forestry. The OPIA website (www.opia.cl) provides access to various resources related to agricultural innovation, such as news, events and publications. The platform is also used to develop digital marketing tools for the agricultural sector.

OPIA seeks to be a showcase and open information platform, and it offers information compiled from different national and foreign sources on opportunities to innovate (grants and funding), training opportunities (courses, workshops, seminars, conferences, lectures, fairs, symposiums, business rounds, meetings, forums, talks, dialogues, etc.), global news (trends, advances, experiences, opinions, etc.), innovation projects supported by different national agencies (FIA, CONICYT, CORFO, FIC, FNDR, FNDR, etc.), and access to documents (manuals, studies, experiences, territorial innovation agendas, food heritage, videos, audios, others).

4.1.5. INIA platforms

The National Institute for Agricultural Research (INIA) has several specific projects that promote the digitalization of information. One of these is the Agrometeorological Network, a website that provides access to data from more than 300 automatic weather stations located throughout Chile, which are used to monitor meteorological conditions and their impact on agriculture (https://agrometeorologia.cl/).
Another relevant program is CorView, a geographic information system (GIS) developed by INIA's precision agriculture program. It allows the visualization of the normalized difference vegetation index (NDVI) maps and other data relevant to precision agriculture. (https://bibliotecadigital.fia.cl/server/api/core/ bitstreams/80f98531-598d- 418f-82c9-d054312c8ec8/content)

4.2. Developments at farm level

4.2.1. Digitalization of holdings

Many farms are beginning to incorporate digital technologies into the management of production processes. Some of them apply technologies for specific functions - drone applications in the rice sector, for example - while others have specific digitalization programs, where this challenge is addressed in a systemic way. This is the case of larger companies, such as Hortifrut, a world leader in the export and marketing of blueberries, blackberries, raspberries and other *berries*.

This company wants to transform itself into an efficient digital platform that covers the entire value chain, from genetics to the end customer. To achieve this transformation, Hortifrut is working on three pillars: processes, data and work culture. The process pillar focuses on achieving the digitalization of critical and strategic processes throughout the company's value chain. The objective of the data pillar is to make available, through technology, access to data to facilitate decision-making with automatic, user-friendly and timely information. The work culture pillar aims to develop a way of working in the organization based on modern agile practices that enable the delivery of technological solutions with greater added value and in less time, generating incremental results (https://www.hortifrut.com/innovation/transformacion-digital/). Part of this work is done through collaboration agreements with INIA.

Another example of digitalization at the enterprise level is the work carried out by INIA with small producers who are users of INDAP and manage greenhouses (INIA, 2022; INIA, 2023; INIA/Regional Productive Development Committee, 2023). This line of work considers technical issues such as: (i) Technified irrigation (water reuse); (ii) Heating; (iii) Synthetic lighting (to increase hours and to extend the number of months with lighting); (iv) Plant health; and (v) Greenhouse management control via mobile phone, linked to the local weather network (irrigation management, timely ventilation, other technical issues), and; (vii) Business strategies associated with greenhouse (sales per kilogram versus sales per unit; capital rotation). See for example (https://www.invernaderosiot.cl/). This system is called the IoT Greenhouse Project and is based on 14 devices that are distributed throughout the country. The platform is up and running and the information is being used by small producers and INIA researchers.

4.2.2. INIA's smart fields

The creation of *smart fields* is part of the public institutional mechanisms that are promoting Agro-tech companies at the national level. This is the case of INIA, FIA and CORFO, which have developed various initiatives with this objective in mind. These include the creation by INIA of two digitalized experimental fields, known as *smarts fields,* in the Metropolitan (Los Tilos Station) and Ñuble regions (Quilamapu Station) (https://www.smartfieldinia.cl/). It is estimated that there is a great potential for impact: in Chile there are around 100 *startups* linked to digital (or projects that are developing an idea), working in the area of food and environmental care.

INIA also has a network of researchers in digital agriculture, looking at various areas: sensorization, satellite mapping and precision agriculture, irrigation, drone management and robotization, and greenhouse management, among other technical areas (Best and Vargas, 2020). To this end, INIA has developed an alliance with its equivalents in Argentina and Uruguay - INTA and INIA, respectively -, with whom it has also signed an agreement with IRTA Catalonia in order to promote digitalization by taking advantage of economies of scale. These four institutions have created Ibero-American Network for the Digitalization of Agriculture and Livestock (RIDAG) (https://ridag.net/), which has received support from ECLAC to promote and accelerate this process throughout the region. To this end, seminars, technical visits and mentoring have been organized for *startups* and projects working in digital agriculture (https://agriculturadigital.cepal. org/en). This network is open to all countries in the region, and also works in coordination with other international organizations such as the IDB, FAO and IICA.

Experience has shown that startups and entrepreneurs work in isolation, pressured by the need to be profitable and survive in the market. In their early stages, many of them lack a more global perspective (financing, knowledge of public policies, contacts, benchmarks, international networks), which is indispensable to successfully manage and project their ventures. Through these mentorships, entrepreneurs had access to professionals with experience and expertise, who provided valuable strategic guidance to increase the level of technological maturity of their ventures and projects (ECLAC, 2024).

Agricultural research institutes have an important role to play in this ecosystem in order to promote the adoption of digital technologies. They have accumulated expertise and provide technical support to producers and agribusiness and service companies through their research projects and pilot digital farms (*smart* fields). The role of INIA and the *smart fields* (or *living labs*) is key: they allow digital innovations to be tested and validated *in situ*, in a public space that is commercially neutral, alongside other companies that are working in the same area. These *smart fields* provide valuable support to *startups*, as they serve as meeting places, technical dialogue, practical experimentation, technology validation, innovation demonstration in the field, learning, and coordination among actors. In addition, this service is necessary to ensure the interoperability of digital equipment and to provide training and technology transfer.

The triad *smart fields* / entrepreneurs (*startups*) / ministerial devices to foster entrepreneurship generates an interesting model of public policy to support producers. During the training, all the participating entrepreneurs indicated that the mentoring was fundamental to clarify their business models and to provide structure to their business plans. In fact, many of them "rethought their projects", "modified their outlook", "were able to sort themselves out" and "adjusted their strategies", thanks to the guidance provided by the mentors. The methodology used to carry out the mentoring has been successfully tested, provoking a "*reframe*" on the part of the entrepreneurs.

In addition to their role as articulators and catalysts of supply, research institutes have an unexplored potential in the area of demand for digital technologies in agriculture. Digital creates the conditions to adequately solve a historical problem that has always limited agricultural research: the connection between experimental stations and producers, between science and business. Today it is possible to improve this connection, for which a strategic alliance must be implemented with development agencies, especially those working in technological transfer with family farming, such as INDAP.

To move in this direction, all these organizations have a new AGTECH call for *startups* that want to work with family farming, in the period between 2024-2026, which will be coordinated with INIA, RIDAG, INDAP, CORFO, FIA, AGTECH Chile and farmers' organizations. In addition, INDAP is starting to work on digital extension, in coordination with the IDB, ECLAC, FAO and IICA.

4.3. Digitisation of extension and marketing systems

4.3.1. INDAP's extension programs

INDAP's work is part of the various efforts being made by the Chilean government to ensure that family farming and the rural world are part of the benefits of the digital era. Among others, we highlight the National Rural

Development Policy, the National Policy for Disadvantaged Areas, the National Rural Digital Connectivity Plan, the INDAP Strategy 2023- 2030 and the National Decentralized Tourism Strategy.

To this end, MINAGRI and SUBTEL created the National Rural Digital Connectivity Plan Roundtable in 2022, which agreed to carry out a pilot project in the Region, in the Itata Valley, categorized as a lagging area at the proposal of the Regional Government (GORE), with a strong presence of peasant family agriculture. INDAP, ODEPA, the Undersecretariat of Tourism, the Undersecretariat of Telecommunications (SUBTEL) and FAO-UN, which operates through its FAO-China-CELAC South-South Cooperation Project, are participating in this Roundtable.

The pilot aims to provide access to (satellite) connectivity in community premises and basic (digital literacy) and advanced (according to requirements) training services to four selected Neighborhood Councils. For this purpose, each Board has been given an infrastructure consisting of 2 computers, 1 printer, 2 desks, 2 chairs and a Starlink account paid for 1 year.

Local communities have received the project positively and have been interested in four central themes: (i) training for procedures; (ii) digital marketing to improve the commercialization of their products and services; (iii) purchase of inputs; and (iv) digital extension. All these topics have a high projection and have been subject to an economic evaluation, which reveals a high impact (Qualitas Agroconsultores, 2024). However, the digitalization of extension services is of particular importance, as INDAP has various technical assistance programs (PRODESAL, PDTI, SAT and Alianzas Productivas) that serve approximately 150,000 producers every year, supported by a network of around 3,000 extensionists who today run a program of face-to-face work, based on individual visits. Extension is articulated with INDAP's credit and subsidy programs, achieving a public policy that has had good results. The possibility of improving this work with the support of digital applications will improve coordination and the possibilities of impact.

Currently, the National and Regional Roundtable is looking to scale up the Itata experience to move on to a second phase, considering the Araucanía and the Ñuble regions as a total universe. The Itata project is part of a broader internal digitalization strategy, which also includes other initiatives, such as the digitalization of the field notebooks of the Indigenous Territorial Development Program – (PDTI), which seeks greater efficiency in the management of this program's indicators. This effort is part of an INDAP institutional program supported by the IDB that seeks to: (i) improve planning systems, with objectives, targets, indicators and deadlines; (ii) rationalize and modernize program offerings; (iii) modernize and digitalize the extension model; and (iv) improve analysis, monitoring and evaluation processes (IDB, 2023).

In parallel to this initiative, INDAP is implementing other projects linked to the digital theme. One of them is related to the INIA-INDAP agreement on digital agriculture, whose objective is to implement a pilot water monitoring and control system-based satellite monitoring technologies and soil moisture sensors as an irrigation monitoring and management tool for INDAP's SAT user groups in the regions of Valparaíso, Metropolitan, O'Higgins and Maule. Under this agreement, 20 INDAP officials were trained in 2023.

4.3.2. INDAP's marketing programs

Marketing is another area of work promoted by INDAP, closely linked to its credit and technical assistance programs. One of the main initiatives carried out in this area are the *Mercados Campesinos* (Farmers' Markets), face-to-face marketing spaces implemented by the PRODESAL program. There are currently 199 Farmers' Markets in all regions of the country, specializing in bee products, livestock, flowers, medicinal herbs, stimulants and spices, fruit and vegetables, wines and spirits, tourism and handicrafts and processed foods. According to a study conducted in 2021, which considered 1,064 surveys, 76.5% of marketing stalls were run by women and 65.1% made sales via the internet. In terms of economic results, 23% obtained incomes below U$ 236 per month, 58.5% between U$ 236 and 625 and 18.5% above U$ 625 per month (FIA-PRODEMU, 2021). There are other marketing programs promoted by INDAP, such as Productive Alliances (suppliers); the INDAP-JUNAEB agreement, which encourages public purchases; the Rural World Shops Network; the *Manos Campesinas* seal; agreements with supermarkets; the agreement with the *Lo Valledor* wholesale market in the

Metropolitan Region; the Handicrafts program; the *Sabores del Campo* program (obtaining a sanitary resolution); the Peasant Wine Competition; and the Rural Tourism network (Jimenez, 2023). In all these initiatives, direct contact between producers and buyers of agricultural products (intermediaries or end consumers) predominates, which determines an essentially face-to-face dynamic. However, to the extent that a social bond is generated, many of these transactions are still regularly carried out through direct contact (for example, sales on the farm), but coordination via WhatsApp is also used, and digital platforms are emerging for *e-commerce* of primary products, such as *Apanio* (https://apanio.com/) or NoRetail (https://www.instagram.com/noretail.cl/), and digital platforms for tourism services, such as Turshop (https://turshop.cl/).

In addition, many specific functions that are carried out within the universe of the promotion system are undergoing a process of digitalization. This is the case of the Follow-up and Monitoring System for Peasant Associative Enterprises (EAC), implemented by INDAP in 2023. This is a support tool designed with the KoboToolbox system, which makes it possible to systematize and standardize criteria for the economic, financial, management and results evaluation of the EACs. This system is expected to: (i) facilitate the collection of information on the associative enterprises supported by the program; (ii) provide online and updated information; and (iii) provide reportable information, which will be available both for the Regional Directorates and Area Agencies, as well as for the Central Level (Jimenez, 2023).

4.4. Capacity building in digitisation

4.4.1. Chile Agrícola (online training)

The Chile *Agrícola* Online Training School (www.chileagricola.cl) is a platform created by the *Fundación de Comunicaciones, Capacitación y Cultura del Agro* (FUCOA), of the Ministry of Agriculture, which offers online content and courses on topics relevant to agriculture. This platform was launched in May 2020 with the objective of making technical, instructional and practical content available to technical advisors of small and medium agriculture, INDAP and key intermediaries, with immediate and free access to topics related to water resources, productivity, skills development, associativity, entrepreneurship and adaptation to climate change, among others, in order to provide more productive opportunities to increase the social and economic well-being of small and medium agriculture.

The courses are study programs on a specific topic presented in modules containing instructional videos and written material (worksheets) that complement what is explained in the video. The courses have from 2 to 10 modules. The platform currently offers 55 training courses and has 15,000 people registered and 18,000 visits per month[4].

The multi-institutional platform is composed of 15 organizing entities and 42 collaborating institutions and offers self-instructive training courses, following certain basic rules of operation. Participants receive a diploma of participation as well as a distinctive badge for posting on social media. On this platform, various videos, manuals and sheets are available, which can be downloaded and posted on social networks and digital channels, classified according to the identification of the main technical and knowledge needs of small and medium-sized agriculture: water, sustainable agriculture, good practices, pest and disease control, entrepreneurship and business management, support and financing instruments, production management, and technology and information. Likewise, the "Chile *Agrícola*" Training School seeks to constitute a meeting place for diverse interest groups for the development of small and medium-scale agriculture. The project will be implemented through a digital community made up of technical advisors from small and medium-sized agriculture, INDAP extensionists, PRODESAL managers, and technical and financial advisors, among others.

4.4.2. First Diploma in Digital Agriculture

This diploma course in Agricultural Digitalization is organized by the Universidad de la Frontera and is run jointly with CORFO, COPEVAL and the IDEA UFRO Institute, with the collaboration of INIA. This diploma course is the first to be offered in the country, and it is aimed at farmers, extensionists and researchers and provides comprehensive training in the

4 Claudio Urtubia, Director of FUCOA, personal communication.

latest technologies and tools of digital agriculture, to make informed and strategic decisions, adopt more sustainable practices, reduce the environmental impact of agriculture and improve efficiency in the use of resources. The first class of this course graduated at the end of 2023, with 30 farmers and professionals participating (https://www.ufro.cl/index.php/noticias/12-destacadas/7040-instituto-idea-ufro-finalizado-primera- version- de-diplomado-en-digitalizacion-agricola).

The course is organized in three modules: (i) Technology literacy, use of decision-making tools and business intelligence; (ii) Agricultural Applications, use of digital technologies to improve agricultural productivity and generate value; and (iii) Technological Innovation Projects, configuration of operational and business structures to scale, learn and improve processes.

It works with learning paths where different methodologies are applied: (i) *Showcase* shows step by step of the technique; (ii) Labs presents *hands on* exercises in controlled environments; (iii) *Challenge* challenges the participant to put into practice what they have learned; and (iv) Mentoring offers personalized accompaniment in the resolution of the challenges posed. Those interested are eligible for a CORFO grant covering 90% of the course fee (total fee: US$ 1,600).

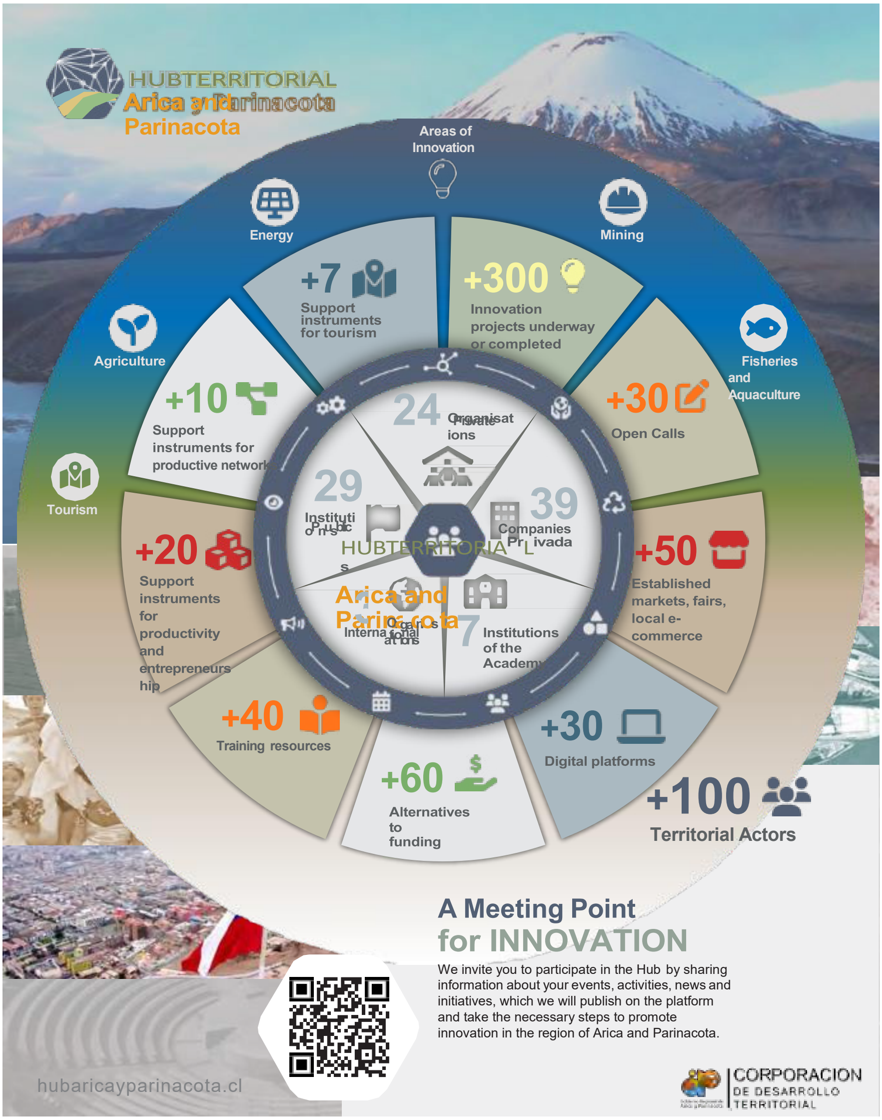
4.5. The regional perspective

The territorial hub of the Region of Arica and Parinacota was built in the framework of an ECLAC project entitled "Productive development and spatial heterogeneity in Latin America: institutions and development of capacities in the programming and implementation of regional policies", which was implemented between 2020 and 2023 together with the University of Tarapacá and the main actors of the regional productive ecosystem (Aedo et al., 2023). Three relevant productive areas were considered for the conceptualization of the Arica and Parinacota Hub: Agricultural Production, Energy and Tourism (https://hubaricayparinacota.cl/). The objective is that all actors with a presence in the territory have a node that allows them to interact with each other through digital and face-to-face schemes, which enables the coordinated structuring and execution of public policies in the territory (Aedo, 2023; Martínez, 2022). In this project, it was considered that this digital platform “packages” (i.e. orders and interrelates) everything that happens in the ecosystem, improving coordination between social actors, companies and the different institutions that operate in the region. This initiative is articulated with the Regional Strategy for Innovation.

The project is a participatory approach that defines an agenda for the economic transformation of the regional territory. To operationalize it, individual users, trade associations, private companies, technical institutes and universities were considered, as well as municipalities and public development institutions working in the areas of agriculture, energy, environment and social development (Figure 1). In order to integrate all these actors, a Technical Editorial Committee was constituted, in charge of the governance of the hub, led by the Arica Productive Development Corporation (Corporación de Desarrollo Productivo de Arica). This Committee functioned under the auspices of the Regional Committee for Science, Technology and Innovation and was composed of different institutions for the promotion of production in the region.

During 2023, there were 8,734 visits from agricultural producers, extensionists, university students, researchers, academics, tourists and other actors operating in the region’s production system. It is noteworthy that the areas of greatest interest are the territorial agenda, the area of innovation and the calls for regional competitions. It is considered that the platform has achieved a good reach, taking into account the small size of the rural sector in the region (ravine agriculture, highlands) and the fact that there are only 2,472 farms and a limited number of tourism enterprises.

Figure 1. Territorial Hub of Arica and Parinacota



Source: Aedo, 2023

4.6. Some discontinued programmes

There are many technological developments aimed at solving specific problems, carried out by different public institutions, which have been very successful as long as they had political support. These initiatives were discontinued after changes of government (or administrations), remaining active in the ecosystem, but with a low diffusion among users. These experiences show that these projects are fragile, that the support of the authorities is not enough to consolidate them, and that the main factor for institutional consolidation is the real demand of users. Some examples include:

- ***Yo Agricultor***: created in 2008 by FIA. It is a digital information service platform for micro and small-scale agriculture that allowed the creation of virtual communities in four production chains (maize, honey, wine and berries). It was discontinued in 2010, with the change of government. (https://bibliotecadigital.fia.cl/items/1c8ef531-13e9-47c4-adac-43cfd14dcd6d)

- ***Yo Joven y Rural*:** created in 2017 by INDAP. It seeks to connect rural youth, encourage their participation and leadership in agriculture and promote sustainable rural development (https://www.face- book.com/groups/yojovenyrural/).

- ***Campoclick*:** created by CIREN and INDAP in 2016. It seeks to contact and reach the producer closest to where the buyer is located, set the shortest route, provide the address, make enquiries, plan the route to the farm and rate the experience, thanks to its free download for most smartphones through Google Play and AppStore. (https://www.campo- click.cl/)

- ***CampoClima* App**: Created by CIREN in 2017, it provides agroclimatic information from various public and private sources on a single geo-intelligent platform. The app automatically links the meteorological and hydrometric station closest to the user's location and the properties registered by the user, and provides real-time information. (https://apps.apple.com/cl/app/campoclima/ id1247656756)

5. Food Consumption and Waste Management

5.1. Consumer advice platforms

In Chile, there are several digital applications used by consumers to find their way around the food market. According to an ODEPA publication, the most important ones are (ODEPA, 2023):

- **Good Meal:** Marketplace application that connects businesses - from greengrocers to international chains - with conscious users. Specifically, subscribed food marketplaces can provide a commercial outlet for their daily food surpluses, offering them at a lower price to registered users of the app, thus avoiding waste. (https://www. goodmeal. app/)

- ***Maifud*:** Online platform that makes "imperfect" food available to consumers, rejected by traditional trade because it does not meet market requirements in terms of size, color, shape or degree of ripeness, despite being in perfect condition for consumption. In this way, foods that were considered discarded are revalued. (https://www. maifud.cl/)

- ***Olio Chile*:** Application created in Great Britain that is present in more than 32 countries (including Chile). Unlike others, users of this platform range from ordinary people to commercial establishments. Specifically, it allows users to upload photos of the food on offer, generating alerts for users. Thus, if interested, the parties get in touch and organize the pick-up of the food, which also involves payment. So, while the provider avoids wasting food, he also receives an economic benefit. (https://olioapp.com/es/%5B1)

- ***Cáscara* Foods:** Although it is not a marketplace or app, it is a venture that transforms food waste into new products through upcycling. Its product includes fiber supplements focused on digestive wellness, made from apple, blueberry and strawberry peels, among others (https://www.cascarafoods.com/).

5.2. Food banks

A food bank is a non-profit organization that recovers surplus food produced in different sectors of society and donates it to the people who need it most, thus avoiding waste and ensuring that the products can be used and consumed safely.

Although this type of initiative has emerged in the private sector, since 2021 it has become the subject of public policy, with the creation of the National Commission to Prevent and Reduce Food Losses and Waste (CN-PDA)[5]. This entity has its technical secretariat in ODEPA and aims to propose, develop and coordinate actions between the public, private and civil society sectors. Its members include representatives of the three food banks present in Chile (*Red de Alimentos, Banco de Alimentos Biobío Solidario* and *Banco de Alimentos Lo Valledor*), which have played an important role in the fight against the coronavirus pandemic and in the subsequent work to combat hunger and poverty in Chile. This commission has also supported the development of the first micro–Food Banks in free fairs, in order to recover fruit and vegetables fit for human consumption (Eguillor, 2021).

The Food Network is a private, non-profit organization, which created Chile's first food bank in 2010. Through an efficient and traceable process, it establishes a connection between companies and people in vulnerable situations, rescuing food, nappies and personal hygiene products that are fit for consumption, distributing them to those who need them most. This achieves a sustainable model with a triple impact: social, economic and environmental.

This network is made up of 216 companies, 457 social organizations and 1,373 centers throughout the country. The Food Network connects 1,141 locations throughout Chile, with 4,000 monthly withdrawals, benefiting 273,734 people in vulnerable conditions in the last 12 months (https://somos.redalimentos.cl/).

To articulate all these actors, the Food Network has a digital application called Virtual Network, a technological platform that manages the available inventory and connects in real time the companies that have products

5 https://www.odepa.gob.cl/coordinacion-publico-privada/comite-para-la-prevencion-y-reduccion-de-las--perdidas-y-desperdicios-de-alimentos

that will not be sold with social organizations that need them. It has an algorithm that calculates the consumption capacity and nutritional requirements of each beneficiary social organization and notifies them when the products they need arrive, both at the distribution centers and at the premises of the partner companies ("Direct withdrawal in shops"). This modality of work is implemented by 10 companies (Walmart, Melt Pizza, Tottus, Carozzi, Pronto Copec, TMLUC, Sodexo, CCU, Bidfood, Vollkorn) that are linked to social organizations that directly collect products at the stores and distribution centers throughout the country (Miranda, 2021).

5.3. Food and beverages in the app store

This category includes digital applications that help users cook, mix drinks, manage and discover new foods and beverages. One line of interest is private platforms that rescue surplus food from shops and supermarkets and sell it in baskets with significant price reductions. In doing so, they combat food waste and make a contribution to the environment and the well-being of the population. One of them is the *Cheaf* app, which is present in Chile and in several other countries (https://www.cheaf.com/cl/#zigzag-1). Some of the main features of *Cheaf* are:

- It connects supermarkets, restaurants and shops with consumers, offering food packages with significant discounts of up to 65%.

- It allows users to download the application for free, register and explore the options available in their location.

- Users can choose the food they want to rescue, add it to the cart and pay through the app, and then pick up their box at the selected supermarket.

This application was created in 2020 in Mexico, arrived in Chile at the end of 2023 and rescues food (with 50% discounts on the original value) in agreement with seven supermarkets in the Los Lagos Region (Soypuer-Tomontt, 2024).

There are other apps that meet the same objectives, such as Good-Meal, which helps reduce food waste by allowing users to buy surplus food from restaurants at reduced prices (https://apps.apple.com/cl/app/goodmeal/id1538879551). Cofood is another app that fights food waste by allowing food establishments to offer ready-made or pre-prepared meals at reduced prices before they expire (https://www.facebook. com/p/Cofoodapp-100063703863635/).

5.4. Waste management

The issue of container collection - especially of agrochemicals - is an area of work developed by the National Association of Manufacturers and Importers of Agricultural Phytosanitary Products A.G., AFIPA Chile, together with municipalities and governmental programs. This is the case of the Campo Limpio program, which this organization runs throughout the country in conjunction with other companies and institutions (https://www.campolimpio.cl/site/). In Chile there are also companies specialized in the collection of packaging waste, which have developed their own internal management systems. This is the case of the company Eco-Lógica (https://ecologica.cl/), which has an online portal and a self-developed software that makes it possible to view all the information on the waste generated, such as: waste documentation, waste declarations, recoverability indicators, invoicing, eco-equivalences and traceability certificates.

It is foreseeable that this area of work will experience great development in the coming years, given the recent approval of the Extended Producer Responsibility Law (Law No. 20.920), better known as the REP Law or Recycling Law (https://leyrep.cl/), in force since September 16, 2023, which seeks to reduce the generation of waste and promote its reuse, recycling and recovery through the establishment of extended producer responsibility.

6. Emergence of a Specialized Guild: Agrotech Chile

This guild was created in 2023 when 25 companies decided to join forces to promote the interests of the sector, with the support of Fundación Chile and Imagine. This initiative seeks to strengthen and promote the development of technology *startups* in the country's agricultural sector in order to address: (i) difficult user and customer acquisition; (ii) slow generation of trust; (iii) low adoption of new technologies; (iv) long sales cycles; and (v) difficulties in raising capital (AGROTECH Chile, 2024).

This association is made up of agricultural *startups* and suppliers, producers, associations, public entities and educational institutions. Its goal is to drive innovation, sustainability and efficiency in Chilean agriculture through the implementation of advanced technologies such as artificial intelligence, blockchain, big data and IoT.

AGROTECH Chile currently groups 92 companies in more than 30 categories. Thirty-nine percent trade internationally, 79.1% have less than 9 employees, 48.8% are micro-enterprises and 18.1% are led by women. Since its creation until now, the association has participated in various seminars and sectoral meetings, seeking to present its views on the digitalization process of the sector. To the same end, AGROTECH Chile has organized two internal events, two international events and one event with investors. The association has also created two coworking networks (with the National Society of Agriculture and the University of Talca), has generated alliances with unions, companies and public bodies, and has created technical working committees. It is also participating in fairs, seminars and other international events, open innovation programs (*Desafíos, Pilotos y Convocatorias y Demodays*), programs with young people from universities and rural schools, as well as with small farmers associated with INDAP and FIA. Finally, AGROTECH Chile is organizing a centralized database of Agtech services, accessible through a smart search engine (AGROTECH Chile, 2024).

The perception of entrepreneurs regarding the Agtech industry has also been collected in a study conducted between September 2021 and January 2022, where 58 national Agtech companies or with operations in Chile and in-depth interviews were conducted with representatives of public institutions, investment funds, trade associations and large companies. This study considered a broad definition of the sector, i.e. "*companies engaged in activities that use technology-based innovation to solve problems directly related to industry*". This includes biotechnological research combined with software and hardware for the improvement of chains. All the actors consulted agree on the need to develop monitoring platforms, tailor-made solutions to face today's major challenges (climate change, among others), as standardized solutions are not efficient for crop management. The study proposes thinking about international scaling, the creation of an ecosystem, the improvement of production processes incorporating R&D&I and the search for disruptive business models (Endeavor, 2023).

7. Conclusions

A general review of the digitalization process of the Chilean food system shows that many initiatives are underway and in the process of consolidation. Firstly, 94.3% of people have access to the Internet, a figure that drops slightly to 89.5% in rural households. At the same time, digital technology is entering companies under different formats and modes of operation: digital platforms, sensors, Internet of Things (IoT), Robots, Drones, Big Data, Cloud Computing, Artificial Intelligence (AI) and Blockchain (ECLAC, 2023). In some cases, these are isolated innovations that are introduced in order to perform a specific technical function. In other cases, especially in larger companies, there are digitization programs that aim to digitalize the company as a whole. The challenge is systemic: it is about conceiving companies as digital platforms, which implies a new digital DNA that is part of internal processes and corporate culture.

The same challenge can be observed at the public policy level. All public and private institutions are implementing digitalization programs. On the one hand, there is the computerization of the internal processes of each agency, which includes digital platforms to serve producers and businesses; on the other hand, there are SUBTEL's infrastructure programs, which have a strong impact on closing gaps. Finally, there are the programs of CORFO, SERCOTEC, FIA, INIA, INDAP and other public entities, which seek to accelerate the adoption of digital technologies to improve business productivity and the coordination of social actors. As in the private sector, some public institutions introduce digital technologies in specific functional areas, while for others digital is not just a tool or an application, but an essential part of policy design.

The challenge is to move towards a more digitalized Chile. We are in an incipient phase; the Chilean food system is progressively digitalizing despite the use of a loosely coupled coordination model, which nevertheless works, and which prepares for the eventual future establishment of a more organic and comprehensive digital agenda. There is progress in all areas: a critical human resource base is being formed and the technology debate is becoming more complex, in all chains and in all agricultural and agro- industrial enterprises. This is reflected in the number of *startups* (92 companies), in their level of organization (creation of AGROTECH Chile) and the emergence of a specialized diploma course (offered by UFRO) that is forming a critical base of trained professionals.

Thus, a final question arises: how to accelerate the digital transformation of the Chilean food system in an inclusive and sustainable way? To answer this question, we envisage the following challenges:

- Move towards the effective implementation of a sectoral digital agenda coordinated by MINAGRI, with the participation of the public and private sectors.

- Further improve the internal operational systems of public and private institutions. Seek interconnections between the platforms of all institutions.

- Improve the regulatory systems governing certain technical areas (e.g. aerial applications with drones), updating them with the application of new digital technologies. Make a cadaster of pending regulations.

- Consolidate a national network of *smart fields* that includes all INIA's Regional Research Centers and already digitalized private farms, which serve as technological beacons for most backward farms and companies. To make effective progress in this area, a special effort must be made to incorporate family farming.

- Set up a mixed extension system in INDAP, using WhatsApp groups (and other digital applications). Apply the same approach to other technical areas (e.g. sanitary control, fire monitoring, livestock and predator control). Embed such an extension system within the national agri-food digital ecosystem.

- Develop more applications, apply them on a national and regional scale and integrate them into the digital ecosystem. The Chilean digital ecosystem has many applications and many interesting things to showcase, but there are also thematic gaps that need to be identified more systematically, in order to find digital solutions.

- Create a Central Service Unit (at INDAP/FUCOA level, with support from INIA and Universities) that selects and edits the didactic material required by producers to improve their productivity. This material should be designed strategically, by production chains and territories, and then disseminated through mixed extension systems, training courses and social networks.

- Address new business tools for larger-scale farmers, especially online shops and digital business wheels.

- Strengthen the three Food Banks and connect them with the IN-DAP network and with wholesale markets and fairs. Disseminate food rescue apps (with price discounts). Digitalize the collection of other waste, taking advantage of the implementation of the Recycling Law.

- Create territorial hubs in the 16 regions of the country, replicating the method used in the Region of Arica and Parinacota. Integrate all these applications, these mixed networks and systems into a single digital eco-system.

- Consolidate the AGROTECH Chile business association, strengthening its links with public programs such as CORFO, INDAP, FIA or INIA.

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7 Characterization of the Public Policy Space for the Digital Agriculture in Costa Rica: an Analysis from the Instruments

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1. Introduction

The so-called digital agriculture has to do with the incorporation of information and communication technologies (ICT) in agricultural production. This is a topic of recent interest in Latin America because of its possible effects in terms of reducing production costs, the search for and/or creation of new markets, besides the creation and dissemination of useful information that can be transferred from producer to producer, or from a technician or extensionist to a group of producers (Sotomayor et al., 2021). Digital agriculture can influence other rural dynamics, such as the discussion on the adopted local development model, the prevention of agro-climate risk and other natural hazards, as well as the use and conservation of natural resources.

Despite its potential, the application of ICT in agricultural production is an issue that has been little studied in Costa Rica (Bastos et al., 2022). There is only one research work that points out the deficiencies in access to

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ICT by Costa Rican producers, which would allow them more efficient and effective production systems (Arévalo Montoya K, 2024). However, this study does not include an analysis of public policies to achieve access to these ICTs.

The first idea that arises from the use of ICT in agriculture is that it is a very sophisticated, specialized and expensive piece of equipment, such as computers aimed at automating processes, sensors for producing data and implementing some automation processes (control of humidity, dosage calibration, for example) or using drones for different tasks. The use of remote sensing, like satellite images and aerial photographs, can also be considered part of digital agriculture. In all these cases, the use of specific software is likely to be necessary, which will also require specialized human skills. If digital agriculture is understood in this way, the potential to make production more efficient would be limited to those who can afford to pay for such equipment and human skills. Agribusiness corporations and large plantation schemes would have a huge advantage over small and medium-sized producers who would not be able to finance these ICTs. Hence, digital agriculture might become another mechanism for inequality and economic exclusion in the rural world.

In the case of Costa Rica, at the local level, there are several well-known experiences in the use of low-cost ICT applications and initiatives for different purposes. Many of these initiatives have been developed based on communication platforms (WhatsApp and other social networks) or other mobile applications available for free for mobile phones. This has been achieved thanks to the wide distribution of electricity (coverage of 99.5% of the national territory) and widespread access to smartphones (96.6% of all households by 2022), most of which are low-cost handsets. According to the Superintendency of Telecommunications (SUTEL), internet coverage in Costa Rica was about 88% of the population by 2023, although there are indeed large disparities between cantons, in terms of internet access and signal quality, especially between urban and rural cantons. Notwithstanding, in the rural world, the smartphone has become a tool for obtaining and distributing useful production information, product promotion, and the creation of alternative markets. Besides, smartphones help generate support networks and community resource management. In this way, digital agriculture can be a catalyst for local development that contributes to creating inclusive agri-food markets, generating economic inclusion and safeguarding production in the face of extreme agro-climate events.

Based on the two previous scenarios, we focus on the following research questions: Is there any public policy (and are there policy instruments) for digital agriculture in Costa Rica? How many? What are their aims or objectives, which social actors are involved and how? Is agro-climate risk management considered in these instruments? To address these questions, we conducted an analysis of the design of public policies by looking at the policy instruments. With this, we characterize the so-called public policy space, given the number of instruments and agencies involved (Howlett et al., 2005). We also performed a first assessment of the consistency and coherence of these policy instruments.

The chapter is organized as follows: the next section presents a brief context of Costa Rica. In the following section there is a review of the theoretical/conceptual framework, followed by the methodological approach. The next section presents a systematic analysis of the selected policy and its agencies. We concluded in the last section.

2. Costa Rica and its Agricultural Sector

Costa Rica is in Central America, limited to the north by the Republic of Nicaragua, to the south by the Republic of Panama, to the west by the Pacific Ocean and to the east by the Caribbean Sea (see Figure 1). It has an area of 51,100 km2 (Bertsch, 2006), and three mountain ranges running from north to south. The country is home to 4.75 % of the world's biodiversity (Donato, 2011). Given these physical characteristics, the country is vulnerable to agro-climate risks and negative socio and economic repercussions (Ishizawa and Miranda, 2019).

Agriculture in Costa Rica has been historically important for the economy and culture. According to the *Secretaría de Planificación Sectorial Agropecuaria* (SEPSA), for the year 2022, the contribution of the agricultural sector to the Gross Domestic Product (GDP) was 4%, and 9% if the expanded contribution (primary sector 4% and agro-industrial sector 5%)

is considered. The employment rate of the agricultural sector is 88.8%, so the unemployment rate is 11.1% (73.3% of the employed population lived in rural areas). In 2022, the value of exports from the agricultural sector was 5,816.1 million *colones*, which represented 41.5% of the country's total exports. Coffee beans, pineapple, bananas and food extracts and preparations accounted for 57.8% of agricultural exports (SEPSA, 2022). Hence, this is an important sector that contributes to the generation of rural employment and value added.

Figure 1. Map of Costa Rica and provinces

Source: https://www.worldatlas.com/maps/costa-rica

The agricultural sector in Costa Rica is highly vulnerable to different crises, such as: 1) the container crisis, which caused an overcrowding of maritime traffic lines that reduced the availability of freighters and increased prices; 2) climate change, which causes increasingly extreme events that induce a high agro-climatic risk, such as threats of droughts during Niño years and floods during Niña years; and 3) the war in Ukraine, which considerably increases the price of inputs of fertilizers and other agrochemicals (SEPSA, 2022). In addition, inflationary pressures at the global level and the appreciation of the *colón* during 2023-2024 have caused a loss of competitiveness of the country's agricultural exports.

Given the above context, the use of ICT and the implementation of public policies that promote these ICTs become crucial to making production processes more efficient and for better management of the risks arising from external shocks.

3. Digital Agriculture as a Determinant of Innovation in the Rural World

Society is in a continuous process of transformation, with variations in organizational, technical, technological and cultural forms and ways of relating to ecosystems. Novelties yielding real lasting social impacts and effects, beyond a specific situation, are considered as an innovation (Segura, et al., 2023). In this sense, innovation should be understood broadly (Orozco, 2017; Rolandi, et al., 2021) as a process that causes changes in behavior and social structure (Rolan- di, et al., 2021), subject to a given context and a *path dependency* (Orozco, 2017). Therefore, innovation is understood as a systemic process, and as result of a complex web of relationships, institutions, policies, ecosystems, techniques and technologies (Edquist, 2010, 2013; Lundvall, 2002; Segura, et al., 2023).

At the agricultural level, there are two prominent strands of innovation, namely bio-economics and digital technologies (Goulet, et al., 2019). Both are considered techno-economic paradigm changes. The application of digital technologies is a cross-sectoral phenomenon, commonly referred to as Revolution 4.0 (Klerkx, et al., 2019). The digital economy imposes itself as a new phase of social development, creating opportunities and risks (Ulezko, et al., 2019). For instance, the Covid-19 pandemic accelerated digitalization, as many activities and interactions had to be moved to digital spaces (Rodríguez-Soto, 2023).

This same acceleration occurred in the agricultural sector (Sotomayor, et al., 2021), affecting production, global value chains, food systems, political participation, disaster risk mitigation and employment dynamics. We understand here digital agriculture as the set of expressions of the digital economy in agricultural and livestock production, at different stages of value chains. Given the impact of digital agriculture on the production chain, production systems (which alter the ways in which production takes place) and distribution (which affect the ways in which supply and demand interact), there are two classifications for technologies.

In production, several innovations are identified in order to improve the efficiency and stability of production systems (Vorobeva, et al., 2021). Smart farms can optimize productivity, reduce labor time and costs (Vorobeva, et al., 2021). They also enable the creation of accurate and in-depth real-time agricultural information systems (Klerkx, et al., 2019). Together, these types of initiatives are grouped under the term precision agriculture (Klerkx, et al., 2019), bringing together technologies such as drones, sensors, irrigation systems, information systems, etc. The use of these technologies implies technical and organizational changes in production systems but, at the same time, they reduce labor time in two ways: first, better precision and knowledge allow for more management efficiency; second, some of them reduce the amount of labour required (Vorobeva, et al., 2021).

Another innovative approach is the use of agro-climate risk management digital technologies for the protection of production (French, 2022). These technologies can provide access to comprehensive and timely information on environmental and atmospheric conditions, which are necessary to mitigate agro-climatic risk (Khan et al., 2020). Such information refers to changes in precipitation, air temperature, solar radiation and even humidity levels, where both atmospheric and soil moisture, are associated with the productivity of agricultural systems (Ramirez-Builes, et al., 2013).

Digital technologies can also help to achieve better income distribution along the agri-chain by increasing the coordination between supply and demand, improving the speed response and accuracy of information flows within food systems (Klerkx, et al., 2019). In addition, platforms and apps offer a new space to market products, bringing the production and consumption sides closer together (Klerkx, et al., 2019). This is important since agricultural chains tend to operate in monopsonistic market structures, with few actors dominating processing/distribution/exporting phases, and oligopolistic competition in retailing, while favoring the accumulation of value in the intermediate links (Jiménez, 2011). Although there are different possibilities for accessing and using digital technologies, there are also strong barriers in some production systems, since they require a certain level of investment or development of digital competencies and human skills. In the case of technologies associated with distribution, there are options of varying degrees of cost and complexity, ranging from the use of free applications and platforms to the development of specialized ones. Given the existence of sectoral and regional asymmetries and the diversity of the agricultural sector in terms of products, productivity and involved actors, the political dimension of transformation must be considered. This political dimension is largely driven by policy instruments. This is very important because policy instruments are essential for achieving innovation in production systems. These instruments target different levels of work and populations (national, sectoral, local, small, medium, and large producers). Depending on how this process is conducted, it can either promote sustainable and inclusive transformation or exacerbate rural asymmetries.

In summary, it is important to analyze how functional public policies promote or not digital agriculture in Costa Rica, and how this transformation takes place. Functional policies are understood as those policies that contain well specified instruments (programs, projects, plans, etc.), that generate an agency relationship with the social actors to whom they are addressed. The characterization of the policy space for digital agriculture consists of identifying this relationship between instruments and agencies.

4. Methodological Framework: The Design of Public Policies

First, we performed an analysis of existing public policies that promote digital agriculture, in terms of their objectives and resources to achieve their goals. In this sense, we started by the identification of policies related to digital agriculture and their functional mechanisms for achieving defined goals, namely policy instruments. By instrument we mean any device that gives functionality to the policy, i.e. laws, decrees, programs, projects, etc., which have specific objectives, mechanisms to achieve those objectives (resources and governance), and specific goals. Instruments are governance devices used by the State to establish its will in relation to the governed, under certain constraints (Howlett, et al. 2005).

We selected an explanatory method of public policy analysis, which allows for a causal explanation and thus a better understanding of how public action is governed and promoted in a specific area of the economy and society (Fontaine, 2015). By means of empirical exercises, whether through individual experience or the analysis of secondary information, relationships between social phenomena can be explained. In this way, we can make an abstraction of the real world by understanding causal relationships. Explanatory methods are thus deductive methods. The selected explanatory method is The Design of Public Policy. The methodology of analysis is exploratory and uses a qualitative approach.

Policy design is a useful framework for analyzing different sectoral policies, such as the ones that promote digital agriculture and its effects on agri-production activities. Fontaine (2015) proposes to start the analysis by typifying the policy instruments according to their objectives and the availability of resources. Two categories of objectives are established: substantive or procedural. In the first case, instruments can be interpreted as having the purpose of modifying social behavior by changing, or controlling, the availability and distribution of goods and services. On the other hand, under procedural objectives, instruments focus on modifying the relationship between the State and other social actors, either by promoting or limiting this relationship (Fontaine, 2015). For both categories, the descriptors of instruments are classified according to four main areas, namely, information, authority, treasure and organization. Hence, an instrument can be typified as having either a substantive or procedural bias, or elements of both.

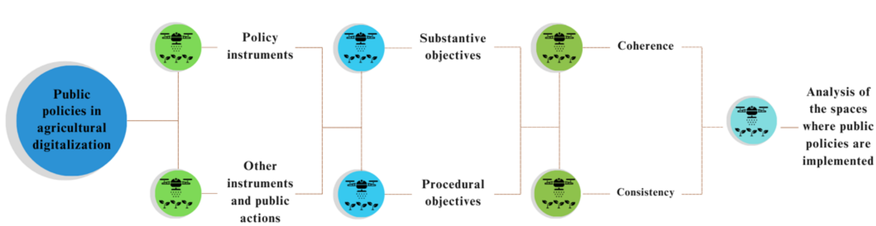
This method allows the analysis of diverse policy instruments, the relationships between each other, and between instruments and social actors (agents). In addition, this method helps to locate and organize different sources of information. Fontaine (2015) proposes three analytical moments:

characterizing the public policy space by establishing the relationship between the instruments and their users (number of instruments and agencies involved) (moment 1); then, a coherence analysis (moment 2) that establishes how coherent the instruments are in terms of goals and resources; and, finally, a consistency analysis of the policy implementation style (moment 3), according to the combination of instruments classified as substantive or procedural (Figure 2). Characterizing the policy space in terms of the number of programs and agencies directly involved allows a categorization of such space as inter-bureaucratic, when several agencies are involved in a program, or intra-bureaucratic, when several programs depend on a single agency. At the same time, a policy space can be simple, when it is made up of a single agency and a single program, or complex, when several programs and agencies are involved (Fontaine, 2015).

In this study, we carried out a review and selection of policies, programs, projects, plans and other instruments with a focus on digital agriculture, by using secondary information available on the Internet. Figure 2 shows the methodological path followed, in which the most important sets of policy instruments are defined. Subsequently, we established the characterization of the policy space, the possible biases of the objectives of the instruments, and finally, we made an initial assessment of their level of consistency and coherence as a set of instruments.

Finally, we identified complementary public actions, which were analyzed by using the same analytical route that was applied for instruments (Figure 2). During these three analytical moments, secondary information was complemented with interviews with policy instruments managers, as well as some other social actors involved.

Figure 2. Methodological pathway



Source: own elaboration.

5. Analysis of Policy Instruments for Digital Agriculture and Other Public and Private Actions

5.1. National level instruments

At the national level, three public institutions were identified as having their own groups of instruments: the Ministry of Science, Innovation, Technology, and Telecommunications (MICITT), which has three large groups of instruments; the Ministry of Agriculture and Livestock (MAG), which has a specific policy for the agricultural sector; and the Costa Rican Foreign Trade Promotion Agency (PROCOMER), which has two specific instruments (see Table 1). These public institutions are the most relevant in terms of having public policy instruments linked directly and indirectly to the promotion of digital agriculture.

The first instrument is the National Strategy for the Digitalization of the Agricultural Sector, presented in 2019 at the Inter-American Institute for Cooperation on Agriculture (IICA). This instrument is part of the National Telecommunications Development Plan, 2015-2021, specifically, of the Business Transformation 4.0 axis. This strategy indicates that MICITT is the main acting organization, responsible for all initiatives promoting digitalization in the sector. Despite this, it considers the participation and collaboration of numerous public bodies and ministries, constituting a complex and inter-bureaucratic space, as multiple agencies are linked around this instrument. The strategy is broad, with many associated instruments, although it should be noted that a significant number of them are under-resourced, raising concerns about their capacity for public action.

Within this strategy, the instruments can be classified under both substantive and procedural dimensions. For instance, there are keywords like mapping and registration measures (substantive-control) and moving red tape and bureaucracy to digital environments (procedural-promotion) (see Table 1). Instruments indicating actions for capacity and competence building are also put forward, but there is no mention of who is to be responsible, nor the resources available to them. In the same vein, treasury-type resources (financial) are mentioned, but their origin is not specified. In other words, many actions are aimed at administrative tasks, while those proposing changes in productive systems, distribution and risk management do not show clear resources.

Despite the complexity of the instrument, there was apparently no follow-up after the change of government in 2022 (personal communication with O. Vega, vice-minister of science and technology, 13 June 2024). In addition, the lack of clarity in terms of resources and decision-makers compromises the coherence of this strategy.

Table 1. Types of instruments for digital agriculture according to State resources and policy objectives

Instrument	Resources				Incidence dimensions
	Information	Authority	Treasury	Organization	
National strategy for the digitalization of agriculture.	Initiatives to map and register national production for control and knowledge.	Digital procedures and registers to facilitate interactions between the private and public sectors.	Not specified, within the National Telecommunications Development Plan 2015-2021.	MICITT, MAG, MEIC, COMEX, PROCOMER, ICE, MINAE, INA, ICT and public universities.	Increased state control of national (substantive) production; promote through changes in formalities (Procedural).
National Science, Technology and Innovation Plan (2022-2027).	Analysis of sectoral needs for the design of innovation programs.	Improving regulatory frameworks for the implementation of digital technologies.	It is mentioned that they are limited or non-existent.	Promotora Costarricense de Innovación e Investigación del MICITT.	Control, avoid concentration (substantive); promote with better regulatory frameworks through tech- (substantive); promote with better regulatory frameworks through tech- (substantive); promote with better regulatory frameworks through technology (Procedural).
Community Innovation Labs Network (LINC).	Jointly building knowledge and innovative solutions in the fields ofterritories.	There is no mention of such courses.	International cooperation (I phase) and Inder (II phase).	MICITT and public universities.	Changing people's behaviour and production by means of extension (Substantive).
Public policy for the Costa Rican agricultural sector 2023-2032.	Development of the technical and soft skills of officials and producers.	Institutional and regulatory improvement to simplify procedures with technology.	MAG resources.	MAG.	Simplifying and changing the relationship between officials and users of digital environments and competences (Procedural).

Instrument	Resources				Incidence dimensions
	Information	Authority	Treasury	Organization	
Green Growth Program.	Technical assistance and accompaniment.	Within PROCOMER's functions.	Seed capital for projects that are green, innovative and have export potential.	PROCOMER	Changing forms of production, promote sustainability and export potential (Substantive).
Descubre Platform.	Identify products with export potential in the agricultural sector.	Simplification of procedures, inter- institutional space.	Promotion and attraction of investment in rural territories.	COMEX, MAG, PROCOMER and CNAA.	Change the composition of production (substantive) and facilitating procedures (Procedural).
INTA's research and innovation programs.	Capacity building and extension services; research; mapping of domestic production.	Under the umbrella of the functions defined for INTA.	INTA resources and international and inter-institutional cooperation.	INTA and MAG.	Monitoring and promotion (Substantive).
PLATICAR Platform.	Access to and exchange of knowledge between researchers, extensionists and producers.	Under the umbrella of the functions defined for INTA.	INTA's resources, to support and update online platform servers.	INTA and MAG.	Promotion of interaction between public and private stakeholders (Procedural).
Microcredit program .	Accompaniment is mentioned, but not specified.	Not mentioned.	Banking for Development Fund (SBD), Development Fund for Micro, Small and Medium Enterprises (FODEMIPYME).	MEIC and (COOCIQUE, COOPEAMISTAD and COOPELECHEROS).	Promoting technical change through financial resources (substantive).
MSME Digitalization Plan 2019-2022.	Trainings, plus the co-knowledge needed to create the web pages.	Not mentioned.	Organization of the American States (OAS), Google and Kolau.	MEIC, OAS, Google and Kolau.	Change in the model of business interface (substantive).

Source: own elaboration

The second instrument is the National Science, Technology, and Innovation Plan (2022-2027), which is clearly not focused on the agricultural sector, but includes policy tools related to it. This policy recognizes the difficulties of the sector and rural territories in implementing digital technologies, as well as the structural concentration of innovation in the cities. In view of this, it proposes that the Costa Rican Promoter of Innovation and Research of MICITT diagnose and analyze the sectoral needs to promote innovation. The analysis is based on previous successful cases; therefore, it carries the risk of replicating the historical pattern. There is no mention of concrete actions after the analysis on how to correct the concentration pattern of innovation.

In addition, this plan postulates the improvement of regulatory frames for the implementation of technologies in the agricultural sector. The plan includes instruments aimed at both substantive (control: changes in the pattern of concentration of innovation) and procedural (in regulatory frameworks and procedures). Again, this is done without clarity on the resources or responsibilities of each organization in the pursuit of its objectives. In this sense, this plan proposes some things that can be questioned in their coherence, as the fact that explicit resources or actions are not always mentioned to achieve the objectives.

On the other hand, this plan includes some really precise and detailed actions, like the Network of Community Innovation Laboratories (see Table 1). The MICITT's Directorate of Innovation and the Directorate of Appropriation is in charge of this initiative. This initiative seeks to create a network of laboratories throughout the territory in order to foster innovative solutions (personal communication with O. Vega, Vice-Minister of Science and Technology, June 13, 2024). The objective of these laboratories is to create spaces for interaction that bring problems and solutions closer in the territories. This policy tool is aimed at the substantive dimension, as it seeks to change people's behavior and ways of producing and promoting innovative solutions.

These laboratories are operated by public universities and act on demand from the population, i.e. they have equipment, specialists, and managers, whose function is to support the joint construction of innovative solutions to local issues. Because of this, they have a broad and flexible scope depending on the demands and difficulties; they could favor changes in productive systems, risk management, or distribution. The objectives and actions of this instrument are coherent, but, for the moment, limited in coverage. The network is currently in the process of expansion.

A third group of instruments are found within the sectoral policy, in the Public Policy for the Costa Rican Agricultural Sector 2023-2032, led by the Ministry of Agriculture and Livestock (MAG). This case encompasses instruments along two lines: capacity and digital competencies, and simplification of procedures and bureaucracy. The first line of action proposes developing the digital skills of civil servants and users. The second one aims to carry out regulatory and institutional improvements through digital interfaces. These actions are classified as procedural; their focus is on streamlining interactions between users and public servants. They are considered partially coherent because the ministry has a limited number of IT specialists.

It is worth mentioning that the aforementioned policy includes numerous ambitious propositions to transform productive systems and commerce channels. But, since it is not specified *how* these changes are going to be achieved and they are written like objectives, they will not be analyzed. The available information does not allow to clearly determine the implementation of resources; therefore, the coherence analysis is impossible; therefore, they are catalogued as instruments with no public action capacity.

Next are the policy tools implemented by the Costa Rican Foreign Trade Promotion Agency (PROCOMER). The first one is the Green Growth Plan. This plan is composed of two concise actions: access to seed capital (treasury-type resources) and technical assistance and support (information resources). The objective of this plan is to promote the development of green production, considering those in line with energy efficiency, renewable energies, emissions reduction, water use, and waste management; this is under the condition that the projects have export potential. Although they are not instruments directly aimed at the agricultural sector, this plan is coherent and has several successful experiences in the agricultural sector, even in vulnerable territories, such as the Atlantic coast.

The last instrument to be analyzed in this section is the "*Descubre*" Platform, which is an inter-institutional cooperation program. It was conceived as a public-private alliance with the aim of revaluing agricultural activities and promoting investment in rural territories. The platform offers information on the exportable potential of products, encouraging diversification and innovation, together with the simplification of procedures and support. Its orientation towards foreign markets allows the incorporation of advanced technologies, as the variability in internal prices is a major challenge to invest in equipment (as pointed out by J. Madriz, INTA engineer, in a personal communication, June 20, 2024). The system is composed of four platforms: 1) prospection, 2) projects, 3) investment, and 4) innovation. It is structured as a follow-up along the value chain, with the involvement of public and private organizations. This initiative operates in a complex and inter-bureaucratic space, and it is coherent.

The above six broad sets of instruments present a relatively good balance between substantive and procedural dimensions (see Table 1). Some seek to promote changes in the forms of production and distribution and to create human capacities (substantive bias), others to change the dynamics of interaction between the State and the policy users (procedural bias). Given the combination of instruments classified as substantive or procedural, namely, three substantive and two procedurals in the case of MICITT, and one procedural and one substantive in the case of MAG and PROCOMER, it could be argued that there is greater coherence in the policy design of MICITT than in the case of the other two institutions.

Finally, it is important to note that the policy instruments analyzed so far are not articulated between each other. Therefore, they represent a fragmented public policy space, lacking a national policy for the digitalization of agriculture that coordinates the actions in a comprehensive way.

6. Other Public Action Initiatives Concerning Digitalization

There is a group of public action initiatives that are not ascribed to any policy or at least do not explicitly state it. Most of them are actions taken by various public entities in the fulfillment of their regular functions; we consider them here as accessory instruments. Many of these operate in a simple and intra-bureaucratic space and they depend on a single organization, although there are others that emerge from cooperation with international organizations. These cases are considered because, even when they are not directly linked to a specific public policy, they are public initiatives to generate public actions.

The first one is the research, innovation, and extension programs of the Ministry of Agriculture and Livestock, implemented by the National Institute of Agricultural Technology (INTA) as part of its functions (see Table 1). For the conciseness of the analysis, INTA's various extension and research projects are compiled and studied as a single instrument. The INTA has research and innovation programs in five areas: grains, vegetables, roots and tubers, fruits, and livestock. Their main resources are of the information category, because they generate new knowledge from research, disseminate it, and promote innovations. They address the substantive dimension and are coherent in their objectives and means. These programs include innovations of various kinds, from bioeconomy to precision technologies.

Within this program, it is worth to highlight a cooperation project with the government of Korea that explores the use of smart greenhouses and their elements in Costa Rica (personal communication with J. Madriz, INTA engineer, June 20, 2024). Currently, this initiative is in an experimental-exploratory phase, testing technologies like remote controls, internal climate regulation and advanced information systems. As a secondary line of work, the specialists are evaluating the potential of these greenhouses to introduce new crops as part of a diversification strategy in the Caribbean. This initiative is coherent, as it seeks to adapt Korean technologies to the conditions of Costa Rica, to develop a technological package transferable to local producers in order to improve their efficiency (substantive bias). However, it is too soon to judge this, as it has not reached the implementation and transfer phases.

The second line of action in this group is also managed by INTA, namely, the PLATICAR platform. This platform has mainly information resources. It is a space to exchange knowledge for researchers, extensionists, and producers. This is the instrument that has been working successfully for the longest time. The program included a process of training and creation of digital competencies among users to promote its use (personal communication with L. Ramírez, INTA engineer, April 5, 2024). This measure is procedural in nature, as it is essentially a change in the space and dynamics of contact and an exchange between public and private actors. It is also presented as coherent in its means, objectives, and processes.

Finally, there are two programs managed by the Ministry of Economy, Industry, and Commerce (MEIC) with potential impact in the digitalization of agriculture, yet, only one is specifically directed to this sector. The first is a microcredit program of a maximum of 18 million *colones* (around USD 35,000), with emphasis on milk production, although it is open to other economic activities. This program operates with funds of the Development Banking System and the Banco Popular de Costa Rica; the funds are managed by three cooperatives (COOCI- QUE, COOPEAMISTAD and COOPELECHEROS). In addition, professional advice in the implementation of innovations is mentioned. This line of work is substantive as it aims to change production systems by facilitating the introduction of new technologies through financial resources. It is coherent, especially given the absence of treasury-type resources in most of the other instruments; however, it is questionable whether these funds are sufficient to cover the cost of advanced technologies.

The second action of MEIC is the MIPYME Digitalization Plan 2019-2022. The name gives the idea of a complex plan, but a closer look reveals that it is a concrete action under a public-private partnership. It stems from an initiative of the Organization of American States, in collaboration with Google and Kolau. Together they make available a tool to create websites (Kolau) and support to promote the sites visibility on the internet (Google). They also offer voluntary courses and training to enhance the digital competencies of the participants.

This instrument is of national scope but has the potential to impact the agricultural sector, by opening new commerce channels and creating alternative markets without intermediaries. This action is aimed at substantive objectives, as it proposes a change in the business model by moving the interactions to digital environments. It is coherent, as its objective is to take economic activities into digital spaces, and the support from companies such as Google and Kolau give it the necessary resources.

These four public actions, considered accessory instruments, operate in a fragmented public policy space too, where they do not respond to public policies. Rather, as indicated at the beginning, they are part of the regular functions of the public organizations that implement them. That is why their incidence tends to be so specific (promote, control, change). However, since they do not belong to a policy plan it is impossible to evaluate their consistency.

7. Other National Public-Private Initiatives

In Costa Rica, the *Instituto Nacional de Aprendizaje* (INA) has training courses in the use of digital technologies. While the national strategy for the digitalization of agriculture mentions the role of INA, when checking its courses offer, only a 44-hours course on the use of digital for agribusiness was found. It is worth mentioning that training in this area may be included in other study plans, but it is not possible to access the curricula to corroborate it. Even if limited, this action has a substantive objective, as it aims to change business models through the creation of digital competencies. Despite that, a single course seems to be rather limited considering the INA's resources and infrastructure.

There are projects in the country, such as the "Monitoring of the flow and composition of gases in Costa Rica's volcanoes" of the Costa Rican Volcanological and Seismological Observatory (OVSICORI) of the National University, that implements early warning technologies for disaster risk management (National University, 2024). This project uses sensors to detect the concentration of volcanic gases and informs about the advisability of planting or removing crops in areas surrounding volcanoes. It is an example of how the agricultural sector can benefit from early warning systems and disaster risk management (MAG, 2023).

The Costa Rican Coffee Institute (ICAFE) (and other public non-State organizations dedicated to support specific crops) has incorporated technology in the coffee value chain that gives hydrometeorological forecasts, including cyclone forecasts five days in advance (ICAFE, 2015). These innovations improve decision-making in terms of the sowing and harvesting of crops. Since 2020 efforts have been made to transform the agricultural sector by implementing technologies and practices that foster adaptation to climate change and reduce the risks of extreme hydrometeorological events through the Nationally Determined Contribution (NDC) (MINAE, 2020).

There are, also, initiatives built in hand with international organizations, like the project "Integrated pilot system for digitalization and agroclimatic information", based on the analysis of data from technological equipment implemented on farms. The MAG, together with the technical team of the Food and Agriculture Organization of the United Nations (FAO) demonstrated the importance of taking decisions in advance in the face of possible agroclimatic risks for small and medium-scale agricultural producers, especially in the cultivation of cassava, cocoa, and pasture (FAO), 2024).

8. Conclusions

According to the analysis, following the categories proposed by Fontaine (2015), the policy space for the digitalization of agriculture in Costa Rica is complex and inter-bureaucratic, due to the participation of various agencies and programs. The public policy space is fragmented, and there is little coordination or cooperation between public agencies. The lack of coordination is rooted in the absence of a policy for the digitalization of agriculture in Costa Rica, to articulate actions, objectives, and interests. There was a strategy for the digitalization of agriculture, but it was not followed up by the government that was elected in 2022, and it only encompasses one axis of the National Telecommunications Development Plan 2015-2021. In addition, although MICITT implemented three policy tools, they are different and there is no evidence of coordination with the other public actions analyzed.

Despite the absence of a national policy, there are several active instruments, some as part of other policies, others as isolated State actions. However, this analysis reveals the State's limited operational capacity, with no specific resources allocated to the digitalization of agriculture. Public organizations are generally expected to incorporate these actions within their regular tasks and budgets. This poses a significant challenge, particularly in the current context: the country is under a fiscal rule that limits the spending of public organizations until the national debt is below a certain point.

It is presumed that these characteristics and the fiscal context explain the tendency to privilege regulation and information actions in the policy strategies, which is proven by the focus on actions to move procedures to digital environments and create information systems. This is true even if the need for integrated information systems has already been recognized by other studies as paramount to improve the country's and the sector's innovation system (Barboza-Arias & Sáenz-Segura, 2019).

In the actions aimed at productivity enhancement, there is a lack of coherence between the objectives and the means to achieve them. Essentially, most of them are written in the form of aspirations, generally with verbs such as "promote", "transform", or "change", without proposing entities or mechanisms for it. Furthermore, there is a lack of treasury-type resources, which are paramount in order to have public action capacity to transform agricultural production systems, considering the fiscal context and the sector's difficulties in accessing credit.

On the other hand, independent public actions or instruments implemented by public organizations are coherent and have the necessary resources to operate. It seems that instruments that operate in a simple intra-bureaucratic space are more likely to work well than those that depend on the joint action of several public agencies. Some of them are effectively developed through partnerships with non-governmental entities, such as Google, Kolau, or IICA. This reveals a frequent problem in the country: the significant difficulties to articulate actions between ministries and a persistent lack of clarity about the responsibilities of each, as was stated in three personal communications with MAG and MICITT. This is relevant for this case, as the digitalization of agriculture is an issue that cuts across the tasks of several ministries.

As for the last phase of work, the consistency analysis, it is only carried out partially because the policy space is fragmented and the information insufficient to make a complete assessment of the balance of instruments. This is not to mention that the absence of a national policy for the digitalization of agriculture makes a full consistency analysis impossible.

The incorporation of technology aimed at agroclimatic risk prevention is not strongly identified, even if there are some hints of it. This constitutes a challenge in order to achieve more efficient and resilient production systems, particularly for the Costa Rican agricultural sector, which is frequently affected by hydrometeorological events that lead to disasters with total or partial losses of production.

In short, the instruments identified often lack well-defined resources in the policy plans and are, therefore, often formulated indistinctly in relation to objectives. Also, the potential of digitalization to create new commerce channels is recurrently mentioned. However, except for one initiative from MEIC, there are no instruments with resources effectively directed toward this line of work. Finally, it is observed that a significant part of the policy tools is directed towards the incorporation of technologies as administrative support, rather than productive efficiency or distributive equity.

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8 Digitalization of Agriculture and Public Policies in Uruguay

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1. Introduction

Around the world, agricultural sectors are undergoing a transformation as a result of the accelerated expansion of technologies that use digital processes. Diverse innovations, such as the internet of things, machine learning, drones or applications for mobile devices that perform tasks associated with agricultural activities, among many others, are increasingly present in the Latin American countryside. Although the multiplicity of technological proposals (products and services) is considerable, the processes of digitalization of agriculture and its associated chains have as a common characteristic the performance of tasks based on different types of data (location, climate, behavior, phytosanitary status, energy use and prices, among others) obtained through the use of devices such as sensors, drones and satellites in order to monitor animals, soil, water, plants and people (Klerkx et al., 2019).

In general, digitalization processes in agriculture are promoted in association with objectives to improve a set of desired goals ranging from farm productivity, environmental sustainability and food quality for the efficient performance of agri-food systems. Global exchanges regarding food policy emphasize the potential of information and communication technologies (ICTs) for agri-food chain development. Numerous public policy instruments at the national level refer to digital transition processes in line with the joint pursuit of productive efficiency and environmental

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sustainability. In the Global North, digital technologies are increasingly used in agriculture and their rapid expansion is promoted by organizations such as FAO and the World Bank, which support the development of national strategies on this subject in southern countries (WB, 2019; Trendov et al, 2019).

Thus, for the Latin American region, the Economic Commission for Latin America and the Caribbean (ECLAC) presents an optimistic vision of the digital transformation with high expectations regarding the possible impact that digital technologies could have on the region's production models (ECLAC, 2021), with the conviction that it is necessary to move towards a digitalized economy with a greater presence of technology-based companies. In agriculture, in particular, positive scenarios can be observed in terms of the possibilities of digital technologies to have a positive impact on value addition and sector differentiation (Sotomayor, 2021). However, the panorama of the different countries in the region is very dissimilar and within countries there are sectors and regions that are polarized in relation to digital transformation. Unlike international organizations, several academic studies are more cautious about the potential benefits of digitalization. In particular, they warn about the potential for digital technologies in agriculture to reinforce existing inequalities between producers (Klerkx and Rose, 2020), increase the power and dependence on large global corporations (Carolan, 2020) and increase the need for skilled agricultural workers with less associated ecological knowledge (Prause et al., 2021).

Starting from the general context, this chapter aims to review some of the policies aimed at digitalization in agricultural sectors that have been promoted in recent years in Uruguay. To this end, we first present an overview of national policy initiatives within the context of digital transformation, followed by two sections that address specific initiatives in this process. The information and data provided are based on the review of the policy documents examined and on interviews with qualified informants at different programmes of the Ministry of Livestock, Agriculture and Fisheries and the Uruguayan Chamber of Information and Communication Technologies. The following section contextualizes the digital transformation process within the Uruguayan agricultural sector.

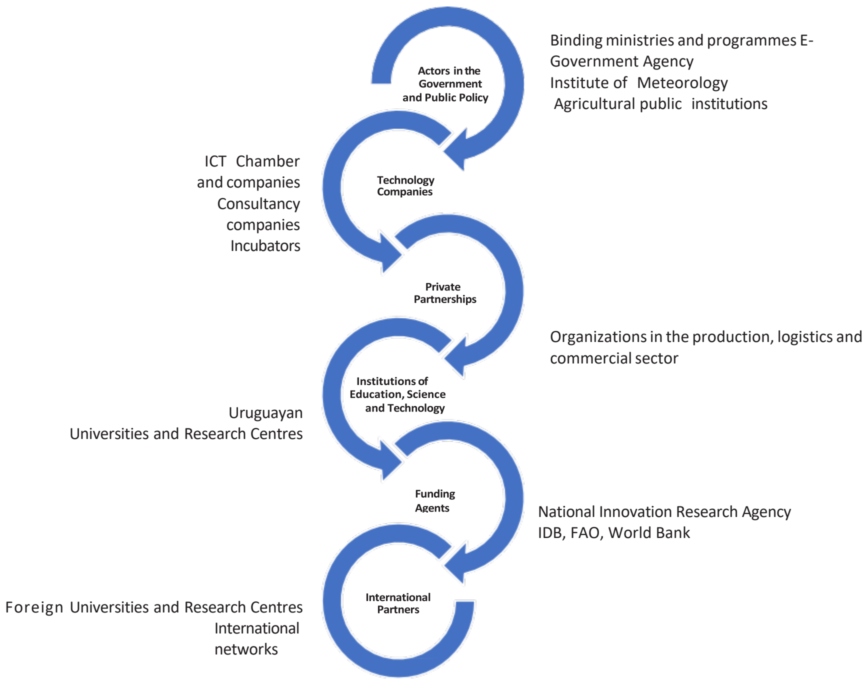
2. Fertile Fields for Digitalization

Agricultural systems are strategic in Uruguay at productive, socio-economic and cultural levels. The different agricultural productions occupy more than 90% of the Uruguayan territory, comprising 17.6 million hectares. Together, agriculture accounts for 10% of GDP and 75% of exports (MGAP, 2023). Cattle and wool livestock farming have historically been the predominant production system, currently challenged by the dynamism of extensive agriculture, which has expanded dramatically during the first two decades of the 21st century. The expansion of forestry first followed by cereal agriculture led to a process of productive intensification that follows a global trend and is reinforced by the increase in the global circulation of standardized food and raw materials of agricultural origin. As a correlate of these productive changes, other long-standing trends have deepened in Uruguay's rural areas. On the one hand, the rural population has reached a historic low of 4% (INE, 2023), so that most people who work in agriculture have permanent urban residences and move to rural areas on a daily basis or for limited periods of time. This has given dynamism to a set of intermediate communities that simultaneously combine rural and urban ways of life and occupation. On the other hand, the agrarian social structure is changing, and land tenure is becoming more concentrated. According to the latest available census data, between 2000 and 2011, the number of family farms fell by approximately a quarter and the size of farms grew by an average of 15% (Sganga et al., 2014).

The digital transformation finds a favourable situation in Uruguay due to the confluence of a series of positive conditions, starting with the basic infrastructure required. Based on investments made by the state-owned telecommunications company, most of the national territory has good connectivity, allowing access to broadband internet via optical fibre. This type of connection reached 85% of accesses to the fixed telephony network, with 91% of fixed broadband services with speeds above 10 Mbps (Ursec, 2023). The provision of electricity from renewable sources is widely available because of changes in the national energy matrix implemented since 2005 as a result of an energy policy agreed upon at the national level (Ardanche et al., 2017). The digital literacy of the population, understood as their relative ability to use ICTs, is advanced due to a decade and a half of a policy to promote equal opportunities in public education through the provision of personal devices to students and teachers in primary and secondary education, in addition to free internet connection in state educational centres. This policy, called Plan *Ceibal* (Basic Computer Educational Connectivity for Online Learning), has been in continuous operation since 2007, promoting the integration of digital technologies in education as an inclusive tool to improve learning processes. In addition, the ICT industry has had an early development, leading Uruguay to become the largest software exporter per capita in Latin America. This is a sector with full employment that brings together more than 500 companies of different sizes, with software development as the main activity, followed in importance by application programming (Uruguay XXI, 2023).

The digitalization of agriculture finds concrete expressions in both policy initiatives that promote the use of ICTs and the development of the software industry, which explores business opportunities in the agricultural and livestock sectors. For some years now, there has been a specific forum driven by the ICT industry, with varying degrees of public activity, which brings together technology companies and some academic actors linked to the AgTech environment. Also, Uruguay participates in the Ibero-American Network for the Digitalization of Agriculture and Livestock through its National Institute for Agricultural Research (INIA). Furthermore, a recent study reports on a number of digital technology companies applied to agriculture that offer products and services grouped into four main groups: agricultural segmentation by environments that consider soil characteristics; crop and livestock monitoring; control of tasks such as sowing or fertilizing crops; other applications such as traceability, management and smart contracts (Lachman et al., 2022). Figure 1 and Table 1 provide an approximation of the ecosystem of actors and institutions that make up the AgTech landscape in Uruguay.

Figure 1. Diagram of the AgTech ecosystem in Uruguay



Source: Own elaboration.

Table 1. Characterization of the AgTech ecosystem in Uruguay

Components	Main Activities	Relevant examples (selection)
Government Public Policy Actors and	Policy making, regulatory guidelines, and national budgets	MGAP: SNIA and sectoral programmes National Development Agency Technological Laboratory of Uruguay National Institute of Meteorology E-Government Agency Regulatory Unit of Communications Services
Technology companies	Promotion and development of digitally based technology products and services	Uruguayan Chamber of Information Technologies Incubators: Ingenio, Idear, Sinergia
Private Partnerships	Representation of technological demands and interests of the agricultural and agro-industrial sectors	Uruguayan Federation of Crea Groups Uruguayan Association for Zero Tillage National Cooperative of Milk Producers Rural Association of Uruguay
S&T Education Institutions	Training of professionals and technicians, research and development of digital solutions, digital literacy	University of the Republic Technological University National Institute for Agricultural Research Pasteur Institute of Montevideo Catholic University ORT University
Funding agents	National and international support and funding for specific projects.	National Agency for Research and Innovation World Bank Inter-American Development Bank FAO-United Nations
International partners	Counterparts in international projects and networks.	Ibero-American Network for the Digitalization of Agriculture and Livestock Multiple universities and research centres

Source: Own elaboration.

3. General Public Actions and Differentiated Policies for Digitalization

Uruguay is developing e-government plans promoted by the Agency for Electronic Government and the Information and Knowledge Society (AGESIC) in coordination with several areas of State action. In recent years, the Ministry of Agriculture, Livestock and Fisheries (MGAP) has been implementing the National Agricultural Information System (SNIA), conceived as a single portal through which it is possible to channel online procedures for citizens and manage information related to the agricultural sector regarding soil, water and climate factors. Currently, the SNIA registers and manages information based on the following five components: efficient use of natural resources, environmental sustainability, food safety, adaptation to climate change and democratization of access to digital services (SNIA Director, personal communication, October 2023). The SNIA utilizes data generated in all areas of agricultural production, which can be consumed through online geographic visualizers to inform public and private decision-making. Data on extreme weather events, soil maps, information to manage specific risks due to contamination from phytosanitary applications or effluents, among other inputs for evidence-based decision-making, are also available. This set of aspects reflects a digital transformation in process, promoted by national governments for more than a decade and which includes consolidated digital-based programmes. Two of these are the National Livestock Information System, which ensures the traceability of individual animals and the safety of meat products aimed for export, and the Soil Use and Management Plans, aimed at soil conservation through responsible planning and a declaration of projected use to control soil loss and erosion. The former was developed in response to the demands from international markets, and the latter arose as a necessity in the context of an accelerated process of productive intensification. These national initiatives were developed based on the conjunction of enabling factors, such as the basic infrastructure of connectivity and information technologies, software specifically developed and regulations that were created and approved in order to implement the instruments. Table 2 summarizes the main policy actions involved in the digital transformation process.

Table 2. Main actions of national agricultural policies with a digital basis

Name	Target objectives	Starting year
National Livestock Information System (SNIG)	Traceability of cattle Food safety Opening of international markets	2006
Responsible Soil Use and Management Plans Management System	Soil conservation	2008
National Traceability System for Apiculture Products (SINATPA)	Food safety Opening of international markets	2013
National Agricultural Information System (SNIA)	Integration of information and data from different sources	2015
Management and Monitoring of Phytosanitary Applications	Environmental sustainability Responsible use of agrochemicals	2019

Source: Own elaboration based on the MGAP website.

Within this general panorama, there are very different realities between production chains and, fundamentally, between family production models and those of a corporate nature, whose production is oriented towards global chains. Some of these disparities are reflected in specific policies implemented in recent years. Although not stated as such, these are science, technology and innovation (STI) policies that aim to stimulate the production, dissemination or use of agricultural knowledge and innovations through the instruments and programmes of public entities. Following a recent review of public policies for the digitalization of agri-food systems including articles published in English (Kukk et al., 2022) we find it useful to distinguish two underlying roles of policies. The first gives rise to policies focused on bridging the gaps and providing some sort of protection to production strata that exhibit incipient digitalization with the aim of reducing the technological divide. The second one serves to foster or accelerate innovation in the framework of digital transformation by bringing S&T capabilities in line with the demands of agriculture. In both cases, there is an implicit policy undertone that positively associates advancing the digital transformation of agriculture with the possibility of moving towards sustainable development goals. The following pages examine two recent programmes focused on digitalization processes that respond to the differentiated roles of bridging gaps and fostering innovation.

3.1. Initiatives for Family Farming: the AgroTic Programme

Among the policies aimed at the digital transformation of the agricultural sectors, courses of action were established to contribute to a more equitable digitalization, facilitating access of groups of producers who are less inclined to try digital technologies or who have socio-economic limitations in accessing them. In this sense, family farms require specific interventions to link efficiently and in accordance with their characteristics and interests to the opportunities that digitalization can offer.

Family production in Uruguay makes up a varied sector of establishments whose distinctive feature is that they develop their activity based on a major portion of work of household members. Since 2008, this type of agricultural and livestock production has been defined by law, establishing a common framework for the targeting of public policies. Although cattle farming is the most frequent main activity, family farming involves diverse production, particularly horticulture, dairy production and poultry farming in the provision of fresh or slightly processed food for the domestic market.

After the COVID-19 pandemic, a nationally representative survey of household production was carried out in order to understand the situation of the sector in relation to ICTs. This study found that there is a wide penetration of mobile telephony with access to the internet in family production, despite the fact that the use of digital applications in productive activity is not widespread (MGAP & Opción Consultores, 2021). For the most part, family farmers use more traditional channels to receive information and technical advice on their production through specialized radio and television programmes and farmers' groups. Access to technologies such as drones, precision agriculture, artificial intelligence applications or remote sensing tools with satellite images is very limited among family farmers, according to this survey.

In this context, the C*all for proposals AgroTic: digital solutions for family production*, developed by the Rural Development Division of the

Ministry of Agriculture, Livestock and Fisheries in 2022, focused on family production and its territorial organizations. AgroTic is part of a larger programme, executed by the Ministry and financed by IDB, aimed at promoting and adopting ICTs and digital solutions as a means to improve levels of innovation and productivity, in addition to optimizing technical assistance actions for family production (Director DGDR-MGAP, personal communication, October 2023). AgroTic was based on the aforementioned diagnostic study, carried out through a quantitative survey in order to determine access, availability, adaptability, knowledge and costs associated with the use of ICTs in family production (MGAP & Opción Consultores, 2021). AgroTic involved subsidies of up to 30,000 dollars per proposal to develop or adapt digital-based technologies over the course of a year to initiatives agreed upon and elaborated between producer organizations and their technical advisors.

The policy design is based on a vision of rural development which aims to promote the sustainability of family production based on productivity improvements through technological adoption and associativity (DGDR-MGAP, 2022). The modality of linking developers and users of technological solutions was adopted by the programme in order to adjust the design of the eventual technological products to the specific needs and contexts of the producers' groups. For this reason, it is required that the initiatives are channelled through family production associations and organizations operating at local or regional levels throughout the country. The anchoring to the specific territories and contexts of family production is relevant in order to facilitate the understanding of the needs and idiosyncrasies of each group, as well as their involvement in the process and use of developed solutions.

As part of the approach promoted by AgroTic, the active participation of producer families in the development or in the adaptation of digital solutions for their production or commercial systems is encouraged. Thus, the proposals receive special weightings in their evaluation when they consider the integration of women and young people up to 29 years old in the different stages of the project to be implemented: identification of the problem, technological development and validation, as well as the training that may be necessary for the use of a specific solution. In this way, the aim is to stimulate access to and use of technologies based on interactive intervention modalities in which users, extension technicians and digital developers distant from the agricultural world can establish fruitful dialogues and facilitate cooperation, as is often the case in initiatives aimed at bridging technological gaps (Kukk et al., 2022).

The proposals submitted to the 2022 Call mainly involved the development of digital applications for mobile devices, sensors and automation of irrigation systems, among others, aimed at facilitating the integrated management of establishments. These include 16 technological solutions of relatively low complexity that, nevertheless, require a process of validation first, and training users later. In this sense, it is a strength that this policy does not reach production establishments individually, but is implemented through local producers' organizations already active and in which associative working relationships, cooperation and also conflicts in the territories are capitalized. These organizations signed contracts with the ministerial body for the implementation of the initiatives, which totalled 315,000 dollars. Table 3 summarizes the themes of funded proposals.

Table 3. AgroTics 2022 call: funded proposals

Themes of the proposals
Temperature control in family poultry houses
Horticultural management
Digital solutions for irrigation
Development of a digital field notebook
Evolution of the traceability and rearing system on dairy farms
Integrated management system for sheep production
Digital solutions for improved management and traceability in sustainable viticulture
Beekeeping monitoring
Alert system for the detection of arthropod pests in pasture implementation dairy production
Adapting digital solutions for cooperative marketing of fruit and vegetables
Developing digital solutions for youth in pasture management
Systematization of productive information in fruit production
Digital literacy and communication

Source: own elaboration based on F. Sganga, DGDR - MGAP (personal communication, May 2024).

3.2. Boosting Digital-based Businesses: AgTech Challenge

A different type of policy seeks to foster innovation in the framework of digital transformation by taking advantage of Uruguay's business experience with ICTs and bringing new S&T capabilities in line with demand-driven ventures in the agricultural sector. The Uruguayan Chamber of Information Technologies (CUTI), which brings together companies in this sector, has been a key promoter of the first initiatives in this direction. This is the case of the *Mesa* AgriTech, referred to in the Introduction. This forum was created in 2018 and currently brings together more than 60 technology companies that operate or have the potential to operate in the provision of ICT solutions for agriculture and agribusiness. Prior to the pandemic, with the sponsorship of the British Embassy in Uruguay, it held a Hackathon at the annual agricultural exhibition held in Montevideo, organized by the Rural Association of Uruguay. These events promoted encounters between technology companies operating in Uruguay, which exchanged possible solutions and advice for specific situations raised by representatives of different agricultural sectors, in an attempt to bridge the gap between two sectors that are both economically sound and disconnected in practice. The idea of "bringing the two worlds closer together," in words of the CUTI representative at this forum, fuels the connection between technological ventures with agricultural organizations in order to "raise awareness of the potential of digital technological solutions" in this sector (CUTI Board Member, personal communication, November 2023).

Since 2020, *AgTech Challenge* emerges as a specific policy focused on the promotion of digital technologies in agricultural sectors. This initiative, which is aligned with the convenience of articulating efforts in order to accelerate digital transformation, takes the form of a competitive call managed by the National Agency for Research in Innovation (ANII) and is directly promoted by the MGAP and the National Development Agency. Its implementation reflects an explicit technological confidence by stating that the use of digital technological solutions allows for improvements in the capacity to adapt to variability and climate change, the sustainability of environmental resources, as well as social inclusion (MGAP-ANDE-ANII, 2022). The promotion of innovation capacity and entrepreneurship are subsidiary objectives to the main task of expanding digital technologies in the agricultural, livestock, forestry and fisheries sectors.

Up to 2022, three editions of the *Agtech Challenge* have been held, calling for innovative ideas with the potential to develop business opportunities in which a variety of proposals have been supported. The total amount directly invested in the selected initiatives is approximately 75 thousand dollars, to which the working cost of mentors who accompany the process of each winning proposal is added.

The technological solutions involved include traceability processes, automation, remote monitoring through sensors and robotization, among others. Each edition included a limited set of challenges that are pre-identified by the agricultural institutions, including INIA, the National Meat Institute and the Uruguayan Secretariat for Wool, among others. When choosing the challenges, the aim is to ensure they are representative of all the existing agricultural sectors, to identify concrete problems and experts in these problems to support the development teams, and to ensure that they can be deployed at a commercial level, as the approach considers the development of a business based on the solution reached. In this sense, the initial direct funding offered is modest: a maximum amount of 5,000 dollars per proposal, which is complemented with valuable intangibles, such as access to production facilities to test the innovative idea in real production contexts, an advisory plan and support for validation at the commercial level.

In a complementary manner, INIA, as a research centre with a mandate directly associated with the production and validation of technologies for agricultural production, has defined strategic lines that converge with the digital transition process. Its current strategic plan expressly includes the cross-cutting promotion of digital technologies in the institutional agenda (Tiscornia et al., 2023). In particular, it identifies as central aspects the promotion of the potential of big data and data mining tools to generate and process information, as well as the development of digital or automation products and tools. The plan argues that the articulation of both aspects enables the analysis of behavioural patterns of productive systems in a comprehensive manner, considering the sectoral, regional and national levels to feed the institution's own research programmes, as well as to quantify impacts for decision-making and new policy design. Along the same lines, the most recent initiative is an agtech innovation platform called Converge. It adopts the format of a living laboratory aimed at facilitating collaborations between different actors for the validation, fine-tuning and dissemination of digital innovations in specific production systems. It is an initiative that arises from the articulation between INIA and CUTI with the support of the Inter-American Development Bank and ANII.

In summary, there is an inter-institutional policy environment oriented to facilitate the conditions and accelerate the development of innovations for digitalization in agriculture. These share an optimistic view on the potential of digital technologies, highlighting their potential benefits on productivity by working on efficiency and process improvement, environmental sustainability and mitigating the effects of climate change. The technologies aim at promoting micro-environment and reducing the use of inputs on farms and favouring the monitoring of agro-climatic and productive risks in real time for the early detection of threats. Favouring articulations between productive and business actors, with technological capacities as a condition for innovation, seems to be a shared goal in view of the understanding that there are opportunities and capacities still not fully exploited.

4. Concluding Remarks

The overview of public policies we have presented shows that digital transformation in Uruguay is an established phenomenon. Since the first policy initiatives stimulated by international markets, that led to the development of a traceability system for the cattle sector in the mid-2000s, the development of digital capabilities and the application of digitally based technologies have been an intentional objective. Its impetus has been largely based on the conviction of the potential of digital technologies to be applied in and out of production establishments along production chains and transversally across sectors of activity, in line with the trends encouraged by international development cooperation agencies.

Within the framework of this trend that permeates the global context, Uruguayan policies are characterized by diverse public-private coordination. The explicit link between technological capacities and users of technological solutions is a window of opportunity for the achievement of tailor-made technological products and services, based on the knowledge and experience of local production systems. Fostering interaction between the agricultural and digital technology sectors is necessary in order to build a common language and develop relationships of trust between areas that are not generally linked. It is opportune to be able to capitalize on these experiences so that technological developments become concrete and maintain their utility in the national productive sphere.

The intervention modalities adopted by the policies are varied and range from family production to export-oriented companies. In the former, the vocation is in line with the equalization of access to opportunities and the reduction of technological gaps, aiming to accompany changes for the integral development of family production establishments and organizations. Among the latter, initiatives jointly seek to encourage new technological ventures and to develop business ideas in consolidated companies, while promoting the digital transformation of agricultural and agro-industrial, commercial and logistics processes. With nuances, the policy initiatives seek to support courses of action based on agendas agreed upon by a variety of actors, which contribute to a better use of public resources in terms of technological sovereignty, although without being able to guarantee it. In both policies there are aspects of tension to consider that involve issues of data ownership, regulation on the use and security derived from the application of digital technologies for which there is still no specific legislation in Uruguay, except for the general regulations on personal data protection and a normative orientation for the use of drones (Agesic, 2018). Similarly, it is necessary to consider possible transformations in the identities of traditional agricultural productions and in the associated labour, knowledge and training requirements that may result from the expansion of the digitalization process in agriculture, which have been pointed out by academic studies in other parts of the world but have not been explored in Uruguay to date.

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9 Towards Strengthening Public Policies for the Digital Transition in Mexican Agriculture

Héctor Ávila-Sánchez

1. Introduction

Digital agriculture has emerged in rural and agricultural development and has had an impact on the restructuring of agri-food systems and the spatial arrangement of rurality. Since the 1990s, the use of remote sensing and modelling through global positioning and geographic information systems has been generated, which mainly supports the knowledge and potential of the material substratum of agricultural production (Cf. Friedman and Michael, 1989; Ponce, 2023). It also affects marketing and the logistics of transport systems to supply and consumption centers (Sotomayor, *et al.*, 2021).

Mexico is a country where differentiated uses of digital innovations are expressed. Although they are carried out under an ambiguous definition of public policies in this area, which recognize their importance for the promotion of agricultural practices, they do not establish consolidated programs or routes to be followed for their dissemination among producers in order to have an impact on the improvement of welfare levels in the Mexican countryside.

The objective of this chapter is to identify the processes or modalities in which the users of innovations (large and medium-sized producers) incorporate the advances of digital technologies into their productive processes, regardless of the normativity of a public policy that promotes and regulates the use and generation of data and information. It also discusses

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the real scope of the use and incorporation of these technologies in the different sectors of agricultural producers.

The methodology used in this text is entirely qualitative. It draws on information available in official documents from the rural sector in Mexico and others produced by international organizations, as well as some scientific articles and journalistic notes. It should be noted that the ideas presented here are merely indicative; they give an idea of the path followed by some representative actors involved in the digital transition in the Mexican countryside.

Since the official statistical information does not give a precise account of digital innovations in agricultural production, nor are the actions and programs described in public policies in the rural sector, this text draws upon a literature review and most importantly, a series of interviews and informal conversations that gathered opinions from scientists specialized in the subject (researchers in public universities and research centres).[1] The opinions of government officials in charge of implementing the technological innovations set out in the official agricultural programs are included. It also relies on some experiences of agricultural entrepreneurs and professionals (agronomists in charge of production processes and leaders of production associations) and analyzes examples from scientific research and business production (high quality flowers for the national market and for export). Therefore, the scope of this chapter has been developed mainly from the point of view of scholars, agricultural entrepreneur leaders and, to some extent, users of digital technologies.

2. The Socio-Territorial Context of Digital Innovations in Mexican Agriculture

In Mexico, international agencies and some scientific circles that are promoting the digital transition in the production processes of the agriculture highlight the increase in production and profitability, the efficiency of production management and transport logistics systems, as

1 Where information is derived from personal communications with a respondent, it is indicated by initials (PC).

well as the traceability of local systems. They emphasize the impact that these technologies have on the organization and operation of productive units in the control of information and the generation of digital data (Ponce, 2023; Prause *et al.*, 2021). In the last 25 years, they have involved in this dynamic the minority food sector under an agro-ecological production regime (in cooperative supermarkets and small independent traders), which sell directly to metropolitan consumers (solidarity economic circuits, Sanz and Yacamán, 2022; Ávila, 2024).

The acceptance of technological solutions in agriculture is conditioned by the existence of a heterogeneous and diverse productive sector, with a large and informal workforce, restrictions on access and connectivity, and low or no training for most agricultural producers[2] (Sotomayor, *et al.*, 2021; Ponce, 2022). For others (Ávila, 2024; Prause, *et al.,* 2021) differentiated use widens the gap of poverty and regional inequality in the Mexican countryside, especially in agricultural regions with greater productive potential and greater capitalization, an environment where permanent technological innovation clashes with the development of practices and forestry as a means of livelihood and social organization.

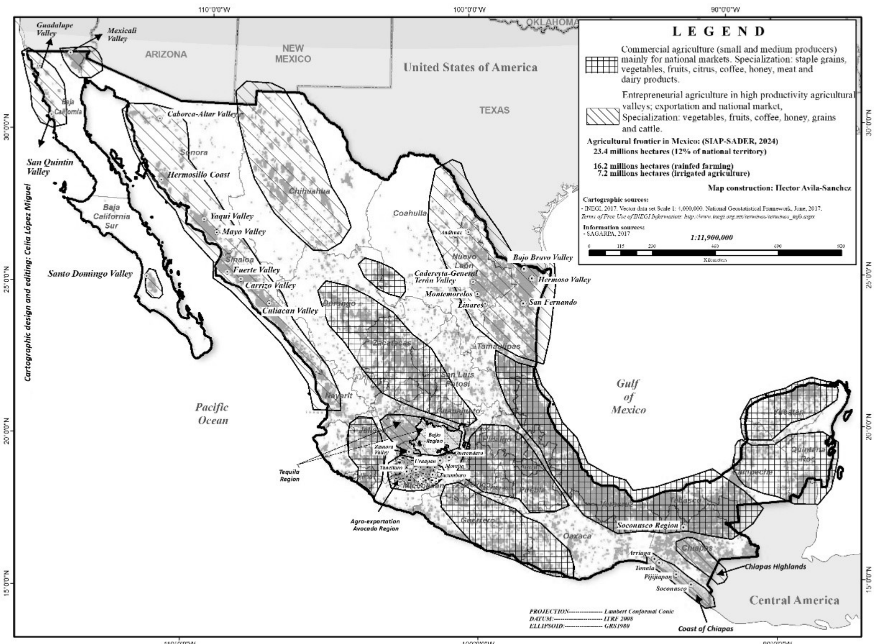
In Mexico, the spatial scope of the introduction of digital innovations and their real impact take place, above all, in the agricultural regions with the highest productivity, which are linked to international markets. The use of digital technologies (4.0 and 5.0) is concentrated in the northwest and north, in the states of Sonora, Sinaloa, Tamaulipas, Chihuahua, Michoacán, Jalisco, Guanajuato (Bajio) and some specific regions in the centre of the country (use of satellite images, robots, various sensors, drones, applications for monitoring pests and diseases, autonomous tractors, laser land levelling, precision agriculture, etc.). These areas are closely linked to the market in the southern United States, where most of the experimental and other applied innovations are carried out, whether by government agencies, research centres, or even privately by individual producers or through farmers' groups (see Figure 1).

2 According to data from the Censo Agropecuario 2022, 65.5% of rural producers in Mexico have only basic education (INEGI, 2024).

National agricultural statistics highlight the potential of agricultural regions with greater technological adoption, where the use of digital innovations has been incorporated (INEGI, 2024; SIAP, 2023). Seven states (Sinaloa, Sonora, Zacatecas, Chihuahua in the north; Guanajuato and Jalisco in the Bajio region; Puebla in the center) grow 62.9% of vegetable production for export and, to a lesser extent, for the national market. Another important agricultural region in the center of the country (Michoacan, Jalisco and Guanajuato) and the Bajio region are the regions producing avocado (86% of national production) and agave for tequila (88% of national production), two of Mexico's main export products. In the agricultural valleys of northern and northwestern Mexico (Sinaloa, Sonora and Tamaulipas), 63.8% of the national grain production (rice, maize, wheat, sorghum, barley, beans) is grown, mainly supplying the domestic market. Similarly, in the north (Sinaloa, Chihuahua and Baja California) and also in the center of the country (Michoacan, Jalisco and State of Mexico), 63.9 % of the national total of diverse crops are grown under protected cultivation.

In the rest of Mexico, there are other agro-exporting spaces where digital technologies have also been incorporated. In the southeast region, they are used in various coffee farms in Chiapas for high quality production, as well as in Tabasco, in cocoa production farms. They are commonly used in areas of the production of berries (raspberries, blueberries, strawberries) in Jalisco and northern Puebla, as well as in areas of citrus production in Michoacán and Colima (center of the country). The use of software and drones for spraying in sugarcane areas in the *Huasteca* de Tamaulipas (northeastern Mexico) has also been recorded (Ponce, PC, 2024; Vargas, PC, 2024). In forestry, private companies that exploit forests use satellite images applied to drones to detect tree diseases or pests; and experiences in the use of drones in forested areas in Michoacan (central) and Durango (north) are known (Ponce, PC, 2024; Muñoz, PC, 2024) (See Figure 1).

Figure 1. Agricultural and livestock production regions in Mexico



It is possible to distinguish two groups of users of digital innovations. On the one hand, business agricultural producers and large agricultural consortiums[3] (Vargas, PC, 2024) are the key drivers of demand for digital innovations to increase productivity, strengthen traceability and ensure safety (Ponce, PC, 2024). Extensive financial and technological capacity is required, either to operate them or to hire technicians and/or services to analyze and process the data. Because of this, the adoption of digital agriculture methods and technological developments in Mexico is carried out by less than 2% of national producers, especially in agriculture under protected environments (Muñoz, PC, 2024).

For example, in Sinaloa, in northwestern Mexico, the use of digital innovations has gradually spread among large vegetable producers, albeit in a differentiated manner. In the Culiacan Valley, young producers (so-called *early adopters*) have incorporated various applications and software

3 According to the Censo Agropecuario 2022 (INEGI, 2024), there were 5 million agricultural producers in Mexico. In the stratum of large producers, only around 17,000 farmers were counted (Ponce, 2023).

(and even robotics), based on artificial intelligence, for diagnostics and decision-making in agricultural irrigation and in the control of humidity and temperatures in very specific productions (berries). Other (medium-sized) grain producers, while still producing with conventional technologies, are incorporating precision methods in sowing and the use of autonomous tractors (Riveros, PC, 2024).

The other group of users, small and medium-sized producers in the regions mentioned above, generally have limited access to these innovations. Not every producer can use them, both because of their cost and the lack of training to operate them (Vargas, PC, 2024). In some cases (mainly regarding medium-sized producers), part of the production process is adopted, especially the use of drones for spraying or for fertilization (hired through specialized companies) (Ponce, PC, 2024; Muñoz, PC, 2024). While drone fumigation reduces costs to less than half (10-12 dollars/hectare), the technology is still expensive for a small farmer (Muñoz, PC, 2024). Another important aspect of the limited or non-existent diffusion of digital technologies among smallholders is related to the generation gap. According to the 2022 agricultural census (INEGI, 2024), 70% of producers are over 45 years old, usually without any knowledge of these technologies.

It is worth noting that among small Mexican producers, the use of various applications in mobile phones and the creation of WhatsApp groups has spread, as well as the multiple options of social networks and internet, to market and exchange advice between producers is widespread (Vargas, PC, 2024). They are frequent users of the marketing applications available in the Agricultural and Fisheries Information Service, (SIAP), a governmental source for knowledge of local and international market dynamics, and even for the placement of crop stocks (Ponce, PC, 2024).

3. Regional Differentiation in the Adoption of Digital Innovations in Mexico

The socio-productive and environmental heterogeneity in agriculture has given rise to the formation of regional spaces with different production patterns and technological capacities in terms of the adoption of innovations.

A study on the capacities for technology adoption in Mexico (Vargas-Canales, 2023), identifies three zones or clusters with different levels of operation of certain variables and levels of access to these capabilities[4]. The region with the best conditions of availability and operation of the variables mentioned is in the northern states of the country, neighbors of the North American market, specialized in agro-export production (states of Baja California, Chihuahua, Coahuila and Nuevo León). In the center and north of the country, 10 states form a cluster with intermediate levels of technological capabilities; in some states in the center-north and south-southeast of Mexico, where the practice of family agriculture predominates, the lowest level of technological capabilities was recorded, as well as the lowest access to internet, computer and mobile phone use (Vargas-Canales, 2023) (see Figure 1).

Regional differentiation is more noticeable when considering the national context of infrastructure for the adoption and implementation of innovations. While electricity coverage for the entire national territory is 99.4 % and 98.6 % in rural areas[5], internet coverage is only 56.5 % in rural areas; moreover, access for agricultural producers is low. Ponce (2023), based on data from the National Agricultural Survey (INEGI, 2019), indicated that of 4.5 million rural production units in the country, only 5.5 percent used a computer; of the same universe, only 7.8 percent had internet access. Similarly, the use of satellite navigation systems was very low (1.8% of the production units). However, the use of telephony was already widespread (88.1%).

4 The variables considered are: 1) information and communication technologies; 2) computer use; internet use; 3) mobile phone use; 4) use of satellite navigation systems; 5) educational level (bachelor's degree); 6) credit availability; 7) agri-food gross domestic product; 8) competitiveness index; value of exports (Vargas- Canales, 2023).

5 In this area, programs such as *Granjas Solares* (Solar Farms), mechanisms of inversion and cooperation between the World Bank and energy-producing sectors in Mexico, for the installation of solar panels in marginal rural areas, mainly in indigenous areas, have been of great importance (World Bank Group, 2017).

4. The Legal-Institutional Underpinning of the Digital Transition in Mexico

Article 6 of the Political Constitution of the United Mexican States establishes the right of all Mexican citizens to access information and communication technologies, broadcasting and telecommunications services, broadband and internet (Ponce, 2022).

The Law for Sustainable Rural Development (LDRS) is the legal and regulatory framework for public policies for the social and productive dynamics that take place in Mexico's rural areas. It establishes the promotion of technological innovations as one of the main axes of rural policy. Likewise, the Federal Telecommunications Institute (IFT) establishes a permanent call to promote the development of digital communications, telephony and internet interconnections throughout the national territory, whether in urban or rural areas.

Regarding the rural environment, technological innovation policies are considered in the Sectoral Program for Agriculture and Rural Development 2020-2024 for the promotion and adoption of 5G technology and artificial intelligence in the primary, secondary and tertiary sectors. One of the central objectives of the National System for Research and Technology Transfer is the permanent promotion of research in order to strengthen sustainable rural development. The LDRS establishes its creation, validation, transfer and appropriation by producers. It recognizes the importance of the latest generation of innovations (digital innovations) and their role in sustainable agri-food production (Ponce, 2022; 2023).

However, the laws, ordinances and various programs on technological innovation for rural development in Mexico have so far implemented isolated experiences, with the intention of strengthening programs and public policies for the dissemination of the transition to digital technologies in agriculture. Most of them are carried out in agro-export production regions, incorporating cutting-edge digital technologies (e.g. control of agricultural irrigation with humidity sensors in the valleys of Sinaloa) and other technological advances based on robotics and remote sensing (precision sowing and use of autonomous tractors in the Bajio region). It should also be noted that, in some cases, digital innovations are carried out as producers' own initiatives, without being part of a specific public program within national rural development policies.

Therefore, it should be noted that, despite not having a defined public policy, in Mexico the study of these innovations is carried out through some governmental initiatives, as well as by specific requirements of producers in precise areas of food production (for example, the development of systems or applications to control nitrogen levels in crops, or ph levels and water stress, etc., or measurement of energy use in the livestock mobility). National scientific institutions are involved because of their interest in incorporating current or dominant lines of research in the international scientific literature and state-of-the-art technological innovations in agriculture.

The development of digital tools in Mexican agriculture is expressed at two levels: The first one is through digital applications developed by the Agri-Food and Fisheries Information Service (SIAP), under the Ministry of Agriculture and Rural Development (SADER). This is the main product of the digital innovations carried out in government bodies. The applications developed have facilitated the marketing of products and access to logistics systems for the mobility of agricultural production, as well as facilitated transactions for all types of inputs. Other important digital services are the Computer System for Traceability of Agricultural, Aquaculture and Fishing Goods (SITM), which incorporates technologies based on satellite analysis with high spatial resolution images and their georeferencing, using Geographic Information Systems (Guerrero PC, 2024). It has been the basis for the creation of other electronic applications, such as *Panorama Agroalimentario* and *Agro Oferta*, in which producers have systematized information on the main agricultural and fishery products in the different areas of the national territory and can offer the products for direct access to national and international markets. Such advances in technology and innovation strengthen production chains (Ponce, 2022; Guerrero, PC, 2024).

The second expression of the digital transition in agriculture has to do with the research carried out by some scientific institutions in order to strengthen the agricultural and rural knowledge base, such as the National

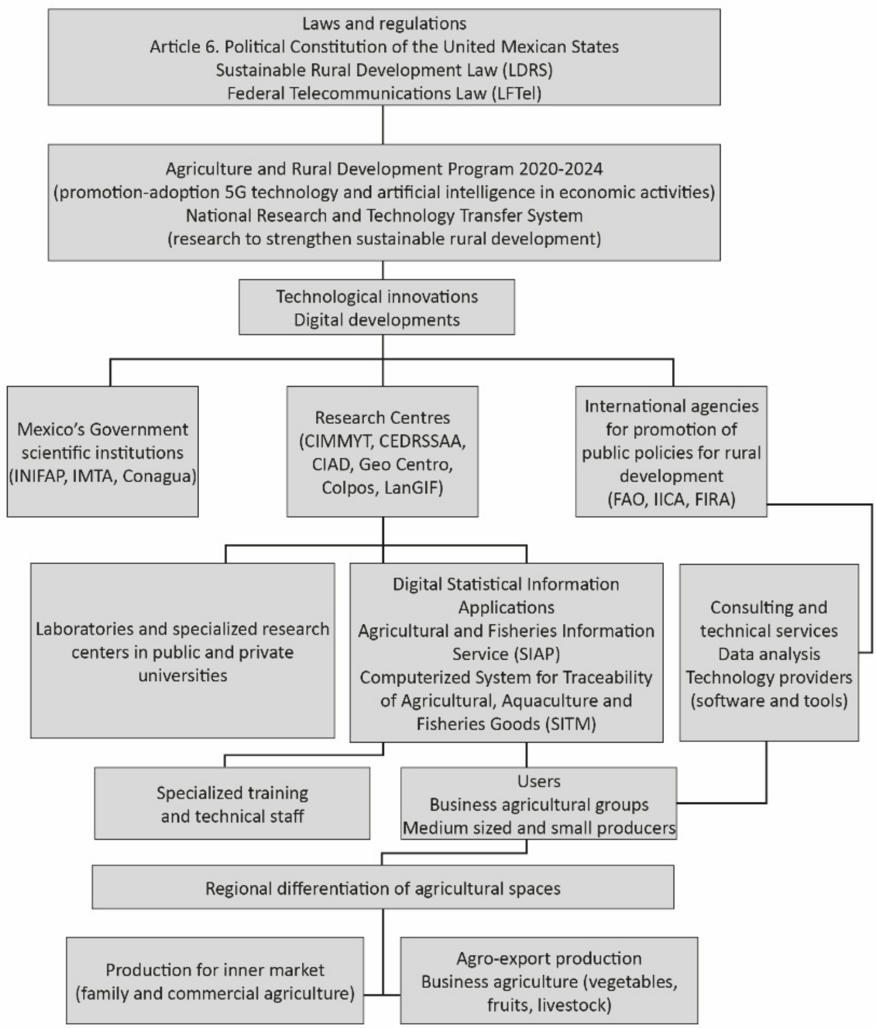
Institute of Forestry, Agricultural and Livestock Research (INIFAP)[6], as well as the Mexican Institute of Water Technology (IMTA). The Mexican Congress, in the Chamber of Deputies, has set up the Center for Studies on Sustainable Rural Development and Food Sovereignty (CEDRSSA), where studies are conducted on one of the central issues in contemporary society: food processes. In the main national public universities, such as the National Autonomous University of Mexico (UNAM), the Autonomous University of Chapingo (UACh), the Antonio Narro Autonomous Agrarian University (UAAAN), the University of Guanajuato (UG) and the University of Guadalajara (U de G), among others, academic spaces have been set up where frontier research is generated on specific topics related to the digital transition in Mexican agriculture, with the intention of disseminating the results to the different sectors of agricultural producers. There are also scientific institutions linked to the national education system, such as the Postgraduate's College (Colpos), the Centre for Research in Food and Development (CIAD), the National Laboratory for the Geoprocessing of Phytosanitary Information (LaNGIF) and the Geo Centre, dedicated to interdisciplinary research in national agriculture. There are also international scientific institutions that operate under various agreements with the Mexican government, such as International Maize and Wheat Improvement Center (CIMMYT), where alliances and services are established through digital platforms for the optimization of agricultural practices and productivity in the different regions of the country (Curiel, 2021)[7]. Likewise, in some private universities, such as the Monterrey Institute of Technology, innovations and digital developments are linked to the teaching of agronomy, especially in the business sector.

Figure 2 outlines an overview of the legal framework, actors and institutions involved in the territorial expressions and manifestations derived from the practice of digital innovations in the Mexican countryside.

6 It is the main agricultural and rural research institution in the federal government. It has 8 Regional Research Centres (CIR) and 38 experimental fields in the different regions and agricultural zones of the country, where technological innovations are generated that seek to impact on productivity and sustainability of agriculture.

7 CIMMYT and Verne Ventures establish a partnership to offer services through digital platforms that optimize agricultural production and facilitate collaboration between farmers.

Figure 2. Digital transition pathway in Mexican agriculture



Construction: Héctor Ávila-Sánchez.

5. Practical Experiences of Research and Digital Applications in Mexico

In the various official programs and documents of the Mexican rural sector, the dissemination and adoption of the latest technological innovations, including digitalization, is established as a central objective. These raise the importance of incorporating these advances and generalizing their advantages and benefits in the different sectors of agricultural producers, especially small-scale producers and *ejido* societies. However, most researchers and the drivers of the digital transition themselves recognize the very limited access that these sectors have to these technological innovations. How can these innovations (digital platforms and robotics) be incorporated into the agricultural practices of small-scale producers? How can mechanisms be established that allow easy access to their uses?

In Mexican scientific institutions, digital innovations are developed at the experimental level, although they are also applied directly to production. Therefore, this text does not suggest there is a lack of applied research in this field, nor is the progress achieved minimized, but rather emphasizes the need to institutionalize complementary programs or policies, which hinder the broad adoption of innovations among producers and, above all, access to them. That is the great challenge.

With reference to the above, some examples are described on the progress of research on the digital transition from governmental scientific bodies, as well as on the modalities of research applied directly in agricultural enterprises.

INIFAP has focused its efforts on creating applications and uses of digitalization for the optimization of water and land use. It has formed highly specialized research areas, such as the National Laboratory for Modelling and Remote Sensing, as well as the National Network of Automated Agrometeorological Stations (RNEAA), equipped with electronic sensors that record meteorological and climatic data. Through these innovations and modelling, agricultural producers are provided with real-time meteorological information for decision-making.

Another scientific development is the SINMAR application (Integrated Irrigation Monitoring and Alert System), developed in 2022 at the Mexican Institute of Water Technology (IMTA). It is a technology based on the use of remote sensors applied to agriculture in order to estimate irrigation times and volumes. This platform has been applied in the Irrigation Districts 010 (Sinaloa, Northwest Mexico) and 020 (Michoacan, in the Centre-West) and is implemented using high-resolution satellite images that monitor each plot in the agricultural areas where the study is being carried out (SADER, 2023). Both interventions aim to raise awareness in small and medium-sized producers on how digital innovations impact profits and maximize production.

At the experimental level, international pilot projects are also being carried out to rehabilitate degraded water bodies and, at the same time, to increase the efficiency of water use for agricultural irrigation. In 2020, following a diagnosis of the degradation of Cuitzeo lake and its basin (in Michoacan, in Central-Western Mexico), the project *1000 Digital Villages* for South-South cooperation CELAC-China-FAO[8] was implemented, in which the National Water Commission (Conagua) and IMTA collaborated. The project aimed to achieve the efficient use of water and fertilizers in an irrigation district (Morelia-Querendaro), as well as the reduction of the water footprint of the crops grown there (*El Acueducto*, 2022). Both interventions aim to raise awareness in small and medium-sized producers on how digital innovations impact profits and maximize production.

On the other hand, there are experiences of technological innovation that are developed on the initiative of large production companies. An example of this occurs in the region of Villa Guerrero, State of Mexico, located 140 kilometers west of Mexico City, where the largest national flower production area (protected and open-air agriculture) is located. *Flores de Chiltepec* is a 100% family-owned company. It has the largest production infrastructure in the region and has specialized in the production of orchids, mainly for export, although it also serves the domestic market with high quality flowers and orchids. For export production, it has introduced technological innovations through computer platforms for the automatic

8 International project for the exchange of experiences and design of digitisation and e-commerce strategies in small and medium-sized family farming. Its objective was to promote digitalization as a post-COVID-19 recovery measure in cooperatives and rural communities in Guyana, Mexico, Chile, Costa Rica and Panama (FAO, 2023).

control and regulation of hourly temperature, light, humidity, vegetative cycle and flowering through a system of sensors regulated by specialized software. This tool is purchased from foreign companies, although they also turn to Mexican companies that provide maintenance for the equipment.

In the specific area of floriculture, large and medium-sized producers consider that there are no state public policies for technological innovation, although there have been some local government programs (marketing strategies or support for production) created in order to influence or improve production or technological innovation. They consider these technologies to be outdated, as they have implemented their own solutions to enter the market, especially the international market. On their own, they have set up their own innovation programs, as well as various forums for training and technological advances and genetic improvement, in which they incorporate local producers with a lower degree of technification. However, the research they carry out is not shared with local floriculturists, as it has been entirely self-financed (Vázquez, 2023).

6. Perceptions of the Digital Transition in the Mexican Agriculture

The diffusion of digital innovations in Mexican agriculture is perceived in different ways, depending on the role played in the agricultural activity (producers, researchers or government officials). Scholars of the subject in question are perhaps the most balanced source for identifying current trends in the Mexican context. The opinions of some specialists dedicated to the study of this type of innovation are presented, in which they analyze the advantages of the main developments and raise their doubts, perspectives and the real scope of such innovations, as well as the state of the regulatory framework and the constitution of public policies regarding the digital transition in Mexican agriculture. They also incorporate the views or opinions of business producers (the main users) and government officials.

7. The Meaning of Digital Innovations in Agricultural Processes

The main purpose of the diffusion of digital technologies in agricultural practices is to generate data that, once processed, provide information for decision-making in the production process. This leads to increased productivity and greater profitability in the agricultural process (lower input costs and lower labor costs, less human labour using drones in fertilization and spraying)[9] (Muñoz, PC, 2024; Vargas, PC, 2024; Ponce, PC, 2024). Some scientists believe that the use of digital innovations would strengthen the sustainability of agricultural activity, with better management in the use of natural resources, especially soil and water (Muñoz, PC, 2024; Vargas, PC, 2024), as well as the recovery and expansion of agricultural food systems. In the end, digital innovations seek to optimize the quality of products and the sustainability of production, fundamental elements in the agro-exporting nature of most of the users of digital innovations.

There are different opinions around the previous use of digital technologies in Mexican agriculture. The use and diffusion of these innovations has been uneven: they have been rapidly adopted by large farmers, while Vargas (PC, 2024) considers ironically that most small producers have not fully assimilated the Green Revolution processes. It is acknowledged, however, that in some sectors of protected agriculture (e.g. flower production in greenhouses), medium-sized producers have gradually incorporated temperature and environment control techniques developed by Thai and Dutch companies (Vázquez, PC, 2024).

The development of digitalization in Mexican agriculture took place during the 21st century (Muñoz PC, 2024). Since 2005, various types of software for the laser levelling of plots began to proliferate in the agricultural valleys of the north of the country and, around the year 2010, precision planting began to spread, especially in the Bajio region. Subsequently, in 2015, the incorporation and widespread use of satellite images and various types of sensors and the operation of autonomous tractors took place. Finally, from 2017 onwards, the use of drones is considered to have become

9 In Tlaxcala (central Mexico), drones are used to spray and fertilize maize crops, which in one day can do the equivalent of 200 days' work (Ponce, PC, 2024).

widespread among medium and large producers, especially in fertilization and spraying (Muñoz, PC, 2024; Ponce, PC, 2024).

8. Research Centers and Universities in the Digital Transition of Mexican Agriculture

Research on the digital transition in Mexican agriculture is not strictly speaking the product of the precise guidelines of a defined public policy on this process. In most research programs on digital innovations in agriculture, developments originate from situations or processes that are already generalized or widely used in the dynamics of agricultural production, mainly due to the need to improve productivity, although they are not always identified with the key axes of national agricultural policy (Ponce, PC, 2024).

In certain national agricultural regions, agri-food production consortia have established partnerships with local scientific and university institutions. In the state of Guanajuato (home to the productive Bajio region), the local government of the R&D area has developed a cluster, which has important links with a local agri-food production cluster (vegetables and dairy), consisting mainly of large agri-food companies located in the region. Together, the two organizations have developed projects on digital innovations for production improvement in the Bajio region. These projects have generally involved organizations such as FIRA (Established Trusts in relation to Agriculture) [10], local governments and foreign investors. [11]

A similar situation has been replicated in the agricultural valleys of Sinaloa (northwest of the country), where groups of entrepreneurial farmers have presented specific needs to public and private universities for the development of applications to be used mainly in precision agriculture (sensors and thermal regulators) (Riveros, PC, 2024).

10 Entity set up by the Mexican government (Ministry of Finance) to support the development of the country's rural, agricultural, forestry and fisheries sectors, through financial intermediaries and specialized companies, the management of credits, guarantees, training, technical assistance and technology transfer to producers and rural enterprises (www. fira.gob.mx).

11 During 2023, the aforementioned organizations were in negotiations with personnel from the UK embassy, who were interested in investing in local agricultural production for export (Vargas, PC, 2024).

In this context, the IFT, as Mexico's telecommunications regulator, tries to influence the development of digital links in all areas of the national economy and, of course, in agriculture. However, as a rule, these calls from the sector are mainly attended by private telephone and telecommunications companies, which are the ones investing in technological developments related to Artificial Intelligence (*FinTech, BlockChains,* etc.). These companies have marketing strategies to position their software production and introduce it into the agricultural sector (Ponce, PC, 2024).

9. Digital Agriculture Policies in Mexico in the Latin America Context

A study by FAO (Food and Agricultural Organization) and CEPAL (Economic Comission for Latin America) shows that the main drivers of digital issues in Latin America are universities and research centers, as well as international cooperation agencies and agricultural producers' organizations, with very specific mandates (Cruz and Aedo, 2021).

The specialists who have contributed their opinions to this text agree that the lack of a precise definition in terms of public policies that regulate the operability of digital innovations in Mexico affects the way in which their impacts on agriculture and rural development are studied. In the Latin American context, Mexico is lagging behind, especially when compared to the progress made in establishing regulations and public policy guidelines for private companies that carry out digital developments and technological innovations in the agricultural export sectors in Brazil (Miglio, 2022; Cepal, 2021), in Chile (Portal AgroChile, 2024), in Argentina (www.kilimo.com) and in Colombia (Agronet, 2024). In these countries, the digital transition is formally considered, to a greater or lesser extent, in public policies for the rural sector (Muñoz, PC, 2024).

It is worth noting that, in 2018, a governmental initiative for developments in artificial intelligence strategies was presented in Mexico called *Estrategia MX*, elaborated by the Ministry of Agriculture at the time (SAGARPA) (Ponce, PC, 2024). A research strategy was designed with the aim of creating public policies to transfer state-of-the-art technological innovations to producers, agro-industry and social and productive organizations. The goal was to address problems such as poverty, low productivity and competitiveness, as well as to promote sustainable practices in agri-food production (SAGARPA, 2018). However, with the change of federal government in 2019, especially due to its ideological orientation, the initiative came to a halt and no significant progress has been made since then in terms of public policy.

Precisely with this change in the new government's approach and objectives for rural development, the promotion of digital technological innovations in the Mexican countryside has not been considered a priority. Official documents do not give it primary consideration, although they recognize its importance and the need to make progress in this area. The Sectoral Plan for Agriculture and Rural Development 2020-2024 (SADER, 2019) identifies as a central objective the restructuring and strengthening of the agri-food sector as a vital element for achieving food self-sufficiency. It also vindicates the role of small producers and peasant groups in the management and practice of sustainable production. It prioritizes the safeguarding of biodiversity and the agro-ecological model in food production. The Mexican Food Security (*Segalmex*) and *Sembrando Vida* (Ávila, 2021) programs were established as the axes of this objective. In neither of these programs does the digital transition figure prominently.

This does not mean that there are no developments or interests in the current government in advancing the digital transition. There are certain advances in the development of applications, such as, for example, what has been called the "digitalization of water", which consists, above all, in optimizing irrigation uses or in tackling natural processes such as water and soil erosion (IMTA experimental programs in highly productive agricultural valleys in Sinaloa and Michoacan); or the research carried out at LaNGIF, where methodologies are developed in order to monitor phytosanitary problems through geo-technologies (remote sensing, geographic information systems and geopositioning), which contribute to the knowledge of the phytosanitary situation in Mexico's agricultural heritage and contribute to the country's food security. Similarly, there are advances in the applications developed by INIFAP through the establishment of specialized geospatial information laboratories based on the analysis of satellite images, as well as the creation of a laboratory-network of meteorological stations to support food production. On the other hand, FIRA has established permanent programs for training in digital innovation, artificial intelligence, marketing and digital development in agricultural production and virtual agriculture. [12]

Another digital instrument in Mexican agriculture is the use of SIAP, whose geo-referenced statistical information functions have been of great use in national agricultural production and is accessed by a large part of producers of all kinds. It provides timely information on the food sector from a specialized geospatial analysis laboratory (Guerrero, PC, 2024; *Agriculture, 4th Report of work 2021-2022*, SADER, 2022).

On the agro-export side, private companies that offer services for digital fertilization management based on scenario modelling have been developed. For example, the private company *Yara* develops applications for the constant monitoring of crops with satellite images for decision-making (*El Financiero*, 2024); other companies offer sales, rental and training in the use of drones for spraying and fertilization, as well as photogrammetric crop analysis (Omega Drone). [13]

Specialists in the field believe that the difficulty of building public policies faces major obstacles in various areas, which hinders this requirement and is linked to the lag in infrastructure in the rural space: the condition of the electrical and electronic infrastructure, the incomplete coverage of internet service; the lack of training of the rural population to incorporate digital advances; the low capitalization of most producers to access the supply of digital services; the absence or lack of companies and services for data processing, and the generational gap between agricultural producers, are among the main problems (Muñoz, PC, 2024; Vargas, PC, 2024; Ponce, PC, 2024).

Another important issue to consider that may hinder the construction of public policies for the digital transition has to do with the absence of regulations to govern the use of data generated by drones, sensors and satellite images. This information is linked to intellectual property and,

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12 https://www.fira.gob.mx/CursosSeminariosXML/

13 https://omegadrone.com.mx/drones-para-agricultura/drones-dji/?gad_source=1&gclid=Cj0KCQjwj9--zBhDyARIsAERjds0l4pa4DyKCZQEco0XMj2JWJNPSxIVHWPJrr8WirQx7RTG7pZSu9kQaAhB- JEALw_wcB

when transferred to those who process it, transfers the possibility of its commercialization. It is a priority task for the IFT to legislate and, subsequently, to monitor its implementation (Muñoz, PC, 2024).

Therefore, the idea is reiterated that Mexico does not have a precise definition of public policies that promote the use and dissemination of digital innovations in agricultural production; in other words, policies that contribute to the consolidation of national R&D based on the dissemination of the uses of digitalization among agricultural producers, especially the smaller ones, who cannot access the use of these technologies. Perhaps there is a wealth of experience with digitization applications in the national territory, but in an experimental and isolated manner, with limited impact and scope.

10. Conclusion. The Current Environment and Prospects for the Digital Transition in the Mexican Countryside

A first conclusion on the digital transition in Mexican agriculture must recognize the incipient momentum of its research on the public agenda and the dissemination of its practical applications. The advances that tend to be applied in agricultural production are still isolated efforts, whose impact on a wide range of producers is still pending. The obstacles are clearly identifiable: limited financial capacity (or even poverty) among rural producers, "digital illiteracy", low capacity to expand the internet access in rural areas, insufficient public or private agencies for data analysis, limited technical training for the dissemination of digital innovations, etc.

A major, urgent task is the skill-building of user-producers, which is very low. Except for mobile telephony, most producers do not have adequate knowledge to use digital technology. The task should be approached in a way that digital education does not lead to the concentration of knowledge and power using information, but rather involves producers with user-friendly programs, in line with their level of education. It is also necessary to strengthen the infrastructure for analyzing and establishing the results of information from drones and sensors, with the aim of reducing the monopolistic effect exerted by large firms on access to different types of software (Vargas, PC, 2024). In this sense, the creation of public or even private companies that share information and permanent training to small producers, at costs appropriate to the purchasing power of those who demand it, should be advocated. Furthermore, it is necessary to have an impact on the generational gap of producers (Muñoz, PC, 2024), which is an issue of great importance, as 70% of the rural population in Mexico is over 45 years old (INEGI, 2024) and is the least receptive to linking up with technological networks. This population group carries out its agricultural work with traditional methods (Ponce, PC, 2024). Another main activity is the establishment of public policies, where public and private companies operate under legal regulations, in which the government controls the generation of data and its analysis in a professional manner to make it accessible to small producers who do not have the intellectual and economic capacity to use it (Muñoz, PC, 2024).

Based on the above, platforms should be created for technical advice, monitoring and control of the production process in order to strengthen specific training to put it at the service of producers, while at the same time enhancing the possibilities offered by artificial intelligence (Muñoz, PC, 2024). Likewise, the perspective of services offered must be considered to seek internal (development banking) and external sources of financing[14] and the adoption of sustainable technologies (Vargas, PC, 2024).

A public policy must be constructed in order to promote a true digital transition, which would have to have differentiated levels in its sectors, according to the receptiveness of the innovations. On the one hand, it would have to be promoted in those population groups that are highly receptive to the proliferation of higher-cost products, and on the others, in the sectors of small and medium-sized producers that participate in the supply of agri-food systems in large metropolises. Consideration should also be given to those sectors of the population that advocate to produce healthy food under traditional agro-ecological systems and in line with the principles of the

14 One example is the establishment of industry-government-academia collaboration agreements between Japan and Brazil to strengthen the establishment of digital and precision agriculture data and technology platforms. https://opsaa.iica.int/resource-209-brasil-y-japon-firman-un-acuerdo-para-desarrollar-la-agricultura-digital (retrieved 29 June 2024).

solidarity and cooperative economy, which can incorporate innovations, while safeguarding their values and cultures in the production process. This public policy should also incorporate young people as a priority, with real incentives for them to remain in their regions and participate in the development of rural economies (Vargas, PC, 2024).

Digitization can impact the social fabric of producers in rural areas. Even so, the transition to digital education would make it possible to optimize the advantages of information and data, incorporating them into the experience and traditional knowledge of producers (Muñoz, PC, 2024). Digital technology could be an option to mitigate the impacts of population and workforce ageing in rural areas (Ponce, PC, 2024).

The construction of a public policy for digital technological innovation in the Mexican countryside must necessarily be linked to other national policies. The Ministries of Agriculture and Rural Development, Communications, Economy, Public Education, universities and governmental science and technology organizations should be oriented in the same logic of the construction of public policies for digital innovation in rural areas, with the intention of systematizing and prioritizing scientific policies and giving a central place to their construction with a multi-scale vision, not only for local, regional and national levels, but also in their international projection. This should be a policy in which the government articulates the roles played by the various institutional actors involved and regulates the use of digital technologies (Sotomayor, et al, 2021). In short, there should be public policies that manage the dissemination of digital innovations to increase or optimise the benefits of the process and productivity, but above all to involve all producers and reduce the inequality, economic and educational gap (Vargas, PC, 2024; Ponce, PC, 2024) and whose priority is digital inclusion (Muñoz, PC, 2024). This is a necessary step to build public policies that have an impact on the redistribution of the benefits of food production in the different agricultural regions of Mexico and that address the issue of inequality, the differentiation of agro-exporting spaces oriented towards external markets and those of domestic production, fundamentally those of family farming (Ávila, 2021).

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10 Economic Instruments as Drivers of the Digital Transition for Family Farming Information Management in Mato Grosso (Brazil)

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1. Introduction

Even with the advance of digital information and communication technologies and the near universalization of access to the Internet and mobile devices in Brazil, there is still a notable lack of reliable (World Bank, 2021) and up-to-date data for decision-making and public policy formulation. This mismatch serves as a starting point for this study.

While large companies use sophisticated systems with algorithms and technologies to find out about Brazilians' digital preferences, habits and routines, governments and organizations (public and non-governmental) still resort to elementary diagnoses with little use of technology and high costs in order to obtain data that, for the most part, is out of date, has various weaknesses and, in many cases, lacks information. Sometimes the data does not constitute information, let alone knowledge for decision-making.

Managers, policymakers and information stakeholders agree on the importance of up-to-date and reliable data as a central input, but are challenged by the costs of collection, lack of recurrence and the disparity of

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information obtained in one-off projects. There are also human and technological barriers (Filgueiras and Lui, 2023) to territorial monitoring in order to generate datasets for different purposes, including supporting healthy food systems and strengthening family farming, the main focus of this chapter. Proponents of digitalization actively argue that it transforms all aspects of the food system, from production to consumption, but also that it has the potential to increase the efficiency, productivity and sustainability of the food system. For some authors, these platforms can connect small farmers to new markets and consumers, as well as provide access to information and financial services, boost productive inclusion and strengthen family farming (Prause, Hackfort and Lindgren, 2021; Nierdele, Schneider and Cassol; 2021).

In Brazil and throughout Latin America, the use of digital technologies for decision-making in agricultural policies, especially in family farming, is limited and the few existing experiences face challenges such as the lack of digital infrastructure, low qualification of users, the high costs involved, the distrust of users and the lack of incentives for research, development and innovation to adapt these solutions to socio-technical needs (Porciello et al, 2023; Bolfe, De Castro and Sanches 2022; Ehlers et al, 2022; Prause, Hacckfort and Lindgren, 2021; Buainain, Cavalcante and Consoline, 2021).

However, before the debate on the pros and cons of technologies and digitalization for agriculture, there is federalism and the role of the State in coordinating and inducing production systems that seek to adopt digital processes. When it comes to federally induced social policies, the most common coordination problems are related to the difficulty in obtaining *buy-in*, generating intersectoral and interfederative coordination (interactions between different federal entities), and the need to ensure that the state can play a role in coordinating and inducing production systems that seek to adopt digital processes (Bonduki and Palotti, 2021) and ensure homogeneity of service provision at the citizen level (Bonduki and Palotti, 2021).

Without incentives and coordination, there is no reason or motivation to systematically generate data and information to support platforms and processes for formulating, implementing, innovating and managing data. Digital platforms and applications are developed and launched in a flurry of initiatives, but quickly become obsolete or forgotten, mainly due to the absence of the central input: primary data, which does not arrive or arrives without planning, recurrence, reliability and quality.

This reality is present in all of Brazil's federal units, with some entities more structured for carrying out studies and diagnoses, such as the Federal District and its technical assistance and rural extension company with installed capacity (Ávila, 2011), and in other cases, such as the state of Mato Grosso, seeking to establish strategies so that the development of policies for family farming and the environment involves multi-actor and multi-level arrangements (Faure, et al, 2007).

The contribution that this chapter aims to make is related to the path undertaken by the state of Mato Grosso, in Brazil, to implement a digital information system for family farming, its strategies, instruments and pathways, and the efforts to decentralize part of the implementation of the State Plan for Family Farming (PEAF). The goal is to understand how the digital information system contributes to the collection, management and dissemination of data on family farming and its impact on the sector's practices and policies, examining the strategies and instruments used in its implementation, identifying good practices, challenges and solutions. Finally, it proposes recommendations for improving the digital system and decentralization strategies, with a view to greater effectiveness and alignment with the objectives of the PEAF.

2. Information Technologies, Digitalization and Rural Development

Governments must help facilitate productive transformation; the needs of the productive sector must be addressed, and incentives are urgently needed for the incorporation of technologies, application of policies, updating of regulatory frameworks and the creation of digital skills and capacities.

Knowing that digital technologies are increasingly important for agriculture around the world, and especially in Low-and-Middle-Income Countries (LMICs), it is understood that technologies can help farmers increase productivity, reduce costs and improve sustainability. However, there is still much to learn about how digital agricultural services can be more effective in these countries.

Porciello et al (2023) identified five main categories of digital agricultural services: i) Information and communication: Providing farmers with information on market prices, weather conditions and agricultural practices; ii) Financial services: Facilitating access to credit, insurance and other financial services; iii) Production management: Helping farmers manage their crops, livestock and natural resources; iv) Marketing: Connecting farmers to markets and buyers; and v) Education and training: Providing farmers with training and technical support.

Ehlers et al. (2022), analyzing scenarios for European agricultural policy-making in the age of digitalization, explore how digitalization is transforming the landscape of European agriculture and present four possible scenarios for agricultural policy-making: Scenario 1: "Light Digitalization": poor digital infrastructure; Scenario 2: "Autonomous Technology": limited integration of digital technologies; Scenario 3: "Digital Food business": special policy issues autonomous technology cannot address; 4: "Digital Regulation": program to support capacities of farms to innovate and produce.

In the last decade, initiatives by governments and different organizations have sought to expand the use of information and communication technologies to support public policies and for the end users themselves, be they farmers, technicians or researchers. A study by ECLAC (2020) indicates that digitalization (the development of advanced technologies such as 5G, the Internet of Things and artificial intelligence) could lead to a 15% reduction in carbon emissions by 2030.

Within the scope of a digital productive transformation, different areas for policy action are identified, including: investment, innovation, skills, regulation and infrastructure, among others.

For Deponti, Kirst and Machado (2017), the relationship between information and communication technologies (ICTs) and family farming represents a potential to be developed in Brazil. Through an in-depth analysis, the authors identify not only how ICTs can strengthen the sector, but also recognize the challenges that need to be overcome for this potential to be fully realized.

According to the authors (2017), ICTs are valuable tools for the development of family farming in various areas, positively impacting production, marketing, management, education and social organization of farmers. In production, for example, they help with efficient management, optimizing resources, monitoring crops and pests, as well as facilitating access to relevant technical information in order to increase productivity and production quality; and in marketing, they open doors to new markets, enable online sales, add value to production and optimize logistics, expanding sales and income opportunities for farmers (Deponti, Kirst and Machado, 2017).

When it comes to management, Deponti, Kirst and Machado (2017) point out that ICTs facilitate property management, financial organization, stock control and access to credit, promoting the organization and sustainability of agricultural enterprises. Also, in the field of education and training, ICTs democratize access to courses, training and technical information, and encourage the sharing of knowledge among farmers, boosting learning and the professionalization of the sector. Finally, in the words of Deponti, Kirst and Machado (2017), ICTs strengthen farmer's social and political organization, facilitating participation in public policies, access to public services and the defense of their rights and interests, promoting empowerment and social inclusion of family farming.

3. Tools, Information and Knowledge in Support of Public Policies

Policy implementation is subject to different analytical lenses (human relations, organizational, political, technical and systemic, or even a combination of these). The underlying idea is that any public policy is composed of a series of means through which the State acts, exercises its power or limits it, such as the use of regulation, subsidies, information campaigns, among others, to influence citizens' behavior and achieve public policy objectives, solving identified social problems and providing citizens with appropriate goods and services (Hood, 1986; Salamon, 2002).

Vedung and Pedone (2021, p.180) speak of three tools or instruments at the disposal of governments: the "stick" - referred to as regulation; the "carrot" - understood as economic measures (incentives or disincentives); and the "sermon" - as information. This vision does not suppress the approach of Lascoumes and Les Galès (2012, p.13), who define an instrument for governing as both a technical and a social device that organizes specific social relations between the public authority and its recipients according to the representations and meanings it carries. In an attempt at synthesis, Moura (2016) points out that public policy instruments can be classified into four main types, although hybrid instruments are also common, with characteristics present in more than one typology: i) regulatory or command and control instruments (Command and Control); ii) economic instruments (EI) - market or incentive-based; iii) cooperation instruments and voluntary agreements; and iv) information instruments.

The perspective of public action instruments, understood here as policy instruments as "the set of techniques through which government authorities exercise their power in an attempt to secure support and effect social change" (Vedung, 1998, p.67), appears to be that of management science, where the terms dispositive, tool and instrument underline the heterogeneous nature of these instruments, all of which, however, consist of three components: a technical substratum, a schematic representation of the organization and a management philosophy.

For Maugeri (2001), management instruments are not essentially aimed at economic performance, but rather at controlling individuals and ensuring their adherence to the organization's objectives. According to Maugeri (2001), public policy instruments are essential tools that structure the definition, implementation and evaluation of government actions, ensuring effectiveness and efficiency in responding to society's needs and problems. They play a fundamental role in translating political decisions into concrete actions, enabling the administration and control of public policies.

4. The Trajectory and Context of Family Farming in the Public Policies of the State of Mato Grosso

Mato Grosso is the first state in the ranking of Greenhouse (GHG) emissions in Brazil[1]. Of the total emissions in 2022, 71% are due to deforestation of the Amazon rainforest, which is closely linked to livestock farming. To reduce these emissions, the state of Mato Grosso created a strategy in

1 https://plataforma.seeg.eco.br/

2015 based on a set of ambitious targets: the Produce, Conserve and Include (PCI) Strategy. One of the main objectives of the PCI Strategy is to guarantee the socio-productive inclusion of family farming and to promote alternative economic activities to livestock and soy, which generate income for families and avoid further deforestation. In parallel, in 2016, Mato Grosso joined the Partnership for Action on Green Economy (PAGE) to develop and implement sustainable policies and strategies, integrate green practices into productive activities, form partnerships with different organizations and sectors, promote local initiatives focused on clean technologies and sustainable management, and establish mechanisms for monitoring and evaluating the impacts of actions.

To broaden the impact of the ICH Strategy on the inclusion of the family farming a joint effort is needed, including: (1) local agreements that promote the inclusion of rural communities; and (2) the effective implementation of government programs, such as the Food Acquisition Program (PAA) and the State Plan for Family Agriculture (PEAF MT), under the State Secretariat for Family Agriculture (SEAF MT), with strategies to improve access to credit, training, technical assistance and administrative support.

The State Secretariat for Family Agriculture of Mato Grosso (SEAF MT), created in 2015, was a milestone for the segment in the state. The first State Secretariat of Agriculture, created in 1979, and its successors planned actions for small scale agriculture, but in the background, to the detriment of agribusiness. These secretariats that preceded the SEAF MT had structured units for managing data and information on soy, corn, cotton and livestock production chains, but with the strengthening of agribusiness entities in Mato Grosso, the activities of collecting, processing and analyzing these data were gradually taken over by the sector itself.

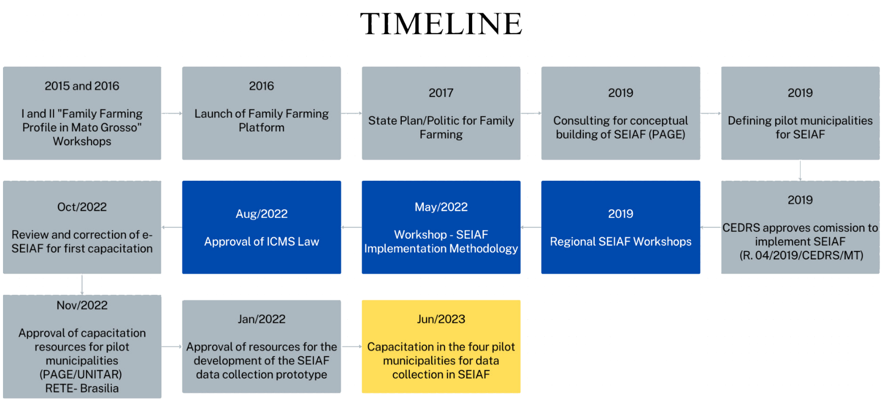
With the creation of the SEAF MT in 2015, without the internal (and unequal) institutional dispute with agribusiness that took place in the previous secretariats, a pilgrimage began in search of data and information on family farming, motivated by the need to obtain subsidies to build more effective initiatives for the segment that has come to occupy a prominent place in the state. Since then, managers, technicians, civil society organizations, social movements and the third sector have mobilized to collect and organize data on family farming in Mato Grosso. Between 2015 and 2017, under the coordination of SEAF MT, with the technical and financial support of the Amazonia Environmental Research Institute (IPAM), several meetings were held with public and civil society organizations linked to family farming to develop strategies for building an electronic database of production, socio-economic, environmental and territorial data and information related to the sector, culminating, in 2017, with the launch of the Mato Grosso Family Farming Platform, which operated until 2022, bringing together secondary data from various official sources on the number of family farming establishments, Technical Assistance and Rural Extension (ATER), Declaration of Aptitude to Pronaf (DAP), credit, production, territorial and environmental regularization, Traditional Peoples and Communities (PCT) and commercialization.

Taking advantage of the evidence and institutional security given to family farming with the creation of the SEAF MT and the articulation and involvement of institutions in the elaboration of the profile of family farming in the state, which subsidized the creation of the Platform, the construction of the State Plan for Family Farming in Mato Grosso (PEAF MT) began, based on an intense process of participation and social control led by the State Council for Sustainable Rural Development (CEDRS MT). The Plan, currently in force, is a guide of actions to promote the sustainable development of family farming in the state, but it is not characterized as a strategic plan due to the absence of some necessary elements, such as targets and indicators.

The State Policy for the Sustainable Rural Development of Family Farming in Mato Grosso, the Platform and the PEAF MT were launched in the same year, 2017, and, together with the creation of the SEAF, almost solidify an institutional framework and legal frameworks for family farming in the state, were it not for the lack of a mechanism for collecting and processing primary data on the segment, since secondary data does not provide all the necessary subsidies for the construction of the Strategic Plan for Family Farming, which would allow for more effective implementation, monitoring and evaluation of public policies for family farmers.

The following year, in 2018, around this demand, which is also included in the PEAF MT, and based on a conceptual idea and a proposal for a data form developed by the SEAF MT, several institutions, especially from civil society, offered to contribute technically and financially to the construction of the Integrated State System of Family Farming in Mato Grosso (SEIAF MT) to collect primary data on family farming in the state. Some of these initiatives and actions are represented in the following timeline (Figure 1).

Figure 1. Chronology of family farming monitoring system initiatives in the state of Mato Grosso.



5. Digital Induction Strategy for SEIAF in Mato Grosso: Between Carrots and ICMS

On an expanded scale, the PCI (Produce, Conserve and Include) strategy is at the heart of a set of actions whose main focus is to raise funds for the state of Mato Grosso with the aim of expanding and increasing the efficiency of agricultural and forestry production, conserving the remnants of native vegetation, restoring environmental liabilities and the socio- economic inclusion of family farming and generating a reduction in emissions and carbon sequestration of 6 GTon of CO_2, by controlling deforestation and developing a low-carbon economy.

The PCI was launched in 2015 during the Conference of the Parties 21 (COP21) of the United Nations Framework Convention on Climate Change (UNFCCC). The PCI strategy brings together government agencies, civil society organizations, farmers' organizations and businesses to help respond to the multi-faceted challenge of climate change.

PCI's shared vision is based on three principles with specific performance indicators: 1) Produce: Increasing efficiency in livestock, agricultural, timber and biofuel production. Increasing productivity is a key objective, as it will allow agricultural production to expand without further deforesting the state; 2) Conserve: Conservation of native vegetation and restoration of degraded areas; 3) Include: Socio-economic inclusion of family farming and the traditional population.

In the specific case of SEIAF, the Secretariat of Family Agriculture used a combination of instruments described in the literature as "carrots" and "sermons" to get municipalities to adhere to the implementation process, which will be detailed below. In order to implement SEIAF, the Secretariat of Family Agriculture combined incentive ("carrot") and penalty ("sermon") strategies: it offered benefits and financial advantages to municipalities that adhered to the system, while imposing penalties or consequences on those that did not, in order to ensure adherence and effectiveness of the process.

The terms "carrot" and "sermon" represent two different types of economic instruments used in public policy to influence the behavior of individuals and organizations. The "carrot" refers to positive incentives, such as subsidies, tax breaks and other financial rewards, which are designed to encourage desirable behaviors in line with policy objectives. On the other hand, "sermon" involves information, education and moral persuasion campaigns in order to change attitudes and behaviors through awareness-raising and communication (Salamon, 2002).

The strategy of the Family Farming Secretariat of the State of Mato Grosso with the Family Farming Information System (SEIAF) refers to the concept of *enforcement* as the idea of force of law and, more broadly, the effort – through some kind of force or pressure – to ensure compliance with certain decisions. The combination of information and economic instruments for adopting the system and decentralization as a strategy for the territorializing of information collection are incentives which, in our analysis, favor the digitalization process and which are portrayed here in their construction and trajectory.

The SEIAF MT is currently implemented by the State Complementary Law nº 746 of 25/08/2022 and its regulation (State Decree nº 1.514 of 04/11/2022), which foresee its use as a necessary factor for access to ICMS collection amounts based on the family farming criterion. The Tax on the Circulation of Goods and Services (ICMS) is a Brazilian state tax on the circulation of goods and services, levied by the states and redistributed to municipalities, and can be used as an instrument to incentivize behavior and public policies, such as adherence to systems that include family farming. Therefore, the ICMS not only serves as an important source of revenue for states and municipalities, but is also a public policy instrument that can be used to promote or encourage certain administrative actions and behaviors.

6. Provisions and Innovations to Induce Adherence to SEIAF in MT

Despite the budget forecast in SEAF MT's official planning instruments to support the construction of the SEIAF MT, little was done with public resources, reflecting the managers' fear of revealing the chronic problems of family farming in Mato Grosso through the data collected and being conditioned to direct the public budget according to the results. SEIAF MT's initial leverage was only possible thanks to the technical and financial support of the Partnership for Action for a Green Economy in Mato Grosso (PAGE MT), a global program of the United Nations (UN), the REDD *Early Movers* Program (REM MT Program) and the *Instituto Centro de Vida* (ICV), which provided consultancy services, public listening events on the SEIAF MT proposal, visual identity, IT material, services for building the prototype of the electronic tool (e-SEIAF MT) and vehicles for the implementation of the system in pilot municipalities.

The construction of SEIAF MT continues to move forward with the support of the CEDRS MT and the addition of more partner organizations, but with little support from the SEAF MT leadership and the state government in general, and the absence of a legal framework to establish the system. In 2020, in the midst of the Covid-19 pandemic, the state government began negotiations with the International Bank for Reconstruction and Development (IBRD) for an $80 million loan to promote sustainable rural development of family farming in Mato Grosso. The implementation of the SEIAF MT is advocated by SEAF MT and considered strategic by the Bank's team, making it one of the key project's main products.

In 2021, while the loan project with the World Bank was still being drawn up, the State Government was asked to reform the criteria for the distribution of the Goods and Services Circulation Tax (ICMS) to municipalities, following the enactment by the Legislative Assembly of Constitutional Amendment 108, of August 26, 2020, which began to benefit municipalities with better management performance. Prior to Constitutional Amendment 108, the distribution of ICMS to municipalities was based primarily on the proportion of added value of goods and services in each locality. There were no criteria that considered the management performance of municipalities, which meant that the distribution of the tax did not encourage administrative improvements or the implementation of local public policies.

The Mato Grosso State Finance Secretariat (SEFAZ MT) then suggested the inclusion of a criterion related to family farming and asked the World Bank (at that time very familiar with the reality of family farming in Mato Grosso due to its participation in the preparation of the project related to the loan) and SEAF MT for details on the Municipal Family Farming Index (IAF).

The initiative was recognized by the Federation of Agricultural Workers of the State of Mato Grosso (FETAGRI-MT), the Association of Municipalities of Mato Grosso (AMM) and the State Parliament. The opportunity had arisen to legally establish the SEIAF MT and to encourage municipalities to join the system through economic benefits.

What is known is that the Municipal Family Farming Index (IAF) is calculated based on several criteria: the coverage of technical assistance and rural extension, the percentage of family farming food purchased for school meals (in accordance with Federal Law 11.947/2009, with a minimum of 30% for school meals) and the index of municipal efforts to boost family farming. This data is used to adjust the share of the ICMS transfer to municipalities, 2% of which are conditional on adherence and performance in SEIAF MT.

The calculation of the IAF includes the evaluation of compliance with data collection requirements and the integration of information into the system, promoting the inclusion of family farming in the formulation and implementation of public policies.

State Supplementary Law no. 746 of August 25, 2022, then provides for the IAF to be calculated taking into account adherence to SEIAF MT, compliance with the adhesion term (which includes data collection, the functioning of the Municipal Council for Sustainable Rural Development and the preparation of the Municipal Plan for Family Farming) and the municipal effort index to promote family farming, which will be calculated annually by SEAF MT.

Mato Grosso state legislation establishes that 25% of the collection of the tax on transactions relating to the movement of goods and the provision of interstate and intercity transport and communication services (ICMS) belongs to the municipalities. The 25% is made up as follows: at least ¾ (75%) in proportion to the value added in the municipality; up to ¼ (25%) in accordance with state legislation. In the state of Mato Grosso, the State Complementary Law 746, of August 25, 2022, defines the Municipal Participation Index (IPM) as a distribution criterion. Currently, the MPI is calculated according to the criteria listed in Table 1.

Table 1. Criteria adopted by SEFAZ to distribute ICMS to municipalities.

	Responsible organization	2022	2023	2024	2025	2026
				%		
Added value	SEFAZ	75	65	65	65	65
Own income	SEFAZ (TCE)	4	2	2		
Population	SEFAZ (IBGE)	4	4	3		
Area	INTERMAT	1				
Social coefficient	SEPLAG	11	11	11	11	11
Conservation Unit/Indigenous land	SEMA	5	4	3	3	3
Educational results	SEDUC		10	10	12	12
Health results	SES		4	4	5	5
Family farming	SEAF			2	2	2
Fundraising efforts	SEFAZ				2	2
TOTAL		100	100	100	100	100

Article 1 of the annex to Decree 1,514/2022 establishes the relationship between the e-SEIAF and the Municipal Family Farming Index (IAF), stating that:

> Art. 1 The Municipal Family Farming Index - IAF will be calculated taking into account the adhesion to the State Integrated Family Farming System - SEIAF-MT, the compliance with the adhesion agreement and the municipal effort index to promote family farming, calculated annually by the State Secretariat for Family Farming - SEAF and sent to the State Secretariat for Finance - SEFAZ before May 31 of each year (cf. art. 12 of LC n 746/2022).
>
> § 1 For the purposes of this annex, the Integrated State System of Family Farming SEIAF MT comprises the electronic tool for the collection of quantitative and qualitative data and information on family farming in the municipalities of the State of Mato Grosso, with the objective of subsidising the construction, implementation and monitoring of actions aimed at strengthening the segment.
>
> § 2 The IAF for each municipality will be calculated annually, starting in 2025, using the basis of the previous year's data, which will take into account the coverage of rural technical assistance in the municipality's territory and the purchases of family farming products for school canteens in the respective municipal network.

The same annex established adhesion to SEIAF-MT as the sole condition for compliance with the IAF:

> Art. 3 Exceptionally, for the calculation of the IAF in 2024, based on the data obtained in 2023, for transfer in 2025, the municipality's membership of the Integrated State System Family Farming (SEIAF MT) shall be taken into account exclusively.

Effectively, the SEIAF will be responsible for generating the information needed by the Secretariat and will be equipped with the e- SEIAF electronic tool, which will allow the collection, entry, organization and storage of family farming data at municipal and local levels. Exceptionally, the accession of municipalities to the e-SEIAF was used as a synonym for the IAF to calculate the 2025 transfer (Textbox 1).

Textbox 1. Impacts and benefits of the implementation of the SEIAF MT in Alta Floresta - Mato Grosso.

The municipality of Alta Floresta has just over 58,000 inhabitants and is located in the territory of *Portal da Amazônia*, in the north of the state, where family farming is present in 1,198 (71%) of the 1,675 establishments in the municipality. In December 2023, the ICMS transfer reported by the Secretariat of Finance to the municipality was in the order of R$ 4,393,091.77. This means that non-adherence to SEIAF could mean a reduction in the monthly transfer of around R$ 87,861.87 (2%) to the municipality's public coffers.

Joining the SEIAF MT also means strengthening local social control and supporting the formulation of the Municipal Family Farming Policy and Plan. The aim is to help build the institutional and legal framework for family farming in the municipalities already consolidated in the state. Another objective is for the system, in its data collection work, to promote greater and better integration at the local level of the institutions involved in family farming.

The index of municipal efforts to promote family farming in each municipality will also be calculated annually by the SEAF MT, taking into account the coverage of technical assistance and rural extension in the territory of the municipality and the purchase of family farming products for school meals from the respective municipal education network, the weight of which will be set at a minimum of 30%, in accordance with Federal Law 11,947 of June 16, 2009, which deals with the National School Feeding Program (PNAE).

According to the new methodology, the improvement of education in the municipalities is equivalent to 10% of the ICMS transfer, value added to 65% and the remaining 25% is transferred according to criteria defined by the state government, with the criterion related to family farming corresponding to 2%.

With State Complementary Law 746 of August 25, 2022, the SEIAF MT is consolidated as a mechanism for collecting primary data and information on family farming in the municipalities of Mato Grosso in order to support the formulation, implementation and monitoring of actions aimed at strengthening the segment. The SEIAF MT and its articulation with the receipt of ICMS have become a unique initiative in Brazil.

Since the publication of the Law, which now has force of law, SEIAF MT managers have given priority to SEIAF MT, including the allocation of their own financial resources to improve the electronic tools of the System (web and app versions). With the institutionalization of SEIAF MT, debate on the data collection methodology, still to be defined, was resumed. To help define it, ICV contracted the *Centro de Gestão e Inovação da Agricultura Familiar* (CEGAFI) of the University of Brasilia (UnB), which proposed a methodology to be tested in pilot municipalities.

Also in 2022, the *Produce, Conserve and Include* Institute (PCI Institute), based in Mato Grosso, which involves the state government in its management with the aim, among others, of raising funds for the socio-economic inclusion of family farming, included the implementation of SEIAF MT as one of its objectives. The Institute has global visibility, including a prominent role in climate conferences (COP), and has taken SEIAF MT around the world. In 2022, the *Produce, Conserve and Include* Institute (PCI Institute), was created by State Law no. 10,383/2017, of July 17, 2017, with the objective of promoting sustainable production, environmental conservation and socio-economic inclusion, and which has the participation of the State Government. The Mato Grosso government has included the implementation of SEIAF MT as one of its objectives.

In 2023, CEGAFI tested the proposed methodology in pilot municipalities along with a prototype of the mobile data collection application, and the "SEIAF MT Manual" was consolidated as a general guide for municipal governments. The same priority given to SEIAF MT by SEAF MT managers after its establishment by law was observed in relationship with municipal managers, with 100% of Mato Grosso municipalities joining SEIAF MT by 2023, attracted by the financial gain due to the transfer of increased value from ICMS.

Specifically in the case of Family Farming, the digital innovation presented here consists of adopting of an instrument that encourages municipalities to cooperate with the subnational state by economic means. There is no gain in joining SEIAF, but not joining implies a loss in the transfer of the ICMS parcel.

7. Experiences, Lessons Learned and Recommendations

The initial implementation of e-SEIAF by the Secretariat of Family Agriculture in the state of Mato Grosso offers valuable experience, highlighting the importance of digitalization in information management for family farming. Data collection in SEIAF MT takes several digital approaches: rural producers can self-declare their own information directly on an online platform accessible by computers and mobile devices; there is also technical support, where professionals assist with data entry, both in person and remotely, using digital tools. In addition, technicians and authorities can collect data directly in the field, using mobile devices connected to the central system to ensure real-time synchronization and updating.

These experiences reveal important benefits of digitalization, such as greater efficiency in data collection, increased accuracy and continuous updating. The integration of multiple data sources provides a more complete view of the agricultural reality, contributing to more effective management. However, these experiences also highlight challenges, such as the need for adequate training for producers and technicians in order to ensure the effective use of digital tools. Digital inclusion emerges as a critical aspect, as not all producers have access to the necessary technology or connectivity, which can limit the system's reach. Managing large volumes of data requires not only a robust infrastructure for data storage and processing, but also compliance with privacy and data protection regulations. Security measures are essential to prevent unauthorized access and maintain the integrity of the information.

The lessons learned result in several recommendations for the continuous improvement of SEIAF MT. For SEIAF MT, it is essential to invest in the continuous training of producers and technicians, ensuring that all those involved can effectively use the available digital tools. To this end, it is important to promote digital inclusion, ensuring that all producers have access to the technological resources and connectivity needed to participate fully in the system. In addition, strengthening IT infrastructures is essential to managing large volumes of data and ensuring compliance with privacy and information security.

It is also recommended that the SEIAF MT digital tool continues to integrate economic and legal incentives to strengthen the commitment of 141 municipalities in the state. The linkage of the 2% ICMS transfer to the implementation of practices that favor family farming and public procurement for school feeding should be maintained, as it ensures the commitment of municipalities to support family farming. This strategy of incentives and penalties not only stimulates municipal participation, but also establishes a monitoring system that aligns local interests with state objectives.

For the coming years, it is recommended continuing to strengthen SEIAF MT with various financial resources and strengthening the generation of primary information on family farming in a systematic and coordinated way, without relying exclusively on federal censuses or private surveys. The proposal to decentralize implementation, directly involving municipalities, must be strengthened to ensure the sustainability and effectiveness of the system.

Finally, it is recommended that a specific strategy be developed that includes the municipalization of data collection activities, including the collection of information on Indigenous Peoples and Traditional Communities. It is also a priority to create a data dissemination channel that is accessible, didactic and easily manipulated by the population, promoting transparency and community engagement.

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11 The Digitalization of Agricultural and Environmental Public Policies in Brazil[1]

Karina Kato, Valdemar João Wesz Junior, Matheus Korting

1. The Digitalization of the Agri-food System and Agriculture: Introduction to the Debate

Digital technologies are rapidly transforming many areas of our lives. The Food and Agriculture Organization of the United Nations has stated that "digital technology is the future and efforts to ignore or oppose it will fail" (FAO, 2019)[2]. In fact, the digitalization of the agri-food system is postulated as the solution to meeting the food demand of a population of 9.8 billion people in 2050 with a more sustainable and inclusive agri-food system.

Documents from international organizations, major NGOs and governments emphasize the connection between digital transformations and the ecological crisis, which Brunori (2022) calls the "twin transition". From this perspective, digitalization is seen as the infinite source of tools to cope with the complexity of more diversified farming systems, optimize the

1 The chapter is part of the reflections undertaken in the research project "The rural in times of financialization and digitalization: business strategies, reformulation of regulatory frameworks and new forms of appropriation of land and nature" (FAPERJ E-26/2010.120/2023).

2 The digitalization of the agri-food system is the trend towards the use of digital and data technologies at all stages of the agri-food system, from production (*on-farm*), services and support sectors to production (*off-farm*) and at all other stages up to the marketing and consumption of food. The digitalization of agriculture therefore corresponds to the processes of applying digital and logical technologies (and digital data) in the decision-making process and in the management of the production process in agriculture.

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use of inputs, reduce the physical effort of farming, simplify administrative tasks, improve communication between producers and consumers, anticipate risks and accelerate adaptation. However, some studies have also highlighted the risks and challenges of digitalization, which are often "forgotten" in more optimistic analyses. These critical studies have pointed to the need to investigate the trajectory of digitalization and its impacts on territories (Lioutas et al., 2021; Trendov et al., 2019).

The debate on the consequences of the application of new digital technologies is not new. At the end of the 1990s, Castells (in his book "The Network Society" 2005) already warned about the impacts of information and communication technologies. The field of science and technology studies offers us interesting ideas for reflecting on these technological transformations. It reminds us that machines and scientific discoveries are not neutral and do not develop in a vacuum (Jasanoff and Kim, 2015): they are the result of the actions of human beings and of the interested institutions that shape them and set them up, promote them and finance them (Jasanoff and Kim, 2015).

We understand that technological systems (and their applications in the agri-food system) are first and foremost social constructions (Jasanoff and Kim, 2015) or socio-technical processes (Klerkx et al., 2019). Technological innovations and society are therefore continuously interrelated in a process of co-production. From this perspective, the "real" and "virtual" are not separate, but co-constructed. The trajectories of technological transformations point to certain socio-technical imaginaries that are "collective, institutionally stabilized and publicly realized visions of desirable futures, animated by and supportive of shared conceptions of forms of social life and social order achievable through advances in science and technology" (Jasanoff and Kim, 2015). These futures create certain worlds, while making others impossible.

In the agri-food system, the application of technologies, computers, peripherals and even networks is nothing new. The technical process of application of digital technologies to convert analog information into digital, increasing storage and processing capacity, is known as digitization. Digitalization, in turn, refers to the deepening of this process, with the potential to alter networks of actors, artifacts, regulations and their relationship with nature (Brunori, 2022).

Currently, the digitalization of agriculture is characterized as a diffuse and multifaceted process: it develops along different technological pathways, ranging from the simple use of smartphones and social networks to artificial intelligence, full robotization and the development of the internet of things (Klerkx et al., 2019). Trendov et al. (2019) classify digital technologies according to their complexity and stage of penetration in the agri-food system: a) the use of mobile devices (phones) and social networks; b) the application of precision agriculture and remote sensing (internet of things, among others); c) the use of big data, cloud storage, analytics and cybersecurity; d) integration and coordination (*block-chain*, digital management platforms, financial and insurance systems); e) the use of new technologies in the agri-food system; and

f) the development of intelligent systems (deep learning, machine learning and artificial intelligence, robotization and autonomous systems).

A gap identified in reflections and analyses on digitalization has been the problematization of the role of public policy (Klerkx et al., 2019). There is little research on the new policy arenas that lead public managers and politicians to increasingly interact with technology companies and *agri-technologies*; the influence of public policies and regulations in shaping an enabling environment for innovations aimed at bridging the digital divide and promoting more sustainable instruments (Kukk et al., 2022; Ehlers et al., 2021); and on the risks of digitalization in shaping an agri-food system centered on corporate and financialized agriculture and the neglect of the state and public policies (Klerkx et al., 2019).

In this chapter, we will look at a specific dimension of the digitalization process in agriculture: the digitalization of policies or public policy instruments. Advancing in this reflection becomes even more urgent if we consider that the process of digitalization of public policies is already a reality. In Latin America and Brazil, an important dimension has been the integration of digital technologies and logics in environmental and land policies, which has led to a complete transformation of the logic of these instruments. Thus, although the literature exalts the role of private companies (EMBRAPA, 2018), there is still a crucial role played by the State.

Brazil is a country that is progressively advancing in the digitalization of public structures (Brazilian Digital Transformation)[3] and plays an important role in the global agri-food system, with a powerful agro-industrial sector subject to social and environmental criticisms and constraints. The Brazilian case can offer important clues for problematizing the digitalization of public policy instruments and its implications for rural areas and agriculture. This case is part of a broader trend in Latin America, as shown by Grain's research (2020), which consists of multiplication of digital records with information on land and natural resources as a guide for credit policies, environmental compliance and land regularization.

Specifically, this chapter will focus on the Rural Environmental Registry (CAR), an initiative implemented at the national level in 2014 as part of the reforms of the Brazilian Forest Code (2012). This experience allows us to reflect on different dimensions of the digitalization process of a cadaster aimed at environmental regularization and its interconnections with land regularization. By reviewing its application in the state of Pará, we will try to highlight how the digitalization of these public policy instruments is influenced by the interests of the most capitalized actors in the territory and how the incorporation of these digital logics ends up reinforcing the dynamics of privatization and expansion of the extractive frontier. To this end, three specific cases were selected that allow us to observe these dynamics in an applied manner: the livestock sector in the southeast of Pará, mining in Canaã dos Carajás and the grain segment in the Santareno plateau. Pará, in addition to being a large Amazonian state (with a larger surface area than Colombia), has been the scene of intense land use changes in recent decades (MAPBIOMAS, 2024), facing a wide and complex set of environmental problems, such as deforestation, and land problems, such as

3 Since the 2000s, the Brazilian government has included information and communication technologies in its Electronic Administration Program. Since then, a series of initiatives have been created to digitalize public services. In 2018, the Brazilian Digital Transformation Strategy (E-Digital) was published, and in 2020, the Digital Government Strategy for 2020 to 2022 was launched, which seek to transform the government and its public policies through digital technologies (Decree No. 10,332). In 2022, the Brazilian Digital Transformation Strategy (2022-2026) was launched, containing actions for the next four years.

the irregular appropriation of public lands (popularly known as "*grilagem*") (Tupiassu et al., Cruz, 2017; Korting, 2021).

In methodological terms, a national and international bibliographic survey was carried out on the research topics, as well as the systematization of secondary and cartographic data. Between 2017 and 2022, fieldwork was conducted in the regions studied, visiting the Pará municipalities of Santarém, Belterra, Mojuí dos Campos, Itaituba, Marabá and Canaã dos Carajás. In total, 39 field and online interviews were conducted (with people from Belém/PA, Redenção/PA, Curitiba/PR, Rio de Janeiro/RJ, Porto Alegre/RS, Piracicaba/SP and Brasília/DF), with representatives of public and private institutions working at municipal, state and federal levels. In addition to farmers, agribusiness managers and researchers, we also interviewed people from the Brazilian Forest Service (SFB), the Ministry of Environment (MMA), the National Institute of Colonization and Agrarian Reform (INCRA), the Brazilian Agricultural Research Corporation (Embrapa), the Environmental Commissions (CMA) of the Federal Senate, the State Secretariat for the Environment (SEMA/PA), Land Institute of Pará (Iterpa), the Pará State Company for Technical Assistance and Rural Extension (Emater), the Federal Public Prosecutor's Office of Pará, the Agrarian Courts of Pará, the municipal departments of agriculture, planning and environment, as well as organizations representing agribusiness, such as the Parliamentary Front of Agriculture, the National Confederation of Agriculture (CNA), the Cattle Breeders' Association of Pará (Acripará), the Union of Rural Producers of Canaã dos Carajás (Sicampo) and the Rural Union of Santarém (Sirsan); environmental representatives from the *Frente Parlamentar Ambiental* (Environmental Parliamentary Front); and representatives of small producers, such as the Rural Workers' Union (STTR) and the Movement of Dam-Affected People (MAB). In the interviews, we used a semi-structured script that recalled the background of the interviewee, outlined the dynamics of the expansion of the agricultural frontier in the territory, mapped the public policies driving this expansion (and their relationship with digitalization) and identified its future prospects.

2. Digitalization of Cadasters for Environmental and Cadastral Purposes in Latin America

The digitalization of public policy is understood as the systematic use of digital technologies for the generation, transmission and processing of data and for the analysis of public policies in their different phases (design, agenda setting, instrument development, implementation and evaluation). Ehlers et al. (2021), analyzing the European case, distinguish between mere data entry (an older process) and digitalization, which allows for the processing and analysis of huge amounts of data, including automatic *feedback*. The authors point out that the digitalization of agricultural policy not only replaces analogue technologies, but completely changes the logic and objectives of policies.

Although the literature often associates the digitalization of public policy with potential positive outcomes, such as efficient use of resources, increased transparency, more effective regulation and oversight, and faster enforcement of sanctions, there is no guarantee that digitalization will be used in this way. Understanding the trajectory of digitalization of public policy and its implications requires studies and analyses that seek to understand how it is happening on the basis of concrete cases. Kukk et al. (2022) list some uncertainties: it is impossible to guarantee that policies, in the process of digitalization, can and will protect public interests; there is a total lack of knowledge about how agricultural policy can affect innovations and technological adoption; and it will depend on each case to define how best to balance the interests of different publics (small and large producers, techno- logical companies, financial market, environmentalists etc.).

Ehlers et al. (2021) develop an analytical framework that systematizes the possible (direct and indirect) influences of digitalization on public policy, the results of which can be more or less inclusive, transparent and participatory. Digitalization can directly affect public policy in three ways:

a. **Promoting policies that focus on correlations between inputs and outputs** (performance measures) that require more effective monitoring of inputs, technologies and practices.

b. **Greater local specificity**, as geo-referencing technologies allow for more precise identification of priority sites (for pollution, deforestation, etc.) and priority *hotspots*, increasing monitoring and regulation capacity.

c. **Inter-temporal flexibility,** which enhances monitoring and the creation of databases on policy trajectory, facilitating adjustments (trial and error) and inter-temporal comparisons.

In terms of possible indirect influences of digitalization on public policy, Ehlers et al. (2021) point to six dimensions:

a. **Discretionary dimension,** which refers to the greater or lesser power of the government to make owners meet a set target in the light of information and monitoring.

b. **Sizing prices and quantities** with instruments that allow the calculation of taxes or subsidies (or production quotas).

c. The **quantity and distribution dimension of costs,** leading to reduced transaction costs (self-declaration, feedback), the use of technologies with economies of scale and scope, and more efficient use of resources.

d. **Degrees of participation** of different audiences: they facilitate the identification of audiences that need more incentives or should be included in digitalization, but also reinforce (or block) the participation of others.

e. **Changes in the quantity and domain of data**: they make it possible to collect and store enormous amounts of data and allow governments (and private actors) to control multiple information and databases (public or private).

f. **Influencing information governance**: they generate information flows, transparency and control of strategic information. The effects are not yet clear.

While the role of public policies in the digitalization of the agri-food system is recognized, the form they take will vary depending on: their thematic scope (agricultural, financial, environmental, territorial, fiscal, etc.); the sectors in which they are applied; the country/state in which they are located; the history of previous policies and regulatory frameworks; the objectives of public institutions and related state capacities; the existence or not of windows of opportunity open to certain proposals; and the willingness (or not) of stakeholders.

In a context of accelerating growth of the commodities market in the 21st century, rather than guaranteeing land rights, the digitalization process of land registries has responded to demands for legal guarantees of areas for the expansion of extractive activities with legal security. The Grain report (2020) found similar processes in the five main areas of agribusiness expansion in South America: Orinoquia in Colombia; Matopiba in Brazil; the Paraná- Paraguay Waterway and the Chaco Seco in Paraguay; the departments of Santa Cruz de la Sierra and Beni in Bolivia; and the Chaco in Argentina (GRAIN, 2020). In all areas, various processes of digitalization of land governance (through geo-referencing) have been identified under the rationale of increasing transparency and ensuring access to land. Recent changes have not only involved the transposition of cadastral registers to digital bases, but also the alteration of the logic of public policy implementation. On the one hand, it is undeniable that technologies facilitate land identification and favor land tracking, which can have positive implications for environmental regularization and the protection of strategic areas (public lands, traditional community territories, environmental preservation areas, among others).

However, depending on how they are incorporated into public environmental and land regularization policies, digitalization can also generate multiple exclusionary effects. If we consider the extremely unequal and conflictive agrarian structures that characterize Latin America (full of public lands with no definition of rights) and the way in which the digital bases were built (methodology), it is not wrong to assume that digitalization favors private logics of relationship with land and nature and the interests of large companies and producers.

In the Brazilian case and in the cases mapped by Grain (2020), the creation of digital cadasters was based on self-declared registers, with little cross-referencing with other registers and official cadasters. This was done for several reasons: to facilitate implementation by initially ruling out the need to integrate different cadasters (excluding interconnectivity problems), to increase the adherence of producers (especially large ones), and to overcome the need to check land registers and carry out on-site inspections. In the Brazilian case, characterized by "land chaos", this is an important dimension. We refer here to the difficulty of managing the national territory, resulting from the disorderly trajectory of land occupation reflected in the multiplication (rather than centralization) and overlapping of cadasters and registries, the difficulty of the State in its multiple spheres of influence to distinguish between public and private lands, and the poor coordination of the public institutions involved in land management[4]. If, on the one hand, this situation can generate legal insecurity, on the other hand, and in a context of the existence of large tracts of public land "unrecognized" by the state, it contributes to the illegal privatization (*grilagem*, in Portuguese) of land, especially in areas of frontier encroachment.

As a result, the gains that could be obtained by digitalizing and cross-referencing official records and archives, increasing the monitoring and protection of public and collective lands, and curbing illegal privatization processes are lost. By adopting a logic focused on private land titling, there is a growing risk that it will reinforce the invisibility of collective and traditional territories (indigenous, *quilombolas*, peasants etc.), which is accentuated in the current context by the paralysis of collective land titling policies, such as indigenous settlements and agrarian reform, as well as by the expansion of land regularization policies (without an adequate survey of their chain of ownership) through private land titles (GRAIN, 2020; Kato, Korting and Menezes, 2022). According to a study by Grain (2020), in Latin America, these dynamics increase the risk of exclusion and favor large producers.

4 Throughout history there have been many unsuccessful attempts to unify registers and cadasters. For more information on this issue and the numerous rural land registries currently in place in Brazil, see Kato, Korting and Menezes (2022).

These experiments with modern digitalized cadasters, conducted in the name of improving land governance, have been widely supported by governments and international organizations (such as the World Bank) under the justification of promoting transparency and the constitution of a land market with defined property rights. Edelman (2013) stresses that these proposals ignore the question of power over land. In this sense, digitalization processes can block or even prevent the participation of the most marginalized segments. These cadasters are conditional on the hiring of specialized and expensive consultants and rely on knowledge and information that is not always available to the most impoverished actors. By prioritizing private property titles, they hinder the inclusion of collective land use logics in their procedures. Thus, the creation of private land markets and titles can operate as a "double-edged sword" (Edelman, 2013). On the one hand, they can secure land rights and access to related public policies (such as credit, housing, etc.), but on the other hand, they can weaken the community ties that run through collective lands, promote the sale or lease of land, and expose farmers to indebtedness.

Another important aspect to be mentioned relates to the discretionary dimension. Digital technologies, especially remote sensing and platforms, enable new forms of land regulation and monitoring. However, in the face of a neoliberal state (unwilling to intervene in the social, environmental, agrarian and land spheres), digitalization has led to the replacement of on-site inspection mechanisms with self-declaring digital tools. Gains in transparency and regulation end up being cancelled out by the increased power of private actors and self-regulation, as we will see in the cases analyzed.

In addition, we highlight the growing tendency to use these registers as an "environmental and territorial seal" that gives producers the status of social and environmental responsibility without, however, implying more systematic inspections and monitoring. In Latin America, these instruments are gaining relevance in the face of an international market with growing environmental and social demands. One example is the European Union legislation that prohibited the import of products from legally and illegally deforested areas (timber, soya, beef, cocoa, coffee, palm oil and rubber) until December 2020. In a scenario of low inspection and cancellation of on-site visits, there is a risk that these records will attest to sustainability and legality that are not demonstrated on the ground.

Finally, following the leads suggested by the anthropological analysis of public policies, it is necessary to advance in the understanding of the multiple ways in which actors, especially from the productive sector (large producers and multinational companies), use these public policies in their strategies to expand their areas of production and their businesses. We will return to this issue later, when we analyze the cases of Pará.

3. Digitalization of Public Policies in Brazil: The Rural Environmental Registry (CAR) and the *Terra Legal* Program

Moving down the scale of analysis, this theme aims to explore digitalization from the perspective of environmental and land regularization instruments in Brazil, such as the CAR and the *Terra Legal* Program. The CAR is a public electronic registry created under the National System of Environmental In- formation (Sinima) and established by the Forest Code (2012). It is mandatory for all rural properties for environmental regularization purposes. It collects environmental information on rural properties and possessions for control, environmental and economic planning and deforestation control purposes. Demarcated indigenous areas are registered by the National Foundation of Indigenous Peoples (FUNAI), forest areas by the SFB and agrarian reform settlements by INCRA. Traditional peoples and communities were subsequently included through a special module.

The CAR was inspired by previous experiences (21 projects in nine states) of remote sensing tools and methodologies to identify, monitor and intensify measures to control and combat deforestation in the Amazon Region (Savian et al., 2014). Its origins date back to the 2000 System of Environmental Licensing of Rural Property (SLAPR) and the Mato Grosso Rural Environmental Regularization Program (MT Legal), both in the state of Mato Grosso (MMA, 2017). In Pará, Decree 1,148/2008 was launched in 2008, establishing the CAR as a condition for obtaining a license. Later, adherence to the CAR became an important criterion for joining the Green

Municipalities Program, in 2011. These state experiences had already drawn attention to the risks of environmental regularization instruments being used for land regularization purposes, the vices derived from being a self-declaratory instrument and the lack of oversight mechanisms (Lima, 2005; Azevedo, 2009).

The CAR, which was institutionalized at national level in 2012[5], has been conceived as the identity of the property. Registration in the CAR is compulsory and self-declaratory: that is, it is the owner himself who declares the environmental data of the property. Once registered, the Registry is automatically activated, allowing access to the benefits of the Forestry Code and other public policies, such as credit and land regularization. It is in this "facility", without the counterpart of inspections, documentary controls or on- site visits, that the main weaknesses lie, given the risks already mentioned in the previous section (Kato et al., 2022).

In order to be validated, the CAR does not require the registration of the property or any other document proving ownership or possession of the land. According to the legislation, once the registration is done, it is up to the state (or sometimes municipal) government to validate it. Eliane Moreira, a prosecutor from the Public Prosecutor's Office in Pará, states that Federal Police operations in the state show that it is not uncommon for CARs to be carried out in previously unoccupied areas in order to legitimize illegal occupation. This is facilitated by the fact that registration does not require any inspection or control, and in practice is only based on self-declaration. Once registered, the CAR is automatically activated and the ability to control and inspect the registered information is highly questionable.

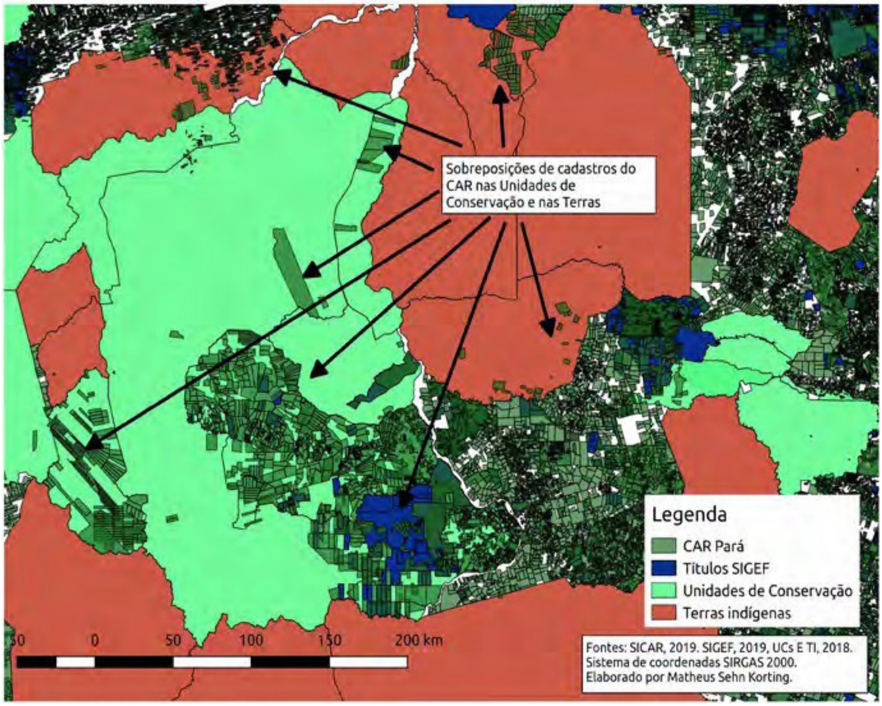
Once entered into the CAR, the system performs an initial analysis of the information, highlighting inaccuracies, restrictions and overlaps (when two owners declare the same area or an area intersects with another public

5 The CAR institutionalizes the requirements of the Forest Code. To register a property with the CAR, it is necessary to identify the owner or holder, identify the property and locate remnants of native forest, permanent preservation areas, restricted use areas, consolidated areas and legal reserves. The area of the property and its physical characteristics (area of the property, land cover, administrative easement, PPA/restricted use, legal reserve) are demarcated. For rural property, the registration number (registered in the cadastre office) and the property code in the INCRA registry (SNCR) are requested, but both are optional and do not condition the registration.

area), creating alerts. These alerts are analyzed by technicians from state or, in some cases, municipal environmental agencies[6]. Most of them refer to overlaps with other properties, inaccuracies in the size of the zone (different from what was demarcated) and the omission of Permanent Protection Areas (APP) and Legal Reserves (RL). The technician generates an opinion that is sent to the owner. In cases of overlap between private properties and public areas (already demarcated), there are no procedures in the CAR to alert governmental bodies in charge of these public areas (such as indigenous areas, conservation units and other areas). In Figure 1, the issue of overlap is quite clear in one region of Pará, where rural producers have self-declared their rural properties in territories belonging to conservation units and indigenous lands.

6 These are requirements of the 2012 Forest Code. Legal Reserve is the area located within the rural property destined to biodiversity conservation (can be exploited in a sustainable way). In Amazonia it represents 80% of the total and in the Cerrado 35%. Permanent Preservation Area is a protected area (untouchable), covered or not by native vegetation, with the function of preserving water resources, landscape, geological stability and biodiversity.

Figure 1. Overlapping CAR records in conservation units and land of indigenous people[7]



Source: INCRA (2019) and SICAR (2019). Prepared by Matheus Sehn Korting.

Despite its weaknesses, many Brazilian states have been using the CAR and its registration system as documents to prove ownership and as a facilitator in land regularization. Since 2019, the government of Pará has created a State Law (8,878) and a Decree (1,190) that digitalize and facilitate land regularization. The Cadaster and Regularization System (SICARF, partnership between the Pará Land Institute and Imazon) was created, which became the official land regularization system and is fed with data and information from other public agencies, including SICAR (CAR's Cadaster System). Therefore, there is a risk that the CAR becomes a driver of land grabbing (as seen in Operation Flying Rivers carried out by the Federal

7 The Territorial Management System (SIGEF) is a system linked to INCRA that allows the visualization of rural properties in a geo-referenced way.

Police, the Federal Public Ministry, the Federal Revenue Secretariat and IBAMA on (06/30/2016). The use of a fragile environmental registration document for land regularization in the country endangers thousands of hectares of public lands, facilitating their regularization as private land.

At the same time, in recent decades, as can be seen in Figure 1, the legal framework for land regularization in Brazil has become more flexible A similar process has taken place in the states. The justification is the need to order the Brazilian territory. With a complex territorial base, the Legal Amazon has been the stage for the advance of extractive activities, on the one hand, and on the other, the laboratory for the implementation of different environmental and land regularization policies (soon to be 'nationalized', such as CAR and Law 13,465).

The Legal Land Program, created in 2009 by Law 11,952/2009 of the Ministry of Agrarian Development, was one of the most ambitious land regularization programs of the Legal Amazon, and had the challenge of regularizing around 67 million hectares of federal land (8% of the entire national territory) . It allowed people who were illegally occupying public land (until July 2008) to legalize rural properties of up to 15 fiscal modules, without the need for tenders. In practice, its actions sought to simplify legal provisions and reduce bureaucracy in land regularization by making the necessary supporting documents more flexible, which resulted in speeding up the issuance of definitive titles, as well as making these procedures more difficult to monitor. In 2017, with Law 13,465, *Terra Legal* was extended to the entire national territory (Kato, Korting and Menezes, 2022).

Figure 1. Recent changes in land regularization in Brazil.

The **1988 Federal Constitution** recognizes:
Private land.
Federal public lands, including vacant lands (public lands that are not under private control and have not been collected or allocated).
State public land.
It states that private property is subject to its social function (economic, social, labor and environmental functions).
Regularization: subject to the fulfilment of the social function, and should be used for land reform purposes, to guarantee the territorial rights of traditional peoples and communities (indigenous peoples, quilombolas, etc.) and for environmental purposes.

Law 8,666/1993	**Law 1,196/2005**	**Law 11,763/2008**	**Law 11,952/2009 (Legal Soil)**	**Law 13,465/2017**
It limited public land ownership to 100 hectares without bidding for those who lived and produced on it.	Regularization in *Amazonia Legal* has been extended to the limit of 500 hectares, without the need for tenders.	It excluded the bidding requirement for properties of up to 15 fiscal modules, not 1,500 hectares.	Provides for the regularization of federal lands in the Legal Amazon. Legalization of farms on public land (occupied until July 22, 2008) up to 15 tax modules, with a limit of up to 1,500 hectares. Up to 1 fiscal module the land is donated; between 1 and 4 modules it is sold below market value; between 4 and 15 it is sold at reference table values. Properties with up to 4 tax modules are excluded from the inspection. Beneficiaries include legal persons, property owners, foreigners and public employees.	- It provides for the regularization of rural and urban land, in particular the regularization of land in the Legal Amazon, and establishes mechanisms to improve the efficiency of federal property sale procedures. Valid for INCRA zones throughout the country (not only Legal Amazon). Legalization of properties with proven direct occupation and exploitation (by you or your predecessors) before July 22, 2008. - The occupation of areas not exceeding 2,500 ha will be regularized. - Up to 1 fiscal module, land is donated. - Between 1 module and 2,500 ha there is no need for tendering. The price of the property will take into account the size of the area and will range between 10% and 50% of the INCRA price list. Occupied areas of more than 2,500 hectares can be partially titled up to this limit. And those occupied after July 22,2008, will be sold for the maximum value of the bare land.

Source: Kato et al. (2022). Prepared by the authors.

In 2023, the latest update available on the website (Figure 2), the number of RAC records exceeded 7 million, of which 27% are still in the analysis phase (cross-checking information and checking for overlaps). Environmental regularity analysis has been completed for only 1.40% of the records. As for the "registers with some kind of analysis", although there is a significant effort on the part of the municipal and state departments, the analyses are carried out by means of a device called "automated analysis", which cross-references and uses artificial intelligence and digitalization as tools for monitoring and inspecting the declarations of rural producers. Automation, combined with the municipalization of environmental inspection, reinforces the weakening of fine enforcement and verification (Korting, 2021).

At the same time, there is a very low number of traditional territories of traditional peoples and communities, less than 3,500 records, while the 2022 Demographic Census revealed that there are about 1.3 million quilombolas, mainly in the Northeast, and 1.7 million indigenous people, mainly in the Legal Amazon (IBGE, 2024). In terms of settlements, the number of records made does not reach 16,500, which is not very significant considering that there are about 1 million families in more than 9,000 settlements in the country (*Agencia Brasil*, 2022). These figures suggest that digital registers end up favoring the regularization of private lands, resulting in the invisibility of collective and traditional territories. During the field research, SEMA's Regional Manager in Marabá was unaware of the "CAR PCTs", which refers to the Registry of Traditional Peoples and Communities. The manager did not even know what the acronym used on the CAR websites was, revealing its low importance.

Figure 2. General data from Brazil on the Rural Environmental Register.

Source: SICAR (2023).

In the case of the state of Pará, 57.63% of the records have undergone some kind of analysis, but only 11.52% of the records have had their environmental regularity analyzed. However, only 143 records were made for traditional communities - out of a total of 135,000 quilombolas and 80,000 indigenous people living in the state (IBGE, 2024) - and 1,400 records for agrarian reform settlements - out of a total of almost 300,000 farms settled in Pará (*Dataluta*, 2020). Thus, although Pará is the first state to adhere to CAR in Brazil, it is clear that there has been little adherence among collective and traditional territories.

4. Portraits of the Process of Digitalization of the Cadaster in Pará

In this section we will analyze some concrete cases in which CAR has been used as a tool for environmental and land regularization and the consequences of this. To do so, we will analyze three sectors in the state of Pará: livestock, mining and cereals.

4.1. Livestock farming in south-eastern Pará

Due to increasing public pressure and alarming deforestation rates, meat processors have invested in building an environmentally responsible image. To control their suppliers, meat processors have improved their tools for monitoring trucks transporting animals to the slaughterhouse. This effort is the result of the Meat Conduct Adjustment Agreement signed between the Public Prosecutor's Office and meatpackers (2009) and the Federal Police's Operation Cold Meat (2017), aimed at reducing the number of cattle coming from deforested land.

The CAR is increasingly used as an environmental certification[8]. Reinforcing this logic, the SEMAS/ ADEPARÁ Joint Normative Instruction of July 27, 2018, made the CAR-PA mandatory for the issuance of the Animal Transport Guide in the state of Pará (GTA) and the granting of state licenses and services. In addition, the Rural Territorial Tax (ITR) and the CAR have been linked in the state. Without the CAR and, therefore, without the GTA, cattle ranchers cannot market their production in Pará, which is the state with the second largest herd in the country (24.7 million head), second only to Mato Grosso (IBGE, 2024).

Socio-environmental monitoring or *compliance* began in October 2009 through a public commitment between Greenpeace and several meat processing companies (JBS, Marfrig, Minerva and Frigol). According to a businessman from the social-environmental compliance sector of meat processing plants in Pará, monitoring has evolved rapidly, allowing them to scan information that is then parameterized. The basis of this activity is the CAR, which is systematically cross-referenced with other data, such as slave labor, public lands and deforestation. When these data overlap, an alert is created. Today there is already an artificial intelligence algorithm that monitors and overlaps the *shapefiles* (geo-referenced information). This private entrepreneur, who develops technologies for refrigerators, told us during the field research how slow SEMA's analysis of CAR was compared to his team's analysis. While the queue for analysis at SEMA is growing longer, the entrepreneur's team of three technicians analyzes up to 700 records per day. The number of records to be analyzed is growing, with

8 Official document for the transport of animals in Brazil containing essential information on traceability.

up to 700 records per day being analyzed by the company's team of three technicians.

In the process, this private company ends up centralizing an enormous amount of information on Brazilian territory, which is systematized (and controlled) for private purposes. Through the use of artificial intelligence algorithms, ownership is controlled. Additionally, the purchase of animals by slaughterhouses is based on this data. We have known of many cases where companies have stopped buying from a supplier without informing them of the reasons. In turn, to find out what was going on, the farmer would have to hire a socio-environmental compliance consultancy and, of course, pay for it.

Figure 3 shows the registers made under the *Terra Legal* land regularization program (properties in red) and the CAR settlement registers (blank settlements and green registers within settlements). The locality of Floresta do Araguaia is a good example of the dismemberment of rural settlements around the rural environmental registry, given that registrations in settlements should not be done by parcels but by INCRA itself collectively, and the *Terra Legal* Program, where settlers or buyers of irregular public land seek to regularize their private situation by dismembering the collective public settlement for private purposes, dividing the parcels and removing them from public management and the interests of the agrarian reform policy. Due to lack of resources, INCRA technicians have been asking settlers to register individually so that they can sell their cattle directly to slaughterhouses.

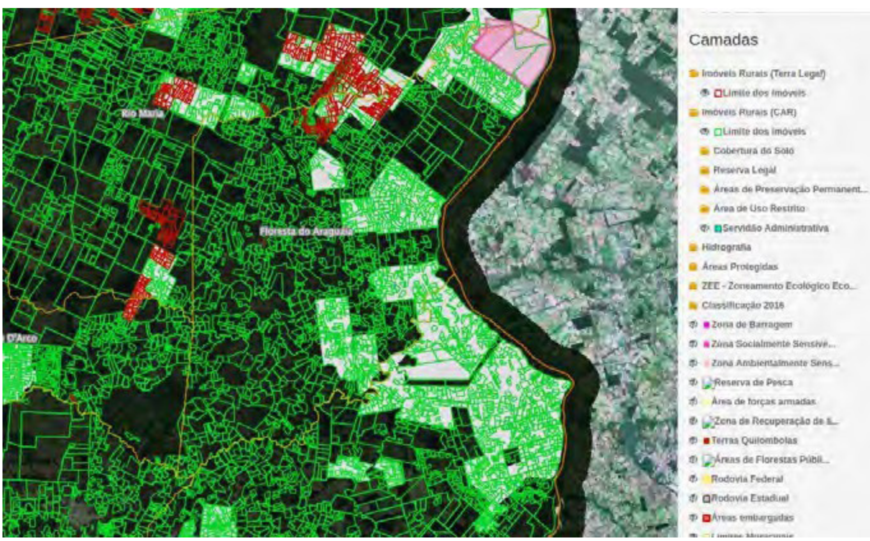
However, when the regularization system detects that the CAR is located within a settlement, it automatically does not accept the transaction, provoking the anger of the settled rural producers. As a solution, INCRA technicians encourage settlers to regularize their properties through private titles accepted by the system[9]. These are complementary digitalization processes that have been generating undesired consequences for public policies: pressure is put on the settlers to issue private titles to their lands,

9 Settlements in Brazil are federal lands ceded for use with the guarantee of sectoral public policies and infrastructure implemented by INCRA. These plots can be passed on to children, but not sold. With Law 13,465/2017, the regularization policy has encouraged the titling of plots with private titles.

which makes the legal and bureaucratic apparatus of the settlements more flexible.

As private titles become possible, pressure has increased on settlers to sell their plots at low prices, especially in areas where the border is advancing, which amplifies conflicts and real estate speculation. This was revealed to us in an interview with the president of the Union of Rural Landlords of Canaã dos Carajás. This person, a rural settler in the 1980s, now owns thousands of hectares and cattle inside and outside the settlement. Our interlocutor revealed that there is also great concern in the region about the advance of real estate pressure throughout the municipality by the mining company Vale S/A, which is discussed in the next sub-theme.

Figure 3. CAR and Terra Legal program records in Floresta do Araguaia (Pará).



Source: SEMAS (2024).

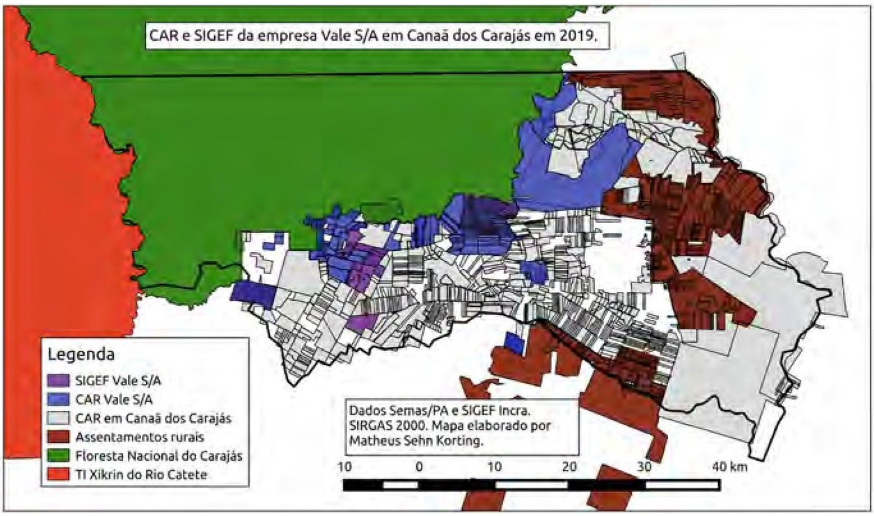
4.2. Mining in Canaã dos Carajás

In the southeast region of Pará is the city of Canaã dos Carajás, which has the S11D mine, owned by Vale S/A, the largest mining company in the country. The municipality is currently the second largest producer of iron ore and one of the largest exporters. The ease with which CAR is elaborated ends up functioning as a land "solution", extending the company's control over the territory. The southeast region of Pará has a complex land base, with many land conflicts and a very significant number of rural settlements. It is a region with a lot of public land owned by the federal government and the state of Pará resulting in undefined jurisdiction between INCRA and ITERPA. It is not surprising that the CAR registers have overlaps, as they take advantage of the self-declaration register in order to initiate land regularizations on public land, which results in an area with a high rate of deforestation via real estate speculation.

The way in which CAR registrations were carried out in the region generated a land rush that mobilized local actors. In order to accelerate CAR registration, the Green Municipalities Program, financed by the Amazon Fund, set a target of registering 80% of the municipality's registrable areas. The program rewarded municipalities that increased their CAR registrations the most, which led local authorities to design strategies with large landowners to accelerate registration. This generated an avalanche and pressure on squatters, landowners and land and environmental institutes. As we have seen, geo-referencing and digital registration procedures tend to favor, especially in the most peripheral areas, companies and large producers who have greater access to information, public institutions and the resources necessary to pay for these procedures. This was no different in Canãa dos Carajás.

Vale was one of the main beneficiaries, owning many hectares in rural settlements and, more recently, in the Campos Ferruginosos National Park, as well as having sub-soil rights for mining. Currently in the municipality, the CAR has operated as one of the main documents for the regularization of possessions, often overlapping with public lands, as in the case of the settlements of PA Carajás I and II, dismembered from public property by land regularization policies (Figure 4). In this sense, the CAR records, while mobilizing actors interested in expanding their territorial control, also reveal, through overlaps, the constant private pressure on public lands, such as rural settlements, conservation units and indigenous lands. Furthermore, the possibility of land regularization through the CAR, according to the Rural Workers' Union of Canãa dos Carajás, has led to increased pressure on settlers to sell their plots. The union suspects that Vale has been negotiating plots in settlements (more than 190) on the basis of weak titles and documents, such as the CAR.

Figure 4. CAR and SIGEF of Vale S/A in Canaã dos Carajás (Pará) in 2019.



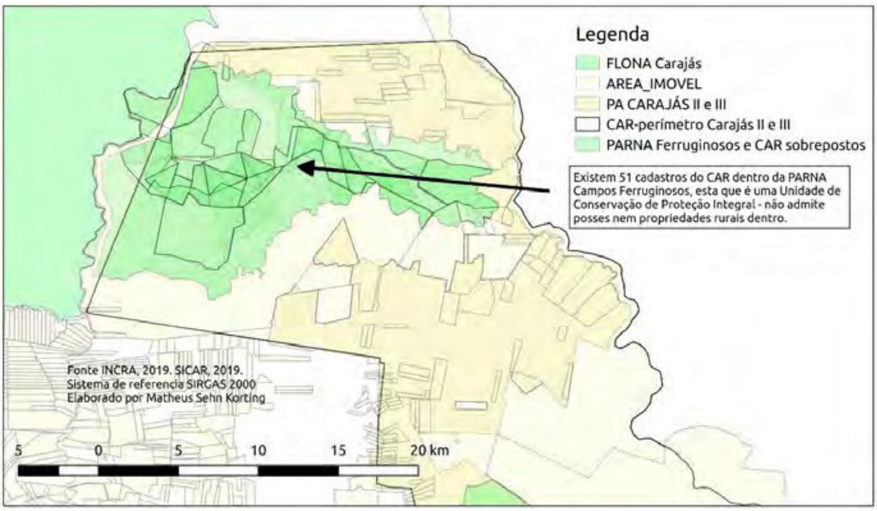
Source: SEMAS (2019) and INCRA (2019). Prepared by Matheus Sehn Korting.

The mining company Vale bought public land illegally for the constitution of the Campos Ferruginosos National Park, in addition to buying land to incorporate it into the Carajás National Forest (FLONA), including the land of Fazenda São Luiz, which was formed by stolen public land. Although the land was purchased illegally, Vale had its CAR approved in 2016 and donated this illegally purchased land to form the Campos Ferruginosos National Park area, as an environmental condition to obtain its own Exploitation License.

Figure 5 shows the existence of 51 CAR registries within the Campos Ferruginosos National Park, an integral protection park that does not allow rural properties or possessions in its territory. It was noted that the company Vale S/A is the holder of many of these records whose lands originally belonged to the rural settlement PA CARAJÁS I and II and has also been submitting several requests for land regularization to INCRA in Marabá, a process facilitated by the CAR policy.

Thus, the digitalization of CAR policy ends up contributing to the illegal sale of land, reorganizing land reform, land regularization and environmental policies, and instead leads to land and environmental problems through the operations and maneuvers of buying and selling public land.

Figure 5. Superposition of CAR records in PARNA Campos Ferruginosos/ Canaã dos Carajás Pará.



Source: INCRA (2019) and SICAR (2019). Prepared by Matheus Sehn Korting.

4.3. Grains on the Santarém plateau

The Santarém plateau, which covers the municipalities of Santarém, Belterra and Mojuí dos Campos in western Pará, has undergone intense transformations in recent decades. While in 1985 forest areas were predominant, nowadays there is an increase in pasture areas and the emergence of temporary crops, which were absent until the early 2000s (MAPBIOMAS, 2024). Among the crops, soybean is the protagonist. This process started in 1997 and has expanded over the years, strongly influenced by the installation of a Cargill bulk terminal in Santarém, inaugurated in 2003, and the establishment of rural producers from the centre-south of the country, with previous experience in the cultivation of the grain (Wesz Jr. et al., 2021). In 2022, the three municipalities planted 110, 000 hectares of soybean, double the area cultivated in 2019 (IBGE, 2024).

In the grain production areas of the Santarém plateau, as in the other cases analyzed, the CAR has been used, on the one hand, as certification that the property complies with environmental legislation (Cargill, for example, only buys soybeans from properties that have the CAR and uses it as an environmental certificate). On the other hand, they use the CAR as a document that reinforces the evidence of occupation of that property and/or as proof of access to various public policies (such as credit and rural housing, among others). In Santarém, for example, access to bank financing is only possible upon presentation of the CAR.

In western Pará, during an interview with a SEMAS technician in Santarém, he drew attention to the deviations and different forms of mobilization of the RCA in Santarém by rural producers:

> “With the ‘land chaos’ in the state of Pará, from the moment a tool is launched that allows the spatialization of land adjudication in that territory, people ended up using the tool as an official means to show their properties. But this is not the objective of the CAR. And there are different issues... people use this tool in the wrong way. For example, the guy thinks “Oh, I want to stay here”, so he puts it there and does the CAR. Sometimes it’s people who are not even from the state, they are from outside, they don’t know, they don’t know spatially where things are allocated and this happens. I’ve seen some of these situations. They go there and register on top of a state forest and negotiate with a third party. They only negotiate on paper, the citizen has never been there, they don’t know where they are.”

In some cases, such as the one described above, the CAR is used as a proof of ownership document and therefore as part of the land regularization processes in Pará. Thus, the CAR is associated with land regularization initiatives. Given that Pará has a large amount of vacant and public lands, rural producers have used various strategies to advance in the regularization of their properties and expand their areas. According to the same informant from SEMAS, producers have opted to regularize small areas (land and environmental), as they fall into the regularization tranches that have a higher subsidy on the price of land, guaranteeing access to the benefits of reducing legal reserve areas of the New Forest Code, as well as allowing for licensing at the municipal level (areas larger than 2,000 hectares end up being the responsibility of the state level). According to the interviewee:

> "Many areas are shared between father, son, uncle, cousin, grandfather and grandmother. This type of agreement allows producers to avoid the obligations imposed by the New Forestry Code by accessing the benefit of not having to replant the legal reserve areas imposed by the Code. Up to four rural modules, the legal reserve is exempted. Many of them do not have 100 meters of vegetation, so the property has no reserve and the whole property can be used for rural production. In other words, if the property [of up to 4 fiscal modules] was deforested before 2008, the New Code allows it to remain unreserved. The module in Santarém is 75 hectares, so 300 hectares is four fiscal modules. So, in Santarém, you can leave up to 300 hectares unreserved because they fall under this benefit. Beyond that size, there has to be 80% reserve. So, if the producer would exceed this limit [of four fiscal modules], he would split with his family and he would manage to fit in, regularize the area and, at the same time, have access to some policies, which he would not have had if it was [a larger area]."

Consultations carried out for the Santarém plateau in SICAR (2019) indicate this movement, with several properties divided between people with the same surname. And when visiting the area or interviewing rural producers, it is found that there are continuous areas of crops, but that they have been fragmented for registration and regularization purposes for various reasons. On the one hand, small-scale CARs are analyzed and validated by the municipality, which would facilitate the process and the dialogue with local authorities, where they have greater political influence. On the other hand, properties of up to four fiscal modules can be regularized more easily, and when occupation is verified until July 2008, the owner is exempted from recomposing the legal reserve areas that have been deforested. In the words of the SEMAS interviewee:

> "An area of 400 hectares that was deforested in 2007, when a legal reserve of 80% was already obligatory, will have to recompose up to 50% of the area... which also comes into play with the zoning. If it is a smaller area, you don't have to do it". Knowing this, rural producers use this "loophole" in the legal regulations to expand their productive areas.

5. Final Considerations

Environmental and land regularization is converging towards remote sensing technologies and self-declaration registers under the justification of more transparent, efficient and less costly processes. It is important to note that this movement has occurred at the same time as inspection and control measures have been reduced, the requirements for documents and records of possession or ownership have been reduced, and visits to the areas to be regularized have been abandoned. Rather than the application of technologies aimed at making procedures more efficient, our research suggests that the use of self-declaration and the digitalization of records has favored regularization schemes for public lands that were not occupied by the applicant, that do not fulfil their social function and that, in many cases, are the object of conflict.

The progressive process of digitalization of public policies, as we have seen, does not occur in a vacuum. Thus, the procedures and the way in which public policy instruments (such as the CAR) are digitalized have the potential to highlight certain attributes of the territory and the land, which are valued, but they also run the risk of making others invisible.

The experience analyzed in this chapter shows how the digitalization promoted by the CAR is based on values of private land ownership, while it has the counterpart of potentially making settlements and, above all, traditional peoples and communities invisible. By prioritizing the digitalization of land through the insertion of geo-referenced polygons and the specification of data and information from the environmental registry, it complicates the processes and makes registration more difficult and costly for small farmers and traditional communities (who usually lack resources and technology).

In addition, we highlight some unexpected results of cadaster digitalization policies that will need to be analyzed more closely in future research. The first refers to the uses given to these cadasters once they are created, which do not always correspond to the objectives listed at the outset, demonstrating how these "creations" end up acquiring a "life of their own" once they are created. In the case of Brazil, the digital cadaster that was initially created was aimed at environmental regularization (and not land ownership), which explains why it was not very demanding in terms of verifying land titles or triangulations. However, once created, the new Cadaster has been increasingly used as evidence for land regularization purposes and for contracting associated public policies, such as rural credit. In Canãa dos Carajás, the CAR has become an important part of the land regularization process and of Vale's progress in the territory.

The second relates to the accelerated process of digitalization of public policies and the concentration of data and information on land in private hands. The case of the meatpacking plants in Pará reveals how CAR has enabled the centralization of a plurality of information on land that can end up in the hands of private actors who possess the databases and have been playing the supervisory role that the state is unable to fulfil. In this case, when the CAR database is manipulated by private actors, it becomes the main parameter used by local slaughterhouses in order to select suppliers, as well as a condition for the sale of soya on the Santarém plateau.

Finally, we are struck by the way in which these digital policies are manipulated and included by territorial actors in their strategies to expand the agricultural frontier. The case of cereals shows how the CAR has been integrated into the different strategies carried out by local actors to regularize irregularly occupied areas or to obtain environmental regularization within the regulatory "gaps". Thus, the CAR, as a self-declaratory instrument, with limited monitoring, has been used for purposes other than those for which it was created. Since the CAR, once registered, is activated even if the analysis has not been completed and does not require on-site inspections, producers register as environmentally regularized (and therefore environmentally responsible) in commercial enterprises, easily accessing the international market and circumventing environmental requirements. It should be noted that all this occurs without effective inspection or control of the properties. As these new uses are normalized (and in some cases standardized) by public and private actors, the policy is acquiring new functions or developments that were not included in its official documents. And, in some cases, it corroborates the dynamics of widening inequalities, legitimizing irregular appropriations and covering up environmental crimes.

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12 The New Rural Product Note (CPR) and Digital Ecosystems in Agricultural Financing in Brazil[1]

Cristiano Desconsi, Giancarlo Moraes dos Santos, Daniela Aparecida Pacífico, Karolyna Marin Herrera

1. Introduction

Since the 2000s, and with greater intensity in the last five years, there has been a strengthening of the processes of financialization in Brazilian agriculture (Santos, *et. al.,* 2022). Among other processes, the creation and expansion in Brazil of private financing instruments, such as Agribusiness Bills of Credit (LCA), Agribusiness Collection Certificates (CRA), Agribusiness Investment Funds (FIAGRO) and Rural Product Note (*Cédula de Producto Rural* - CPR) stand out. These initiatives are promoting a change in the way credit is obtained and granted to agri-food chains through constant processes of creating financial titles related to natural resources and agricultural production, which can be classified as *immobilization* processes (Birch and Muniesa 2020)[2]. One of the instruments that deserves attention

1 The data from this study are part of the research project entitled Interfaces Between Financialization Processes and Digitalization in Agriculture: Analysis of Digital Ecosystems in the Financing of Agricultural Commodities in Brazil, which is being carried out within the framework of the Rural Studies Laboratory (LERU) of the Agricultural Sciences Centre (CCA) of the Federal University of Santa Catarina (UFSC), Brazil. Website: https://leru.paginas.ufsc.br/. The text is an improvement of the initial version prepared by Giancarlo Moraes Santos as an Agronomy Degree Final Project at UFSC in 2023.

2 Official rural credit refers to the types of credit linked to the National Rural Credit System (SNCR), is part of Brazil's agricultural policy.

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is the Rural Product Note (CPR), which, although it has existed since 1994, has gained ground through digitalized credit and has become an alternative to the "official" rural credit that makes up Brazilian agricultural policy.

Private financing instruments operated through digital channels are presented as a solution to speed up the credit granting, increase the volumes available and reach small and medium-sized farmers in the various rural regions of the country. However, all of this has new implications, such as reduced state involvement in promoting agricultural production, increased influence of the capital market in the sector, and the digitalization of finance with new control mechanisms over the production process (Souza, 2022).

With this problem in mind, this chapter aims to understand the process of granting private finance to agricultural production, focusing on the Rural Product Note (CPR). The chapter is organized in the following sections, in addition to this introduction: section two initially presents the method used to carry out the research, which involves a basic review of the topic and the methodological procedures used to collect and analyze the empirical data. This is followed in section three by a theoretical reflection on financialization and digitalization, which are references for the empirical analysis of CPR. Section four presents data and discussions on the operationalization of CPR, examining a digital ecosystem composed of traditional actors in production chains (producers, agro-industries, input distributors), financial market actors (investors) and new actors mediated by platform networks. Finally, section five, Concluding Remarks, systematizes the main contributions of the chapter and suggests new studies in order to understand the recent phenomena of the interfaces between finance and digitalization in agriculture.

2. Materials and Methods

The research adopts the qualitative method of data collection and analysis suggested by Creswell (2007), consisting of the stages of data collection, systematization and analysis based on theoretical references. The methodological procedure adopted consists of five stages in order to gain a qualitative understanding of how the Rural Product Note is configured as an instrument for the financialization and digitalization of agriculture. In terms of procedures, the five stages are detailed below:

Step 1: An exploratory survey was done on the issues of financialization and digitalization of agriculture, as well as on private financing instruments in agribusiness production chains, the main formulations of which can be found in section 3 of the literature review and which serve as a basis for the analysis of the Rural Product Sheet.

Stage 2: Information was compiled on the Rural Product Note in terms of regulation and operability. To this end, we analyzed the evolution of legislation from the creation of this instrument to the present day, documents and data generated by the Ministry of Agriculture, Livestock and Supply (MAPA), organizations representing the sector, as well as presentations on the subject made by private finance start-ups. For this stage, the document analysis procedure was adopted, according to Gil (2010) and Lima Junior *et. al.* (2021). According to these authors, the analysis should not be carried out by considering only the content of the documents, but by seeking to make sense of the selected documents, understanding their production in their historical context and the actors involved.

Phase 3: Mapping and analysis of CPR operationalization. In this stage we selected some companies operating in the credit chain and in the operationalization of CPR using open access sources such as: the Agtech Brazil Radar, Mapping of Brazilian Startups of the Brazilian Association of Startups (Abstartups) and Fintechs (Abfintech) conferences and webinars and other thematic events that featured presentations by companies operating in digital financial services for agribusiness, with emphasis on the 2nd and 3rd Workshops on Financial Innovations in Agribusiness promoted by Enagro in 2021 and 2022.

Step 4: From this general mapping, three companies were selected based on the following criteria: i) they work exclusively in agricultural production chains; ii) they interact with the borrower(s) of the credit and/or digitize the collateral; and iii) they have been outstanding companies in the operationalization of digital CPR since 2017. These are Agrométrica, Agrodocs and Bart Digital. Their characteristics and ways of operating in the organization and functioning of the digital ecosystem to operate CPR and other agro-industrial securities are detailed. This descriptive analysis uses publicly available information from the platforms and/or companies' institutional websites, institutional reports, talks by company representatives at events, presentations and interviews available on YouTube, LinkedIn and Instagram.

Step 5: Systematization, data analysis and presentation of results and discussions.

3. The Rural Product Note in the Context of the Financialization and Digitalization of Agriculture

3.1. Interfaces between the process of financialization and digitalization of agriculture

The financial sector is increasingly integrated into the daily lives of individuals, companies and institutions, from large financial corporations to the simplest commercial transactions (Santos, *et. al.*, 2022). One aspect that has gained prominence in recent decades is that it is increasingly independent of the productive sector. This is one of the prerogatives of the theoretical debate on the subject that seeks to highlight the aspects that differentiate financial capital in contemporary capitalism, understanding that although financial capital has already been mentioned by economists (such as Karl Marx, in the 19th century), the current phase of capitalism presents new facets, such as: (i) the process associated with a greater detachment of financial capital from other economic spheres; (ii) the power of large financial corporations in the current context; (iii) the intensification and expansion of direct control by financial market actors; and (iv) diffuse forms over other spheres of societal life, the economy and the environment (Chernais, 2016).

In this process of the new facets of capitalism, it is worth making some considerations to distinguish financial capital from the process of financialization of the economy in general and agriculture in particular. According to Delgado (2012, p. 34), financial capital can be defined as "an abstract and general social relation commanded by institutions that control liquidity and the means of financing as a whole, which implies the growing monopolistic organization of markets". The author also highlights the centrality of the agricultural policy introduced in the 1960s, with the creation of the National Rural Credit System (SNCR), which created "a pattern of rural financing with a predominance of state banking, highly favorable interest rates and a whole set of financial policy parameters" (Delgado, 2012, p. 29).

The SNCR will mobilize financial resources to provide liquidity and shape the profit margin expectations of rural activities. In the following decades, the model lost strength in terms of interest rate subsidies and the provision of resources exclusively from public sources, giving way to the formation of business conglomerates that include banks and other financial institutions to control markets. This is the integration between capital (agrarian, banking and industrial) and the processes of technical-productive integration that have expanded in Brazil in recent decades (Delgado, 2012).

In turn, financialization is a networked transformation of interrelated processes through which finance extends its influence beyond the market, with a broader process of productive restructuring involving various interconnected social, political and technological factors (Van Der Zwan, 2014). This process of financialization, according to Santos *et. al.* (2022) began in the 1970s with a set of legislative reforms, institutional changes and technological innovations that led relationships to become increasingly involved in the financial market. This is no different in the agricultural sector, where finance is involved in all stages of the production chains, from the acquisition of land and other natural assets to the purchase of inputs, production, marketing and sale of production (Santos *et al.*, 2022).

The financialization of agriculture expanded in Brazil when the state created a system for raising private credit from the 1990s onwards, with the participation of institutional investors and private banks (Santos, *et. al.*, 2022). In the following decade, this process was intensified in agribusiness with the agenda of large financial companies, especially after the rise in the price of agricultural commodities from 2000 onwards. This rise in prices was fueled by the changing food base in Asian countries such as China and the climate crisis, which put agri-food systems in the spotlight, awakening the interest of the financial market in their assets. Another intensifying factor was the financial crisis of 2007-2008, which led these institutional investors to seek safer investments, land, natural resources and commodities as an increasingly important part of the financial market (Flexor and Leite, 2017; Sauer and Borras, 2016).

For analytical purposes, the process of financialization can be seen in different dimensions in rural areas. In the last two decades, most studies on the subject have focused on the entry of financial market actors into land acquisition and the appropriation of natural assets (forests, conservation areas, genetic assets). The discussion on *land grabbing (land grabbing* or *green grabbing*) (Sauer; Borras, 2016) has marked studies by highlighting diffuse processes of "entry" of investment funds in land acquisition in various countries. Studies such as the one by Bernardes *et. al.* (2018), among others, have highlighted the scale of these deals and the effects on Brazilian rural land resulting from this process.

Particularly in the case of Brazil, financialization is increasingly gaining ground in the financing of production chains, and can be linked directly or indirectly to the foreignization of land and the appropriation of natural resources. This is evident for two reasons: i) the Brazilian State's initiative to strengthen the participation of private credit in agriculture and the creation of new sources of financing for official rural credit by raising funds on the market; ii) the interest of large corporations that control agricultural commodity chains, both downstream (inputs) and upstream (marketing), to extend their control over the system through new financial and digital mechanisms.

However, this financialization movement is occurring in parallel with digitization, which is speeding up transactions and increasing the number of financial assets accessible to investors (from investment funds to small investors) in the market. Digitalization has been driven by technological development and the internet, which has been changing the market, causing a transformation in finance through Information and Communication Technologies (ICTs), which have altered the dynamics of capital market operations and the current functioning of stock exchanges (Paraná, 2019). For example, through mobile apps and the internet it is possible to access a variety of platforms that offer financial products and services in the most diverse areas. In this sense, the digitalization of finance has broadened its scope in terms of the actors that have come to participate in the financial market at different levels, in addition to paving the way for the expansion of finance in segments of society and the economy where its presence was more limited (Birch; Muniesa, 2020).

3.2. Financing agriculture: between public and private investors

Studies on agri-food systems have highlighted the presence of new actors controlling the financing of production, environmental assets and the trade flow of agricultural commodities, as well as the decoupling of agri-food products from their expression as an asset in the financial market (Clapp, 2014). In addition to the traditional actors involved in the production, processing and distribution chains and their financing (agribusinesses, retail companies, trading companies and public and private banks), financialization and its interface with digitalization open up space for the control and operation of four main points: i) institutional investors and individual investors in the capital markets of companies involved in agribusiness and production financing; ii) platform companies that monitor data on producers, companies, price behavior and asset valuation; iii) start-ups and IT companies created to act in the commercialization and trading of agricultural products, analysis and risk management, offering financing via private credit; and iv) professionals and companies specializing in the development of digital solutions, which model processes, products and services in the digital world, paving the way for financial innovations. All these points incorporate other actors that become linked to agribusiness in different ways, as well as broadening the spectrum of the term itself.

Among the weaknesses of the National Rural Credit System (SNCR). In the case of the National Program for Strengthening Family Farming (PRONAF) (Troian; Machado, 2020), there is a notable disparity in the distribution of resources, with a significantly higher proportion going to large-scale agricultural producers compared to smaller-scale producers (Xavier; Penha, 2021), as demonstrated by the National Program for Strengthening Family Farming (Troian; Machado, 2020). Producers face significant challenges in accessing credit and rural insurance, including obstacles arising from bureaucracy and eligible collateral requirements, as well as lack of adequate guidance and delays in the process of releasing funds (Xavier; Penha, 2021).

If the prospect of private finance in agriculture is currently on the agenda of the institutions and agents involved in the different production chains, we should not forget that it has always existed integrated in the production chains and mobilizing resources from different sources. It is not new that the agents that sell agricultural products and the companies that sell inputs and services to this productive sector have mechanisms to finance their farmers (clients). The financing of the cost of agricultural production has been dominated by these financing formats, whose rules, conditions and volume of resources are impossible to estimate (Lopes *et. al*, 2016).

Many of these financing transactions were "paperless" or mediated by contracts, many of which were not notarized. Studies in the soybean market confirm the existence of these modalities based on the personal trust established between the parties (Wesz, 2014). It should be noted that what may appear to be private financing offered by cooperatives, agribusinesses and marketing companies to producers might often come from resources accessed in financing from the National Rural Credit System (SNCR). For example, an agro-industry takes credit from the SNCR and finances the cost of crops for its clients, conditioning the delivery of the harvested product to it.

In these terms, it should be understood that the new instruments are affecting these "traditional" forms of private financing, seeking to open up space for actors, institutions and rules that were hitherto confined to the financial market. According to Wesz (2014), ABCD[3] trading companies control around 70% of the global food commodity production, in segments ranging from insects and seeds to reception, crushing and export, with a central role in marketing. One of the instruments they control is a financing system (*bart* or barter) in which they make advance purchases or forward contracts (with or without a legal signature) and the producer accesses the package (fertilizers, seeds, agrochemicals, technical assistance), assuming the commitment to deliver the product of the harvest to the financing firm. This is the main costing mechanism operated in Brazil, which is private credit. In many of these operations, the land (pledge) is offered as collateral to the financier, in addition to the agricultural product (promissory notes).

3 Acronym for ADM, Bunge, Cargill and Louis Dreyfus.

3.3. The Rural Product Note as a financing instrument for agriculture and livestock farming

Between 2020 and 2022, the Central Bank of Brazil (BACEN) together with the Ministry of Agriculture, Livestock and Supply (MAPA), representatives of production chains and agricultural financial agents, modulated important regulatory changes aimed at leveraging the participation of private investment in agriculture. The rationale for the new legal framework was to make the granting of finance to agriculture more modern and efficient, with innovations in the means of guarantees, broadening the scope of existing market instruments, the number of beneficiaries, and the volume financed, as well as digitalizing the whole process. As the MAPA representative pointed out: "Technology companies and digitalization are the paths that will allow investors to reach the crops" (Enagro, 2022).

One of the instruments that underwent this change was the Rural Product Note (CPR). Created by Law No. 8,929 (1994), the CPR is intended to legally represent the promise to deliver rural products. In its genesis, the settlement was made only with the physical delivery of the product. Its creation standardized one of the main instruments for the private financing of agricultural production and opened up space for attracting resources from the financial market. Understanding the regulatory evolution of the CPR from its creation to Law 14,421 (2022) is fundamental, since it is a matter of understanding how a contractual instrument in barter operations, established between rural producers and agricultural resellers, as well as in tradings or agricultural cooperatives, became today an asset in the financial market.

Law no. 8,929 (1994) established the CPR as a credit instrument, representing the obligation to deliver the original product of agricultural production. Law nº 10,200 (2001) allowed the financial settlement of the CPR, which until then could only be done through the physical delivery of the product. This change opens the way for a gradual process of transformation of a contractual marketing instrument into a financial guarantee. At the same time, the actors involved in the economic relations involute with CPR changed, e.g. opening space for the entry of banks (public and private), both in the settlement process and receivers of CPR as collateral for access to finance for enterprises (agro-industries, cooperatives and retailers). As a result, companies in the production chains were able to finance the cost of production; they did not need to have a structure in order to receive the physical product. Public and private banks started to finance the cost of production through the CPR, or to use it as collateral for other types of financing.

Recently, Law No. 13,986 (2020) created the "new CPR", bringing as a novelty the standardization of the digitization of this title and expanding its scope within the agribusiness production chains[4]. The main points of the law are: i) the creation of the "Green CPR" - aimed at raising funds in the market using private preservation areas as assets; ii) the standardization of the digitalized issuance of book entries regulated by the Central Bank of Brazil; iii) the expansion of issuers and the inclusion of new "products" to be financed by the CPR, which until then was limited to the main agricultural commodities (soybeans, corn, cotton, coffee, sugar cane, among others). It includes rural products eligible for CPR issuance, such as those obtained from agricultural, livestock, planted forests, fishing and aquaculture activities, as well as those related to native forest conservation and sustainable management.

In addition to rural producers and their associations, legal entities with a corporate purpose related to rural production, associations and cooperatives focused on the production, marketing and industrialization of rural products were also included as of 2020. This made it possible to systematize a centralized registry and the deposit in entities authorized by the Central Bank of Brazil (BACEN), as a negotiable security that acquires the character of a financial asset. As of 2020, the Central Bank of Brazil was empowered to establish the conditions for CPR bookkeeping and to authorize and supervise this activity.

The previous legislation only provided for certain types of collateral that could be used in transactions, such as security interests (mortgages or pledges) and personal guarantees (sureties or sureties)[5]. Under the new

4 This modality is not the subject of analysis in this paper, as it presents particularities in the capture and operationalization of the link that should be examined in other studies.

5 It corresponds to the segregation of assets, allowing the fragmentation of rural property records into smaller parts with a view to offering them as collateral for credit operations.

Law 14,195 (2021), two more guarantee instruments have been added: the Patrimony of Affectation, in Article no. 14-A, and the Solidarity Guarantee Fund (FGS), in Article no. 14-F. The law now provides greater legal certainty for issuers and, above all, for creditors. Costs, time and documentary complexity have decreased (Caffagni, 2020), as previously they had to be registered in the Land Registry offices located in the municipalities where the real estate (e.g., surface area) or pledged assets were located. The change in legislation has meant that this registration can be carried out through the Electronic Property Registration System (SREI) in a digital form and can be carried out by a specialized institution or company, i.e. not directly by the producer or other borrower.

Law 14,421 (2022) adds adjustments to the previous legislation. A new list of agricultural products, forestry activities, extraction of vegetables, production or sale of agricultural inputs, agricultural machinery and implements, and industrialization of products mentioned in Law 13,986 (2020) were included as eligible rural products. This means that, from a regulatory point of view, the CPR could be an instrument for raising funds in the financial market for various stages of the production chain and could be used for almost all products in the country's primary sector.

With regard to the collateral registry, the possibilities of using a simple, advanced or qualified electronic signature have been established in the CPR and in the document describing the assets linked to the collateral. In the case of the register of collateral consisting of movable and immovable property, the use of an advanced or qualified electronic signature is permitted. The digitalization of the registration of collateral and the issuance of the CPR allows the rural producer himself to issue them directly through the electronic system of a registration agency authorized by the BACEN[6], without the need for third party intervention, with the entire centralized registration or deposit of the assets.

It should be noted that the operationalization regulated by the law could only take place in conjunction with the digitalization process capable

6 The Brazilian Stock Exchange, an entity authorized by the Central Bank of Brazil (BACEN) to register various types of agro-industrial financial securities, including the CPR. For more information see: https://www.b3.com.br/pt_br/produtos-e-servicos/registro/renda-fixa-e-valores-mobiliarios/cedula-de- pro- duto-rural.htm

of connecting the investor, on the one hand, and the borrower, on the other (agribusiness, retailer, rural enterprise or producer) through digital networks and platforms. In the specific case of BACEN's actions, it is now responsible for self-regulating the companies and entities that will act in the process. One example was that Law 13,986 (2020) authorized B36 to work with this type of securities, and then two other securitization companies began to work with the digitized registry. Authorizations by groups of entities allowed this process to encompass digital ecosystems built to operate the CPR, such as the one presented in subsection 4.2.

Start-ups, fintechs and technology companies have innovated in the operationalization of CPR using financial technologies, such as digital platforms, mobile applications and other services. These solutions enable rural producers to issue, manage and trade CPR more efficiently and securely (Enagro, 2022a). This innovation has opened space for the creation of digital ecosystems specialized in financial services for agriculture, particularly in the operationalization of new private finance instruments. However, it is necessary to understand the meaning of "ecosystem" in this context. The term has been used to denote the interaction and collaboration between multiple economic actors in business networks, providing complementary or competing services (Alt and Huch, 2022). The notion of an ecosystem emphasizes the interaction of networks of actors and digital systems (platforms, applications) which, interconnected, constitute avenues for carrying out the financialization process.

We will analyze an example of a digital ecosystem that has been fundamental to the operation of CPR, detailing and analyzing how they are organized and function in practical terms, based on empirical research.

4. Results and Discussion

4.1. Granting of private funding of CPRs

The public sector has played an important role in the expansion of private capital in agribusiness, with the creation of new laws and regulations that encourage private sector participation.

With Law no. 13,986 (2020), CPR issues, which were previously made only in physical registers and traded in the over-the-counter market, will now have a centralized register, which can be made in the B3 (Brazilian Stock Exchange), in the CERC (Receivables Center) or in the CRDC (Central Registry of Credit Rights), which allows data to be compiled from 2020 onwards. In April 2024, the Ministry of Agriculture and Livestock (MAPA) launched an Agribusiness Private Finance Bulletin with the recent history of CPRs and other securities issued since 2020 (when the law came into force).

The data show the gradual evolution of the centralized registration of the security with BACEN. The evolution of the registry is based on Resolution no. 4,870-20 of the National Monetary Council, which makes it compulsory to register or deposit CPRs in entities authorized by BACEN as of January 2021, according to the dates and amounts set out in Article no. 2, starting with registrations of more than R$ 1 million, then intermediate amounts until all registrations become compulsory as of January 2024.

To prepare for this process of monitoring private financing, the MAPA created the Agricultural Sector Financing Department (SPA/DEFIN/CGMF), within the Secretariat for Agricultural Policy, for the following private financing instruments: Rural Product Note (CPR), Agribusiness Credit Certificates (CRA), Agribusiness Credit Notes (LCA) and Agribusiness Chain Investment Funds (FIAGRO).

One of its actions is to publish information on the volume of private funding in a monthly newsletter starting in November 2022. One of the graphs from the newsletter, from March 2024, is shown below (Figure 1).

Figure 1. Evolution of CPR stocks.

Source: MAPA/SPA/DEFIN/CGMF, March 2024.

With the standardization of the centralized register in BACEN, it is now possible to analyze the volume and number of transactions of new private finance instruments, such as CPR. Previously, CPR operations (and other types of private finance, such as *barter*) were only marketing or market instruments, which were carried out between two parties (for example, a producer and a company or a reseller of agricultural commodities) in the production chain and which, when formalized, took the form of an account entry (paper or notary registration) (Linhares; Campos; Junior, 2022). There were estimates of the volume of resources and operations, but it was impossible to specify the scope of instruments such as the CPR within the financing of production chains.

To examine the significance of the growth in both volume and transactions between August 2020 and February 2024, this chart expresses the start of the centralized series of CPR transaction records, as well as the (gradual) obligation to record transactions from highest to lowest value, in accordance with Article 2 of the Law. It is not possible to verify the actual growth of CPR transactions and volume, because it also expresses the growth of CPR transactions that are now digitalized (subject to centralized recording). In this sense, it will only be possible to know the actual volume and number of transactions of this value in stock as of January 2024, because of this monitoring.

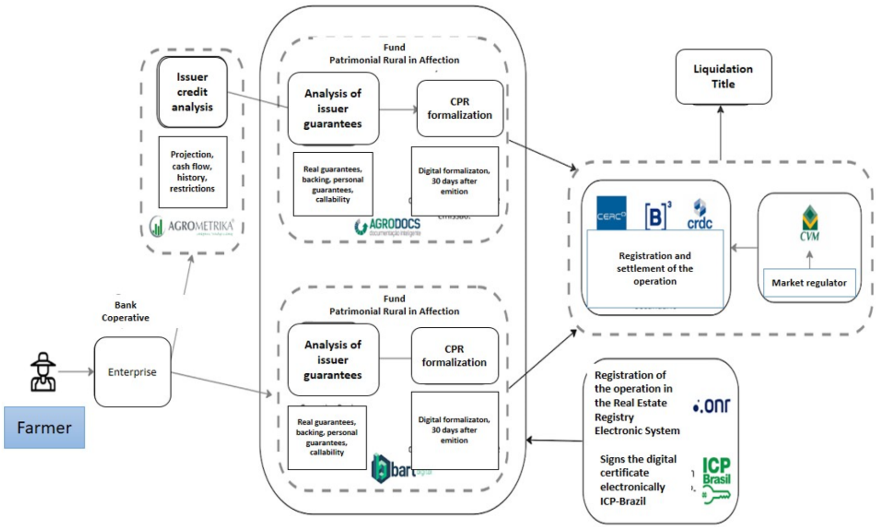
Despite the importance of the initiative for monitoring the operations of the new instruments, it is not possible to obtain important information, such as: i) who the issuers are, given that Law 13,986 (2020) broadens the range of possible issuers; and ii) which agricultural products and activities are the object of the securities. The bulletin only presents a table of agricultural products, in line with the expansion of products and production chains that can use CPRs to raise funds in the market. This type of information is essential in order to understand who the borrowers are and what type of production is being financed. It is assumed that, in the short run, detail on operations could be part of the monitoring process, as the centralized registry provides more data on the securities issued and their characteristics.

4.2. Innovations in the implementation of CPR

The publication of Law no. 13,986 (2020) has enabled the use of electronic systems to create a digital credit market. This operationalization between financial market investors and potential borrowers has opened a space for the creation and entry of technology companies with solutions for the operationalization of the Note. The relevance of the construction of digital platforms was highlighted by the former Secretary of Agrarian Policy of the Ministry of Agriculture, Livestock and Supply (SPA/MAPA) in an event on the subject, in the following statement: “These companies have a fundamental role, as they will be the path, the way between the producer and the investor, guaranteeing the operationalization of what is in the Law” (Enagro, 2021a).

To better understand the operationalization of private credit through CPR, we sought to identify the formation of a digital ecosystem composed of a series of actors and interfaces between platforms that manage data flows, such as collateral checks, risk analysis and processes to formalize the financial assets that are fundamental to make the financing effective, from the borrower to the investors (Figure 2). These companies also ensure the validation of these documents, in accordance with the requirements set by the Central Bank of Brazil, in addition to performing the necessary registrations to validate collateral and negotiate security.

Figure 2. Digital ecosystem case for operationalizing CPR.



Source: Cycle I 2nd Workshop (2021) adapted by the authors.

Agrometrika operates in the credit supply market, offering software as a service (SaaS) to its customers. According to the company, its customers include trading companies, grain growers, food industries, banks, input distributors and cooperatives. The amount paid for the platform depends on the size of the customer, the number of securities, complexity and other factors. The software, which can be integrated with a business management system (ERP), is used to manage the loan portfolio.

Institutions wishing to lend to rural producers use Agrometrika to analyze their credit risk. The platform has more than 4,000 users and manages a credit portfolio of R$ 37 billion. In this way, the company helps actors in the production chain to make safer credit decisions.

Agrodocs and Bart Digital are working on the formalization of the CPR, credit stage in which the main innovations and changes have taken place in accordance with Law no. 13,986/2020.

Agrodocs is used as the primary means of formalizing CPR guarantees, integrating Agrometrika credit information to create the guarantee policy, verifying the ballast using field equipment or satellite imagery, in order to form a digital document. The collection of signatures can be done on paper or in the form of a book entry (in digital form), and there is a transition phase towards electronic registration at the land registry office due to the obligation imposed by Law no. 11,977 (2009) and Law no. 13,986 (2020). The registration is done at the National Registry Operator (ONR), which is connected to the registry institutions CRDC, CERC and B3. According to an interview with a company employee on April 25, 2023, it was found that the title in digital format is still little used, mainly by rural producers who are not familiar with digital signature tools. However, large companies in the sector are already benefiting from the digitization of the title. The interviewee confirms that the main clients of the tool at this stage are large agricultural commodity companies (soybean, corn, cotton and meat), and that even large producers do not have access to the new CPR resources directly, but indirectly link with resellers, buying companies and trading companies. In this way, the tool does not popularize access, but maintains the polarization that already existed.

Bart Digital started its activities in 2016 with the aim of offering solutions for digitizing receivables in the agricultural sector. In the case of CPR, it made its first fully digital contract in 2018, i.e. before the enactment of Law No. 13,986 (2020), which standardized the digitalization of this instrument. Data for 2024 available on the company's website indicate that it currently serves more than 200 clients, including agribusinesses, securitization companies, cooperatives, resellers, rural producers and fund managers, managing more than R$200 billion in contracts. To this end, the company provides an agricultural asset origination platform that offers automatic document issuance, electronic and digital signature, as well as electronic registration with notaries and central registries (Bart Digital, 2024). It is important to note that companies like this play in some ways a role in operationalizing CPR by digital means, formalizing barter transactions that were not always registered even in registry offices.

It should be noted that the Bart Digital platform is offered in three contracting models, depending on the customer's profile. The first model is aimed at one-off requests, with registration in central registries and notary's offices. The second model, called *Software as a Service* (SaaS), aimed at customers with recurring demands, who are provided with a license to use all the software tools for the parameterization of minutes, collection of digital signatures and search for certificates and records in central registry offices and notaries' offices. The third model, on the other hand, is designed for one-off demands and allows the customer to use the software tools for personalized credit management, through a white-label solution, with integration through an API, digital wallet and other services available in the full version of the software (Enagro, 2022).

With the information provided by Agrometrika, the lender can formalize the loan in collaboration with Bart Digital or Agrodocs. These companies help to analyze the guarantees offered by the borrower, proving their enforceability and making the process more transparent. The CPR is issued with an electronic signature. In the case of collateral, such as real estate, the operation is registered in the Electronic Real Estate Registry System (SREI), with both companies using the ICP-Brazil digital certificate.

The Agrodocs platform is responsible for registering the CPR with a registrar authorized by the Central Bank in a maximum of 30 working days from the date of issue. This centralized registration provides access to information on the quantity, value and terms of transactions, as well as enables secondary trading on the financial market, i.e. the buying and selling of CPRs. Investors interested in purchasing CPRs on the secondary market register on the B3 platform, providing the details of the CPR and the issuer. In the case of stock exchange trading, the Securities and Exchange Commission (CVM) plays a key role in supervising and regulating the transaction.

Once the CPR has been negotiated, it will be settled on the date agreed in the security, following the conditions established between the parties, and a settlement record will be drawn up.

4.3. Implications of the expansion of private capital for productive finance

With the increasing provision of private finance by the CPR, significant impacts on the agribusiness chain are expected, which will be discussed below.

Expanding the quantity and quality of agricultural finance

"In the long term, the promise is that producers will have access to cheaper alternative credits", according to José Angelo (Enagro, 2021b). According to Angelo, market rates for private financing in 2022 are 20-23% for small producers and 15-17% for medium-sized producers, compared to 10-13% per year for large producers. The argument of lower credit costs is essentially linked to digitalization as a mechanism for reducing transaction (operational) costs in granting and monitoring financing operations. Issuing platforms have made it possible to automate the analysis of documents, offering legal advice, validation of signatures and guarantees in a single place (Souza, 2022). The digitalization that marks these new private credit instruments puts into perspective the efficiency of access to financial resources for agriculture, especially in relation to the operating model of the National Rural Credit System (SNCR).

In addition, changes in the collateral offered, such as the possibility of using rural property in affectation instead of fiduciary disposition, can reduce creditor risk and improve the issuer's financial analysis in the market. The use of *Open Banking* has allowed banks to access past financial information on debtors, which helps to make credit cheaper. Finally, there is the possibility of issuing the Note in any region and at any time, using mobile devices, without the need to travel (Souza, 2022).

However, increased private credit could reduce the government's role in rural finance, which could diminish its ability to influence resource allocation in the sector. The SNCR has always worked to subsidize credit to rural producers, even at negative interest rates (Dornelas, 2020). Through this instrument, the state has encouraged the production of certain agri-food products, for example, those that are strategic to ensure the supply of the country's population, or the strengthening of productive sectors in certain less favored regions, as well as categories of rural producers who would not have access to financial resources on the market. This was one of the perspectives with the National Program for the Strengthening of Family Farming (PRONAF), which not only aimed to offer specific financing conditions to a group of farmers, but also served as an instrument to encourage and strengthen the production of strategic food products for the country's supply.

There is insufficient data to say which agricultural activities and which types of production chain actors are accessing the new private credit modalities. However, there is evidence to suggest that, as these are private sector actors, there is a tendency for the new credit instruments to be concentrated in agricultural commodity production chains and corporate agriculture because (i) these are products that are already part of the financial market (pricing, financing, companies controlling the whole production chain); (ii) the main issuers of the new credit modalities are not producers, but agribusinesses, companies involved in the sale of inputs, machinery and companies that market agricultural production; and (iii) it is agricultural commodities that offer the greatest attraction for companies that are creating and modulating the digitalization of finance, which is essential to broaden the ballast for the operationalization of this type of financing.

Increased control of agri-food companies through platforms

In this sense, the profile of their founders caught our attention when mapping the digital ecosystems presented above[7]. They were founded by people with long professional careers in private rural lending and worked closely with large corporations in the agricultural input segment, such as BASF, Bayer, Monsanto and Syngenta, as well as having networks of relationships with major input distribution companies. This is consistent with the findings of Prause et al, (2021), that multinationals in the agri-food system have initiated and propagated digital learning models through the development of platforms, as well as establishing new forms of data-driven control and value extraction to extend their control of production chains

7 Verification available on LinkedIn and Instagram of the companies

and, at the same time, strengthen their capital market operations through new market instruments.

Partnerships and exchanges (of borrower databases) between corporations in the input segments may be key to understanding the portfolio expansion and the strong growth of these companies in terms of new securities transactions and financial instruments. Agrometrika's CEO, in an interview at a trade fair, highlighted its long-standing involvement in the private credit market, emphasizing its participation with the Ministry of Agriculture, Livestock and Supply (MAPA) and the Central Bank of Brazil (BACEN) in the development of regulations (such as the recent laws mentioned in this chapter). The business presentation report highlights the platform's interface with Siagri (Agrometrika, 2024), one of the main software used by input distribution companies, and effective partnerships with companies in the sector. At the same time, we find direct links between these ecosystems and big techs through: i) support from major tech companies (Microsoft and Google) in the acceleration phase directly or through subsidiaries; ii) partnerships for the use of infrastructures (Azure platform - implemented in partnership between Agrometrika and Microsoft)[8] for the operation of digital systems and platforms. In the other segment, these specialized digital ecosystems are open systems that connect with specialized players in the financial market, such as venture capital firms and funds specialized in investing in and 'accelerating' start- ups.[9] This is the case of Bart Digital, which has received investments from SP Ventures and Bossa Invest, specialized in this segment and with a recent track record of investing in start-ups linked to agri-food systems.

Thus, there is a tendency for private investment to be directed predominantly towards the financing of traditional agricultural commodities (particularly soya, maize, cotton, beef, pork and poultry in the case of Brazil), as these products are easier to standardize and therefore present less market risk, as well as being the most traded through barter operations. However, the expansion of private financing for the main agricultural

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8 Available at https://news.microsoft.com/pt-br/agrometrika-usa-plataforma-azure-para-levar-sistemas-de-credito-e-gerenciamento-de-risco-ao-agribusiness/

9 News linked on the company's website, available at: https://www.bartdigital.com.br/post/ agfintech-bart-digital-capta-r-5-milh%C3%B5es-para-criar-ecossistema-e-lan%C3%A7ar-novas-verticais

commodities could be considered positive, as it is precisely these products that are currently the most banked within Official Rural Credit, competing with other agricultural products and activities that often do not have private credit as an alternative. It should be noted, however, that there is no evidence to suggest that the expansion of private financing to agricultural commodities and large producers implies a lower use of agricultural policy resources by this same segment.

Although producers of different categories can issue CPRs, as stipulated in article 4 of the Law, the evolution of the CPR market and its implications for Brazilian agriculture needs to be carefully monitored. For the time being, this instrument focuses on the financing of intermediary agents in the agri-food system. The profile of the clients served by the companies studied (which in most cases are also issuers of CPRs) is made up of agricultural input companies and their distribution networks, agribusinesses and business groups active in the agricultural production of the main agricultural commodities.

5. Final Considerations

There is much evidence of interfaces between the processes of digitalization and financialization taking place in the economy and society, but little evidence of their presence in agri-food systems. In this sense, this study sought to elucidate one of these interfaces present in the financing of Brazilian agriculture. The *Cédula de Procduto Rural* is a financial instrument whose recent standardization has opened space for the construction of specific digital ecosystems to operate this and other instruments through digital platforms. These are configured as routes that, in addition to a specific digital route, broaden the range of actors that are beginning to act directly or indirectly in agri-food systems and new forms of organization of the agents themselves. Technology companies, start-ups and other professionals specializing in the financial market and in the operation and modulation of platforms are joining the traditional players in the production chains, linking them to the big techs.

In the case presented in this chapter, it is observed that the digital ecosystem, with its actors and networked platforms, is closer to agri-food system corporations (especially large corporations in the input and agribusiness segment, business groups that control farms in various parts of Brazil). This reinforces the idea that private financing, such as the Rural Product Note, tends to prioritize the financing of agricultural commodity chains (soybeans, corn, cotton, beef, pork and poultry), presenting an attractive portfolio for financial market investors.

It is important to note that the lack of consolidated data and information on private investments in agribusiness limits the overall understanding of the changes that are occurring with the digitalization of finance. A more in-depth analysis with data showing which products are most financed by the Note, as well as information on the region and the profile of the issuers of these securities, is not yet possible. Obtaining this data would allow a more precise understanding of the economic impacts on the agro-industrial chain and on the countryside, analyzing both environmental and social changes in the latter.

While this chapter aims to clarify how these changes in the operationalization of CPR are taking place, it is necessary to recognize that the discussion presented here is only a first step towards a deeper and more precise understanding of these processes.

There is an expectation that the digital rural credit market offers more favorable conditions for granting credit to rural producers, as well as providing greater agility and security in carrying out financial transactions. However, it is necessary to assess the possible impacts of these changes on market dynamics and the relationship between the actors involved.

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13 Digital Transition, Inequality and Livestock Farming: Assessments and Lessons Learned from the Implementation of the National Livestock Information System in Tacuarembó, Uruguay

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1. Introduction and Rationale

Since 2006, the Uruguayan State has been implementing a compulsory Animal Information and Registration System (SIRA) for the identification of cattle born in the national territory in order to build the traceability of animal products, under the orbit of the Ministry of Livestock, Agriculture and Fisheries (MGAP) (Law 17,997, 2006; Magallanes, 2008).

The SIRA (system) is part of a continuum of institutional transformations that began in the 1970s aimed at strengthening the meat sector through technological innovation, value addition, and international trade integration.

The creation of the National Livestock Information System (SNIG) and the Electronic Meat Industry Information System, predecessor platforms that materialized the SIRA, are catalogued as part of the main advances in the socio-technical trajectory of the livestock sector in recent decades.

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The traceability policy of the meat sector deserves special attention, both because of the mandatory nature of animal registration and identification[1] and the generalization of its use in all links of the meat chain, as well as its potential for international trade insertion in Global Value Chains (GVC) and its contribution to the construction of collaborative knowledge networks for its design (Zurbriggen and Sierra, 2015). Although Uruguayan regulations have made it compulsory to declare information on the ownership, title and transit of livestock for the primary link, as well as to declare the submission of slaughter for the industrial phase[2] since 1973, the SIRA-SNIG system aggregates information on individual and group animal traceability for all links in the chain and integrates it systemically to improve access to information for the development of the sector.

In the context of growing health and food safety requirements, traceability favors compliance with protocols, norms, standards, and certifications (Rey, 2021) that enable the Uruguayan meat sector to enter new market segments and niches. Its universalization, given the obligatory nature of the statement of the aforementioned declaration of information, aims to control and encompass all livestock and producer establishments in this policy. The underlying rationale is that access to information is a common good that favors the reduction of gaps and the improvement of competitiveness within the chain.

A central element in the creation of the SIRA-SNIG system concerns the digital animal traceability component. This posed a twofold challenge to the sector's technical trajectory. On the one hand, it required the migration of pre-existing livestock information, previously recorded in hardcopy format, into digital platforms. This data had been maintained by the National Directorate of Cattle Control, a division of the Ministry of Livestock, Agriculture and Fisheries (DICOSE–MGAP), since 1973, for national-level cattle stock control, safeguarding private property, and ensuring production accounting. On the other hand, it compelled various stakeholders across the production chain to adopt new technological tools,

1 Law Nº 17,997 of 02/08/2006.

2 Decree No. 700/973 and Decree No. 1,066/973, respectively.

engage in new learning processes, and break with traditional practices of livestock registration and management.

The second challenge, the implementation of the SNIG policy on a multilevel basis, is the main motivation for this research.

This paper aims to explain how the National Livestock Information System operates in the primary segments of the beef production chain. It seeks to analyze characteristics and gaps in the process of implementing the National Livestock Information System in Uruguayan family livestock production in 2023, taking into account the digital transition and the formation of National Innovation Systems. To this end, the recent trajectory of institutional change is reconstructed, locating the SNIG as a key milestone in this evolution. It characterizes public policy with a special focus on the incorporation of digital technologies into the process of generating and managing livestock information in the primary phase of the chain. It explores the assessment and perceptions of people dedicated to livestock production within the stratum identified as family production[3].

The guiding hypothesis of this paper proposes the unequal appropriation of digital tools in Uruguayan family livestock production, which presents greater difficulties for the digital transition and determines a differential implementation of traceability policy in the different strata of the primary phase of the chain, to the detriment of small-scale production. In turn, it is based on pre-existing evidence on the difficulties of innovation and technical change in the livestock sector in the long term (Mondelli & Picasso, 2001; Álvarez, 2014), especially on a smaller scale (Albicette et al., 2017). This indicates limitations in achieving the effective universality of traceability and the democratization of opportunities for the diversity of actors, especially for the most vulnerable groups in the chain.

The methodological design of this work is qualitative, descriptive in scope, focused on characterizing the process and perceptions of the digital transition in Uruguayan family livestock farming after the implementation of the SNIG, from the perspective of the protagonists. Qualitative techniques

3 The MGAP's definition of Family Producer, a targeting criterion for public agricultural policy, is used as a criterion for the segmentation of the population in this study. This segmentation of smaller scale enterprises establishes parameters of physical size, income, and the predominant use of family labour for production (Resolution No. 1,013/016 MGAP Definition of Family Agricultural Producer).

were used for the construction of information, based on the documentary review of institutional documents and previous bibliography, as well as 10 semi-structured interviews with family-scale livestock producers and 5 with technical actors of the MGAP linked to the implementation of the traceability policy in the primary phase and at the local level.

This is followed by a summary of the characteristics and institutional trajectory of livestock information in Uruguay, with a focus on the SNIG-SIRA system. Subsequently, the conceptual framework underpinning this research is presented: it approaches from the New Institutional Economics (Hodgson, 2006) and National Innovation Systems in Latin America (Arocena & Sutz, 2013) on historical-economic and technical-productive change, and contributions from the perspective of Digital Transitions and Digital Inequalities (Van Deursen, Helsper, Eynon, & Van Dijk, 2017). These approaches share the perspective of a systemic and cumulative process of historical change in technological adoption in production. Finally, the emergence of the information gathered in the fieldwork and a general synthesis of the research process are analyzed, returning to the initial hypotheses.

2. Characterizing the SNIG: a History of Registers and the Emergence of a Public Good in the Digital Juncture

2.1. Description of the SNIG today: the what and why of institutional design

In Uruguay, the MGAP is the governing body for agricultural policies and is therefore responsible for the SIRA-SNIG system. Its main objective is to strengthen the efficiency of control and political-technical decision-making for livestock farming, through the control and monitoring of the movement of livestock, as well as to enable livestock producers and operators in the meat sector - movement operators, slaughterhouses, intermediaries, local fairs and any other company or person owning livestock – to access relevant information on the origin, trajectory and destination of livestock in real time. It also seeks to guarantee food safety, animal health, product quality and the competitiveness of the sector in international markets.

The provision of information for the control of livestock has been a requirement set by the State to agricultural producers and establishments since 1973[4], through the completion of annual affidavits required by DICOSE-MGAP (General Directorate of Livestock Services of the MGAP). However, there are records of animal ownership and livestock health control regulations since 1895 (MGAP, 2001). The creation of the SNIG system is framed in the previous compliance regulations, so its original obligatory nature is linked to the compliance of annual affidavits and the registration of signs and marks.

Considering a universe of 86,097 registered livestock holders[5], the SNIG annually processes one million documents. There are 230 million events documented during the life of the animals, 18 million commercial transactions registered per year, and since the system was launched, there have been 50 million traceability tags provided free of charge to producers. There are 3,150 movement operators working in the system who are authorized by the MGAP, and approximately 80,000 active producers. Thus, it aims to reflect "instantly" the current and historical situation of the basic attributes, ownership, location, and health status of the national herd. Table 1 summarizes the potential of the SNIG system, which depends on the implementation of tools associated with various areas of the MGAP involved in the traceability process and the effective adoption by the actors that make up the meat chain throughout its links.

4 Decree 700/973 of 8 August 1973; Law 16,736 of 1996.

5 Data reported by the SNIG in the virtual dissemination days. Available on the MGAP YouTube https://www.youtube.com/watch?v=s4NGZut7PYo&t=476s

Table 1. Potential of the SNIG according to areas of intervention.

Accounting and Control of Animal Stock	Sanitary Control and Food Safety	Quality, transparency and access to information
• Management of records generated from Annual Sworn Declarations submitted by producers to DICOSE, covering: -Updates on livestock inventory (cattle, sheep, swine, equines). -Enterprise data, ownership, exact location, land use and extension of the establishment. • Processing and recording of physical movements and commercial livestock transactions through the systematization of Property and Transit Forms (DICOSE). • Calculation of the national livestock stock and current balance of movements and transactions.	•Permanent and unique identification for the traceability of each individual animal. • Identification of the entire herd for traceability through a group identification system with unique and permanent ear tagging. • Recording of basic animal information and relevant health events throughout the life cycle: diseases, treatments, vaccines, reproduction, mortality, inspections and health checks. • Standardization and professionalization of traceability: training of human resources and compliance with requirements for operator certification by the State.	•Development of an integrated information system linking primary production to the industrial phase for the traceability of beef cuts post-slaughter. •Prior to each livestock movement, the system verifies participant authentication and the absence of sanitary, judicial or administrative restrictions. Verification via web or Interactive Voice Response (IVR). •Automated data processing ensures real-time availability of information, covering the entire process from farm to consumption. •The document management system enables reporting, monitoring, continuous updating and validation of geo-referenced information, accessible to system users and Ministry of Livestock (MGAP) officials for decision-making, management, and planning.

Source: Own elaboration based on Zubriggen C & Sierra M, 2015 and MGAP, 2010.

The SNIG includes functionalities to manage multiple stock and points of sale at the national level, ensuring that official identification devices can only be delivered by distributors, with given quantities to producers, previously authorized by the MGAP. This allows for detailed tracking of who has each device, even before it is placed. In Uruguay, the devices are given free of charge to producers. The registration of the breed, sex, age, place of birth, and owner of each animal can be done directly by the producer: electronic format or paper forms, through the annual affidavits submitted by the producers before DICOSE at the end of each year. Thus, the SNIG system progressively incorporates the digitalization of the information stated, associated with a DICOSE number for the identification of the owner of the herd and one of the owners of the establishment. The paper format for declarations is accepted up to 15 days before the deadline for submission. The information is available on a web portal, a digital resource developed by the State in order to facilitate the implementation of the system.

Table 2. Online services and procedures available on the SNIG web portal.

ACCESS TO THE SNIG PORTAL	• Request for access credentials for Producer and Veterinarian Users. • Appointment scheduling for in-person procedures.
BOVINE TRACEABILITY	• Request for reprinting of the Animal Registration Form (Form D1, MGAP). • Update of data and vital events of animals in the SNIG. • Request for ear tags for individual livestock traceability. • Manual Electronic Movement Form registration for transfers between farms involving up to 30 animals
LIVESTOCK CONTROL	• Registration and deregistration request for DICOSE Numbers (identifiers of livestock and property ownership). • Update of information regarding the registered business name of the farming unit (e.g., changes in legal status, ownership, or substitution). • Submission of records for registration under the establishment's DICOSE number. • Submission of Annual Sworn Declarations. • Request for acquisition, renewal, or transfer of brands and/or marks for livestock identification.

Source: Own elaboration based on https://www.snig.gub.uy/principal/snig-tramites-y--servicios-tramites-en-linea-nevo consultation: July to 2024).

This portal is designed with a user-oriented approach – targeting producers, operators, and veterinarians. It enables the completion of procedures and access to services (Table 2), the visualization of maps, data, and statistics, reception of news updates, communication with system officials, access to user-specific services and related information systems, as well as the registration of user information through a secure login using a personal username and password. The website can be viewed and accessed from fixed and mobile devices. However, its suitability for mobile devices, especially mobile phones, is an aspect that could be improved, and its design is more accessible from computers.

2.2. Chronology of SNIG system in the livestock sector and its digital component

The historical trajectory of the SNIG system in Uruguay has developed over several phases, each one marked by significant advances in the implementation and evolution of the system (Zubriggen C & Sierra M, 2015). These are also framed in a dynamic global context that is challenging the country's positioning on the international meat market, and in the rise of the information society in a context of globalization, technology, and digitalization. Table 3 summarizes the most relevant features of each stage.

From the phases of the process, Zubriggen & Sierra (2015) suggest some lessons worth highlighting. First, there is the cumulative trajectory of institutional and technological changes, given the Uruguayan State's vocation to formulate registries and comptrollers for more than a century. This allowed the incorporation of innovations in previous institutional practices of data availability and the registration process. Second, public-private articulation and multi-stakeholder integration for the construction of collaborative knowledge networks fostered a favourable ecosystem for innovation, validated by the tool users at an initial level. The leading role of the State in this process is a third lesson, marking a centrality of public policy, but a broader social anchoring under the umbrella of regulations and norms for the institutionalization of change. However, the exponential effect and sustainability of the learning are not yet clear. The transfer of knowledge and technology to the rest of the chain, especially smaller-scale producers in the primary phase, is not necessarily a spontaneous or immediate effect. It forces us to consider a temporal and distributive dimension of access to knowledge and technology: its availability does not linearly imply its appropriation, which requires at least time and resources. Below, we seek to understand the process from theoretical frameworks that explain this distributive dimension of the 'public good' and technology, as a sectoral development strategy.

Table 3. Chronology of the genesis and creation of the SNIG.

Background (1973–2002)	• Context of the Second Globalization: the emergence of the internet, the collapse of the State-Led Industrialization Model, the opening of global markets, and access to new information technologies. Civic-military dictatorship in Uruguay (1973–1985) and Latin America (1970s–1980s). • Outbreak of "mad cow disease" in England increased sanitary requirements for accessing international livestock export markets, especially in the European Union (EU). Its impact on humans through consumption of infected meat heightened interest in traceability: knowing the origin and production process of the product for prevention and sanitary control became a global demand (EU Regulation 820/97). • Since 1973, Uruguay has had legal and administrative tools for controlling livestock stocks and movements (Decree 700/973), and the international context promoted the regulation of Law 16,736 of 1996, mandating the use of Guides for Livestock Transit and DI.CO.SE registration, along with a sworn declaration. This system promoted individual traceability and emphasized the existence of livestock records. • The system of brands and ear tags, as well as sanitary regulations, dates back to the 19th century, establishing the basis for the registration and group identification of livestock per establishment.
Phase I (2002–2004)	• Context of crisis and deregulation: collapse of the neoliberal model in the 1990s. Health, financial, and social crisis in the Southern Cone. Expansion of digital technologies and the internet. • Impact of the 2001 crisis in Uruguay: increasingly demanding markets and consumers pushed the Uruguayan state to move towards the implementation of an internationally recognized individual traceability system. • In 2002, the state contracted a consortium promoted by the private sector (ITC, ONDA Uruguay S.A., GeneXus Consulting) to develop the individual traceability project (2004–2006). • The National Meat Institute (INAC) commissioned the Meat Industry Strategic Information Center (SEIIC), a public-private platform for information exchange in production, processing, and commercialization chains, with strong articulation with the private sector. The project included a new institutional and governance model. • A national pilot plan for individual traceability was launched in different regions and production actors, with technical assistance from the MGAP, call centers, and telephone help desks for support.
Phase II (2005–2010)	• The Uruguayan government and MGAP created the Animal Identification and Traceability Working Group to redesign the SNIG, with over 30 participants from public institutions and the meat production chain; collaborative networks were established to identify and promote new products. • This group drafted the foundational document for the creation of the Animal Identification and Registration System, which mandated the identification and registration of all livestock under Law No. 17,997 (2006). Individual traceability was defined as the ability to access the complete life history of the animal from birth to slaughter. • A toll-free helpline (0800) and physical spaces for consultations were established. • INAC enhanced the SEIIC by creating the Meat Information System, unique worldwide, to ensure transparency and guarantees in the registration of information. This supported its integration with the traceability system, which was extended to slaughter and final consumption, including a digital sworn statement for slaughterhouses.
Phase III (2010–2014)	• Information technologies were no longer just support tools but key components across all sectors, creating value collectively. Law No. 18,656 made it mandatory to identify all livestock in the country. • Emphasis was placed on the convergence of information and communication technologies (ICT) and biotechnology (bovine DNA traceability, genotyping of sires, Genomics Project, and meat quality improvements through genetics and animal selection). • SEIIC–SNIG integration was consolidated, and the process of technological adaptation was strengthened. Geographic Information Systems (GIS) were included. • The National Agricultural Information System (SNIA) was created, transcending MGAP and linking public and private institutions, academia, and civil society at national and international levels to improve interoperability of agricultural information systems.
Phase IV (2015–present)	• Ongoing research on new technological developments, improvements in livestock genetics and quality, aiming to boost global competitiveness. • Traceability extended from livestock to soil and agronomic traceability, exploring new functionalities for value-added innovations (e.g., improved classification guides, GPS tracking in identification devices). • A new food safety and health strategy advanced towards registration and control of veterinary drugs, certification of livestock processes (electronic meat traceability, genetics, slaughter control), and final consumption labeling. • New online procedures have been incorporated: e.g., in 2022, brand renewals, title downloads, and registration of livestock brands and tags.

Source: Own elaboration based on Zubriggen C & Sierra M, 2015 and MGAP, 2010.

3. Conceptual Framework: Micro-Macro Approaches to Technological Change and Inequality in Times of Digital Transition

3.1. State, innovation and technology in the explanations of economic development: the SNIG as a bet on R&D in a traditional sector

For endogenous economic development theories, technology is a central element in explaining the economic growth and development of societies. Those that invest more in Innovation + Development (I+D) have better conditions for development, which generates a spiral of reproduction of the relative divergence of developed economies over those with less investment in I+D. This dynamic is articulated in broader processes of historical change, defined by the New Institutional Economics as *path dependence* (North, Wallis, & Weingast, 2009), which gives a cumulative and transitional sense of technical and economic change at a structural level.

Latin American productive specialization oriented towards the production of primary goods with little diversification, structural heterogeneity and vulnerability to changes in the terms of trade explain the lag of the regional economy for neo-structuralist thinking. In the case of Uruguay, the livestock sector shows long-standing backwardness, low technological development, primarization and dependence on external economic cycles (Moraes, 2021; Álvarez, 2014). The Uruguayan State's investment in technological aggregation in the livestock sector – main export sector of its economy – through the modernization of information systems is a strategy for the country's development.

Technological investment will be key to development, together with an increase in social equity, which implies State intervention to promote structural change and redistribution. The digitalization of the SNIG system in its universal pretension corresponds to this idea of equity and democratization of welfare through access to technological change and improved international competitiveness. The idea of the SNIG as a 'public good' or 'common good' (Moore, 1995; Ostrom, 2009; Zurbriggen & Sierra, 2017) points precisely to its contribution as a tool for social change, through ideally universalized access to information and the market. In this sense, the theory of endogenous development gives greater explanatory weight to the institutional factor, particularly in the area of R&D.

3.2. The perspective of National Innovation Systems as an opportune framework for the study of digital transitions in Latin America

The notion of National Innovation Systems (NIS) introduced in the 1980s by authors such as Freeman (1987) and Lundvall (1985; 1988) allows us to approach, from a reading of developed economies, the relevance of the science-technology-innovation (STI) triad. They highlight the systemic perspective, which allows us to conceive of an organizational network of institutional arrangements and relatively hierarchical relationships that permeate the sphere of production but also others, such as academia, educational centres, markets, States, and political decision-making, producing learning that is favorable to innovation. For Lundvall (1985), the specific cultural framework is relevant, in the national sense, since innovation arises from the encounter between user needs and specific technical opportunities. National States have a central role in channelling the needs of the weakest, an aspect in tension in the face of globalization (Lundvall B., 2010).

Arocena and Sutz (1999; 2013) highlight the NIS approach and its systemic proposal, but question its applicability in the Latin American context. They argue that, in this context, NIS are an *ex ante* notion, given that no systemic behavior patterns are identified between production processes and scientific-technical knowledge, and with isolated and fragmented innovation experiences prevailing with little impact on the countries' productivity. They highlight the relevance of a normative approach to STI, for which Lundvall's proposal appears biased, claiming the need to define an orientation of the NIS appropriate to the Latin American particularity as a trend horizon.

It is necessary to integrate a distributive dimension that arises from the unequal exchange between open economies, where Latin America occupies a position of almost structural relative backwardness. It is necessary to deepen strategies that combine improvements in external insertion and the development of sustainable technological innovations at the internal level.

The potential and sustainability of innovations is related to established local capacities, such as institutional architecture, physical infrastructure, social capital, and human capital. Digital transitions in agriculture are framed in this space of multidimensional interaction and require complex and systemic approaches. A cumulative understanding of change requires a look at formal and informal institutions in order to understand the mechanisms of technological adoption in individuals and of the digital transition in a community. Inequality in STI development between countries has an intra-country correlate, as the countries lagging furthest behind tend to coincide with those with the greatest socio-economic inequality in their populations. In this sense, it is necessary to analyze digital transitions within the framework of digital inequalities (Helsper, 2021; Díaz, Dodel & Menese, 2022).

3.3. Digital Transitions in Uruguay 2000-2024: A thriving public policy with a stratified and uneven impact

Recently in Uruguay, there have been significant experiences of public policies to improve access to information and communication technologies, aimed at reducing gaps in access to information, knowledge, and transparency in different sectors of the population. The creation of the Agency for Electronic Government and the Information and Knowledge Society (AGESIC) in 2005[6] is a milestone in the institutional trajectory of the development of the Information Society in Uruguay, "*with emphasis on the inclusion of the digital practice of its inhabitants and the strengthening of society's skills in the use of technologies*"[7] and as a strategy to promote the construction of a digital citizenship through e-Government and Open Government.

Since the 1990s, the National Informatics Commission (CONADI), the Committee for the Reform of the State (CEPRE) and Uruguay in Network Red (*Uruguay en Red*) have been highlighting the importance of addressing the issue in the public agenda, within the orbit of the Presidency of the Republic. In 2015, the national government decreed that AGESIC's

6 Art. 72 Law nº 17,930 of December 2005

7 Art. 2 Decree no. 205/006 of June 2006 regulating the functioning of AGESIC and defining the general objectives of the organization.

competences include contributing to *"(...) the formulation of policies, plans and development programs in the field of the Information and Knowledge Society"* and *"(...) advising public, state and non-state entities in the formulation of e-government plans and policies, as well as their implementation"* (Decree 184/015). This institutional framework serves as a regulatory and public policy framework for the development of e-government agricultural policy, as promoted by the SNIG. The SNIG offers a platform for the producers, who access individual information on their livestock and the possibility of carrying out procedures online[8] via a personal user (Producer User). But it is also a platform open to the community, since the SNIG makes aggregated and geo-referenced information available on a national scale and disaggregated information at the level of enumeration area[9] in an annually updated web portal based on the Affidavits of Stocks kept by the Directorate for the Control of Livestock (DICOSE).

However, precedents indicate that the genesis of and changes in the launch of the SNIG in around 2005 caused tension in its trajectory between its purpose as a livestock information system and a livestock identification and registration system for animal traceability (Zubbrigen & Sierra, 2017). These "misunderstandings" marked the subsequent functioning of the SNIG in the face of its implementation: the working group[10] *"(...) took on functions that were not in the terms of reference, such as training and the Help Desk, which contributed to raising awareness among producers of the importance of traceability"* (Zubbrigen & Sierra, 2017: 145). These authors identified a set of lessons learned from the SNIG design process that determine a successful reading of the process by the actors involved; they focus their analysis on the construction and validation of the system at the level of public policy design and in the early stages of implementation. They highlight the flexibility and adaptability, the interdisciplinary approach, the public-private participation

8 See Table 2 of this document.

9 The Enumeration Area is the minimum territorial unit used in Uruguay by the National Institute of Statistics for the survey of census information, so its use in the SNIG favors the transversal compatibility of national statistical information with the information surveyed by the System.

10 Animal Identification and Traceability Working Group created to redesign the SNIG under the coordination of the MGAP, made up of actors from the meat chain and public institutions; for the establishment of collaborative knowledge networks and the development of new products to strengthen the platform (see Box 3).

of multiple actors, the cooperation of the market and institutions, social legitimacy and the proximity to producers for the valuation of the SNIG, among others.

The passage of time and the continuity of the tool's implementation in local scenarios partly motivate this work. Reviewing the perception of the SNIG's success with actors who are more distant from the design may reveal blind spots in public policy making process, which may help to clarify and update the assessment of the opinion based on new empirical findings. In particular, this paper focuses on the implementation of the SNIG in the family livestock producers and in territories with lower levels of local development and populations with higher levels of socio-economic inequality.

In this regard, the social science literature on digital inequalities is structured in two main strands: the standardization model and the stratification model (Norris, 2001). The normalization approach assumes that the spread of technology will tend to be normalized by the generalization of the product. As a set of the population gains access to the good, the demand for the technology slows down, its cost decreases, and favors near-universal access market forces, so that inequalities are eliminated through convergence of access. At the other extreme, the stratification model assumes that differences in origin between individuals in terms of technological adoption are taken into account: those who are in more disadvantaged positions in the distribution of wealth will tend to have greater difficulties in accessing and adopting technology, an aspect that increases as the availability of ICTs increases. Thus, the digital divide is sustained and widens as the wealth gap widens (Goldin & Katz, 2010). But to the extent that digitalization brings profits in the productive world, the digital divide ends up reinforcing the unequal distribution of income (Dodel, 2021; Díaz, Dodel & Menese, 2022).

4. Method

The methodological strategy followed in this work is based on a qualitative design, with an exploratory descriptive scope. This approach aims to analyze the SNIG implementation process from the perspective of the digital transition and the creation of National Innovation Systems (Lundvall, 1985; 1988). The aim is to know and understand the perceptions of the actors directly linked to the implementation of the SNIG about the lessons learned, limitations and ruptures in the process of technological adoption. Thus, a qualitative approach brings us closer to the mechanisms, incentives and motivations and rescues the individual and common subjectivity in change (King et al . 2000).

For the collection of information, the semi-structured interview technique was used, applied in 10 interviews with men and women of different ages and educational levels, dedicated to family livestock production. In turn, five qualified informants linked to the SNIG were interviewed, both at the central and territorial levels. In this regard, the technical reference of the SNIG-MGAP Tacuarembó and the General Directorate of Rural Development-MGAP Tacuarembó were interviewed. The selection of cases was intentional, trying to balance variance and theoretical saturation.

This study is particularly concerned with the distributive dimension that underlies the process of technological adoption towards digitalization; therefore, the population sample used sought to access the voices of people dedicated to family livestock production because of their history of resilience in the face of structural and technological changes in agriculture. The study focuses on the department of Tacuarembó, in the Northeast region of Uruguay, as it has a long tradition of livestock production and is home to a significant portion of the region's family production (Childe et al., 2022), while at the same time it has lower levels of regional development performance than the country average (Rodríguez Miranda et al., 2017) and the highest rates of internal inequality (Mariño Velázquez, 2023).

5. Results and Discussion

- **SNIG as a common good: topicality, new aspects and accessibility**

The SNIG in Uruguay is positioned as a public policy of reference in food safety and animal health as a common good. The quality of the services provided and their growing development mean that it has a relevant role in the construction of an integrated vision of information systems within and outside the MGAP. Public companies, departmental governments, and private actors have resorted to the analysis capacity available in the system to address other issues, such as drought and flood impact assessment, activity mapping, and sectoral policy evaluation, among others. Although it is a generalized tool, the actors interviewed state that its universality is a guiding horizon, rather than an actual reality, as the use of the information by producers is mainly restricted to the fulfilment of control and not necessarily digital (Table 4).

Table 4. Excerpts from Qualified Informant Interviews (QIIs) and User Interviews (UI).

"There's still a long way to go for universal digitalization; it's been planned for a while. They started with the 15-day paper form, and then it all stayed the same... there's a lot of outreach work that I can't do alone, and that means people don't know, don't find out, we just monitor them." (QIS 4)

"Currently, they've added tools to the platform that weren't there before, but people don't know, and many still come to me expecting me to complete the procedure for them." (QIS 3)

"... [Users] don't see it as something very positive; now they practically only do the digital sworn statement, but then they go back to paper..." (QIS 2)

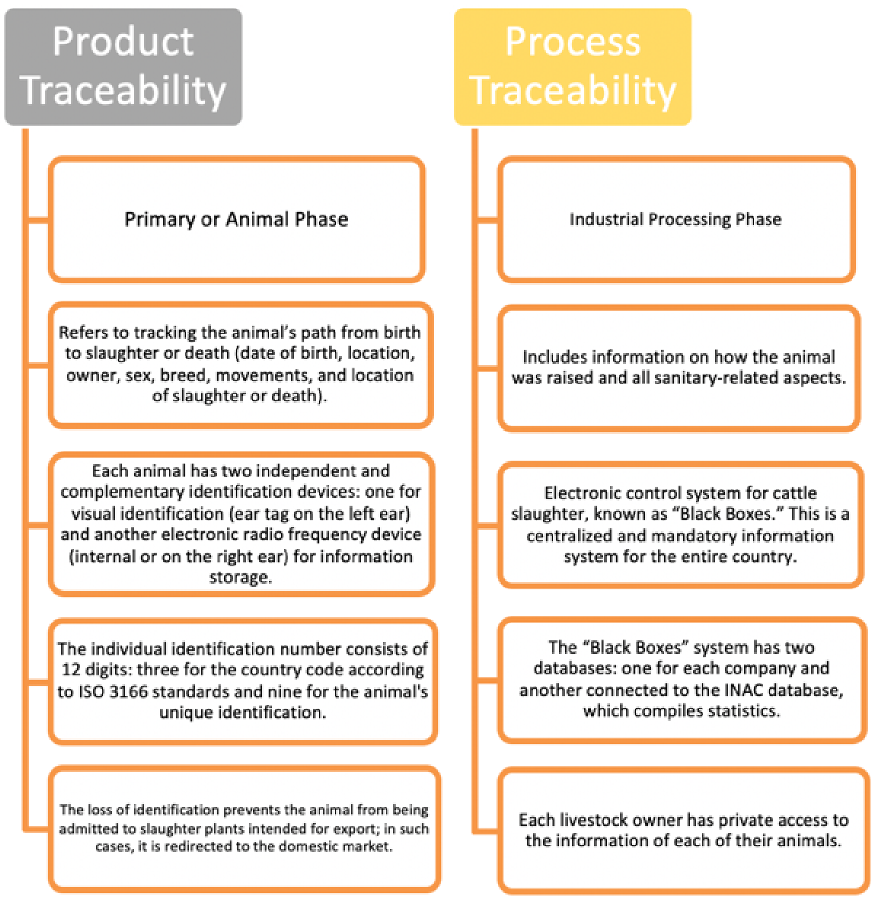
"Some people don't want to, some can't, and some don't have access, so it's hard to require them to do it electronically... But I tell those in Montevideo: come up North! Go to Cañas? Here we have no access, it's really difficult..." (UI 3)

The establishment of a common definition of traceability of the Uruguayan meat chain facilitated the accessibility and openness of the SNIG (Figure 1). This legally established[11] definition configured a shared horizon on the information and processes to be considered by the State and the users of the system and its publication. It implies the technical capacity to identify an animal from birth to the end of the marketing chain of its various products, as well as the ability to identify them as far along the production sequence as necessary. For the SNIG, it means that the animal has been correctly entered into the register and that the subsequent events

11 Article 1 Law 17,997 of 2006. Declaration of national interest. Animal identification and registration system.

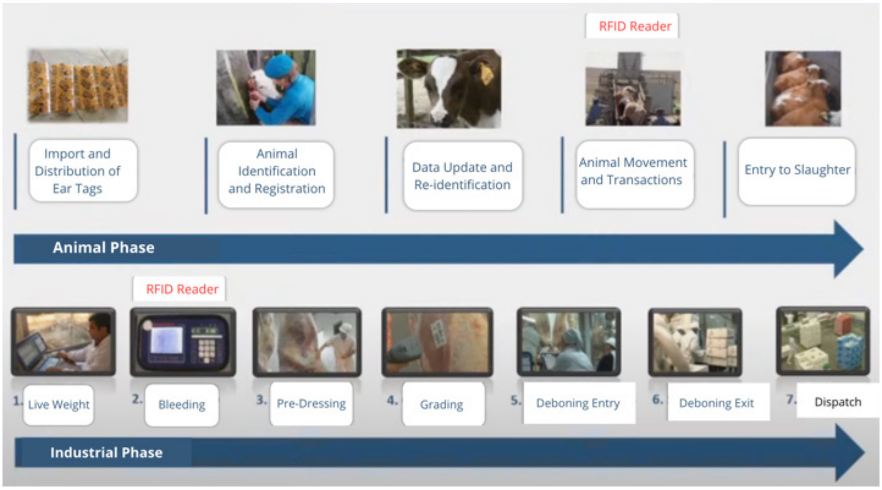
have been recorded without interruptions or inconsistencies (Figure 2). This involves the combined application of permanent visual and electronic identification devices, which cannot be altered or reused, making it possible to associate a unique, non-repeating number to each animal throughout its life (Figure 3).

Figure 1. Traceability of the beef chain in Uruguay by stage of the chain.



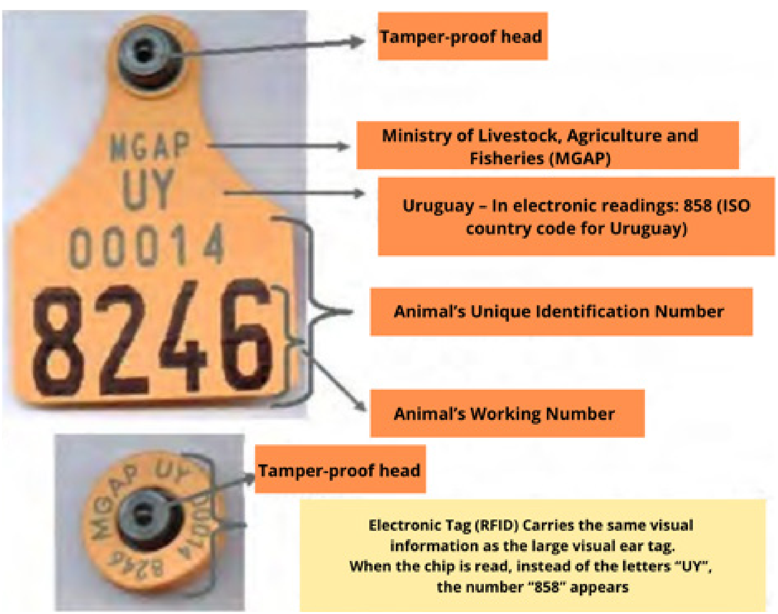
Source: Own elaboration based on interviews with qualified informants from SNIG, MGAP.

Figure 2. Traceability process of the meat chain in Uruguay.



Source: SNIG, 2022[12].

Figure 3. Individual cattle identification devices in Uruguay.



Source: SNIG, 2004[13].

12 Available at https://www.youtube.com/live/s4NGZut7PYo.

13 Extracted from SNIG (2004) "Document G2 1-04. Fundamental Concepts of Individual Traceability", MGAP

At a general level, the SNIG has accompanied these definitions with the development of support and communication channels, especially aimed at producers. However, except for the reference of the territorial technical teams and the telephone line (0800), the support systems are predominantly technical assistance systems through virtual channels: web consultation and massive training through virtual meeting platforms. The Helpdesk provides face-to-face assistance at the central level, in Montevideo, the national capital. Direct promotion and training activities with users at the territorial level depend on the capacity of the SNIG's technical teams to plan them. In the territory of this study, the team is integrated by a single person, who centralizes the functions of direct attention, support, inter-institutional interaction, supervision, and capacity building.

Access to information is enabled at two levels. At the user level, upon request, each producer has a private access account to register the identification and vital events of their herd, as well as to view its history. This information is visible to those who make annual affidavits in digital and paper format, as the SNIG processes the forms. However, its availability does not necessarily imply its adoption. As for the publication of the information, it is published in Open Data format under annually updated indicator reports, published on the SNIG website.

In the last decade, INAC (National Meat Institute) has made progress in the generation of certifications[14] of meat products in the agro-industrial phase, taking advantage of the traceability of the SNIG. Quality certification, which differentiates meat products on the basis of traceability and compliance with sanitary and international standards, has allowed access to demanding markets that value transparency and safety in the food production chain. Although this adds value to the final product, this value is not perceived as a profit by the smaller producers in the primary link of the chain.

The digitalization of processes related to the identification and traceability of livestock has enabled value addition and potential access to information by producers and operators in the meat sector in a personalized

14 Uruguay's Certified Natural Meat Programme (bovine and ovine) and Animal Welfare Certification in slaughter plants (INAC, 2024)

and secure way. However, it imposed certain structural challenges that differed for the different strata of the sector.

- **The territorial anchoring of the SNIG as a digital tool and its nature as a public good in tension**

Going from the inception of plans and programs to their implementation is always challenging. This challenge increases as the implementation process moves towards the territorial space: resources and actors interact with relative virtuosity, public policy levels require simultaneous coordination, and local dynamics impose their own logic, capacities and limitations. Thus, when reviewing the SNIG experience from a local perspective, some statements about its collaborative nature and its scope as a public good can be relativized.

From the interviews, it is clear that in the Tacuarembó area, the use of the SNIG digital platform by family livestock production is still restricted (Table 5). Although all the interviewees recognize its existence and its mandatory nature, as well as the power of the tool in relation to global changes in the sector, they express a certain distance and resistance to its use in their own experiences, reporting difficulties in its appropriation and the predominance of a control function in the representation of the tool.

Table 5. Excerpts from Qualified Informant Interviews (QIIs) and User Interviews (UI).

"Fear, fear of what do you think? Right? Fear that they might want to know more about you, like they don't want to open up to the world, let's say. That kind of fear—fear that they'll get into your private stuff. At least the ones who are somewhat close to me, they think the digital world is too much, like a privacy invasion..." (UI 9)

"People aren't really into technology. Out in the countryside, folks are more closed off, it's hard to even get someone to text you. I feel like people are either scared to try or just give up halfway because it's confusing or they don't know how to use tech. I end up crying." (UI 7)

"I mean, yeah, I get a little scared too, like paying bills online—your data's out there whether you like it or not. So yeah, I'd say I'm also a bit scared of that." (UI4)

These expressions are associated with different limitations linked to the local space and to perceptions of individual capacities and loss of priority. Regarding the limitations of the local space, interviewees mainly refer to the infrastructure characteristic of rurality. In particular, access to electricity is still limited in deep rural areas of the department, which generally limits the use of electronic devices. In those areas where electrification is available, there are limitations associated with internet access and its proper functioning.

Although the department has increased in the last decade by around 60% in the coverage of the electrical grid, in rural areas, progress has been close to 19%[15], supported by the organization and resources of the community to achieve this. This generates differences between rural areas of the department as well as limitations for those who cannot fully or partially afford the construction of electricity lines to their homes.

In terms of internet access, access limitations in rural areas appear as conditioning factors for the use of the SNIG digital platform in the accounts (Table 6). Most of the interviewees refer to this difficulty as a substantial aspect, since even when they have internet access in their homes, connectivity is difficult and of poor quality. Although Uruguay is part of the group of countries with High Significant Rural Connectivity (Ziegler & Arias Segura, 2022), the territorial and social distribution of this access is probably biased towards areas and sectors with a higher level of development, although no disaggregated and published data are available to show this. In the population interviewed, the predominant form of internet access in households tends to be through mobile telephone devices, which act as modems to provide internet to the family unit. However, the quality of operation of these devices is relative to the standard of technology available, which is generally limited in family livestock production. In addition, these devices are usually for individual use, which conditions internet access for the whole family unit.

15 According to official data extracted from https://www.gub.uy/presidencia/comunicacion/noticias/ute-incremento-61-extension-red-electrica- departamento-tacuarembo-ultimos-10

Table 6. Excerpts from Qualified Informant Interviews (QIIs) and User Interviews (UIs).

"No, it doesn't really work for me. I have to spend hours waiting for the internet to connect. I mean, yeah, having internet at home for calls and everything is pretty tough. I have to find a little corner here where it works, or move around until it does. I have to stay still in that exact spot where it catches the signal — if I move it drops." (UI 3)

"Not having internet access — even if you live kind of far, but not that far — makes things hard. One time I was filling out the declaration and the internet cut out right when I was about to pay. I ended up getting penalized for not paying on time, and I didn't even know. I was flagged and missed the deadline..." (UI 8)

"You can't use all the features of the SNIG website everywhere... I mean, even places not that far from Tacuarembó, like 20 or 30 kilometers away — you just can't use it there." (QII 1)

Regarding the accessibility of the electricity grid and access to internet connection, the interviewees add the dimension of territorial mobility as a difficulty. In order to access electricity and internet, many have to move from their homes to other areas with better connectivity, both inside and outside their properties. In this sense, the weaknesses of roads operate as infrastructure limitations to access to services such as electricity and internet, but also to basic services such as education and health, so that mobility for the use of digital technologies takes second place in their stories and is seen as a costly movement in their daily lives, in both material and symbolic terms.

As the traceability and declaration of livestock is a legal obligation for all livestock enterprises, family livestock producers seek their own strategies to resolve these limitations. However, it is clear from the interviews that their use tends to be restricted to two activities: requesting tags for animal traceability and providing information for the sworn declarations. This makes it difficult to take advantage of the platform in its greatest expression in terms of its constitution as a public good, since they do not identify the possibility of a daily use of the information for the monitoring of the productive operation of the farm or a differential in the value of their production from the use of the tool. In fact, most of the interviewees refer to the SNIG as an obligation and a cumbersome aspect that adds work without any apparent direct benefit, especially because it requires an associated registration system that they usually keep in physical paper format, and then have to migrate to the platform. This migration often involves the logic of production management at the farm level, which is seen by those interviewed as a duplication of work time rather than an investment in innovation in their production. In the minority of interviews, the main advantage is the speeding up of deadlines for the application for traceability tags and for the completion of livestock movement guides, in contrast to the previous bureaucracy that required authorizations at the central level of the MGAP, which lengthened the processes.

- **The gap in question: layering and adaptation strategies towards the digital transition in livestock traceability**

The stratification model of technological adoption affirms the existence of possible differential virtuous and vicious spirals depending on the socio-economic position of the population under study. In the case of Uruguayan family livestock production, the adoption of technology has been dragging along previous trends of low innovation and intensification, while its population carries out its activity in conditions of agronomic, environmental and social vulnerability (Soca, 2019). Moreover, this intersects with another set of inequalities associated with national demographics: an ageing rural population, gender and generational inequalities in access to and control of resources, inequalities in human capital and access to formal education, invisibility of ethnic inequalities and territorial inequalities.

In the case study, the interviews indicate that there are some conditions that favour the process of adaptation (Table 7): women tend to have a greater predisposition to learn digital skills and tools. The initial hypothesis of age bias does not seem to hold true, at least in this set of interviews. Younger interviewees (5 out of 10 testimonies) do not necessarily show a greater predisposition to use the digital platform of the SNIG, although they do express daily use of digital devices for social and recreational purposes. The factor that seems to have the greatest impact, after gender, on the predisposition to digitality is the previous experience of using digital tools at work outside the livestock production activity. In other words, those with more diversified employment and educational trajectories tend to have a greater propensity to value and use the tool positively than those who have spent their whole lives in livestock farming. This can be interpreted as a greater permeability and capacity to adapt to changes and, therefore, to learning, in a logic of *learning by doing* in scenarios of greater diversity than the traditional extensive livestock farming typical of family livestock farming.

Table 7. Excerpts from Qualified Informant Interviews (QIIs) and User Interviews (UIs).

"We use it mostly to watch series and scroll through Facebook, but always from the phone... she handles all that. She pays for the app and does everything on her phone. (...) I'm not that old, but I don't really do it — maybe because she does, you know... out of convenience." (UI 7)	*"I was the one who knew how to use the devices. I went to a talk and did a course on traceability systems to help my dad — and also to get a job. I was already studying nursing. I did the classes and learned a lot, but I never got the system update so I could keep working." (UI 5)*
"I'd rather go out. I mean, I know I could set everything up online, but locking myself into that world isn't really my thing. I'm more of a face-to-face person. I like hugging people, seeing folks. Talking to someone — even if I don't know them — just being active, you know? Like, having a real social life, not just a digital one." (UI 1)	

The strategies mentioned by SNIG users in the interviews in order to circumvent the limitations of digitalization usually refer to the use of paper to the maximum extent possible and the payment of services provided by private companies when the use of digital is unavoidable. However, in the narratives, it emerges that digital is "becoming mandatory", finally eliminating paper from the system's operations. In the face of this, the expressions are of fear, resistance and warning of problems in the face of conditions that have not yet been met. This is not only due to the need to grasp the digital realm, but also because of changes in the dynamics of life. From their point of view, the role requires them to leave the farm, to link up with other actors and to outside countryside, prioritizing face-to-face contact.

- **SNIG as a multi-level policy: synergies and tensions between actors and institutions since implementation**

At the territorial level, the virtuous multi-stakeholder articulation in the design of the SNIG at its inception does not seem to be sustained. At the local level, the technical teams linked to the SNIG are somewhat solitary in the performance of their tasks (Table 8): there is only one person for the department, who also performs functions outside the departmental boundaries. At the national level, there are eight territorial referents for 19 departments.

At the same time, they refer to role overload, since the articulation of an administrative and control function is in tension with the need for local actions for capacity building and learning about the use of the digital tool. Thus, the SNIG's main action in the territory tends to focus on the ordering and control of information and case-by-case support for users/problems. This limits the planning of training from the local level, as these are usually delivered from the central level and use digital platforms such as Zoom or YouTube for their delivery, which implies self-selection biases in participation.

The main articulation of the SNIG at the territorial level is with MGAP's own institutions, with DICOSE and with the General Directorate of Rural Development (DGDR). In the first case, the interaction is usually in the provision of support in the face of possible individual difficulties with the affidavits and procedures for livestock security. With the DGDR, the articulations have been few and punctual, originating mainly at the request of the Tacuarembó Departmental Rural Development Board in the face of requirements and regulatory and bureaucratic changes. This brings us back to the historical trajectory of the system: its tension between a livestock information system, an animal traceability register and a certification system reveals divergences between an interest in access to information and transparency, and a historically predominant interest in control and monitoring. Thus, training devices have been generated from centrality, with massive distance lectures and standardized contents in virtual devices/

platforms, which makes their accessibility difficult. The underlying view of learning seems to be a transferential and reproductive process, rather than a process of empowerment and social redistribution of knowledge.

Table 8. Excerpts from Qualified Informant Interviews (QIIs) and User Interviews (UI).

"Holding outreach talks is super centralized. Sometimes it's hard to get it done — I do it when they ask, like with the Rural Development Board, but only if someone specifically requests it..." (QII 2)

"We don't have a training plan, not even at the central level. What they do are those big Zoom sessions that they post on the website. They're Zoom talks, but it also depends on whether people can join — sometimes the room fills up and there's no space left, so many producers can't get in. That's the closest thing to training we've got. Some tech folks joined in on that work, but it's really more for specific people." (QII 4)

"If you need things to be digitalized, well, provide tools for that, otherwise things won't work... Personally, I prefer to do it myself than pay, but there are people who don't. A few years ago, I heard about people who were scammed by others who do the paperwork and charge you even for the caravans, which are free. They can charge you 2,500 pesos for a sworn statement, 3,000 or so for a trademark or deposit procedure... But yeah, the producer is also responsible, the password is private, if you give it to a manager and it goes wrong, the responsibility is yours..." (QII 7)

"...There's this guy who does sworn declarations for everyone — I can't remember what he does for a living — but he handles that. And yeah, we have to pay him to do it from home, so I keep everything saved, really detailed. They say we could do it ourselves online, but he teaches me, and I end up doing it myself. And if I don't, I have to pay again. Ah, I don't know... Maybe 1,600 pesos, or whatever it was for the sworn declaration." (UI 9)

An interesting and little explored role is that of producers' organizations in the territory, key agents of social organization in the implementation of public policies for rural development. However, the SNIG does not currently articulate actions with them on the territory with a view to building sustainable local capacities.

From the institutional point of view, actions do not show a systemic network of articulation, but rather isolated impulses. The Police Sections, which depend on the Ministry of the Interior, have historically been relevant in the collection of information and continue to be an official channel for SNIG support in the territory. There are also private companies that charge for providing support services, mainly managers.

On the other hand, the DGDR is developing a Program of Digital Inclusion and Access to Agricultural Information for decision-making in the face of climate change, with a gender perspective, whose Component 1 is “Digital Literacy”. This program provides digital devices and training to women, but in order to gain access, those interested must register on a web form, among other requirements, repeating self-selection that is mitigated by institutional action but is not sufficient for greater equity. Furthermore, this initiative is not necessarily articulated with the SNIG, for example, livestock information is not part of the content of the thematic training.

6. Conclusion

The digitalization process of the SNIG contributes significantly to the country’s development, integrates plural visions and actors in its design and favors the appraisal of primary goods at the aggregate level of the economy. However, the future and its progress in implementation require sharpening the lens and assessing its effect as a public good, in distributive and local dimensions. Small-scale family livestock production units seem to be the last refuge of Uruguayan family production: it is essential to know the impact of sectoral public policies on this population. The SNIG manifests itself as a cost, with utility limited to control and based on an unequal structure of access to basic infrastructure in rural areas, as well as social inequalities. Part of the system’s role in the territories ends up remedying irregularities, rather than promoting learning and appropriation of the tool.

The digital transition is based on a set of socio-economic factors that go beyond technology transfer and require thinking about a social and collective dimension of learning and innovation. This network of collaboration and knowledge of the initial design is diluted in the local space: the potential for articulation with rural development policy and rural social organizations is wasted. The centralization of the training function determines that at the local level the SNIG is a case-by-case support resource and the building of digital capabilities is a transferential and stratified process. The centralization of the SNIG generates needs of producers that are taken up by the market, increasing economic and symbolic costs to production.

The SNIG, in this scenario, requires, on the one hand, the technical updating of the platform, through computer updates and improvements in the visualisation of the platform. On the other hand, it also requires articulation with rural and social development policy in favour of improving social inclusion and mitigating the digital divide. To this end, the participation of less visible actors, such as producer organizations and the most distant families in the valuation of the tool and its daily impact, should complement the macro analysis of the system. This work seeks to be an initial contribution in this sense, rescuing the voices from a particular territory and the subjectivities of those who, in general, tend to act in a silent and solitary manner.

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Additional Spanish version chapters of the book (abstracts)

Digitalization of Family Farming in Latin America: Reflections and Considerations from the Experience of the European Union and Spain

Néstor Caal, José Emilio Guerrero, Mario León, José Arze

The chapter analyzes the main public policies related to the digitalization of the agricultural and rural sector in the European Union and Spain, highlighting the crucial role of their institutions in the design and implementation of strategies, regulations and funding to promote digital transformation. It examines Spain's Digitalization Strategy for the Agri-Food and Forestry Sector and the Rural Environment, which seeks to integrate digital technologies throughout the agri-food chain and reduce digital divides in rural areas. In addition, it describes the Digital Innovation Centers, public-private collaboration spaces that facilitate the adoption of digital technologies by producers, highlighting their importance as key tools in the digitization strategy of the European Union.

Then are presented reflections from knowledgeable people on the achievements and areas for improvement of the institutional systems for agricultural and rural digitalization in the European Union and Spain, including the Digitization Strategy for the Agrifood and Forestry Sector and the Rural Environment, and Spain's Digital Innovation Centers. These reflections include suggestions for strengthening systems for Latin American agricultural digitalization and integrating family farming into digitalization efforts.

Finally, the authors offer reflections on factors that facilitate the implementation of digital policies in the European Union and Spain and that could be considered in Latin American policies, such as policy continuity, institutional framework, regulatory framework, stakeholder participation, public-private collaboration, financing, rural connectivity, among others.

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Proposals for innovation and digitalization policies in Latin American food systems: Challenges and alternatives for inclusion in family farming

Iván G. Peyré Tartaruga, Mireya Valencia Perafán, Fernanda Queiroz Sperotto

The importance of food systems is unquestionable for the development and functioning of society and the economies of regions and countries. Furthermore, these systems play a fundamental role in global environmental sustainability. In this context, the essential aspect of food production is the generation of technical and social innovations. Among the main actors in these systems are farmers, who need these innovations to provide the planet with food that ensures food security and sustainable development. The objective of this text is to discuss and use the concepts of rural productive inclusion and inclusive innovation to propose innovation, science and technology policies that promote inclusive, sustainable and healthy food systems, with a particular focus on the use of digital technologies in family farming in Latin America. Through research conducted in 2021-2022, several cases of inclusion and innovation in family farming in the Northeast, North and South of Brazil were analyzed. This study made it possible to create a typology of family farming experiences in different niches by degree of innovation and social cooperation. In total, four groups of innovation niches were identified, ranging from those that are highly innovative and cooperative, at one extreme, to those with lower, but equally important, levels of innovation and cooperation. Based on this typology, appropriate policies were proposed for each of the groups, allowing the emergence of new opportunities, taking advantage of the specific conditions of each context and reducing socioeconomic inequalities, with the vital contribution of digital technologies in this context.

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Functional-structural analysis of the Digital System of Agri-food Innovation of the Maule-Chile region.

Laura Castrillón, Pablo Villalobos, Laurens Klerkx

The adoption of digital technologies is a challenge for the Chilean agri-food sector, in its aim to transform the current agricultural systems towards sustainable and resilient spaces that contribute to climate change mitigation, natural resource management, and to consolidate a Digital Agri-Food Innovation System (SDIA), aligned with a policy framework that positively impacts production systems. The objective of the chapter was to analyze the Maule SDIA under the combination of the functional and structural approach to innovation systems recommended by the scientific literature, with the purpose of identifying its limitations, from a systemic point of view, and establishing the critical aspects for each function.

The analysis showed strengths and weaknesses at the level of the structural components of the system, revealing systemic failures associated with the presence and quality of digitalization networks, actors' capabilities, financial infrastructure and orientation by guidelines for digitalization. Interactions between the factors limiting innovation were evidenced. Finally, taking into consideration the results, it was possible to establish a set of recommendations to improve the implementation of the SDIA.

This chapter is a contribution to the knowledge on the functioning of the regional SDIA, contributing to the strengthening of the components that drive the transformation and design of digitization strategies in regional agricultural innovation systems.

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Rural social organizations and digital dialogues in relation to rural digitalization public policies in Colombia and Antioquia

José Aníbal Quintero Hernández

The Eastern region of Antioquia, made up of 23 municipalities, is one of the most food-producing areas in Colombia; historically it has been impacted by the armed conflict, mining and energy projects and the high use of agrochemicals. However, this area with potential for food production, generates productive practices from rural social organizations that respect the use of natural resources, health and those who consume the food. This research focuses on conducting case studies in four municipalities in the department of Antioquia, with an equal number of organizations, using a qualitative methodology with interviews and a documentary review. From the theoretical point of view, territorial studies and analysis on the implementation of public policy from a relational approach to the territory are taken into account. The objective is to identify and analyze the relationship of rural social organizations in relation to the rural digitalization policy from the Department of Antioquia and from the central government in Colombia. As results, it is identified that public policies have no interaction with the rural social organizations addressed and that these have autonomously implemented a digital dialogue within the organization, but also with external actors in production, marketing and food processes and other aspects, which have allowed the strengthening of the social, economic and political conditions of the organization.

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Digitalization and resilience in small Andean agriculture in Ecuador: challenges and opportunities

Christian Franco-Crespo, Cristian Borja

Digitalization has gained relevance in agriculture as a response to contemporary challenges and as a mechanism to improve capacities, especially in family and peasant agriculture. The objective of the study is to identify the characteristics of small-scale agriculture in the Andean zone of Ecuador to access digitization as a resilience mechanism. The methodology combines bibliographic analysis and semi-structured interviews with 15 experts, in addition to a survey conducted to 103 farmers in the provinces of Cotopaxi, Tungurahua and Chimborazo. Tools such as Python, Excel and ATLAS.ti were used to process qualitative data and linear regression was used to observe the relationship between variables. The results reveal that the adoption of technologies such as drones, mobile devices and management software are positively perceived within the group of producers, with a significant positive impact on profitability and agricultural sustainability. However, there are economic and training barriers that limit their implementation. The results also identify automated irrigation, training in the use of technologies and improvement in the quality of products with a significant relationship in technological adoption, explaining 78.2% of the variability observed in the use of technology. In conclusion, although digitalization presents opportunities to improve efficiency and sustainability in Andean smallholder agriculture, it is crucial to address economic and training barriers to maximize its impact. Public policies should focus on improving digital infrastructure and providing training programs to promote the use of digital technologies in the agricultural sector.

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Digitalization and agri-food value chains in Mexico: a study on mezcal and coffee value chains

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Although value chains have existed for hundreds of years, the COVID-19 pandemic gave them a boost and positioned them as a strategic tool in the field of trade policy. In this context, one of the main factors that has driven the transformation of these chains is digitalization, which unfortunately occurs asymmetrically among the participants in these chains, implying a restructuring of the governance dimension. Thus, this paper analyzes the transformations undergone by the agrifood value chain and focuses on two case studies that are very important in the Mexican case: mezcal and coffee. The paper found that the different participants in the value chains are seeking digitalization as a strategy to increase competitiveness, but the conditions they face are different and therefore the results favor those with greater capital stocks.

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Digitalization in Family Farming: challenges and contributions of Cegafi-UnB and the Colheita Digital Ecosystem

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Family farming faces significant challenges in the face of the digital divide in rural areas, which characterized by low digital skills, lack of infrastructure and a youth exodus that threatens the sustainability of the countryside. The Center for Management and Innovation in Family Farming (Cegafi) stands out in the search for solutions to these challenges. Since 2014, it has been implementing innovative technologies and methodologies, such as Colheita Digital, an ecosystem of integrated data collection, training, communication and advocacy strategies. This chapter aims to present the gamification and chatbot strategies and methodologies used in the Letramento Digital, Observa-CI, Monitora Orgânicos and Monitora Safra Saudável projects. Cegafi's initiatives demonstrate the importance of integrating digital technologies in family farming to increase productivity and create a more attractive and sustainable rural environment. However, for the digital transformation to be inclusive and effective, it is essential to ensure access to technologies and adequate training for young people and farmers, especially in the most disadvantaged communities.

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Socio-technical imaginaries and digitization of agriculture in Brazil: reflections from three digital agriculture platforms

Karina Kato, Matheus Sehn Korting, Claudia Job Schmitt, Otto Santos de Sousa

Digital agriculture has been projected as a necessary way to transform agri-food systems in an environment marked by the climate crisis, the prospect of increased food demand and deep social inequalities. In the social sciences, this topic has been approached from different angles: the adoption of digital technologies by producers, the ways in which digital agriculture value chains function, the new economies related to agricultural information, ownership and power relations, among others. This paper seeks to analyze the emergence of digital agriculture in Brazil as a new socio-technical imaginary. Through exploratory research, we analyze three digital platforms (Climate FieldView - Bayer, John Deere Operations Center - John Deere and Atfarm - Yara). Rather than a comparative analysis, we seek a transversal view of the cases, using the platforms as fertile ground for reflection on the digitalization of agriculture in Brazil. Our objective is, therefore, to reflect on how digital platforms for agriculture have been configured as socio-technical arrangements (exemplifying concrete processes of structuring Agriculture 4.0), while operating as performative devices that legitimize certain ways of organizing agriculture and the agri-food system. The methodology used consisted of a literature review and an analysis of the functioning of the different platforms, based on various materials available on the Internet, systematized according to key categories. It was observed that the platforms act as devices capable of "sedimenting" certain modes of organization and business models, while contributing to legitimize digital agriculture as a future to aspire to.

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Climate services as public goods designed by entities of the Latin American agri-food sector: case study in Guatemala

Emmanuel Zapata-Caldas, Diana Giraldo, Melissa Bonilla Barrillas, Carlos Eduardo Navarro-Racines, Elmer Orrego, Andrea Gardeazabal, Juan Francisco Low, Anna Müller

This chapter analyzes how a digital climate service can become a public good for the Central American agri-food sector. To demonstrate this, we worked on the design of an agroclimatic bulletin whose purpose is to disseminate information to farmers in the Guatemalan Altiplano and contribute to their decision-making on planting, management and harvesting of their crops. Following the principles of human-centered design (HCD), high-fidelity prototypes of this tool were developed. The thesis of this study argues that the adoption of the HCD approach by an institution that generates climate services allows them to be recognized as public goods. This adoption process is referred to as the "institutionalization" of the HCD approach. The results describe i) the mapping of actors in the Guatemalan digital ecosystem, from which the Climate Change Research Institute (ICC) was identified as a suitable actor to implement the HCD in the creation of the agroclimatic bulletin, and ii) the identification of user profiles (or "personas") and the agroclimatic bulletin prototype that responds to the needs of the user profiles. The chapter ends with a reflection on the gap that is being closed in Guatemala as a result of the implementation of the HCD by the Bioversity-CIAT Alliance and ICC.

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Strengthening the agricultural extension system with ICT (information and communication technology): evidence with potato farmers in the Peruvian Andes

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A digital agricultural extension project was implemented between 2019 and 2020 targeting small potato farmers in the northern highlands of Peru, using smartphones. The effectiveness of a two-way communication system between farmer groups and a specialized agricultural extension team was evaluated. Farmers organized themselves into groups and participatively elected a delegate, who transmitted queries from their members via WhatsApp. Experts received the queries and provided relevant recommendations. A randomized controlled trial was designed in 40 communities, involving about 600 potato farmers. Half of these communities (N=20) were assigned to a treatment with access to the group digital extension platform.

Modest levels of participation were found: only 18% of farmers consulted the experts. The project improved farmers' ability to correctly identify different plant diseases and their knowledge of improved cultivation practices. There was also suggestive (although mixed) evidence of adoption of improved practices and measures for the treatment of agricultural diseases. The research results do not allow us to conclude that the digital extension tool significantly increased farmers' production or yields, due to a small sample size. Participation in the WhatsApp groups was influenced by the dedication of producer group delegates, raising the need for further research on appropriate incentives to improve such effort.

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