Strategies for Developing Digital Innovation Ecosystems in Agricultural Cooperatives

Estratégias para o Desenvolvimento de Ecossistemas Digitais de Inovação em Cooperativas Agrícolas

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Abstract: This study investigates strategies that agricultural cooperatives can use to overcome the challenges of developing digital innovation ecosystems in agriculture. Using an exploratory qualitative design, we combined semi-structured interviews with cooperative leaders and focus groups with specialists in agricultural cooperativism. Content analysis identified 22 first-order challenges grouped into eight second-order categories, as well as 37 strategies to address them. The findings show that digital ecosystem development is constrained by interconnected barriers across digital literacy, rural connectivity, financial limitations, solution design, intercooperation, leadership, governance, and data ownership. In response, participants emphasized permanent digital training, user-friendly and modular platforms, collaborative arrangements among cooperatives, professionalized management, formal governance rules, and clear principles for data sharing and protection. The study contributes by offering an integrated view of digital ecosystem development from the perspective of agricultural cooperatives, an actor still underexplored in the literature. It also provides practical guidance for cooperative leaders seeking to build more inclusive, resilient, and strategically autonomous digital ecosystems.
Keywords: digital transformation, digital ecosystems, cooperatives, agriculture, Brazil

Resumo: Este estudo investiga estratégias que cooperativas agrícolas podem usar para superar os desafios do desenvolvimento de ecossistemas de inovação digital na agricultura. Utilizando um desenho qualitativo exploratório, combinamos entrevistas semiestruturadas com líderes de cooperativas e grupos focais com especialistas em cooperativismo agrícola. A análise de conteúdo identificou 22 desafios de primeira ordem, agrupados em oito categorias de segunda ordem, bem como 37 estratégias para abordá-los. Os resultados mostram que o desenvolvimento de ecossistemas digitais é restringido por barreiras interconectadas relacionadas à alfabetização digital, conectividade rural, limitações financeiras, desenho de soluções, intercooperação, liderança, governança e propriedade de dados. Em resposta, os participantes enfatizaram treinamento digital permanente, plataformas amigáveis ao usuário e modulares, arranjos colaborativos entre cooperativas, gestão profissionalizada, regras formais de governança e princípios claros para o compartilhamento e a proteção de dados. O estudo contribui ao oferecer uma visão integrada do desenvolvimento de ecossistemas digitais a partir da perspectiva das cooperativas agrícolas, um ator ainda pouco explorado na literatura. Também fornece orientações práticas para líderes de cooperativas que buscam construir ecossistemas digitais mais inclusivos, resilientes e estrategicamente autônomos.
Palavras-chave: transformação digital, ecossistemas digitais, cooperativas, agricultura, Brasil

1. Introduction

Digital innovation ecosystems have become a central organizational form of the contemporary economy, as digitally connected actors combine resources, data, and complementary capabilities to co-create value beyond traditional firm boundaries (Bonina et al., 2021; Subramaniam, 2020). This transformation has also reached agribusiness, where digital agriculture increasingly integrates data analytics, artificial intelligence, and precision technologies to improve productivity, sustainability, and coordination across the value chain (Dibbern et al., 2024). At the same time, the rise of platform-based ecosystems has intensified concerns about asymmetries in value capture and control, since digital platforms often decentralize value creation while centralizing governance and appropriation in the hands of a focal orchestrator (Gawer, 2022).

These dynamics are particularly visible in agribusiness, where large multinational corporations have advanced rapidly in structuring digital ecosystems and bundling services, data, and interfaces around their own platforms (Sauvagerd et al., 2024). Yet the literature on digital innovation ecosystems in agriculture remains comparatively limited and has focused more strongly on technologies, platforms, and corporate-led initiatives (Wolfert et al., 2025; Barile et al., 2026) than on the processes through which such ecosystems are developed from the perspective of agricultural cooperatives (Dawson et al., 2024). This omission is consequential because cooperatives represent an alternative organizational arrangement with the potential to support technological inclusion, preserve producers' autonomy, and coordinate collective value creation in more balanced ways (Ciruela-Lorenzo et al., 2020; Golovina et al., 2023). Despite this potential, relatively few agricultural cooperatives have effectively participated in digital innovation ecosystems (Dawson et al., 2024), raising an important question about how they can position themselves in an increasingly platformized environment.

Against this background, this study addresses the following research question: Which strategies can agribusiness cooperatives adopt to overcome the challenges of developing digital innovation ecosystems in agriculture? To answer this question, the study aims to identify the strategies that agribusiness cooperatives can adopt in this process. Empirically, the research focuses on coffee and dairy production cooperatives because they play a central role in both value chains (OCEMG, 2025). Methodologically, the study adopts an exploratory qualitative design, drawing on 15 semi-structured interviews with leaders of coffee and dairy cooperatives and three online focus groups with specialists in agricultural cooperativism.

We contribute to the literature in two main ways. First, we advance research on digital innovation ecosystems in agribusiness by incorporating the perspective of agricultural cooperatives, which remains underexplored in prior work, and by offering an integrated view of the challenges surrounding ecosystem development in this context. Second, we move beyond generic discussions of digitalization by showing that the development of digital innovation ecosystems by cooperatives depends on addressing a systemic set of barriers related to digital literacy, infrastructure, investment, intercooperation, leadership, governance, and data ownership. From a managerial perspective, we provide practical recommendations for cooperative leaders seeking to create, govern, and sustain digital innovation ecosystems, thereby strengthening cooperatives' ability to create and capture value while preserving their strategic relevance in a sector increasingly shaped by digital platforms (Sauvagerd et al., 2024).

2. Literature review

2.1. Innovation ecosystems and the digital reconfiguration of value creation

The concept of innovation ecosystem emerged to explain forms of value creation that cannot be reduced to isolated firms or dyadic alliances. Early formulations emphasized interfirm collaboration around coherent customer solutions (Adner, 2006), while later work expanded the field with concepts such as hub-based, open innovation, and platform-based ecosystems (Nambisan; Baron, 2013; Gawer, 2014). Digital ecosystems provide a useful lens for understanding this broader view of innovation. A central contribution of the ecosystem literature is the distinction between value creation and value capture. Gomes et al. (2018) argue that the field moved from a business ecosystem perspective, more associated with value capture, toward an innovation ecosystem perspective centered on collective value creation. Innovation ecosystems, therefore, can be understood as evolving collective arrangements in which multiple actors jointly create value while pursuing differentiated forms of appropriation (Jacobides et al., 2018).

Governance and risk are intrinsic to ecosystem functioning. Prior research shows that ecosystems vary in centralization, openness, and types of innovation, ranging from hub-based systems to open-source communities, research consortia, and crowdsourcing arrangements (Nambisan; Sawhney, 2007; Nambisan; Baron, 2013). Across these forms, governance remains non-hierarchical in principle, yet still requires coordination devices, participation rules, and incentive alignment (Thomas; Autio, 2020; Hoffmann et al., 2023). Digital innovation ecosystems build on this foundation but introduce a distinct sociotechnical architecture. The

literature traces a progression from early definitions that framed them as sociotechnical systems composed of human and non-human actors (Kolloch; Dellermann, 2018) to formulations emphasizing interorganizational interactions in digital value creation (Suseno et al., 2018), structural complexity and institutional embeddedness (Beltagui et al., 2020). More recent conceptions portray ecosystems as dynamic, decentralized, and interdependent configurations of actors sustained by continuous learning (Cvar et al., 2020; Wang, 2021). Gorelova et al. (2024) synthesize these developments by defining digital innovation ecosystems as complex sociotechnical innovation ecosystems aimed at creating new products and services through digital technologies.

Accordingly, digitalization alters both coordination and power. Nambisan and Baron (2013) and Nambisan, Lyytinen, and Yoo (2020) show that digital interfaces enable real-time collaboration, resource recombination, and distributed access to capabilities, but also increase coordination complexity because heterogeneous actors must interoperate through shared standards. Subramaniam (2020) further argues that digital ecosystems intensify data-driven feedback loops and network effects, expanding opportunities for innovation while favoring actors with superior data aggregation and analytics capabilities. This gives platforms a dual role: they enable distributed innovation yet can centralize control over critical interfaces and value flows. Gawer (2022) describes this as the central paradox of digital platforms.

2.2. Digital innovation ecosystems in agribusiness

The agribusiness context gives particular salience to these issues because digitalization in agriculture is both technologically expansive and organizationally uneven. The literature on digital agriculture describes a transformation driven by the integrated use of information and communication technologies to collect, transmit, store, and analyze data across agricultural value chains (Dibbern et al., 2024). This transformation includes sensors, drones, IoT, artificial intelligence, and big data analytics to enhance productivity, traceability, resilience, and sustainability (Singh et al., 2024). At the same time, digital agriculture differs from digitalization in other industries because it unfolds in rural environments marked by infrastructural constraints, dispersed actors, and dependence on local production conditions (Nasirahmadi; Hensel, 2022).

Empirical studies identify several facilitators of digital adoption in agribusiness. Dibbern et al. (2024) emphasize perceived usefulness, prior experience, willingness to take risks, age, education, and the influence of informal social networks. Chkarat et al. (2023) add

that alignment of incentives, institutional support, and visible environmental benefits can accelerate the convergence between digital platforms and sustainability goals. Yet adoption remains uneven across regions and actor groups. In the Brazilian case, initiatives such as Embrapa's AgroAPI illustrate a more open path by offering public APIs for data and services, thereby expanding interoperability and potentially democratizing access to digital resources (Romani et al., 2023). Even so, national platform prototypes also reveal the continuing need for rural infrastructure, governance capabilities, and investment (Goryanin et al., 2023).

Despite these possibilities, the agribusiness literature shows that the development of digital ecosystems has been driven largely by powerful corporate actors. Studies on the sector document how incumbents such as Bayer and John Deere combine sectoral expertise, installed assets, and digital infrastructures to create integrated ecosystems that bundle products, services, data, and interfaces across the agricultural value chain (Kenney et al., 2020; Bohnsack et al., 2024). These strategies may improve efficiency and create sophisticated service architectures, but they also reinforce asymmetries. Agribusiness digitalization should therefore be understood not only as technological modernization, but also as a redistribution of coordination power and value appropriation.

2.3. Agricultural cooperatives as potential orchestrators of digital innovation ecosystems

Within this broader landscape, agricultural cooperatives occupy a distinctive position. Unlike purely corporate orchestrators, cooperatives are collective organizations historically designed to aggregate demand, reduce transaction costs, improve market access, and provide infrastructure, technical assistance, and knowledge diffusion for producers. This organizational logic makes them potentially well-suited to act as digital intermediaries or platform orchestrators in agribusiness. Ciruela-Lorenzo et al. (2020) argue that cooperatives can operate digital platforms that support collective purchasing, market access, and service provision. Golovina et al. (2023) suggest that cooperatives may be particularly well-suited to managing agricultural data and digital technologies while preserving producers' autonomy.

The literature thus presents cooperatives not merely as beneficiaries of digitalization, but as organizations capable of shaping its trajectory. Their role can include digital training, extension services, intermediation of financing, and the aggregation of demand and data, all of which are especially relevant for small and medium producers who would otherwise face higher barriers to digital adoption (Mendes et al., 2023; Silveira et al., 2023). Cooperative-led ecosystems may also offer an alternative to the centralized control associated with dominant

corporate platforms by retaining data governance closer to producers and embedding digital transformation in collective decision-making structures. The SmartCoop case illustrates this possibility by showing that digital tools can strengthen producer–cooperative relationships while keeping ecosystem control closer to users (Dawson et al., 2024).

At the same time, several studies point to substantial constraints. Ciruela-Lorenzo et al. (2020) note that financial constraints, digital capability gaps, and cultural resistance are particularly significant for smaller cooperatives or those operating in regions with weak technological infrastructure. Golovina et al. (2023) emphasize that digitalization may require changes in governance, decision-making, and benefit distribution that conflict with traditional cooperative principles. More broadly, digital innovation ecosystems in agribusiness face interconnected challenges involving digital literacy, engagement, governance, infrastructure, resources, and performance assessment.

Taken together, this literature shows that ecosystems are useful for understanding innovation when value creation depends on complementarities and coordinated interdependence among multiple actors. Second, digitalization intensifies both the generative potential and the governance complexity of ecosystems by introducing data, platforms, interfaces, and network effects. Third, agribusiness cooperatives appear to be particularly relevant yet insufficiently understood actors in this process. They may serve as more inclusive orchestrators of digital innovation ecosystems, yet they face sociotechnical, organizational, and governance barriers that differ from those of dominant corporate platforms. What remains underexplored is not simply whether cooperatives matter for digital transformation, but how they can develop digital innovation ecosystems under the specific conditions of agribusiness.

3. Method

3.1. Research design

This study seeks to identify the strategies that agricultural cooperatives can adopt to overcome the barriers to developing digital innovation ecosystems. The research adopted an exploratory qualitative design, conducted in two stages. The first focused on identifying the main challenges in developing digital innovation ecosystems in agricultural cooperatives. The second stage was designed to deepen and extend those findings by discussing strategies to mitigate or overcome the challenges identified earlier. This sequencing creates a cumulative analytical logic: interviews generated the first-order empirical map of barriers, and focus groups were then used to elaborate, validate, and refine strategic responses.

3.2. Empirical setting

The empirical setting was bounded to agricultural cooperatives in the state of Minas Gerais, Brazil. This selection was theoretically and substantively motivated. It is an especially relevant context for examining cooperative digitalization because it combines strong agribusiness importance with a dense and heterogeneous cooperative base. The area brings together cooperatives of different sizes and levels of organizational maturity, increasing variation in the empirical material and enabling the study to capture multiple perspectives on the challenges and strategies associated with digital ecosystem development. The state contained 191 cooperatives, more than 197,000 members, and revenues above R$40 billion in 2023, making it a robust empirical context for investigation.

The choice was further narrowed to the coffee and dairy sectors, which are highly representative of Minas Gerais' agribusiness structure and in which cooperatives have historically played a central role. On the other hand, the coffee and dairy chains face increasing pressure to undergo digital transformation, which makes questions of technological inclusion, governance, and ecosystem orchestration especially salient. In practical terms, the field selection allowed the study to capture views from singular cooperatives, central cooperatives, and federations, thereby incorporating not only firm-level but also interorganizational perspectives on ecosystem development.

3.3. Data collection

Data collection was conducted in two complementary stages. In the first stage, the researcher conducted online, semi-structured, in-depth interviews with leaders of agricultural cooperatives in Minas Gerais to identify the main challenges associated with creating and developing digital innovation ecosystems. Interviewees were initially selected through referrals from the Organization of Cooperatives of the State of Minas Gerais (OCEMG), with a focus on coffee and dairy cooperatives, and additional participants were reached through snowball sampling. The interview guide comprised four sections: (1) introduction and conceptual clarification of digital ecosystems, (2) general information about the respondent, (3) a broad question on barriers to digital ecosystem formation, and (4) specific questions about cultural, economic, social, and technological barriers.

The study included 15 interviews with cooperative leaders conducted between 29 April and 30 June 2025. In the second stage, we conducted three online focus groups to discuss the

challenges identified in the interviews and to generate strategies to address them. The focus group procedure is explicitly grounded in a constructivist understanding of data collection, since the insights produced are socially constructed through group interaction (Merriam; Tisdell, 2015). To guide the discussion, we prepared a presentation outlining the eight second-order categories and their respective first-order challenges, with brief descriptions of each. The discussion was then organized into eight thematic blocks, one for each second-order category, so that participants could propose strategies in response to each of the previously identified challenges.

The focus groups added breadth and triangulation to the data. The first group, held on 8 July 2025, included five cooperative leaders from coffee cooperatives and two researchers specialized in agricultural cooperativism and lasted 105 minutes. The second, held on 9 July 2025, brought together four leaders from dairy cooperatives and one researcher specialized in cooperativism and lasted 95 minutes. The third, held on 30 July 2025, included three cooperative leaders and lasted 88 minutes.

3.4. Data analysis

The empirical material from both interviews and focus groups was analyzed using content analysis (Bardi, 2011; Merriam & Tisdell, 2016). Within this framework, analysis is understood as an interpretive process by consolidating, reducing, and interpreting participants' statements. In operational terms, all interviews and focus groups were recorded, transcribed, and later reviewed. The analytical procedure followed the classic stages of pre-analysis, material exploration, and interpretation of results, thus combining systematic coding with interpretive refinement.

The coding strategy was hybrid, combining deductive and inductive elements. Initial categories were informed by the theoretical review, but new themes were allowed to emerge from the recurrence and relevance of participants' accounts. Through this iterative process, we identified 22 first-order categories, which were subsequently grouped into eight second-order categories. This structure provided the analytical backbone for the results section. The first stage of analysis thus generated a hierarchical coding architecture that captured both theoretically expected barriers and context-specific issues emerging from the cooperative setting. The focus group material was analyzed in direct connection with the interview findings. Strategic propositions discussed in the groups were extracted from the full transcripts, coded, compared, and grouped by their adherence to the previously identified challenge categories.

4. Results

4.1. Empirical context: cooperatives under pressure to digitalize

The study captured considerable heterogeneity in organizational scale and structure, including singular cooperatives, central cooperatives, and federative arrangements. The organizations represented in the sample ranged from approximately 900 to more than 20,000 members and from roughly R$70 million to R$14 billion in annual revenue. This heterogeneity matters because the reported challenges were not restricted to a single cooperative profile; rather, they appeared across different organizational sizes and both coffee and dairy chains, although some barriers were perceived as more acute in one segment than in the other. Cooperative leaders are already aware that digitalization is strategically necessary, but they also perceive ecosystem development as a demanding collective project rather than a simple technology adoption effort.

The content analysis of the 15 interviews identified 22 first-order challenges, subsequently grouped into eight second-order categories: (1) culture, education, and digital literacy of cooperative members; (2) infrastructure and internet access in rural areas; (3) required investments and lack of government support; (4) complexity of digital innovations, solution design, and usability; (5) inter-cooperation challenges; (6) leadership formation and qualification; (7) governance and management of the digital innovation ecosystem; and (8) data ownership and security. The focus groups then generated 37 strategies aligned with these eight categories. Taken together, the empirical material suggests that the development of digital ecosystems in agricultural cooperatives is constrained by a layered set of sociocultural, infrastructural, organizational, and governance-related difficulties that are interdependent in practice.

4.2. The role of people and rural infrastructure in ecosystem development

The first set of findings shows that ecosystem development is hindered when cooperative members lack the educational, cultural, and infrastructural conditions required to engage with digital tools. The category *"[I] Culture, education, and digital literacy of cooperative members"* concentrated five first-order challenges: (1) low educational level, (2) low digital literacy, (3) difficulties among older generations in using digital technologies, (4) cultural resistance to technology adoption, and (5) succession problems among dairy producers. These findings show that leaders do not see digital ecosystem participation as a purely technical

matter. Instead, they repeatedly describe it as dependent on cooperative members' ability and willingness to interact with digital tools in everyday production and management practices.

Interviewees were especially emphatic about the relationship between low formal education and resistance to technological change. One director argued that "low education goes together with resistance to new technologies," adding that "this difficulty in reading something new creates difficulties" (E9). Leaders also described low digital literacy as one of the most immediate barriers to participation in the ecosystem: "low digital literacy is a serious problem… there are many small cooperative members who live on the farm and are really digitally illiterate" (E4).

Several respondents associated low digital capability with the older age profile of many producers, especially those still leading family farms. One interviewee stated that "the age group we work with has more difficulty accessing technology" and that the typical producer "has a more advanced age profile" (E1). Alongside age, leaders emphasized cultural resistance. One respondent noted that there is much technology available that producers "do not use because they do not want to, because they think it is difficult" (E2). Another described the issue as "a cultural challenge," emphasizing the persistence of traditional habits and the slow adoption of new techniques, even among younger family members (E9). In dairy cooperatives, the challenge was compounded by succession problems. Respondents described farms where "the children are leaving and not returning" (E3), turning generational renewal into both a labor and a digitalization problem.

The same foundational logic appeared in the second category, *"[II] Infrastructure and internet access in rural areas"*. Here, the most salient first-order challenge was (6) limited internet access among cooperative members, followed by (7) energy supply interruptions. Interviewees portrayed connectivity not as a secondary issue, but as a condition of possibility for any digital ecosystem. One director stated that internet access "does not occur in all of our producers' properties" and remains "a limiting factor" in mountainous regions (E1). Another summarized the problem as "a gigantic challenge" because farms without connectivity, digital controls, and internet-based tools "have no control" (E8).

The focus groups did not dispute these diagnoses. Instead, participants translated them into a portfolio of strategies aimed at gradual inclusion. To address literacy and cultural barriers, participants proposed permanent digital training programs, engagement campaigns with attractive, simple content, generational succession initiatives, individualized support, and the use of already adopted channels such as WhatsApp. One focus group participant argued that

many producers are not "so distant from this process" because they already use WhatsApp and described a training cascade in which educational cooperatives and consultants supported digital transformation in hundreds of farms (GF3P1). Another emphasized that content "has to be very attractive," simple, and relevant to the cooperative member's reality in order to stimulate engagement (GF1P6). For infrastructure barriers, participants suggested partnerships with telecom operators, political advocacy, satellite or hybrid offline/online solutions, collaborative internet contracting, and alternative energy solutions such as solar power. In short, the proposed response was not to wait for full readiness but to reduce entry barriers through training, simplicity, and pragmatic adaptation to rural conditions.

4.3. Financial constraints and poor design

A second group of findings concerns the economic and design conditions required to move from interest in digitalization to actual ecosystem development. In the category *"[III] Required investments and lack of government support"*, leaders identified three first-order challenges: (8) the cooperative's own investment capacity, (9) the lack of government support, and (10) the investments that producers themselves would need to make in order to participate in a digital platform. The unanimity surrounding government support is especially noteworthy. Interviewees repeatedly described the absence of public policy, financing, and infrastructure support as a structural bottleneck. One leader described government support as "very precarious" regarding the instruments and resources available for technological evolution (E2). Another referred to "a total lack of government support" and "no credit line in this direction" (E14). A third argued that he had "never seen a public policy to keep the rural producer in the region," linking the lack of support not only to digitalization but also to the younger generation's declining interest in livestock activity (E5).

Financial pressure also operates at the producer level. Some interviewees stressed that joining a digital platform requires investments in equipment, connectivity, and farm-level preparation that many members cannot easily afford. One director observed that producers starting "from zero" face a major challenge because they "need help and need resources," in a country with extremely high interest rates (E8). It reveals that ecosystem development is financially cumulative: cooperatives need funds to build and maintain digital solutions, but producers also need resources to become usable nodes in those ecosystems.

A related but distinct obstacle emerged in the category *"[IV] complexity of digital innovations, solution design, and usability"*. Here, the dominant problem was a lack of fit

between digital solutions and producers' actual needs. The first-order challenge (11) "difficulty identifying the real needs of cooperative members in specific contexts," was mentioned by two-thirds of interviewees. One respondent warned that "the demand of each producer is very different," even within the same mountainous region, and concluded that "there is no single solution to a given problem" (E10). A smaller but still relevant problem concerned (12) the complexity of some digital solutions, which could become difficult to use even for users with some technological capability. As one interviewee explained, producers' routine workload leaves little time to engage with "a slightly more sophisticated tool" (E5). Together, these findings suggest that ecosystem development is hindered when platforms are designed from a technical logic rather than from the practical logic of farm activity and producer routines.

The strategic responses generated in the focus groups were correspondingly concrete. Participants proposed modular digital platform models in which users would pay only for the services they actually used, government credit lines specifically targeted at digital agribusiness, and collaborative cost-sharing among cooperatives. One respondent argued that a platform "cannot be a single price for everyone" and must be "modularized" to be attractive and viable (GF1P4). For the design problem, the emphasis was on producer-oriented solutions, simple, user-friendly interfaces, personalization tailored to each cooperative's needs, AI-enabled simplification, incentives for continued use, and gradual adaptation for different user profiles. A participant who had been directly involved in a digitalization initiative insisted that the system "has to be easy" and "made for the producer's needs," because "it makes no sense to build the technician's platform and want the producer to use it" (GF3P1).

4.4. Leadership and governance problems

The third set of findings concerns the organizational architecture required to transform isolated digital initiatives into a cooperative ecosystem. The category *"[V] inter-cooperation challenges"* revealed two recurring barriers: (13) difficulty promoting collaboration among cooperative leaders and (14) the lack of standardized systems and applications across cooperatives. One respondent described the main challenge as getting "leaders of cooperatives to talk and start working together," adding that coordinating agricultural cooperatives is "more challenging" than getting semi-literate producers to cooperate (E2). Another associated the problem with "personal vanity" that still obstructs inter-cooperation in practice (E9). One interviewee argued that "lack of standard" is among the first barriers, because if a central structure needs to develop one program "for Zé, another for Mané, another for Antônio, it will

not work" (E2). The results, therefore, show that inter-cooperation is not blocked only by strategic divergence; it is also hindered by incompatible systems and by reluctance to sacrifice local particularities for shared digital arrangements.

A closely connected category concerns *"[VI] leadership formation and qualification"*. Here, two first-order challenges stood out: (15) the lack of managers with the expertise needed to lead and coordinate a digital ecosystem, and (16) the need to update and level cooperative leadership around digital transformation. Interviewees repeatedly described a shortage of qualified people capable of making strategic decisions about digital investments and orchestration. One interviewee noted the "great difficulty" of finding people in the region with the capabilities required to lead such a project (E9). Another stated that, without expertise, cooperatives end up "in the hands of others," uncertain whether they are making the right investment or "just tearing money apart" (E12).

The empirical material shows that leaders understand the category *"[VII] governance and management of the digital innovation ecosystem"* to be decisive conditions for ecosystem viability. In the governance category, (17) the absence of clear rules for the ecosystem was among the most frequently cited barriers, along with (18) the lack of expected ethical standards and, in a smaller number of cases, (19) the lack of a cooperative management model with a strategic focus on technology. One respondent described governance as "one of the big problems" for cooperatives moving into digital environments because few still have "active ethics councils" and effective statutes in place (E4). Another stressed that if there are no "clear rules defined," actors may lose their bearings and suffer significant damage (E14).

Finally, in the *"VIII data ownership and security"* category, the main concerns were (20) resistance to data sharing, (21) data security in line with law requirements, and (22) uncertainty about data ownership. Leaders reported that producers often ask, "What do I gain from giving my data?" and refuse because they "do not know where it will go" (E5). Others expressed fear that personal information might be disclosed publicly (E9), while one director warned about the risk of cyberattacks that could leave the cooperative inoperative (E6). These statements show that ecosystem development depends not only on adoption and investment but also on trust, legitimacy, and clearly defined rights over data flows.

The strategic responses proposed in the focus groups mirrored this collective governance problem. For inter-cooperation, participants recommended forums for leaders, a shared vision built around mutual gains, back-office standardization, and API-based integration to enable interoperability without forcing all cooperatives into a single system. For leadership,

they proposed professionalizing cooperative management, creating joint immersion experiences, mobilizing institutional support, and developing technologically inclined leaders as multipliers. One participant criticized the still-prevalent logic of cooperative management as "volunteering" and argued for greater professional recognition of those actually prepared to manage strategically (GF3P2). Another described a two-day seminar that brought leaders together after international visits and generated a shared conviction that innovation would be faster, cheaper, and more robust if done jointly (GF3P1).

For data ownership and security, participants recommended internal regulations, adherence terms, explicit ethical principles, professional strategic management, transparency and accountability mechanisms, clear entry and exit rules, trust-building for data sharing, strict law alignment, explicit recognition that "the data belongs to the cooperative member," and incentive systems to encourage participation. As one participant put it, "when dealing with a cooperative, we have to start from the principle that the data is the cooperative member's" (GF3P1). In this empirical account, ecosystem development becomes viable only when the cooperative can combine trust, rules, and collective coordination with technically usable digital solutions.

5. Discussion

The findings confirm that digital transformation does not unfold as a purely technological process but as a sociotechnical reconfiguration that depends on the interaction among infrastructures, organizational arrangements, and actors' capabilities (Kolloch; Dellermann, 2018). Our study shows that low digital literacy, low educational levels, cultural resistance, and succession problems emerged as major barriers to ecosystem development in cooperatives. This pattern is consistent with prior studies that identify digital literacy and basic educational limitations as key obstacles to the adoption of digital technologies in rural contexts, particularly in developing-country settings (Bhaskara; Bawa, 2021; Mushi et al., 2024). The empirical results, therefore, confirm that digital ecosystem development in agriculture depends not only on the availability of digital tools but also on the farmers' ability to understand, trust, and incorporate them into daily routines. At the same time, the study adds an important nuance by showing that these barriers are mutually reinforcing in cooperative settings: low schooling, weak digital literacy, generational aging, and cultural resistance do not operate independently, but combine to slow engagement with digital platforms.

The results also corroborate the literature that emphasizes infrastructure deficits as a critical constraint on agricultural digitalization. Prior studies have shown internet access, connectivity gaps, and broader infrastructural deficiencies as recurring bottlenecks in the development of digital ecosystems in agriculture (Mushi et al., 2024; Wang, 2019). Our study confirms this pattern and extends it by showing that connectivity challenges are compounded by energy supply interruptions, which undermine the stable operation of digital tools in the field. This is important because it reinforces a broader point in the digital ecosystem literature: platform-based coordination and data-driven value creation depend on reliable infrastructural conditions. The findings support the argument that digital ecosystems are sustained by technical infrastructures and interoperability conditions that go beyond the boundaries of the focal organization (Nambisan et al., Yoo, 2020; Wang, 2021).

A second contribution of the study lies in reframing the role of cooperatives in the ecosystem literature. Earlier work had already suggested that agricultural cooperatives could operate as digital intermediaries or alternative orchestrators, given their collective ownership structures, their role in technical assistance, and their ability to aggregate resources and demand (Ciruela-Lorenzo et al., 2020; Golovina et al., 2023; Mendes et al., 2023; Silveira et al., 2023; Strong et al., 2022). The present findings support this view, but they also show that cooperative distinctiveness does not automatically translate into ecosystem readiness. Rather than simply being more inclusive alternatives to dominant corporate platforms, cooperatives face specific organizational and political coordination problems of their own. The barriers related to inter-cooperation, lack of standardization across systems, insufficiently qualified leadership, and the absence of professionalized strategic management suggest that ecosystem development in cooperatives depends on building orchestrative capacity, not merely on possessing a collective governance structure. In this respect, the study extends the literature by showing that cooperative-led ecosystem development is contingent on intra- and interorganizational alignment mechanisms that are often taken for granted in normative discussions of cooperatives as collective solutions.

These findings connect directly to the literature on innovation ecosystem governance. Prior work argues that ecosystems require coordination without fully hierarchical control and that governance may be enacted through rules, interfaces, incentives, and orchestrative mechanisms rather than formal authority alone (Nambisan; Sawhney, 2007; Nambisan; Baron, 2013; Thomas; Autio, 2020; Hoffmann et al., 2023). Our results confirm the importance of governance, but in a more concrete way: the lack of formal rules, ethical principles, clear entry

and exit conditions, and transparent accountability mechanisms was perceived by interviewees as a direct barrier to cooperative ecosystem development. This finding also resonates with the broader literature on platforms, which stresses that digital ecosystems create value through distributed participation while simultaneously requiring coordination devices that structure interaction and reduce uncertainty (Subramaniam, 2020; Gawer, 2022). In the cooperative context, however, the governance problem is sharpened by the need to reconcile digital coordination with democratic and collective organizational principles.

The study also reinforces and qualifies the literature on data governance in digital ecosystems. Prior research has emphasized the dilemmas surrounding data ownership, control, privacy, and ethical use, as well as the concentration risks associated with platforms that simultaneously control data and analytical capabilities (Pedraza; Vollbracht, 2023; Nitzberg; Zysman, 2021). The empirical findings are broadly consistent with the literature showing resistance to data sharing, concerns about compliance with laws and regulations, and uncertainty over data ownership (sources). Yet the study extends the debate by showing that, in cooperatives, these issues are closely tied to trust and legitimacy rather than to technical compliance alone. The strategies generated in the focus groups suggest that data governance in cooperative ecosystems depends on convincing members that digitalization will not undermine their autonomy. This is a meaningful extension because it indicates that the governance of data in cooperative ecosystems is not only a regulatory issue but also an organizational and relational one, anchored in preserving member control over collectively mediated digital infrastructures.

Finally, the study contributes by offering a more integrated understanding of barriers that earlier studies had often treated separately (sources). Rather than revealing a single dominant bottleneck, we show a layered configuration of obstacles spanning member capabilities, rural infrastructure, financing, platform design, intercooperation, leadership, governance, and data. This extends the agriculture ecosystem literature (sources) by suggesting that ecosystem development in cooperative settings is shaped by a multilevel challenge structure. Some barriers sit closer to producers and daily use, others to organizational capabilities, and others to broader institutional and infrastructural conditions. The evidence does not support strong causal claims about which factor is primary, but it does indicate that successful ecosystem development is likely to require coordinated responses across these levels.

6. Conclusion

This study aimed to identify the strategies that agricultural cooperatives can adopt to overcome the challenges in developing digital innovation ecosystems. Taken together, the findings show that ecosystem development in cooperatives is conditioned by a broad and interrelated set of barriers involving digital literacy, infrastructure, financial constraints, solution design, inter-cooperation, leadership, governance, and data ownership. In this sense, we conclude that the development of digital innovation ecosystems in cooperatives depends less on the isolated adoption of technology and more on the coordinated treatment of sociocultural, organizational, and institutional conditions that sustain digital transformation over time.

The study makes three theoretical contributions. First, we offer an integrated, systemic view of the challenges surrounding the development of digital innovation ecosystems within agricultural cooperatives. Second, the study advances the literature by placing agricultural cooperatives at the center of the analysis. By bringing the views of cooperatives into the debate, the study fills an important gap and broadens the empirical base from which theory on agricultural digital ecosystems is being built. A third contribution concerns inter-cooperation and coordination among cooperatives. The results show that inter-cooperation is not merely a matter of strategic alignment or of balancing social and economic objectives. It also involves operational and technological barriers, such as a lack of system standardization, difficulty defining common patterns and leaders' resistance to relinquishing individual interests.

Considering practical recommendations for cooperative leaders, the most immediate implication is that digitalization efforts should begin with permanent digital training, generational succession initiatives, and individualized support for members with greater difficulty using technology. These actions are especially relevant because educational limitations, low digital literacy, and cultural resistance remain foundational barriers to ecosystem participation. A second implication is that cooperatives should prioritize simple, intuitive, and context-sensitive digital solutions rather than overly sophisticated platforms disconnected from producers' routines. In parallel, the findings indicate that ecosystem development requires intercooperation mechanisms that build trust and shared vision among leaders, reduce duplication, and create minimum technological standards for collaboration.

Before concluding, we have to recognize two main limitations. First, the evidence reflects the perceptions of cooperative leaders and specialists, without directly incorporating the perspective of non-leader members. Second, the study is temporally bounded. Because

digital transformation in agriculture is highly dynamic, the challenges and strategies identified here reflect a specific technological and regulatory moment and may change rapidly as innovations advance, legal frameworks evolve, and new public policies emerge.

Based on these limitations, we suggest four avenues for future research: expanding the analysis to other countries and agricultural sectors, adopting quantitative methods, such as surveys with larger samples of cooperatives and producers, exploring the perspective of non-leader cooperative members, and conducting longitudinal studies to examine the implementation and effectiveness of the strategies identified here over time. These suggestions are important because they indicate that the present study should be read as a grounded and contextually rich contribution to an emerging research agenda, rather than as a final or exhaustive account of cooperative digital ecosystem development.

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