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DIGITAL COMMERCIALIZATION IN THE AMAZON BIOECONOMY: A FRAMEWORK FOR SOCIOTECHNICAL VIABILITY

COMERCIALIZAÇÃO DIGITAL NA BIOECONOMIA AMAZÔNICA: UM FRAMEWORK PARA A VIABILIDADE SOCIOTÉCNICA

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ABSTRACT

Objective: Digital commercialization can expand market access and reduce asymmetries in Amazon bioeconomy chains, but its viability remains conditioned by structural, institutional, and market constraints. This study analyzes the sociotechnical conditions that influence the viability of digital commercialization of bioeconomy products in the state of Acre, in Southwestern Brazilian Amazon, and proposes an analytical framework for sociotechnical viability. **Theoretical approach:** The study distinguishes technological adoption from sociotechnical viability and understands digital commercialization as a territorially situated form of commercialization whose operationalization depends on material, market, organizational, and institutional conditions. **Method:** A

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qualitative and exploratory study was conducted in the state of Acre, based on semi-structured interviews with eight producers and traders and two experts. The data were subjected to content analysis and integrated with analytical domains from the literature through comparison, abstraction, and synthesis to construct the framework. **Results:** Digital commercialization does not constitute an autonomous mechanism of transformation. Its viability results from the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. High receptiveness to digital solutions contrasts with their low use, while logistics and connectivity constraints, dependence on intermediaries, limited digital capabilities, and weaknesses in institutional mediation condition their operationalization. **Conclusions:** The study shifts the analysis from the availability or adoption of technology to the sociotechnical conditions that sustain digital commercialization. The proposed framework explains its viability through the interaction among four dimensions shaped by territorial conditions and provides an analytical structure for interpreting the factors that enable or constrain digital commercialization in sociobiodiversity chains.

Keywords: Bioeconomy. Digital commercialization. Sociobiodiversity. Territorial development. Amazon.

RESUMO

Objetivo: A comercialização digital pode ampliar o acesso a mercados e reduzir assimetrias nas cadeias da bioeconomia amazônica, mas sua viabilidade permanece condicionada por limitações estruturais, institucionais e de mercado. Este estudo analisa as condições sociotécnicas que influenciam a viabilidade da comercialização digital de produtos da bioeconomia no Acre, na Amazônia Sul-Ocidental brasileira, e propõe um framework analítico de viabilidade sociotécnica. **Abordagem teórica:** O estudo distingue adoção tecnológica de viabilidade sociotécnica e compreende a comercialização digital como uma forma territorialmente situada, cuja operacionalização depende de condições materiais, mercadológicas, organizacionais e institucionais. **Método:** Foi realizada pesquisa qualitativa e exploratória no Acre, com entrevistas semiestruturadas com oito produtores e comerciantes e dois especialistas. Os dados foram submetidos à análise de conteúdo e integrados aos domínios analíticos da literatura mediante comparação, abstração e síntese para construir o framework. **Resultados:** A comercialização digital não constitui um mecanismo autônomo de transformação. Sua viabilidade resulta da interação entre infraestrutura material, estrutura de mercado, capacidades sociotécnicas e mediação institucional. A elevada receptividade às soluções digitais contrasta com sua baixa utilização, enquanto limitações logísticas e de conectividade, dependência de intermediários, capacidades digitais limitadas e fragilidades na mediação institucional condicionam sua operacionalização. **Conclusões:** O estudo desloca a análise da disponibilidade ou adoção da tecnologia para as condições sociotécnicas que sustentam a comercialização digital. O framework proposto explica sua viabilidade pela interação entre quatro dimensões moldadas pelas condições territoriais e oferece uma estrutura analítica para interpretar os fatores que possibilitam ou restringem a comercialização digital em cadeias da sociobiodiversidade.

Palavras-chave: Bioeconomia. Comercialização digital. Sociobiodiversidade. Desenvolvimento territorial. Amazônia.

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INTRODUCTION

The consolidation of the bioeconomy as a development strategy in the Amazon is marked by a persistent tension between its normative ambitions and the conditions under which it can generate territorial change (Bergamo et al., 2022; Garrett et al., 2024). Although associated with environmental conservation, social inclusion, and the sustainable use of biodiversity, the Amazon bioeconomy continues to operate within productive and commercial structures marked by logistical constraints, limited market access, and persistent asymmetries in the distribution of value (Castro et al., 2026; Vieira et al., 2024).

These tensions are particularly visible in the commercialization of sociobiodiversity products. Dependence on intermediaries, low local value addition, informality, and limited income predictability continue to constrain the autonomy of small producers and local traders and their ability to access more favorable markets (Costa et al., 2024; Trindade et al., 2024). Commercialization therefore represents more than the final stage of the value chain: it is one of the points at which logistical limitations, market power, and institutional coordination directly affect who accesses markets and who appropriates the value generated by Amazonian products. Without changes in these conditions, the expansion of bioeconomic activities may remain disconnected from broader transformations in territorial development (Lesenfants et al., 2024; Pinsky et al., 2024).

Digital commercialization has gained relevance in this context because digital platforms and e-commerce models can create new channels for connecting producers and markets, reducing information asymmetries, and increasing the visibility of socio-environmental and cultural attributes associated with Amazonian products (Abramovay et al., 2021; Silva et al., 2025a). Yet the relevance of these solutions cannot be assessed only in terms of technological availability or market reach. In territories where production is geographically dispersed and commercialization depends on logistics, coordination, market intermediation, and collective organization, the capacity to use a digital channel does not necessarily mean that digital commercialization can be effectively operationalized and sustained (Favareto et al., 2024; Preiss et al., 2024).

The conditions under which digital commercialization becomes viable in territorially complex settings remain insufficiently understood, particularly the interactions among market structure, local capabilities, institutional mediation, and material infrastructure that shape its viability (Bao et al., 2025; Clement et al., 2024; García-Gallego et al., 2025). The issue is

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therefore not limited to whether producers are willing or able to adopt a digital solution, but to the territorial configuration that enables such a solution to function as a sustained form of commercialization.

Accordingly, this study examines the viability of digital commercialization as a sociotechnical and territorially situated phenomenon shaped by the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. It addresses the following research question: What sociotechnical conditions influence the viability of digital commercialization of bioeconomy products in the state of Acre, in the Southwestern Brazilian Amazon?

To answer this question, the study draws on qualitative evidence from producers, traders, and experts to analyze the conditions underlying the viability of digital commercialization in this territorial context. Based on this analysis, it develops an analytical framework that explains how these conditions interact and how their configuration can enable or constrain digital commercialization in sociobiodiversity chains.

The study contributes to the debate by moving beyond explanations centered on technological availability or adoption. It conceptualizes sociotechnical viability as an emergent property of the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation, thereby shifting the analytical focus from the digital solution itself to the territorial conditions under which it can operate and be sustained. The resulting framework provides a basis for interpreting how different territorial configurations can enable or constrain the viability of digital commercialization across sociobiodiversity chains.

THEORETICAL BACKGROUND

Digital commercialization and sociotechnical viability in the Amazon bioeconomy

The operationalization of the Amazon bioeconomy depends on arrangements that connect value chain organization, territorial conditions, market structures, and institutional coordination (Bergamo et al., 2022; Pinsky et al., 2024). In sociobiodiversity chains, commercialization outcomes are shaped by the logistical, institutional, and market arrangements through which products reach markets and value is distributed, with direct implications for producer autonomy and local value appropriation (Lesenfants et al., 2024; Rodrigues et al., 2024; Vieira et al., 2024).

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Digital platforms and e-commerce models have been used as mechanisms for expanding market access and reducing information asymmetries (Borrero & Mariscal, 2022; Robichaud et al., 2024). Existing approaches have emphasized the efficiency and market integration gains associated with these technologies, often treating them primarily as instruments of economic coordination. This perspective has limited explanatory capacity for understanding the conditions that enable or constrain their viability in territorially complex contexts (Bao et al., 2025; D'Amico et al., 2022). Moreover, the introduction of digital platforms does not necessarily eliminate intermediation relationships and may shift coordination and control functions to new actors while reproducing asymmetries in market structures (Sauvagerd et al., 2024).

The adoption of digital technologies in rural and peripheral territories depends on multiple factors, including digital literacy, connectivity, operating costs, and organizational capabilities (Arion et al., 2024; Doloi, 2025). These factors indicate that digital commercialization is not an autonomous mechanism of transformation but a form of commercialization whose viability depends on specific sociotechnical conditions and may either reduce or reproduce territorial inequalities (Hassoun et al., 2023; Petropoulos et al., 2025).

From this perspective, sociotechnical viability has a broader scope than technological adoption. While adoption concerns the incorporation and use of a given solution by actors, viability can be understood in terms of the material, market, organizational, institutional, and territorial conditions that enable digital commercialization to be operationalized and sustained (Favareto et al., 2024). Producers' willingness to use a platform therefore represents only one condition within this process and does not, by itself, ensure its viability.

In the Amazon bioeconomy, these conditions include the integration of digital commercialization with capacity-building, logistics, certification, and collective organization strategies, which can reduce uncertainty, strengthen trust, and connect producers to more structured markets (Gazolla & Aquino, 2024). Cooperatives, associations, and other support organizations can perform mediation functions between local capabilities, supply organization, market requirements, and territorial conditions, embedding digital commercialization within broader institutional arrangements (Preiss et al., 2024).

The viability of digital commercialization therefore extends beyond individual capabilities and technological infrastructure to the institutional arrangements through which actors, resources, knowledge, and market access are coordinated (Carraresi, 2024; Pinsky et

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al., 2024; Starke et al., 2024). Within such arrangements, digital platforms can be understood as components of broader territorial strategies for organizing commercialization and coordinating value chains.

Cultural and symbolic attributes associated with sociobiodiversity products add another dimension to this process by constituting sources of differentiation and value creation (Ardenghi et al., 2026). Narratives of origin, cultural identity, sustainability, and territorial ties can contribute to the differentiation and valorization of these products by connecting market attributes to their ecological and sociocultural characteristics (Águas & Gitahy, 2025; Basile et al., 2025).

Digital commercialization can increase the visibility of these attributes and incorporate them into differentiation strategies for sociobiodiversity products (Rodrigues et al., 2024; Silva et al., 2025a). Its relevance therefore extends beyond market access to the communication and valorization of territorial attributes, while its capacity to perform this function remains conditioned by the material, market, sociotechnical, and institutional arrangements in which commercialization takes place.

METHODOLOGY

This study adopts a qualitative and exploratory approach, appropriate to the relational and territorial nature of the object under investigation (Lim, 2025). This approach enables the analysis of interactions among productive, institutional, sociocultural, and technological dimensions from the perspectives and practices of actors involved in sociobiodiversity value chains. Figure 1 summarizes the methodological design, highlighting its main stages and analytical linkages.

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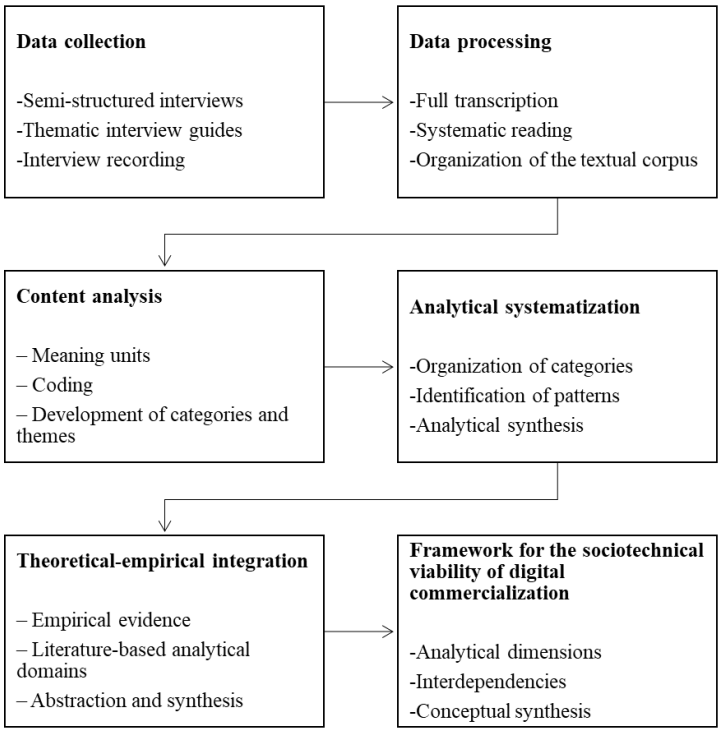


Figure 1. Methodological flow of the study.

Source: Elaborated by the authors (2026).

The research was conducted in the state of Acre, located in the Southwestern Amazon, with ten interviewees divided into two groups. The first group consisted of eight local producers and traders involved in the production and commercialization of bioeconomy products, such as açaí, cassava flour, natural oils, and phytotherapeutic products. The second group consisted of two experts identified through snowball sampling and selected based on their recent scientific production on the bioeconomy and practical experience in territorial development projects in the Amazon (Mohammadi et al., 2026). Both hold doctoral degrees and have established experience in research on regional development, sustainability, and sociobiodiversity value chains.

The eight producers and traders were purposively selected to encompass different products, forms of commercialization, production scales, and territorial contexts. This purposive composition enabled the analysis to capture variation in commercialization experiences while identifying recurring patterns related to market access, logistics, digital technology use, intermediation, and institutional support. Interviews with the experts were used

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to deepen and contrast the interpretation of these conditions from the experiences of actors directly involved in production and commercialization.

Data were collected through semi-structured interviews using interview guides adapted to the two groups of participants (Buys et al., 2022). The guides were organized around common thematic axes informed by the theoretical background and the study objectives. These axes provided a common basis for the interviews while allowing participants' experiences and perceptions to be explored through open-ended questions.

The initial thematic axes guiding the interviews covered: (i) current forms of commercialization; (ii) logistics and infrastructure challenges; (iii) dependence on intermediaries; (iv) access to and use of digital technologies; (v) perceptions of digital commercialization platforms; (vi) expected benefits; (vii) barriers to adoption; and (viii) conditions required for the implementation of digital platforms targeting the Amazon bioeconomy.

The interviews were conducted either in person or remotely between April and August 2025, depending on participants' availability. All interviews were recorded with prior consent and subsequently transcribed in full with the assistance of AI-assisted transcription tools.

Data were analyzed using content analysis, following the stages of pre-analysis, material exploration, and treatment of results, inference, and interpretation proposed by Bardin (2016). The analytical process involved repeated reading of the transcripts, identification of meaning units, coding, condensation, and the subsequent development of categories and themes, in line with contemporary approaches to qualitative content analysis (Lindgren et al., 2020). Coding was conducted independently and in parallel by two researchers, and interpretive disagreements were discussed with a third researcher until consensus was reached on the final categories.

Data systematization resulted in analytical tables that synthesized patterns, convergences, and divergences between the experiences reported by producers and traders and the perspectives provided by the experts, organized according to the categories and thematic axes developed during the analysis. These tables constituted the primary basis for interpreting the results.

The interpretation of the results involved contrasting the experiences of producers and traders with the perspectives of the experts and the analytical domains derived from the theoretical background. This process enabled the empirical categories to be compared with insights from the literature and progressively refined. Analytical transparency was supported

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by the description of the methodological procedures and the use of representative excerpts from participants' statements, identified by alphanumeric codes to preserve their anonymity.

Based on the categories and patterns identified, an integration stage was conducted to develop the framework for the sociotechnical viability of digital commercialization. The empirical categories were compared with the broader analytical domains derived from the theoretical background, particularly those related to material and territorial conditions, market organization and intermediation, digital and organizational capabilities, and institutional coordination (Favareto et al., 2024; Pinsky et al., 2024; Preiss et al., 2024; Sauvagerd et al., 2024).

Through an iterative process of comparison, abstraction, and synthesis, these broader literature-based domains were integrated with the empirical categories and their relationships and reformulated into four framework dimensions: material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. The relationships among these dimensions were then examined to represent how their interaction shapes the sociotechnical viability of digital commercialization in territorially specific contexts (Jaakkola, 2020).

Regarding ethical considerations, participants were informed in advance about the objectives of the study, the voluntary nature of their participation, and the procedures adopted to ensure confidentiality. All interviews were conducted after obtaining free and informed consent, and the data were used exclusively for academic and scientific purposes.

RESULTS

Conditions shaping digital commercialization from the perspective of producers and traders

Based on interviews conducted with producers and traders from different municipalities in the state of Acre, the results show that the viability of digital commercialization in the Amazon bioeconomy is conditioned by interrelated factors associated with logistics, market relations, digital infrastructure, producers' capabilities, and institutional support mechanisms. Together, these factors constitute a sociotechnical arrangement that shapes both the commercialization strategies adopted and producers' opportunities to access broader markets.

Eight producers and traders (E1 to E8) participated in this stage. Their involvement in different sociobiodiversity products, production scales, and territorial contexts provided a basis

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for identifying recurring patterns in commercialization practices, the challenges faced, and perceptions of digital solutions.

The analysis combined categories derived from the theoretical framework with patterns identified in the interviewees' narratives, resulting in thematic axes organized through a hybrid approach. These axes were systematized in Table 1, which presents the analytical dimensions, empirical categories, identified patterns, and their implications for digital commercialization.

Table 1. Analytical dimensions of digital commercialization in the Amazon bioeconomy: empirical patterns and analytical implications.

Analytical dimension	Empirical categories	Identified pattern	Analytical implication
Forms of commercialization	Traditional channels; occasional direct sales	Predominance of intermediary-based channels, with limited incidence of structured direct sales	Producers' subordinate position in commercialization chains, with limited capacity for direct market access
Logistics and infrastructure	Transportation; connectivity	Significant logistics bottlenecks and unstable connectivity, particularly in rural areas	Structural constraint on competitiveness and integration into broader markets
Dependence on intermediaries	Intermediation; price formation	Concentration of bargaining power among intermediaries, with asymmetric price setting	Unequal appropriation of value along the chain and limited economic autonomy of producers
Access to and use of digital technologies	Limited or no experience	Restricted use of digital tools, concentrated on informal communication (WhatsApp)	Limited incorporation of technologies as instruments for structured commercialization
Perceptions of digital commercialization	Economic benefits; social benefits	High receptiveness to digital commercialization, associated with expectations of increased income and expanded market access	Potential for the adoption of digital solutions, conditioned by the sociotechnical conditions required for their incorporation
Institutional needs and support	Capacity-building; logistical and financial support	Demand for training, technical support, payment mechanisms, and certification	Dependence on institutional mediation to enable digital market participation

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Expected benefits of digital commercialization	Product valorization; local development	Association between digital commercialization and the valorization of origin, identity, and sustainability	Potential for symbolic and territorial differentiation of sociobiodiversity products
Barriers to digital adoption	Individual limitations; structural limitations	Low digital literacy, apprehension regarding use, and inadequate infrastructure	Sociotechnical exclusion that constrains the effective adoption of digital commercialization

Source: Elaborated by the authors (2026).

The commercialization of bioeconomy products in the Southwestern Amazon remains concentrated in traditional channels, particularly through intermediaries and sales at local fairs and markets. Interviewees describe this arrangement as the "strongest channel today" (E1), present across different value chains, such as açaí (E2) and cassava flour (E7, E8).

Although intermediaries play an important role in moving products to market, their activities take place within commercial relationships characterized by asymmetries in price formation and bargaining power. According to the interviewees, intermediaries frequently "set" or "dictate the price" (E2, E7) and are perceived as those who "earn more than the producer" (E6). This pattern indicates an unequal appropriation of value along the chain and restricts producers' economic autonomy. Dependence on intermediaries is also associated with small-scale production, logistical constraints, and the lack of structured alternatives for direct commercialization (Costa et al., 2024; Trindade et al., 2024).

Logistical limitations deepen these asymmetries by restricting access to more advantageous markets. The accounts highlight poor rural roads, high freight costs, and worsening transportation difficulties during the rainy season, a situation described as a "headache" (E8). The commercial consequence is directly expressed by E1: "the guy has the product, but he has no way to take it somewhere that pays better." Thus, transportation conditions constrain not only the movement of products but also the possibility of accessing better-paying markets (Silva & Miranda, 2023).

Inadequate digital infrastructure constitutes another constraint on digital commercialization. Producers describe internet access as "unstable" (E6) or "weak" (E7), with some situations in which access is limited to local Wi-Fi networks without mobile phone coverage (E2). Irregular connectivity hinders the continuous use of digital technologies for

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commercial purposes and compounds the constraints faced by rural producers seeking to participate in digital channels (Gazolla & Aquino, 2024; Favareto et al., 2024).

In this context, the use of digital technologies remains concentrated on communication functions, particularly through WhatsApp, which is used for informal contacts but rarely as a structured commercialization channel. Although some interviewees report occasional initiatives on social media, described as "very amateur" (E5), limited experience with digital commercialization predominates, associated with a lack of technical knowledge and apprehension regarding its use, as expressed by E7: "I don't know how to do that" and "I'm afraid it won't work."

Despite these limitations, producers demonstrate high receptiveness to digital commercialization, associating it with the possibility of direct sales, reduced dependence on intermediaries, fairer prices, and expanded market reach. Its adoption is even described as a potential "revolution" (E6), while other interviewees emphasize expectations of "earning more" with a "fair price" (E7) and selling to "more places" (E8).

This perception extends beyond strictly commercial benefits. The accounts associate expanded market access with improvements in families' economic conditions, as summarized by E1: "we have good products; all we lack is opportunity." Similarly, E3 emphasizes the need for "something that opens the way to sell better," which, according to the interviewee, "changes families' lives."

Convergently, digital commercialization is perceived as capable of strengthening producers' agency in commercial relationships and enhancing recognition of their work. E4 summarizes this perception by stating that "the producer has more of a voice," while E7 highlights the valorization of producers' work and product origin. Expanded reach also appears in the accounts, as expressed by E8 when referring to the possibility of "showing our work to all of Brazil."

Interviewees also attribute a cultural and territorial valorization function to digital commercialization. Platforms are perceived as a "showcase" (E3), capable of making visible the origin, quality, and "face behind the product" (E5). This dimension extends the strictly commercial function of these solutions by associating them with the valorization of local culture, traditional knowledge, and the territorial identity of sociobiodiversity products (Garrett et al., 2024; Silva et al., 2025a).

However, the realization of these benefits is conditioned by the availability of technical and institutional support. Interviewees emphasize the need for "simple training" (E7), practical

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guidance (E1), and adapted educational materials (E2), as well as logistical support for delivery and freight (E5, E6, E7). Secure payment mechanisms and certification of origin are also mentioned as necessary elements for building trust in transactions (E2, E5).

The results also reveal barriers to the adoption of digital commercialization that combine individual and structural limitations. Low digital literacy, apprehension regarding use, and resistance to technology are particularly evident among producers with less familiarity with digital tools (E8). These limitations are compounded by inadequate connectivity, costs, and the absence of institutional support, creating conditions of sociotechnical exclusion that hinder the incorporation of these solutions into commercialization practices (Favareto et al., 2024; Gazolla & Aquino, 2024).

The limited use of digital commercialization does not stem predominantly from a lack of receptiveness among producers, but from the conditions required for its effective incorporation. Its viability depends on the articulation of infrastructure, sociotechnical capabilities, market relations, and institutional support mechanisms, which assume specific configurations within the territorial context analyzed. The perspective of the experts, presented in the following section, further develops the interpretation of these conditions and their implications for digital commercialization.

Conditions shaping digital commercialization from the perspective of experts

The interviews with the experts (EXP1 and EXP2) deepened the interpretation of the sociotechnical conditions shaping digital commercialization by incorporating a systemic perspective on the relationships among production, markets, sustainability, and governance. The main interpretive patterns and their implications for the viability of digital commercialization are summarized in Table 2.

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Table 2. Analytical dimensions of digital commercialization in the Amazon bioeconomy from the perspective of experts: analytical patterns and implications

Analytical dimension	Empirical categories	Identified pattern	Analytical implication
Foundations of the bioeconomy	Concept; current state; potential	Risk of the bioeconomy being discursively appropriated as a "fad" when disconnected from structural foundations	Need to anchor the bioeconomy in economic, ecological, and social criteria to avoid conceptual dilution
Logistics and infrastructure	Logistics bottlenecks; transportation; connectivity	Persistent structural constraints that compromise production costs, quality, and predictability	Systemic constraint on competitiveness and reinforcement of dependence on intermediaries
Intermediation and market structure	Intermediation; price formation	Concentration of market access capacity and unequal appropriation of value in intermediation relationships	Reproduction of economic asymmetries and restriction of productive autonomy
Digital commercialization	Use of digital technologies; barriers; requirements for digital solutions	Technological ambivalence: potential to reduce uncertainty versus adoption constraints	Viability of digital commercialization conditioned by infrastructure, capacity-building, and institutional mediation
Sustainability and territoriality	Environmental conservation; cultural valorization	Association between the bioeconomy and the maintenance of forests and traditional ways of life	Differentiation based on the symbolic and territorial attributes of products
Governance and institutional coordination	Public policies; partnerships; credit	Relevance of integrated institutional arrangements for enabling initiatives	Importance of multiscalar coordination and articulation among government, academia, and society
Expected impacts	Market expansion; economic security	Expectation of market expansion and reduced production uncertainty	Potential to foster territorial development and support continued residence in rural areas

Source: Elaborated by the authors (2026).

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The interviews reveal a perspective that is both critical and strategic regarding the Amazon bioeconomy and, more specifically, the conditions underlying the viability of digital commercialization of sociobiodiversity products. From the experts' perspective, the viability of digital commercialization must be understood within the broader context of the Amazon bioeconomy, whose consolidation depends on the articulation of economic viability, ecological sustainability, and social inclusion. This understanding moves away from interpretations that treat technology as an autonomous solution to the challenges facing Amazonian value chains.

The experts warn of the risk that the bioeconomy may become merely rhetorical or instrumental, turning into a "fad" (EXP1) when disconnected from consistent structural foundations. Bergamo et al. (2022) similarly question approaches to the Amazon bioeconomy that prioritize market opportunities without adequately addressing environmental protection, social equity, and the interests of local communities. From this perspective, bioeconomic initiatives linked to sociobiodiversity chains are understood through the articulation of productive, cultural, and territorial dimensions. EXP1 emphasizes the need to reconcile "economic viability, ecological prudence, and social equity," while EXP2 notes that the exploitation of forest products such as açaí can become "extremely unsustainable" when driven exclusively by market logic. Concerns over the environmental and social consequences of market-driven expansion in natural resource-based value chains are also raised by Lesenfants et al. (2024) and Rodrigues et al. (2024).

Regarding logistics, there is convergence in identifying longstanding constraints that undermine the competitiveness of Amazonian value chains. The experts associate these limitations with poor road conditions (EXP1), high river and land transportation costs, and losses resulting from product transportation (EXP2), all of which affect production quality, costs, and predictability. Dependence on intermediaries is interpreted as a consequence of this structural context, since these actors concentrate the capacity to move products to market, often purchasing them at "negligible prices" (EXP2), thereby contributing to the unequal appropriation of value generated along the chain.

In response to these limitations, the experts advocate the creation of production and logistics aggregation hubs or centers capable of reducing losses, improving production standards, and connecting small producers to more structured markets. Integrated territorial arrangements have also been identified as important for strengthening small-scale value chains (Carraresi, 2024; García-Gallego et al., 2025).

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Digital commercialization is interpreted as an ambivalent component of this process. On the one hand, it has the potential to reduce production uncertainty by increasing demand predictability and providing price references, functioning as an "element of security for production" (EXP1) and reducing the fear of "producing, spending, and not selling" (EXP2). On the other hand, its viability remains conditioned by connectivity, producers' digital capabilities, and the availability of institutional support. Limited connectivity, insufficient capacity-building, and digital exclusion therefore constitute sociotechnical conditions that constrain its effective incorporation (Hassoun et al., 2023; Petropoulos et al., 2025).

The challenges facing digital commercialization are not limited to infrastructure. The experts also identify constraints related to trust and familiarity with digital technologies. Distrust of external initiatives is associated with previous experiences marked by discontinuity and limited effectiveness (EXP1), while EXP2 highlights the existence of groups with limited familiarity with digital technologies, described as "digitally illiterate." These factors reinforce the understanding that the adoption of digital commercialization also depends on processes of trust-building, learning, and institutional mediation.

This understanding leads the experts to converge on the view that digital commercialization should be conceived as part of a broader territorial governance arrangement. EXP1 highlights the relevance of origin certification mechanisms, while EXP2 emphasizes the role of cooperatives and associations in the curation, standardization, and mediation of commercial transactions. This interpretation reinforces the need to integrate technology, social organization, and institutional arrangements, moving beyond approaches that treat digital solutions as sufficient to promote structural transformations (Basile et al., 2025; García-Gallego et al., 2025).

Sustainability is also closely linked to the legitimacy of digital commercialization and its integration into value chains compatible with forest conservation and the valorization of traditional ways of life. Products such as plant oils are cited as examples of activities directly dependent on environmental conservation, while digital platforms are understood as mechanisms capable of communicating origin, identity, and territoriality, thereby enhancing the symbolic value of sociobiodiversity products (Rodrigues et al., 2024; Silva et al., 2025a).

Enabling digital commercialization, in turn, requires structuring public policies, appropriate credit instruments, and long-term institutional partnerships. The lack of specific financing for sociobiodiversity chains is identified as a significant constraint (EXP2), reinforcing the importance of financial mechanisms adapted to the Amazonian context (Costa

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et al., 2024; Dias & Galina, 2025). The experts further highlight coordinated action through the triple helix (government, academia, and society) as an important element in consolidating systemic solutions (Pinsky et al., 2024).

The assessment of the economic and social potential of digital commercialization is positive. The experts associate these solutions with market expansion, reduced commercial asymmetries, and greater economic security for producers, with their potential described as "enormous" (EXP1). Potential contributions to keeping populations in their territories, reducing rural outmigration, and strengthening local development are also mentioned.

The experts' perspective indicates that this potential depends on the conditions that support the incorporation of digital technologies, including infrastructure, producers' capabilities, institutional coordination, and the valorization of territorial assets. Digital commercialization is therefore understood as one component of a broader sociotechnical arrangement and not as an isolated solution to the challenges facing sociobiodiversity chains. This perspective complements the findings from producers and provides elements for the development of the sociotechnical viability framework presented in the following section.

An analytical framework for the sociotechnical viability of digital commercialization in sociobiodiversity chains

Digital commercialization does not constitute an autonomous driver of transformation in sociobiodiversity chains. Its viability is conditioned by the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation, whose effects vary according to the territorial conditions in which these dimensions are configured (Hassoun et al., 2023; Petropoulos et al., 2025). The framework proposed in this study was developed by integrating the analytical domains identified in the State of the Art with the empirical categories and patterns derived from interviews with producers, traders, and experts. Through this process of comparison, abstraction, and synthesis, four interrelated dimensions of sociotechnical viability were identified, as summarized in Figure 2.

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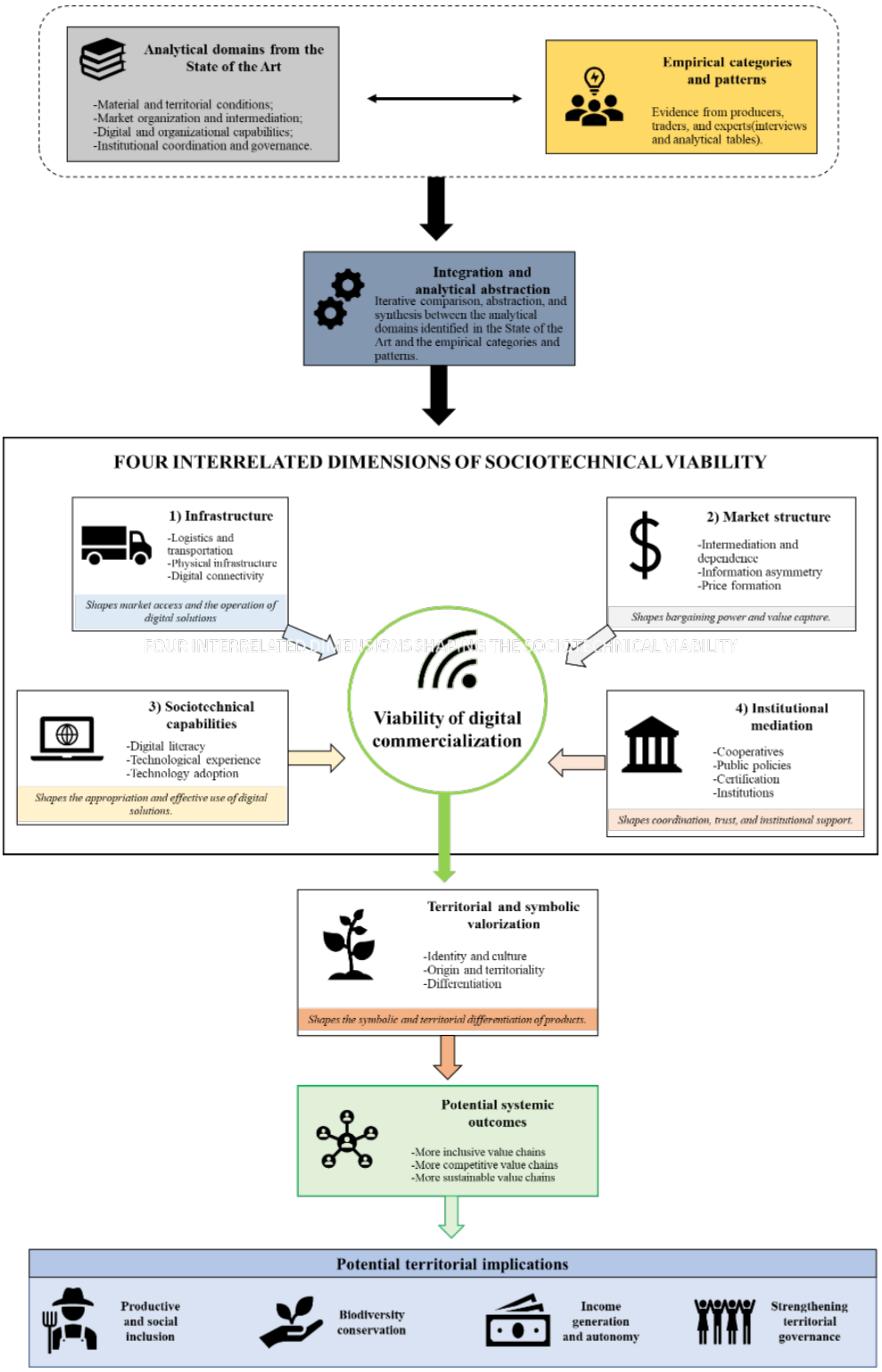


Figure 2. Analytical framework for the sociotechnical viability of digital commercialization in sociobiodiversity chains

Source: Elaborated by the authors (2026).

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The analytical construction of the framework combined the domains identified in the State of the Art with the empirical evidence systematized in Tables 1 and 2. The former provided an initial analytical basis concerning material and territorial conditions, market organization and intermediation, digital and organizational capabilities, and institutional coordination. These domains were then compared with the categories and patterns identified in the interviews, allowing convergences, complementarities, and relationships between the literature-based analytical domains and the empirical evidence to be examined. Their progressive integration and abstraction provided the basis for organizing the framework into material infrastructure, market structure, sociotechnical capabilities, and institutional mediation.

Material infrastructure provides the operational foundation for digital commercialization by defining the conditions for the physical movement of products and territorial connectivity, thereby shaping both market access and the operation of commercial transactions. Market structure reflects the power relations within sociobiodiversity chains, characterized by the role of intermediaries, asymmetric price formation, and constraints on direct access to commercialization channels, all of which influence the distribution and appropriation of value along the chain.

Sociotechnical capabilities represent the set of skills, knowledge, and cultural factors that enable the effective incorporation of digital solutions. This dimension encompasses levels of digital literacy, previous experience with technology, trust in new forms of commercialization, and other sociocultural factors that shape their use, demonstrating that technological availability alone does not automatically translate into productive use. Institutional mediation, in turn, encompasses the role of cooperatives, associations, public policies, and certification mechanisms that, in addition to reducing uncertainty and coordinating collective processes, perform an articulating function by connecting producers' capabilities, supply organization, logistics support, and market access.

These four dimensions are interdependent but do not necessarily perform equivalent functions within the sociotechnical arrangement. Persistent weaknesses in one dimension may constrain the positive effects associated with the others and, consequently, limit the viability of digital commercialization as a strategy for strengthening sociobiodiversity chains. Within this arrangement, institutional mediation assumes particular relevance because of its capacity to articulate actors, resources, and processes associated with the other dimensions, without implying primacy over them. The framework thus shows that the viability of digital

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commercialization depends on how material infrastructure, market structure, sociotechnical capabilities, and institutional mediation interact within each territorial context. The availability or adoption of technological solutions alone does not ensure viability. This interdependence is contextually situated and does not assume equivalent weights, universal minimum levels, or predefined compensatory relationships among the dimensions.

Distinct from these viability conditions, the territorial and symbolic valorization of sociobiodiversity products operates as a value-generation mechanism associated with digital commercialization. By increasing the visibility of attributes such as origin, cultural identity, and sustainability, it supports product differentiation in markets and the creation of symbolic value. Within the framework, this value-generation mechanism connects the viability of digital commercialization to potential systemic outcomes, such as more inclusive, competitive, and sustainable value chains. These outcomes may contribute to productive and social inclusion, income generation and autonomy, biodiversity conservation, and strengthened territorial governance. These implications represent analytical possibilities and were not directly measured by the study; therefore, the relationships represented in the framework do not imply a deterministic causal sequence.

This architecture also helps explain why, in contexts characterized by logistics constraints, poor connectivity, limited capabilities, and the absence of institutional mediation, digital commercialization tends to reproduce existing asymmetries, thereby restricting its potential benefits. Conversely, when embedded in territorial configurations in which these dimensions support its implementation, digital commercialization may expand market access, reduce production uncertainty, and strengthen producer autonomy, thereby supporting the potential systemic outcomes and territorial implications represented in the framework.

Beyond synthesizing the conditions identified empirically, the framework provides an analytical structure for interpreting the viability of digital commercialization across different sociobiodiversity chains. Its application requires diagnostic assessments of how material infrastructure, market structure, sociotechnical capabilities, and institutional mediation interact within each territory, making it possible to identify bottlenecks, establish intervention priorities, and inform public policies, territorial strategies, and digital commercialization initiatives that are better aligned with the concrete conditions of the Amazon.

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DISCUSSION OF THE SOCIOTECHNICAL VIABILITY OF DIGITAL COMMERCIALIZATION

The Amazon bioeconomy remains caught between its potential as a sustainable development strategy and the concrete conditions for its implementation within the territory, particularly given structural, institutional, and market constraints that hinder value addition and the consolidation of more inclusive value chains (Bergamo et al., 2022; Garrett et al., 2024). In the context analyzed, these constraints limit producers' autonomy and their appropriation of value, creating a territorial arrangement that shapes their opportunities to access broader, higher-value markets (Vieira et al., 2024).

This dynamic is particularly evident in intermediation relationships. Small producers in Amazonian and agri-food value chains often operate within asymmetric market relationships that constrain their bargaining power and appropriation of value (Favareto et al., 2024; Trindade et al., 2024). The findings extend this interpretation by indicating that the problem does not lie in the existence of intermediaries itself, but in the concentration of strategic functions such as logistics, access to market information, product distribution, and price setting. Intermediation thus performs an ambivalent function: it enables market access in contexts of limited coordination capacity, but also concentrates bargaining power and favors the unequal appropriation of value, keeping producers in economically subordinate positions (Costa et al., 2024).

Logistical constraints deepen these asymmetries. Infrastructure plays a central role in the development of Amazonian sociobiodiversity chains, particularly because of the territorial conditions that shape production and circulation (Abramovay et al., 2021; Clement et al., 2024). In the context analyzed, its effects extend beyond operating costs: inadequate transportation, high freight costs, climatic seasonality, and losses during transportation undermine production predictability and restrict access to broader markets. Infrastructure therefore plays a structuring role, as it shapes not only the movement of products but also producers' opportunities for value addition and market participation (Lesenfants et al., 2024).

These conditions also challenge overly optimistic interpretations of the transformative potential of digital commercialization. Studies on digitalization in rural contexts show that technological adoption depends not only on connectivity but also on skills, trust, and support structures (Arion et al., 2024; Gazolla & Aquino, 2024). In the context analyzed, poor connectivity and low digital literacy confirm these limitations but also reveal that digital exclusion is broader in scope, encompassing producers' ability to appropriate technologies and

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incorporate them into commercialization practices. The viability of these solutions is therefore conditioned by the articulation of access, capacity-building, institutional mediation, and adaptation to territorial specificities, limiting the ability of technology alone to promote productive integration or expand market access (Doloi, 2025).

Producers' receptiveness to digital commercialization solutions contrasts with their current level of use. Receptiveness was considerably higher than the effective use of these technologies, indicating that low adoption does not stem predominantly from resistance to innovation. Although concerns, uncertainties, and limitations in use persist, interviewees associate these solutions with market expansion, reduced dependence on intermediaries, greater economic predictability, and increased recognition of productive work. The contrast between willingness to adopt and the effective capacity to use these solutions therefore indicates that low adoption is primarily related to the sociotechnical conditions required to translate interest into effective use.

Territorial, institutional, and organizational conditions influence the adoption and appropriation of digital technologies (Borrero & Mariscal, 2022; Hassoun et al., 2023; Silva et al., 2025a). The findings advance this understanding by distinguishing adoption from sociotechnical viability. Producers' willingness and capacity to incorporate digital solutions do not, by themselves, ensure the logistical, market, and institutional conditions required for digital commercialization to be operationalized and sustained within the territory.

This distinction helps explain why the interviewees view digital commercialization as a component of a broader market access strategy, not as an autonomous solution. The experts emphasize that its effectiveness depends on certification mechanisms, logistics support, curation, continuous capacity-building, and structures capable of organizing supply and reducing transactional uncertainty. Collective organizations and mechanisms of support, coordination, and legitimation can play an important role in the operation of digital platforms and marketplaces (García-Gallego et al., 2025; Preiss et al., 2024). In the Amazonian context, long distances, dispersed production, and heterogeneous local capabilities increase the importance of such mediation and make solutions based on full disintermediation unlikely to be viable.

The central issue, therefore, appears to be not the elimination of intermediation, but its reconfiguration. Digitalization does not necessarily imply disintermediation, since platforms may assume functions of coordination, information control, and market access previously performed by other actors. From the perspective of platformisation, understood as the growing

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organization of market activities and relationships through digital platforms, digital ecosystems may reinforce dominant positions and create new forms of dependence when data, services, and coordination capabilities become concentrated in platform operators (Sauvagerd et al., 2024). This dynamic may lead to processes of reintermediation, in which the actors and mechanisms of mediation change without necessarily reducing power asymmetries. In the context analyzed, this perspective broadens the issue of dependence on intermediaries by directing attention to who performs mediation functions, under what conditions, and with what implications for producers' appropriation of value.

The quality of mediation therefore becomes more relevant than its mere presence. Institutional forms of mediation can strengthen value chain coordination and promote a more balanced distribution of value without concentrating commercial functions and bargaining power in a limited set of actors. Cooperatives, associations, logistics hubs, and public or hybrid mechanisms for certification and technical support can perform these functions, preventing digital commercialization from merely reproducing historically asymmetric structures in new forms (Preiss et al., 2024; Trindade et al., 2024). This interpretation broadens the discussion of governance in the bioeconomy by showing that institutional mediation not only facilitates technological adoption but also shapes the conditions under which producers participate in markets, in line with approaches that view the bioeconomy as a systemic process dependent on multiscalar coordination and articulation among multiple actors (Carraresi, 2024; Pinsky et al., 2024; Starke et al., 2024).

Digital commercialization also expands the possibilities for communicating the territorial, cultural, and symbolic attributes associated with sociobiodiversity products. In the interviewees' accounts, platforms are conceived as means of making product origin, history, and identity visible, indicating that their function can extend beyond market access. This finding adds to the commercial dimension a value-creation mechanism based on territorial differentiation, particularly in value chains where traditional knowledge, narratives of origin, and links among products, territories, and ways of life are integral to the economic value generated (Águas & Gitahy, 2025; Ardenghi et al., 2026; Rodrigues et al., 2024).

This relationship between commercialization and territorial differentiation shifts the analysis from technological efficiency to how value is produced and communicated. In sociobiodiversity chains, competitiveness depends not only on the material attributes of products but also on the capacity to make their ecological, cultural, and territorial distinctiveness recognizable. Digital commercialization can therefore combine market access

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with greater visibility for these attributes, articulating economic and territorial value. Its potential lies not only in making commercialization more efficient, but also in enhancing the capacity of territorial actors to communicate and appropriate the value associated with product origin.

This discussion also calls for caution regarding the meaning attributed to the bioeconomy itself. Abramovay et al. (2021) and Bergamo et al. (2022) warn of the risk that the concept may become predominantly rhetorical when disconnected from concrete criteria of sustainability and inclusion. The concern expressed by the experts in this study reinforces this issue and adds an implication for digital commercialization: neither the incorporation of technologies nor the market valorization of sociobiodiversity products is, by itself, sufficient to characterize a territorially consistent bioeconomic transformation.

From this perspective, digital commercialization initiatives are more closely aligned with a territorially grounded Amazon bioeconomy when they combine economic viability for producers, ecological prudence in the use of natural resources, and equity in the distribution of opportunities and benefits. This perspective makes it possible to distinguish initiatives that merely incorporate digital tools from those aimed at transforming the conditions under which producers participate in markets, without separating economic performance from environmental conservation and social inclusion.

The viability of digital commercialization depends on the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. Logistical constraints limit the reach of digital channels; limited capabilities hinder their effective appropriation; the concentration of commercial functions reinforces producers' dependence; and the absence of support organizations undermines certification, standardization, and market access processes. The effects of each dimension therefore depend on its interaction with the others and on their configuration within each territorial context.

The viability of digital commercialization can thus be understood as resulting from the interaction among the dimensions of this sociotechnical arrangement, without assuming fixed or equivalent relationships among them. Its implementation therefore requires more than the development of platforms; it also depends on material conditions, sociotechnical capabilities, mediation mechanisms, and market structures capable of supporting their appropriation by territorial actors. In contexts marked by weaknesses across these dimensions, digital technologies may reproduce existing asymmetries; when articulated with more favorable

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territorial conditions, they may expand market access, reduce uncertainty, and strengthen producers' bargaining capacity.

CONCLUSIONS

The analysis showed that the viability of digital commercialization in the Amazon bioeconomy does not result from the mere incorporation of technological tools, but from the articulation of material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. In the context of the Southwestern Amazon, logistical and connectivity constraints, limited appropriation of digital technologies, asymmetries in market relations, and insufficient support structures operate interdependently, restricting producers' ability to access more advantageous markets and appropriate the value generated along the chains.

At the same time, interviewees associate digital commercialization, when aligned with the territorial specificities of the Amazon, with the potential to expand market access, reduce production uncertainty, and enhance the territorial and symbolic value of products. Digital solutions are seen not only as sales channels, but also as means of broadening access to market information, reducing dependence on asymmetric forms of intermediation, and increasing the visibility of attributes related to product origin, identity, and sustainability. These potential effects remain conditioned by the sociotechnical dimensions identified in the study and do not arise automatically from digitalization.

Within this arrangement, cooperatives, associations, and other territorial support structures can perform coordination, certification, logistics support, and trust-building functions, connecting local capabilities, production organization, and market access. Their effectiveness also depends on public policies, physical and digital infrastructure, capacity-building, and financial instruments compatible with the characteristics of sociobiodiversity chains.

From a theoretical perspective, the study contributes by proposing a framework that explains the sociotechnical viability of digital commercialization through the interaction among material infrastructure, market structure, sociotechnical capabilities, and institutional mediation. These dimensions are interdependent and assume specific configurations within each territorial context, without presupposing equivalent weights or predefined compensatory relationships. The framework thus shifts the analysis of digital commercialization from an understanding centered on technological availability toward a relational and territorial

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approach capable of explaining why similar solutions may encounter different conditions of viability across sociobiodiversity chains.

In practical terms, the framework can guide interventions based on the bottlenecks present in each territorial configuration, combining investments in logistics and connectivity, capacity-building for the productive use of technologies, the strengthening of collective organizations, certification and commercialization support mechanisms, and financial instruments suited to sociobiodiversity chains. Digital commercialization should therefore be conceived as a component of broader territorial strategies in which economic viability, ecological prudence in the use of natural resources, and social equity in the distribution of opportunities and benefits remain interconnected.

The findings should be interpreted in light of the qualitative, exploratory, and territorially situated nature of the research. The study focused on the state of Acre and involved a purposively selected group of producers, traders, and experts associated with different sociobiodiversity chains. This diversity enabled the identification of cross-cutting conditions but does not allow their configuration to be assumed to occur in the same way across different value chains or other Amazonian territories. Furthermore, the study examined commercialization experiences and perceptions regarding the adoption of digital solutions without longitudinally tracking the implementation and outcomes of a specific platform. The proposed framework therefore derives from the integration of qualitative evidence and the theoretical framework and has not yet been comparatively validated in other territorial contexts or through longitudinal application. Its applicability beyond the context analyzed therefore requires further empirical validation.

Future research could examine the framework in other Amazonian regions and specific sociobiodiversity chains to assess how different productive, institutional, and territorial configurations shape the relationships among its dimensions. Quantitative studies and mixed-methods approaches could test the proposed analytical relationships and measure economic, social, and environmental outcomes associated with digital commercialization. Pilot initiatives and longitudinal studies of platforms implemented in practice could also examine governance models, financial sustainability, producer participation, and changes in value chain coordination, value distribution, and territorial value creation.

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Declaração de conflito de interesse

Os autores declaram que não há conflito de interesse.

Declaração de contribuição dos autores

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Declaração de disponibilidade de dados da pesquisa

O conjunto de dados de apoio aos resultados deste estudo não está disponível ao público.

Declaração de uso de IA

Durante a preparação do manuscrito, foi utilizado o TurboScribe como ferramenta de apoio à transcrição das entrevistas, com posterior conferência dos registros em relação aos áudios originais. As ferramentas ChatGPT (OpenAI) e Claude (Anthropic) foram utilizadas para revisão linguística, aprimoramento da clareza e organização textual. Os autores revisaram os conteúdos produzidos com auxílio dessas ferramentas e assumem integral responsabilidade pelo conteúdo do artigo.

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