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Food Markets in the Brazilian Western Amazon: Challenges of Digitalization and Possible Strategies

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Resumo
A digitalização das cadeias produtivas tem sido amplamente discutida ao longo da última década, com impactos significativos no campo dos mercados alimentares. No entanto, na região Norte do Brasil este cenário ainda não se consolidou, de forma que as pesquisas recentes indicam a quase inexistência de mercados digitais. Com o objetivo de compreender essa realidade, este artigo analisa os desafios da digitalização em mercados alimentares na Amazônia Ocidental brasileira, mais especificamente no Sul do Estado do Amazonas. A pesquisa empírica baseou-se em 40 entrevistas, realizadas com dois grupos de agricultores: cafeicultores de Apuí e açaicultores de Manicoré, municípios que apresentam contextos logísticos divergentes. Os resultados demonstram que a digitalização dos mercados alimentares amazônicos não é limitada apenas pela baixa conectividade, mas, sobretudo, pela infraestrutura logística precária, tanto fluvial quanto rodoviária. Essa condição revela a existência de uma grave dívida logística-digital na Amazônia ocidental, na qual a exclusão digital soma-se à exclusão logística. Estratégias para a superação deste quadro incluem o fortalecimento das malhas viárias, o desenvolvimento de modelos multimodais, e o incentivo a organizações coletivas que operem a digitalização, visando reduzir a dependência de atravessadores e promover sistemas alimentares sustentáveis.
Palavras–chave: Digitalização. Logística. Amazônia. Mercados Alimentares. Agricultura Familiar.

Food markets in the western Amazon: challenges of digitalization and possible strategies

Abstract
The digitalization of production chains has been widely discussed over the last decade, with significant impacts on the field of food markets. However, in the Northern region of Brazil, this scenario has not yet materialized, with recent research indicating the near non-existence of digital markets. Aiming to better understand this reality, this article analyzes the challenges of digitalization in food markets in the Brazilian Western Amazon, specifically in the South of Amazonas State. The empirical research was based on 40 interviews conducted with two groups of farmers: coffee growers in Apuí and açaí producers in Manicoré, municipalities that present divergent logistical contexts. The results demonstrate that the digitalization of Amazonian food markets is not limited solely by low connectivity, but, above all, by precarious logistical infrastructure, both fluvial and road-based. This condition reveals the existence of a severe logistics-digital divide in the Western Amazon, where digital exclusion is compounded by logistical exclusion. Strategies to overcome this situation include strengthening road networks, developing multimodal models, and encouraging collective organizations to operate the digitalization, aiming to reduce dependence on intermediaries and promote sustainable food systems.

Keywords: Digitalization. Logistics. Amazon. Food Markets. Family Farming.

Mercados alimentarios en la Amazonía occidental: desafíos de la digitalización y estrategias posibles

Resumen
La digitalización de las cadenas productivas ha sido ampliamente discutida a lo largo de la última década, con impactos significativos en el ámbito de los mercados alimentarios. Sin embargo, en la región Norte de Brasil este escenario aún no se ha consolidado, de modo que investigaciones recientes indican la casi inexistencia de mercados digitales. Con el objetivo de comprender esta realidad, este artículo analiza los desafíos de la digitalización en los mercados alimentarios de la Amazonía Occidental brasileña, más específicamente en el sur del estado de Amazonas. La investigación empírica se basó en 40 entrevistas realizadas con dos grupos de agricultores: caficultores de Apuí y productores de açaí de Manicoré, municipios que presentan contextos logísticos divergentes. Los resultados demuestran que la digitalización de los mercados alimentarios amazónicos no está limitada únicamente por la baja conectividad, sino, sobre todo, por la precaria infraestructura logística, tanto fluvial como vial. Esta condición revela la existencia de una grave deuda logístico-digital en la Amazonía occidental, en la cual la exclusión digital se suma a la exclusión logística. Las estrategias para superar este escenario incluyen el fortalecimiento de las redes viales, el desarrollo de modelos multimodales y el fomento de organizaciones colectivas que impulsen la digitalización, con el fin de reducir la dependencia de intermediarios y promover sistemas alimentarios sostenibles.

Palabras clave: Digitalización. Logística. Amazonía. Mercados alimentarios. Agricultura familiar.

Introduction

Among the innovations experienced by food systems since the turn of the century, digitalization has emerged as a development with considerable transformative potential across all stages of production chains (Massruhá et al., 2020; Favareto; Tolocka; Fonseca, 2024; Wepner et al., 2025). In the field of food marketing, the adoption of digital tools at the farm level is an even more recent phenomenon, gaining prominence in research agendas during the COVID-19 pandemic, when the use of digital tools became a necessity. Since then, researchers have sought to understand how digitalization has been effectively incorporated into food systems and what effects it has had on rural households.

Regarding family farming characterized by small-scale production and diversified production systems, initial studies have identified innovative collective initiatives in this field, with significant outcomes in terms of diversifying marketing channels, increasing the autonomy of rural households, and expanding the consumer base. However, Brazil's continental dimensions give rise to such considerable heterogeneity among food systems that any generalization risks being incomplete or inadequate, as it may fail to capture regional diversity and specificities. The studies by Gazolla and Aquino (2022) and Gazolla and Aquino (2024) support this argument.

Building on these studies, the research question that emerges from this discussion and guides the present study is: what are the challenges of market digitalization in inland regions of the Brazilian Western Amazon? To contribute to the growing body of scientific knowledge on this topic and provide insights into the particularities of food marketing in remote regions, this study aims to analyze the challenges of digitalization in food markets in the Brazilian Western Amazon, more specifically in the southern part of the state of Amazonas. As an empirical basis, two groups of farmers were interviewed: a group of coffee growers from the municipality of Apuí and a group of açaí producers from Manicoré. The two cases share relevant similarities, as both involve small-scale family farmers located in inland areas of the state of Amazonas. However, they also present significant differences related to their geographical locations and the conditions under which their products are transported to markets.

By addressing the challenges of market digitalization under these circumstances, this study shifts its emphasis toward the dimension of logistics infrastructure, a topic that has received relatively little attention, even in specialized research. Finally, the study also seeks to contribute to the identification of possible strategies for improving food systems and, particularly, food marketing with a view to promoting sustainability. To this end, the article is organized into four sections, in addition to this introduction and the concluding remarks. The next section presents a literature review on the digitalization of food markets, followed by a section outlining the methodological foundations of the research. The subsequent results sections present the primary and secondary data collected and compiled throughout the research. Finally, these data are examined considering findings from other studies to reflect on the challenges of market digitalization in Amazonian regions.

Literature Review

The digitalization of production chains is a recent phenomenon that has increasingly featured on research agendas over the past decade. The scientific

literature currently encompasses a wide range of studies seeking to identify digital tools across all stages of production chains, including sectors associated with pre-production (biotechnology, bioinformatics, and the development of genes resistant to climate change), production (agricultural automation, precision agriculture, and robotics), and post-production (Big Data, blockchain, artificial intelligence, and various integrated platforms) (Massruhá et al., 2020; Rolandi et al., 2021; Favareto; Tolocka; Fonseca, 2024; Gazolla; Tonin; Cunha, 2024; Wepner et al., 2025).

It is important to emphasize that the digitalization of production chains is part of a broader process of technological transformation in agriculture, frequently associated with so-called Agriculture 4.0, characterized by the incorporation of information and communication technologies (ICTs), automation, artificial intelligence, the Internet of Things, and data-intensive processing (Massruhá et al., 2020; Albiero et al., 2020). These transformations are taking place globally and have stimulated research in several countries (Rijswijk et al., 2021; Bahn; Yehya; Zurayk, 2021; Rolandi et al., 2021), although their effects have manifested unevenly across regions, sectors, and social actors. While digitalization has been rapidly and comprehensively incorporated into production processes in certain contexts, structural barriers persist in others, including inequalities in access to connectivity, limited opportunities for technical training, and a lack of adequate public policies. In this regard, researchers have highlighted the need to understand not only the potential benefits of digitalization but also its contradictions and asymmetries, particularly in developing countries.

This study focuses specifically on agrifood markets, whose dynamics have been significantly affected by digitalization processes. More broadly, e-commerce platforms have been a reality in Brazil for approximately two decades, although their operations have predominantly focused on retail, as illustrated by the various online marketplaces operating in the country (Niederle et al., 2021; Gazolla Gaievski; Aquino, 2024). In rural studies, the innovation observed over the past decade, particularly during the last five years, lies in farmers' access to these technologies, which they had not previously used to market their products.

Regarding the incorporation of digital tools into different types of markets, it is important to emphasize the heterogeneity of these technologies. Considering that food can be marketed through integrated platforms, websites, dedicated e-commerce applications, and instant messaging applications, one might argue that one of the few features these tools share is their reliance on the internet in the marketing process. Beyond this common feature, however, their development and adoption processes, associated costs, modes of operation, and relationships between producers and consumers differ substantially (Niederle, Schneider and Cassol, 2021; Tonin, Niederle and Schneider, 2024; Putrick; Silva; Carvalho, 2020).

The questions arising from market digitalization led to the emergence of a research agenda that became firmly established during the COVID-19 pandemic, when websites, platforms, and marketing applications became widely disseminated. One important insight from this research is that, although the term "digital markets" is commonly used, markets operating through digital platforms do not constitute a new type of market (Niederle et al., 2021; Gazolla; Tonin; Cunha, 2024). Rather, digitalization represents a transformation of different agricultural markets through the incorporation of digital tools. This transformation may occur in direct markets,

collective markets, public procurement markets, or even conventional markets, according to the classification proposed by Schneider (2016). In this context, the challenges faced by rural households in marketing food through digital tools constitute an important research concern. Moreover, not only researchers but also decision-makers and policymakers need access to robust studies addressing the realities of Brazilian food markets, particularly those in the Amazon.

The challenges associated with the digitalization of markets and production chains encompass both general and context-specific dimensions. Territorial particularities therefore constitute important objects of research, given that different territories have distinct conditions and demands, especially in Brazil, where rural heterogeneity extends across a vast continental territory. From a broader analytical perspective, research has identified several challenges that must be overcome to ensure that the incorporation of digital tools into agrifood markets becomes accessible and sustainable, without perpetuating the inequalities that already characterize food production worldwide.

To synthesize the challenges identified in the literature, the findings can be organized into four main categories: (i) physical infrastructure; (ii) digital inclusion and training; (iii) governance and regulation; and (iv) sustainability and social impacts. The first category encompasses physical constraints affecting market digitalization, including connectivity (network availability and signal quality), infrastructure (storage and distribution facilities, transportation capacity, and logistics), and technological interoperability (integration among platforms, transportation modes, and types of markets) (Niederle et al., 2021; Bahn; Yehya; Zurayk, 2021; Gazolla; Tonin; Cunha, 2024; Favareto; Tolocka; Fonseca, 2024; Wepner et al., 2025).

The second category emphasizes inequalities in access to digital tools, to which low levels of education and regional disparities contribute significantly. In this case, the challenge extends beyond internet access, which is already a major obstacle, to include access to reliable connectivity and the skills required to operate in markets mediated by the internet (Brunori, 2022; Niederle et al., 2021; Rolandi et al., 2021; Kitole et al., 2023). In many situations, internet access and mobile devices are used exclusively for exchanging messages, meaning that a binary assessment of this reality—whether individuals use digital technologies or not—fails to capture the complexity of market digitalization.

The third category, which addresses governance and regulation, suggests that digitalization has progressed more rapidly than society's capacity to understand and adequately regulate it. Consequently, issues such as data ownership and use, information privacy, cybersecurity, and platform regulation have become urgent concerns, not only in rural areas but also in society as a whole (Brunori, 2022; Ehlers et al., 2021; Niederle et al., 2021; Rolandi et al., 2021).

Finally, the fourth category highlights the vulnerabilities of a system predominantly driven by economic considerations at the expense of social and environmental concerns, which have become central issues during the first quarter of the twenty-first century. When insufficiently regulated or understood, the digitalization of production chains tends to deepen inequalities by limiting equitable access under adequate conditions. It also threatens commitments to sustainable development, as embodied in the widely recognized Sustainable Development Goals (SDGs) (Rijswijk et al., 2021; Bahn; Yehya; Zurayk, 2021; Niederle et al., 2021; Gazolla;

Tonin; Cunha, 2024). These impacts also include the environmental costs associated with digital infrastructure, such as the substantial water consumption of data centers (Silva; Eccard; Cavalcante, 2025).

Although existing studies extensively address the main contradictions and challenges that need to be overcome, the limited emphasis on logistical aspects is particularly striking, especially in Brazilian research. More specifically, road accessibility and transportation modes have received relatively little attention. In general, studies highlight infrastructure challenges related to storage, distribution centers, and the difficulties of connecting the virtual stages of marketing processes with their physical operations. This may reflect an analytical perspective grounded in regions where such problems have been partially addressed over the past half-century, as is the case in southern and southeastern Brazil. However, the regional particularities of northern Brazil make it essential to revisit a central issue in development debates: logistics infrastructure and the transportation of agricultural products to markets.

According to the latest official data cited in this study (CNT, 2022), the state of Amazonas, Brazil's largest state by area, has only 2,229.6 km of paved roads. By comparison, Pará, the country's second-largest state in terms of area, has 72% more paved roads than Amazonas, despite having a territory that is 21% smaller. Furthermore, in Amazonas, nearly all paved roads are concentrated around the state capital, Manaus. This characteristic is fundamental to understanding not only market digitalization but also the consolidation of production chains more broadly. During the rainy season, which lasts approximately half the year, the few existing highways become virtually impassable, severely restricting the movement of people and the efficient transportation of food products. This also helps explain why the number of collective digital platforms for food marketing in northern Brazil was zero in 2021 (Gazolla; Aquino, 2022) and only one in 2024 (Gazolla Gaievski; Aquino, 2024). In studies addressing the challenges of market digitalization, logistics and road accessibility tend to receive only secondary attention, with some exceptions, such as Bahn, Yehya and Zurayk (2021), who examine the Middle East and North Africa, and Buanain, Cavalcante and Consoline (2021), who address systemic factors in the Brazilian context.

These conditions not only hinder market digitalization but also pose significant challenges to increasing the value of products derived from local sociobiodiversity. This is particularly relevant because one strategy for sustainable income generation involves promoting value chains based on locally produced products associated with sustainable production systems that can provide profitable alternatives while keeping forests standing and requiring relatively small areas of land. Examples include agroforestry systems involving açaí, Brazil nuts, coffee, guaraná, cupuaçu, and numerous other products. Given their high added value, the development of these value chains makes it possible to compete with large-scale crops that increasingly characterize the landscape of northern Brazil (Le Tourneau, 2025). This issue also relates to a broader debate on regional and territorial development. The literature has emphasized that development processes are not evenly distributed across space, as regions differ in their economic, social, institutional, and infrastructural conditions, as well as in their forms of integration into broader networks and scales.

Silveira (2020) argues that regional development must be understood in light of territorial specificities and the relationships among territory, scale, and networks. Similarly, Favareto (2010) emphasizes the importance of territorial approaches in overcoming strictly sectoral interpretations of rural development, while Deponti et al. (2024) associate the reduction of regional inequalities with the recognition of the particularities of different territories. In the Amazonian context, this perspective is especially relevant because transportation conditions and infrastructure affect the integration of production chains into markets, with logistics forming part of the relationships among networks, productive organization, and territorial development (Monié, 2011). Thus, an analysis of food market digitalization must also consider the territorial conditions that underpin the transportation and marketing of agricultural products.

Theoretical and Methodological Foundations

To address the objectives of this article, the definition of digital food markets adopted here is based on the propositions of Niederle et al. (2021) and Gazolla, Tonin and Cunha (2024), according to which food and other products are marketed through digital tools, even when payment and the completion of transactions take place in person. These transactions occur primarily at local and regional levels, although they may extend to broader geographical areas. The analysis presented in this article is based on 40 interviews, of which 21 were conducted between August and December 2024 in rural areas of the municipality of Apuí and 19 between September and November 2025 in Manicoré, both located in southern Amazonas. Apuí emerged along the BR-230 Highway (Trans-Amazonian Highway), while Manicoré developed along the banks of the Madeira River.

The semi-structured interviews consisted of open-ended questions organized into three sections: (i) characteristics of the respondents and their farms; (ii) dynamics of food production and marketing; and (iii) the main challenges faced by these farmers in food markets. Following transcription, the collected material was analyzed using methodological approaches widely employed in qualitative research, including Bardin (2011) for content analysis and Minayo (2001) for qualitative research in applied social sciences. In the content analysis, the three themes (characteristics, dynamics, and challenges) constituted the three analytical nodes around which the analysis was organized. The main information associated with each of these overarching themes was extracted, with particular emphasis on the third theme, given the scope of the study. Combined with a discussion of the literature available in major academic databases, this analysis formed the qualitative dimension of the study. From a quantitative perspective, the questionnaire enabled a descriptive characterization based on distance from the municipal center, total farm area and usable agricultural area, respondents' age, and educational attainment.

All interviewed households shared a common productive activity: coffee cultivation in agroforestry systems in Apuí and açaí production in Manicoré. However, these crops were not their only sources of income. Activities such as dairy production, beef cattle farming, and the production of various food products, all carried out on a small scale, illustrate their diversification strategies. All interviewed households meet the criteria for family farming established under Brazilian legislation (BRASIL, 2006).

The field research conducted for this study was approved by a Research Ethics Committee, under CAAE 76744423.3.0000.5020.

Secondary data from the 2017 Agricultural Census (IBGE, 2019), obtained through the SIDRA/IBGE platform, were also used. In addition to primary and secondary data, an integrative literature review was conducted (Favareto; Tolocka; Fonseca, 2024), bringing together theoretical and empirical studies addressing agrifood markets, digitalization, and the development of sustainable food systems in the Brazilian Amazon. Priority was given to studies published over the previous ten years in recognized academic journals in the field. Searches were conducted in the following databases: Scopus, Web of Science, SciELO, and Google Scholar.

Finally, it is important to emphasize that, although field research plays a fundamental role in illustrating the reflections developed throughout this article, the study is not intended to be merely a case study. Rather, it seeks to provide a broader reflection on the challenges of digitalization in geographically and economically marginalized regions, drawing on real-world situations to illustrate the arguments presented throughout the article to engage with concepts such as the digital divide and logistics. The findings are presented in two stages. First, the current situation of food marketing in peripheral regions of the Brazilian Amazon is examined. Subsequently, the discussion engages with the main concepts employed in the study and presents a synthesis of possible strategies to overcome the challenges affecting Amazonian food systems.

Empirical Foundations for Understanding the Challenges of Digitalization

This section discusses the current circumstances of food marketing among family farmers, emphasizing the challenges of digitalization in the Amazonian context. The analysis draws on empirical evidence from two groups of farmers located in different settings within the state of Amazonas. The group from the municipality of Apuí consists of 21 farming households whose main source of income is coffee production, while the group from Manicoré comprises 19 households engaged in açaí production. Both municipalities are located in the southern mesoregion of the state of Amazonas, specifically within the Madeira River basin, in the southeastern part of the state.

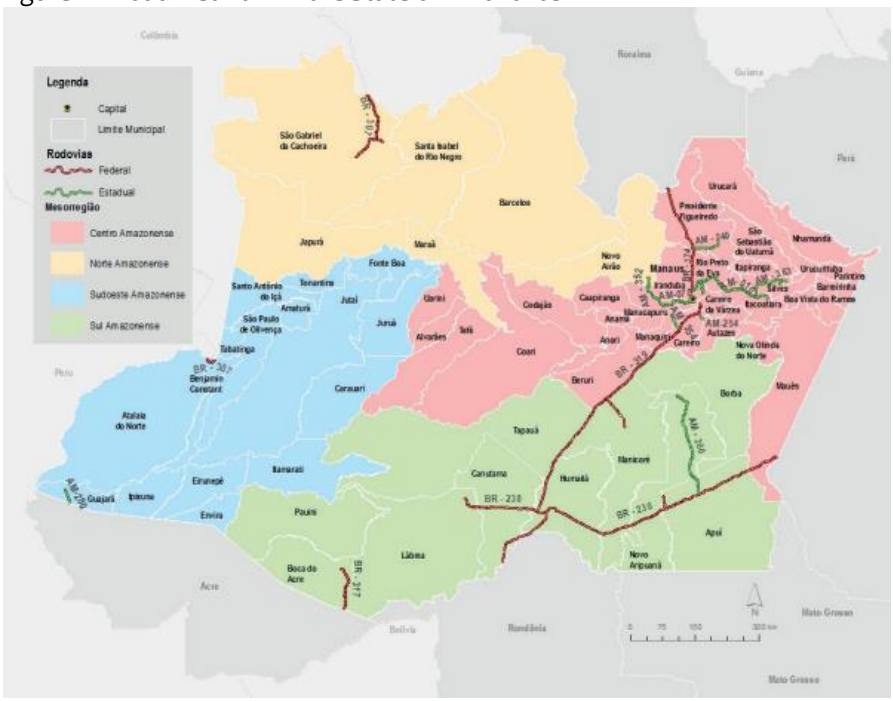
These two cases can be considered typical of family farming units with landholdings of less than 100 hectares. This characteristic is observed among 92.1% of the interviewed households, reflecting the broader situation in northern Brazil (86.3%) and the state of Amazonas (89.1%), according to data from IBGE (2019). In much of southern and southeastern Brazil, a 100-hectare property would not qualify as a family farm because the fiscal module in these regions is approximately 20 hectares[1]. In contrast, in Manicoré and Apuí, the fiscal module corresponds to 100 hectares (BRASIL, 2022). In other words, the properties examined in this study are smaller than one fiscal module.

[1] Among other criteria, the maximum land area for a rural property to qualify as a family farm is four fiscal modules (BRASIL, 2006).

Furthermore, it is important to recall that in areas of the Amazon rainforest, at least 80% of a rural property's total area must be maintained as a Legal Reserve (BRASIL, 2012). Another important characteristic shared by both groups is their production profile, which is marked by considerable diversification, including food production for household consumption and marketing, although coffee and açaí remain their main commercial crops. Despite these similarities, geographical location, logistical dynamics, and, consequently, the challenges associated with marketing agricultural products differ significantly between the two cases, justifying the selection of these groups for the study.

The 21 coffee producers from Apuí who participated in this research live on rural properties located an average of 23.3 km from the municipal center, with distances ranging from 8 to 30 km. As with other products from the region, the coffee produced by the local community is not entirely consumed within the municipality. Instead, it is integrated into medium- and long-distance distribution chains. Apuí is situated along the Trans-Amazonian Highway (BR-230), one of the few highways in the state of Amazonas (Figure 1). Its municipal center is located approximately 400 km from other municipal centers, and its main connection is with the municipality of Humaitá (400 km to the west), particularly because of Humaitá's advantageous geographical position in relation to Porto Velho, the capital of the state of Rondônia, which is approximately 200 km away via paved roads.

Figure 1 – Road Network in the State of Amazonas.

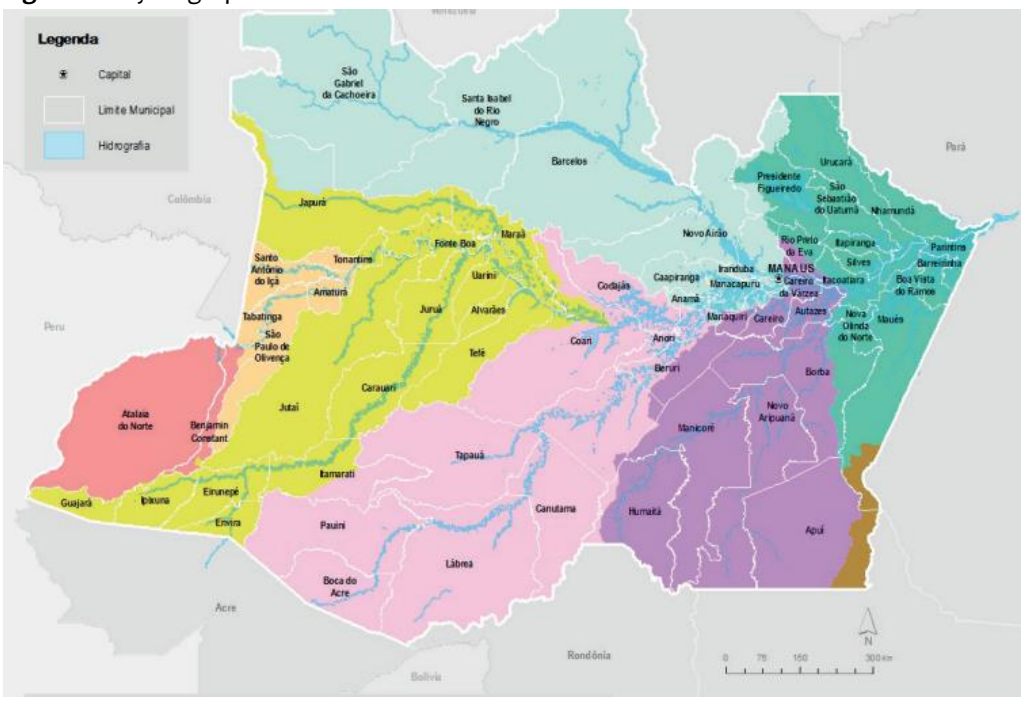


Source: SEDECTI, 2020.

The 400 kilometers separating Apuí from Humaitá, in turn, are entirely unpaved and constitute the main transportation route for people, food, agricultural inputs, and all other goods entering and leaving the municipality. In general, unpaved roads constitute the main transportation network connecting municipalities in southern Amazonas, particularly the Trans-Amazonian Highway, which begins in Lábrea, 200 km west of Humaitá, and extends to the Brazilian coast, covering more

than 4,300 km. At this point, one might question the role of waterways in local logistics, given the importance of this transportation system not only for moving agricultural products to markets in the Amazon but also for transporting people. In this regard, it is important to emphasize that, in the southern portion of the Amazon basin, the river system generally follows a northward drainage pattern, flowing toward the Amazon River. This is the case for the Madeira River, as well as the Purus and Tapajós rivers, both of which run roughly parallel to it (Figure 2).

Figure 2 – Hydrographic Sub-basins of the State of Amazonas.



Source: SEDECTI, 2020

On the one hand, the conditions described above help explain the widespread use of waterway transportation for goods and passengers between Porto Velho, Humaitá, Manicoré, and Manaus, for example. On the other hand, they also help explain the limitations of river transportation in the east–west direction (or vice versa) in the southern mesoregion of Amazonas, as in the case of Apuí. This is partly due to the configuration of the river network, whose main rivers flow predominantly from south to north, making cross-regional river connections more difficult. This situation contrasts sharply with that experienced by farmers in Manicoré, who are also located in the southern mesoregion of the state but currently lack road connections to other municipalities. This is because the 85 km separating the municipal center from BR-319 (which connects Porto Velho, Rondônia, to Manaus, Amazonas) include closed bridges and road conditions that make travel impossible. Even if the road were passable, Manicoré would still be 430 km from Humaitá and 460 km from Manaus, with more than 300 km of unpaved roads. In other words, while Apuí relies predominantly on road transportation, despite its precarious conditions, Manicoré depends on waterway transportation along the Madeira River. A boat trip to Humaitá takes approximately one day, while a journey to Manaus typically takes between two and three days.

Thus far, the analysis has shown that, although the two groups of farmers share several similarities, their logistical conditions introduce a degree of heterogeneity that is particularly relevant for analyzing food marketing dynamics and, above all, the challenges of production chain digitalization. This is a highly contemporary issue that occupies a central position in major research agendas in Brazil (Massruhá et al., 2020).

To characterize the cases under analysis more specifically, the group of farmers from Apuí—hereafter referred to as Group 1—consists of 21 households whose main source of income is coffee production in agroforestry systems. Field data indicate an average farm size of 62.3 hectares, with the largest property covering 120 hectares and the smallest 27 hectares. Most farmers have lived in the region for more than ten years, and their histories are connected to the major migration movements from southern Brazil toward the Amazon during the second half of the twentieth century. Of the 21 households, 15 receive benefits from social assistance programs, such as Bolsa Família or similar initiatives, indicating a situation of socioeconomic vulnerability.

Regarding market organization, a local coffee production chain has been established over the past six years, bringing together non-governmental organizations and private entities to provide technical assistance and subsequently market the coffee beans. In this arrangement, farmers are not directly responsible for selling coffee to final consumers. Instead, their responsibility is limited to delivering their production to the local facilities of the company that commits to purchasing their coffee while supporting the establishment of coffee cultivation and providing technical assistance to farming households.

In the case of households from Manicoré (Group 2), the group comprises 19 families primarily engaged in açaí production, which constitutes their main source of farm income. Other food products are also produced, including bananas, watermelons, Brazil nuts, and maize. However, the relatively small production volumes make these products economically secondary, although they remain highly relevant to household food security. The communities where the interviews were conducted (Água Azul, Boa Esperança, Santa Maria, and Urucury) are located approximately 30 km from the municipal center of Manicoré. Nevertheless, because transportation is carried out exclusively by river, covering this distance takes approximately two hours. Both the distance and travel time can be considered relatively short in the Amazonian context.

Unlike Group 1, only one of the 19 households comprising Group 2 is not originally from the Amazon region, suggesting that the expansion of agricultural and livestock activities into the Amazon through migration from southern Brazil has not been particularly significant in this area. In terms of landholding size, the vast majority of households in this group have less than 10 hectares of total land, generally located near rivers and streams. Overall, the marketing of agricultural products, particularly açaí, takes place through intermediaries, with no associations or cooperatives operating at this or any other stage of the production chain. According to our field research, one intermediary accounts for a substantial share of purchases from these communities on a weekly basis. Furthermore, during the harvest season, passenger boats traveling to Humaitá via the Madeira River also purchase agricultural products, thereby serving as an occasional marketing channel.

The empirical evidence from these two cases reflects the heterogeneity of the Amazon region in terms of food marketing. In both cases, these markets can be classified as conventional markets according to Schneider (2016), representing the most vulnerable market category for farmers, as they do not ensure minimum levels of autonomy or reciprocity, particularly in light of the debate developed by Ploeg (2008; 2009). This situation creates a form of monopsony and allows prices to be set below prevailing market levels. On the other hand, the absence of these intermediaries would prevent products from reaching markets and could even threaten the existence of certain production chains, given that many households are unable to market their products independently.

At this point, it is important to recognize that conventional markets do not constitute a homogeneous category. The two cases examined here support this interpretation. While Group 2's markets are characterized by intermediaries operating in the traditional sense, Group 1 benefits from a governance arrangement that has established a production chain and provides support to farming households, ensuring a degree of formality in marketing arrangements that is highly valued by these families. Nevertheless, in both situations, local conditions impose substantial challenges to food marketing, to the extent that households depend almost exclusively on intermediaries.

Regarding market digitalization, neither group presented any evidence of farmers directly engaging in digital marketing activities, including the use of instant messaging applications, a practice that has been increasingly documented in the literature since the COVID-19 pandemic (Niederle et al., 2021). In Group 1, however, the previously mentioned consortium, which is responsible for supporting farmers and purchasing their coffee, processes and subsequently markets the product, including through online channels. In this case, digital tools are indeed being incorporated into food markets, but not directly by farmers. This finding supports the argument that individual farmers face considerable difficulties in establishing and operating digital markets independently.

When digitalization emerges from collective initiatives, such as associations, cooperatives, or producer groups, greater autonomy, participation, and decision-making power are expected for small-scale farmers regarding market organization, price determination, and payment conditions. This is because the fundamental purpose of an association, for example, is to provide services to its members, as discussed by Tonin, Niederle and Schneider (2024). In the case examined here, however, digital sales are conducted exclusively by the company that purchases coffee from farmers, without the direct participation of rural households, which simply supply their products through physical market transactions. In other words, the company does not provide a marketing service on behalf of farmers but rather purchases their products directly.

It should be emphasized that this arrangement is not inherently disadvantageous. By using e-commerce, even for a relatively small share of the coffee marketed, the company diversifies its sales channels and expands its consumer base. It also introduces innovations by promoting the development of a production chain aligned with the principles of sustainability, agroforestry, and carbon emissions offsetting, which are of interest to both farmers and the production chain as a whole.

However, because farmers do not participate in the stages following the sale of their products, digitalization cannot be considered to have occurred at the farmer level.

The challenges faced by these groups reflect the contexts in which they operate and the particularities of the Amazonian environment, necessarily involving both access to communication networks and logistics infrastructure. Regarding the former, Table 1 illustrates the heterogeneity of rural Brazil, particularly the disadvantages experienced by the country's Northern Region and, more specifically, the state of Amazonas. The data are drawn from the most recent Agricultural Census (IBGE, 2019). Notably, 88.8% of agricultural establishments in Amazonas had no internet access, while 68.6% did not even have a telephone at home.

Table 1 – Availability of Telephone and Internet Access on Agricultural Establishments in Brazil, the Northern Region, and the State of Amazonas.

Telephone Availability and Internet Access	Brazil		Northern Region		Amazonas	
	No.	%	No.	%	No.	%
Total	5,073,324	–	580,613	–	80,959	–
Telephone available – Yes	3,194,862	63.0%	259,558	44.7%	25,457	31.4%
Telephone available – No	1,878,179	37.0%	321,014	55.3%	55,502	68.6%
Internet access – Yes	1,430,156	28.2%	91,080	15.7%	9,035	11.2%
Internet access – No	3,643,168	71.8%	489,533	84.3%	71,924	88.8%

Source: Prepared by the authors based on IBGE (2019).

The data become even more concerning when the overall averages are disaggregated to allow for a more detailed analysis at the municipal level. Table 2 shows that fewer than 3% of agricultural establishments in Manicoré and Apuí have access to telephone services and the internet. This situation is also influenced by the limited availability of telephone networks. According to an official publication (AMAZONAS, 2016), one of the telecommunications providers operating in the state has a presence in 100% of its municipalities. However, it is important to note that this information refers solely to the availability of a signal within municipal boundaries, rather than the proportion of the territory covered by the network. In this regard, our field research reveals a situation in which signal availability is almost exclusively restricted to urban areas, with virtually no coverage in rural areas. This discussion is important because, even before addressing the skills required to operate electronic devices and access the internet, it is essential to ensure that such services are available.

Table 2 – Telephone Availability and Internet Access on Agricultural Establishments in the Municipalities of Apuí and Manicoré.

Telephone Availability and Internet Access	Apuí		Manicoré	
	No.	%	No.	%
Total	1,091	–	2,650	–
Telephone available – Yes	379	34.7%	485	18.3%
Telephone available – No	712	65.3%	2,165	81.7%
Internet access – Yes	30	2.7%	64	2.4%

Internet access – No	1,061	97.3%	2,586	97.6%

Source: Prepared by the authors based on IBGE (2019).

Although the data are somewhat outdated due to the time elapsed since the survey and the rapid technological advances experienced by society, in the absence of more recent official data, the latest Agricultural Census and official reports serve as references for this analysis and demonstrate the regional disparities that characterize Brazil in terms of technological access. It is expected that the forthcoming Agricultural Census, which is about to be conducted, will provide data that contrast with this situation and reveal a reduction in inequalities in access to these resources.

In addition to the growing use of telephones, internet access is expected to have increased substantially compared with the previous Agricultural Census. This is because satellite-based connectivity has made it possible to access the internet without the need for cables (as in fixed broadband connections) or towers (as in radio-based internet services and mobile networks). On the one hand, these developments might suggest that the digital divide (Warschauer, 2003) now has a greater chance of being overcome in these regions. On the other hand, even if this challenge were overcome, two other obstacles that are considerably more difficult to address would remain: electricity supply and logistics infrastructure.

Regarding the first aspect, it is important to highlight the substantial number of agricultural establishments that still lacked access to electricity in 2017. While the Brazilian average was 16.4% of rural properties without access, the figure reached 45.2% in the state of Amazonas, considerably higher even than the average for the Northern Region, which stood at 27.4% (IBGE, 2019). Unlike internet access and telephone use, electricity supply requires a much more complex form of territorial infrastructure, as discussed by Favareto, Tolocka and Fonseca (2024).

Logistical challenges, in turn, are no less complex. According to the most recent CNT Transport Yearbook (CNT, 2022), the road network in the state of Amazonas extends over 14,449 km across a territory of 1,558,706 km². This means that Amazonas ranks by far first among Brazilian states in terms of territorial area per kilometer of road network, with 107.88 km² of territory for every kilometer of road. Pará ranks second, with 29.05 km²/km. These disparities become even more pronounced when compared with the averages for other Brazilian regions: South (1.49 km²/km), Southeast (1.73 km²/km), Northeast (3.48 km²/km), and Central-West (7.82 km²/km).

Regarding the waterway network, the State Secretariat for the Environment (AMAZONAS, 2024, p. 16) reports that the state's waterway system had an estimated average of 19,000 kilometers of economically navigable waterways, based on navigation data collected between 2016 and 2018. With respect to the use of this network, the two groups examined in this study present contrasting situations. While Group 1 has limited access to waterways due to local geographical conditions (Figure 2), Group 2 depends almost exclusively on river transportation for moving goods and people, particularly southward toward Humaitá and Porto Velho and northward toward Manaus.

In this context, it is important to consider that even established waterways experience substantial fluctuations in their transportation capacity due to the natural

seasonal water-level variations characteristic of the Amazon biome. This is the case of the Madeira River, which plays a major role in transporting grain from Brazil's Central-West Region to the port of Itacoatiara, Amazonas. Under normal conditions, the Madeira River's water level fluctuates by approximately 10 meters throughout the year, reaching around 5 meters during the low-water season and approximately 15 meters during the high-water season. However, as has been occurring across Brazil, extreme weather events have profoundly altered this dynamic. In 2024, the Madeira River reached a record low water level of 0.25 meters in Porto Velho, affecting not only transportation logistics but also the availability of drinking water for riverine communities (Zogahib et al., 2024). In contrast, its water level reached 16.77 meters in 2025, while the historical maximum of 19.74 meters was recorded during the 2014 flood season (SACE, 2025). These figures demonstrate that the potential of waterways in the Amazonian context is as significant as the challenges associated with their use.

The Limits of Digitalization and Strategies for Overcoming Them

Discussing food marketing in the Amazon region raises important and necessary questions, particularly when the focus is on the digitalization of production chains. This region is characterized by a substantial digital divide, a concept that refers to inequalities in access to Information and Communication Technologies (ICTs) associated with factors such as income, race, ethnicity, gender, age, and geographical location (Warschauer, 2003). Recent studies examining the relationships between production chain digitalization and sustainability suggest that, although there are concerns about the homogenization of landscapes resulting from increased productive efficiency in digital economies (MacPherson et al., 2025), digital tools have considerable potential to contribute to the development of sustainable food systems and improve access to various services and resources, including technical assistance, healthcare, and education (Massruhá et al., 2020; Rolandi et al., 2021; Wepner et al., 2025; Meng; Li, 2025).

However, overcoming this digital divide requires addressing the four major challenges identified earlier: physical infrastructure, digital inclusion, governance, and sustainability (Niederle et al., 2021; Bahn; Yehya; Zurayk, 2021; Gazolla; Tonin; Cunha, 2024; Wepner et al., 2025). This is essential to ensure that digitalization, as an inevitable process, unfolds in a balanced, fair, and equitable manner. The empirical evidence presented in this study demonstrates that these challenges are not equally significant in the Amazon. Physical infrastructure emerges as the main limiting factor, particularly the logistical dimension, which prevents, increases the costs of, or imposes substantial constraints on the transportation of goods of all kinds, as well as people.

Under these circumstances, the findings of this study indicate that logistical challenges may be as important as, or even more decisive than, connectivity-related barriers. Technological advances can, to some extent, expand internet access in remote regions, as already demonstrated by the rapid expansion of satellite internet services (Abreu et al., 2025). Nevertheless, market digitalization is not feasible without the physical movement of goods and people, which is consistent with the understanding of circulation and infrastructure as dimensions of territorial

development (Silveira, 2020; Monié, 2011). In other words, digital exclusion is compounded by logistical exclusion, creating a dual obstacle to the digitalization of food markets and giving rise to what may be termed a logistical-digital divide. It is important to emphasize that this problem affects family farmers, riverine communities, and traditional peoples and communities living in the Amazon on a daily basis. These populations need to travel not only to market their products and secure their livelihoods but also to access essential services and resources, such as schools, hospitals, supermarkets, and recreational facilities.

Although this discussion may initially appear outdated, it remains highly relevant to the Amazonian context and represents a gap in Brazilian research on food markets and family farming, where basic transportation infrastructure is often overlooked as an object of investigation. This situation resembles the conditions experienced in many countries and regions considered to be developing, such as the Middle East and North Africa (Bahn; Yehya; Zurayk, 2021), where the authors identify inadequate logistics infrastructure (limited regional integration and insufficient transportation and storage capacity) and the fragmentation of markets and value chains (dispersed, informal markets lacking vertical integration). In this regard, regional specificities must become central to the development of responses to existing challenges, recognizing that strategies adopted in southern and southeastern Brazil cannot simply be transferred to the Northern Region, which faces fundamentally different environmental, social, and economic conditions. Failure to address this problem means perpetuating a vicious cycle of exclusion and encouraging exclusionary rural development processes.

It would be unreasonable to assume that the logistical challenges facing this part of the Amazon could be resolved simply by constructing highways in a region containing the largest expanse of preserved native forest. This means that addressing the logistical-digital divide discussed here cannot be separated from environmental concerns. This situation creates the following paradox: on the one hand, the expansion of road networks has historically been associated with deforestation, illegal land appropriation, and unregulated occupation, not only in the Legal Amazon; on the other hand, the precarious condition of the limited existing road infrastructure creates serious obstacles precisely for production systems more closely aligned with environmental conservation, such as coffee and açaí agroforestry systems, which depend on regular product transportation and minimally functional marketing channels.

Thus, the lack of adequate logistics infrastructure also reinforces extensive production models with greater environmental impacts, which drive large-scale illegal deforestation. Controlling such deforestation is the responsibility of the State and should be achieved directly through monitoring, enforcement, and sanctions, rather than indirectly through inaccessibility. Accordingly, overcoming the logistical divide can also contribute to the development of sustainable food systems by enabling the establishment of production chains based on sociobiodiversity products and encouraging more sustainable food production and marketing arrangements. Overcoming this challenge does not mean reproducing a road-centered development model, but rather developing alternatives compatible with forest conservation, such as strengthening river transportation, developing multimodal logistics systems, and making use of territorial potential, in accordance with territorial development

approaches that recognize and value regional specificities and potential (Favareto, 2010; Deponti et al., 2024).

Furthermore, targeted, low-impact improvements to critical and strategically important road sections are essential for regional and national logistics, ensuring adequate road accessibility and mobility for Amazonian communities. Such strategies are central to strengthening the autonomy of rural households and encouraging the diversification and digitalization of food markets. Otherwise, existing power asymmetries and farmers' dependence on external actors may intensify, as illustrated by the role of informal intermediaries, who currently constitute the main marketing channels and ensure that agricultural products reach markets. The findings of this study suggest that formalized market arrangements can promote fairer and more equitable market dynamics. This is the case, for example, of agroforestry coffee producers in Apuí, whose production chain operates through formalized arrangements. In this regard, the State has an important role in ensuring technical assistance and rural extension services to support the development and consolidation of food markets.

Despite the difficulties inherent to the Amazonian context, market digitalization can represent an alternative for production chains, provided that they are sufficiently organized and operated collectively. This observation highlights the importance of collective organizations in rural areas. Their fundamental purpose of providing services to their members rather than pursuing profit, a concept that does not apply in the same way to the cooperative economy, allows these organizations to operate in ways that can benefit family farmers and local communities by facilitating the establishment of both digital and physical marketing channels. However, Brazil's Northern Region has the lowest proportion of farming households belonging to associations or cooperatives, at 25% of the total (IBGE, 2019), indicating that strengthening social organization is also an important strategy for improving digital food markets.

In summary, strategies for the digitalization of food markets in inland areas of northern Brazil, particularly in Amazonas, must involve not only expanding access to digital tools and developing the skills necessary to use them, but also, and perhaps most importantly, ensuring adequate physical logistics infrastructure for the effective functioning of food markets. Such improvements would also have positive implications for the quality of life of local populations and their mobility. These transformations must necessarily take local characteristics into account, including seasonal water regimes characterized by floods and low-water periods, the coexistence of different transportation modes, particularly roads and waterways, the importance of preserving and valuing local ecosystems, and the need to ensure broad access to essential services and resources, especially for rural populations, including healthcare, education, recreation, and transportation.

Conclusions

The findings of this study demonstrate that, in the Western Amazon, the limitations of agrifood market digitalization stem not only from inequalities in access to information and communication technologies but also from a set of structural barriers that constitute a genuine logistical-digital divide. The comparison between

Apuí and Manicoré shows that, even in different contexts, the physical movement of goods, people, and information remains the main factor shaping food marketing. Thus, overcoming digital exclusion necessarily depends on measures aimed at improving territorial infrastructure, particularly road accessibility, available transportation modes, and the integration of road and waterway networks.

Digitalization, when accompanied by adequate logistics infrastructure, can contribute to the development of production chains based on sociobiodiversity, the valorization of agroforestry systems, and the establishment of sustainable food systems. However, without addressing inadequate logistics infrastructure, any progress in digitalization will remain limited, perpetuating the cycle of socioeconomic marginalization that characterizes the region. Accordingly, this study contributes to repositioning logistics as a central analytical category in the debate on food markets in the Amazon and identifies potential pathways for more integrated, territorially grounded, and sustainable public policies.

Regarding the limitations of this study, it is important to emphasize that the two cases examined are located in the southern part of the state of Amazonas. This geographical concentration does not undermine the study's findings, as the cases were analyzed to provide empirical grounding for the discussion developed throughout the article. Nevertheless, empirical investigations in other parts of the state, such as its western half, where logistical challenges are even greater, could provide further insights into the challenges of production chain digitalization and the marketing of food and other products in the Amazon region, particularly in the state of Amazonas.

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