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Small Agroindustry, Digital Markets and Regional Agrifood Systems: the red rice production chain in the Sertão do Apodi territory, state of the Rio Grande do Norte, Brazil[1]

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Abstract
The objective is to analyze the production chain of rice farming in the Sertão do Apodi region, in Rio Grande do Norte, with a focus on red rice cultivation. The study seeks to understand how this activity contributes to the structuring of a regional agri-food system, integrating family farming, small-scale agro-industries, and the development of digital markets. The research also examines the interface between productive inclusion, cooperatives, and public policies. As a methodology, the small-scale red rice agro-industry was defined as the unit of analysis, evaluated through digital markets, particularly those operated by the Regional Information System for Family Farming (SIRAF). Regarding data collection, a survey was conducted with 364 family farmers across 6 red rice processing units, or small-scale agro-industries, located in the municipalities of Apodi and Felipe Guerra, both in the Sertão do Apodi region. It is acknowledged that public policies for rural areas have stimulated initiatives for small-scale agro-industries and market development, introducing the concept of innovation production within family farming. As a result, the

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structuring of a regional agri-food system based on red rice cultivation was identified, with prospects for expanding innovation production and building digital food markets.

Keywords: Family farming. Production chain. Cooperatives. Markets.

Agroindústria de Pequeno Porte, Mercados Digitais e Sistemas Agroalimentares Regionais: a cadeia produtiva do arroz vermelho no território Sertão do Apodi, Rio Grande do Norte

Resumo
O objetivo é analisar a cadeia produtiva da rizicultura no território Sertão do Apodi, no Rio Grande do Norte, com foco na cultura do arroz vermelho, busca-se compreender como esta atividade contribui para a estruturação de um sistema agroalimentar regional, integrando agricultura familiar, agroindústria de pequeno porte e a construção de mercados digitais. O estudo também examina a interface entre inclusão produtiva, cooperativas e políticas públicas. Como metodologia, foi definida como unidade de análise a agroindústria de pequeno porte do arroz vermelho, sendo esta avaliada a partir dos mercados digitais, em especial o operacionalizado pelo Sistema de Informação Regional da Agricultura Familiar (SIRAF). Quanto à coleta dos dados, foi feita uma pesquisa com 364 agricultores familiares em 6 unidades de beneficiamento de arroz vermelho, ou agroindústria de pequeno porte, localizadas nos municípios de Apodi e Felipe Guerra, ambas no território Sertão do Apodi. Reconhece-se que políticas públicas para o meio rural têm estimulado iniciativas de agroindústria de pequeno porte e construção de mercados, trazendo a ideia de produção de novidades na agricultura familiar. Como resultado, foi identificada a estruturação de um sistema agroalimentar regional, a partir da cultura do arroz vermelho, com possibilidades de ampliação da produção de novidades e da construção de mercados alimentares digitais.
Palavras-chave. Agricultura familiar. Cadeia produtiva. Cooperativas. Mercados.

Pequeñas Agroindustrias, Mercados Digitales y Sistemas Agroalimentarios Regionales: la cadena productiva del arroz rojo en el territorio del Sertão do Apodi, estado del Rio Grande do Norte, Brasil

Resumen
El objetivo es analizar la cadena productiva de la Rizicultura en el territorio del Sertão do Apodi, en Rio Grande do Norte, considerando el arroz rojo en la estructuración del sistema agroalimentario regional, integrando la agricultura familiar con la agroindustria de pequeña escala y la construcción de mercados digitales de alimentos. en una interfaz entre inclusión productiva, cooperativas y políticas públicas. Como metodología, se definió como unidad de análisis la agroindustria artesanal del arroz rojo, analizada con base en los mercados digitales, especialmente el operado por el Sistema Regional de Información de la Agricultura Familiar (SIRAF). En cuanto a la recolección de datos, se realizó una encuesta con 364 agricultores familiares en 6 unidades procesadoras de arroz rojo, o pequeñas agroempresas, ubicadas en los municipios de Apodi y Felipe Guerra, en el territorio del Sertão do Apodi. Se reconoce que las políticas públicas para las zonas rurales han estimulados iniciativas de agroindustria de pequeña escala y la construcción de mercados, trayendo la idea de producir nuevos productos en la agricultura familiar. Como resultado, se identificó la estructuración de un sistema agroalimentario regional basado en el cultivo de arroz rojo, con posibilidades de ampliar la producción de nuevos productos y la construcción de mercados digitales de alimentos.

Palabras clave: Agricultura familiar. Cadena productiva. Cooperativas. Mercados

1 Introdution

One of the greatest challenges faced by planners, and especially by those responsible for implementing public policies in the context of Brazilian territorial development, is directing actions and resources towards structuring and operationalizing thematic chambers. Among these chambers, the one addressing productive inclusion is particularly noteworthy as it deals with building economic production infrastructure and structuring more diversified and sustainable agri-food systems, which are strategically essential for boosting territories through production chains. Instead of adopting a more assertive strategy combining diversification and propulsion actions through production chains, those responsible for executing territorial policies have historically chosen to replicate strategies akin to contract offerings based on quota systems.

In this approach, quotas of access or resource amounts are offered, along with defined conditions for family farmers to express interest and qualify to receive their share of the contract. This approach perpetuates a vicious cycle that significantly reduces the potential and effort required to stimulate economic dynamism and diversify productive bases to create economic density and a robust social fabric within territories. Consequently, the potential for inclusion through integrating family farming with small-scale agro-industries, often coordinated by cooperatives, could foster processes that strengthen local markets and activate regional economies through well-structured production chains. (ALVES DA SILVA; NUNES, 2023).

In the state of Rio Grande do Norte, the operations of the National Policy for Territorial Development, especially those supported by the Infrastructure and Services Projects in Rural Territories (PROINF), aim to integrate family farming with small-scale agro-industries and build markets through cooperative coordination. However, in the Territorial Collegiate, agreements are typically made between the funding agency (Caixa Econômica Federal) and the proposing entity (municipal, state, or federal bodies). Often, these governmental agencies make decisions on operations without considering production chains, relying instead on conditions resembling "counter contracts" (NUNES *et al.*, 2015).

One production chain that has received specific attention from territorial policy in Rio Grande do Norte is red rice farming, cultivated by family farmers in rural communities within the municipalities of Apodi and Felipe Guerra, in the Sertão do Apodi territory. The specificity of this production chain justified its selection for this study, as red rice was introduced into school feeding programs in Rio Grande do Norte. However, being considered an invasive plant in regions of significant commercial production, red rice was not listed by CONAB as a food product for human consumption, complicating its commercialization in institutional markets.

Red rice is an essential item in the food basket of Northeastern Brazil, particularly in regions of Rio Grande do Norte and Paraíba. Nonetheless, the red rice farming chain faces five major challenges for family farmers and their collective organizations to achieve growing returns: 1) high production costs due to expensive electricity, heavily used in irrigation; 2) insufficient credit to purchase modern machinery and equipment for planting, harvesting, and processing red rice; 3) low

qualification of agents in the red rice production chain; 4) limited availability of technical assistance and research on agroecology; and 5) deficient infrastructure from planting to commercialization.

In light of these issues and recognizing the importance of the topic, the following question arises: how does the red rice farming chain enable productive forces and constitute a regional agri-food system within the dynamics of rural development in the Sertão do Apodi territory, integrating family farming with small-scale agro-industries, building digital food markets, and balancing productive inclusion initiatives, cooperative action, and public policies?

This study assumes that the red rice farming production chain holds promise for driving economic dynamism in the Sertão do Apodi territory, Rio Grande do Norte, given that red rice has become a culinary delicacy and an important food product. Furthermore, this chain has been structured as a regional agri-food system, incorporating innovations and accessing institutional markets through the digital platform of the Regional Information System for Family Farming (SIRAF/Northeast). Institutional target markets include the Food Acquisition Program (PAA), the National School Feeding Program (PNAE), and the recent State Program for Family Farming and Solidarity Economy Governmental Purchases (PECAFES). However, despite its potential, the red rice farming chain still shows weaknesses in terms of collective organization, credit access, small-scale agro-industry infrastructure, market integration, and waste management.

Thus, this article aims to analyze the importance of the red rice farming production chain in the Sertão do Apodi territory, Rio Grande do Norte, focusing on red rice cultivation as a basis for structuring regional agri-food systems. This involves integrating family farming with small-scale agro-industries and constructing digital food markets, coordinated by cooperatives. The study highlights the perspective of innovation and value-adding production for diversifying regional economies and local markets, creating opportunities, preserving regional diversity, and fostering development in the Sertão do Apodi territory.

This article is structured into sections. Section 2 presents the theoretical framework guiding the study, emphasizing small-scale agro-industries, production chains, and the construction of digital food markets within regional agri-food systems. Section 3 describes the methodology. Section 4 discusses the results, analyzing the red rice farming chain in the Sertão do Apodi territory. Finally, Section 5 provides conclusions.

2 Theoretical Framework

2.1 Small-Scale Agro-Industries and Production Chains

Two perspectives are employed to better interpret and explain the dynamics of small-scale agro-industries and production chains, or value chains, in processes that foster regional rural economies: 1) the strategy of their integration with family farming and market construction, coordinated by cooperatives; and 2) the perspective of innovation (innovation production) and adjustments with the emergence of novelties (novelty production).

Regarding small-scale agro-industries, contributions from authors such as Wilkinson (1986), Mior (2005), Gazolla, Niederle, and Waquil (2012), Santos Junior and Waquil (2012), Ploeg (2013, 2018), and Nunes, Lima, and Freitas (2023) emphasize rural agro-industrial initiatives as promising strategies for the emergence of rural development dynamics. These initiatives establish key endogenous production structures that are capable of leveraging and adding value to local products, strengthening markets, and creating more opportunities in rural areas. This contributes to generating regional economies with greater economic density and a stronger social fabric. This more diverse and dynamic scenario is triggered by a virtuous cycle characterized by the greater diversification of regional economies, facilitated by small-scale agro-industries operating intensively in production chains. They help to raise income levels by adding value and including more individuals in better-paying activities, particularly when they internalize processes of rural industry integrated with family farming, which are coordinated by cooperatives for market construction.

According to the authors, actions involving the integration of family farming with small-scale agro-industries are often linked to two factors: 1) as a response to the needs of a family or group producing collectively and building infrastructure that constitutes what Ploeg (2018) defines as a resource base for a productive unit, region, or territory; and 2) due to the pursuit of an intense and continuous process of learning and reconversion, creating the need for governance structures, management models, and a favorable environment to internalize innovation and novelties. From the perspective of rural development, as noted by Silva and Nunes (2021), small-scale agro-industries integrated with family farming, coordinated by cooperatives to build markets, demonstrate potential to prepare family farmers to be increasingly strategic and assertive in constructing socioeconomic reproduction strategies as alternatives to the modern standards set by large agricultural corporations and industries.

According to Mior (2005), family agro-industries gained prominence with the restructuring of agri-food markets, as demand for healthier foods with certification of origin from family farming increased. Similarly, as highlighted by Gazolla, Niederle, Waquil (2012), Santos Junior and Waquil (2012), Almeida, Nunes, and Silva (2017), organic and agroecological foods, for instance, became associated with concepts of tradition, nature, craftsmanship, and locality, which provided certain advantages for family farmers who are now rewarded by consumer markets. This also represents a valorization of small-scale agro-industries, as they provide family farmers with the opportunity to build and access increasingly specific markets. Rural family agro-industries can be understood as organizational forms where rural families produce, process, and/or transform part of their agricultural and/or livestock production, primarily aiming to add value to their products. These experiences also promote more autonomous processes for farmers in terms of production and market engagement, demonstrating mastery over enterprise management (MIOR, 2005).

As a strategic action for farmers' economic production and social reproduction, small-scale agro-industries stand out for their differentiated character. In this activity, market access and construction occur differently from traditional commodity production and commercialization methods. This distinction

arises as family farmers, either individually or collectively, engage in producing their own raw materials for processing and marketing their final products or articles (WESZ JUNIOR; NIEDERLE, 2007).

According to Nunes et al. (2015) and Nunes, Lima, and Freitas (2023), small-scale agro-industries function as intermediary links within a value chain, generating connections and, by adding value, preventing a portion of the wealth generated from being drained away. This process increases local income levels and fosters a denser economy. This economic density arises from the diversification generated within production chain performance, which retains the wealth created and enables regional inclusion, and consequently, income distribution. Small-scale agro-industries play a crucial role in supporting family farming through rural small-scale industrialization.

For Nunes, Lima, and Freitas (2023), the Brazilian agricultural model has, over the decades, established a crushing pricing system that marginalizes family farmers, depriving them of access to marketing chains, whether short chains (local, domestic markets) or long chains (global export markets). This historical deficiency in commercialization processes has left family farmers vulnerable to price risks, often forcing them to succumb to intermediaries, who restrict and destroy any potential for collective organization (e.g., cooperatives) to add value through small-scale agro-industries and to establish and access markets. In this context, small-scale agro-industries, as part of a strategy integrating family farming and cooperative coordination, present an opportunity for family farmers to better prepare for and overcome barriers imposed by the restrictive and overwhelming agricultural model. Notably, the family agro-industry segment has grown in recent years. Estimates from the Ministry of Agrarian Development (MDA) indicated approximately 37,000 agro-industries in Brazil in 2010, with 16.7% of rural establishments reportedly processing and/or industrializing some type of raw material (GAZOLLA, 2012).

Regarding production chains, there is a strong case to be made that they are the foundation of economic dynamism and density, where the social fabric is robustly constructed by family farmers. Central to this argument are contributions from authors such as Batalha (1997); Ploeg and Wiskerke (2004); Oostindie and Broekhuizen (2008); Oliveira, Gazolla, and Schneider (2011); Zylbersztajn, Neves, and Caleman (2015); and Nunes, França, Lima, and Medeiros (2018), who discuss innovation production and novelty production. Drawing on these authors, novelty production operates in opposition to traditional innovation production models in two keyways: the manner in which novelties are produced and the results they yield.

While innovations are characterized as standardized, global, and exogenous—exclusively produced by institutions within the dominant technological paradigm—novelties represent radical changes that typically emerge from the periphery of hegemonic standards. Novelties are diverse, localized, and endogenous, as discussed by Oostindie and Broekhuizen (2008). They are closely associated with socio-technical adjustments, adaptations, or refinements, as noted by Wilkinson (2019), Azevedo and Nunes (2013), and Nunes, Silva, and Sá (2020a). Novelties encompass new products, processes, technologies, and markets aimed, among other purposes, at achieving greater autonomy and sustainability in activities developed endogenously within production chains. These initiatives, as

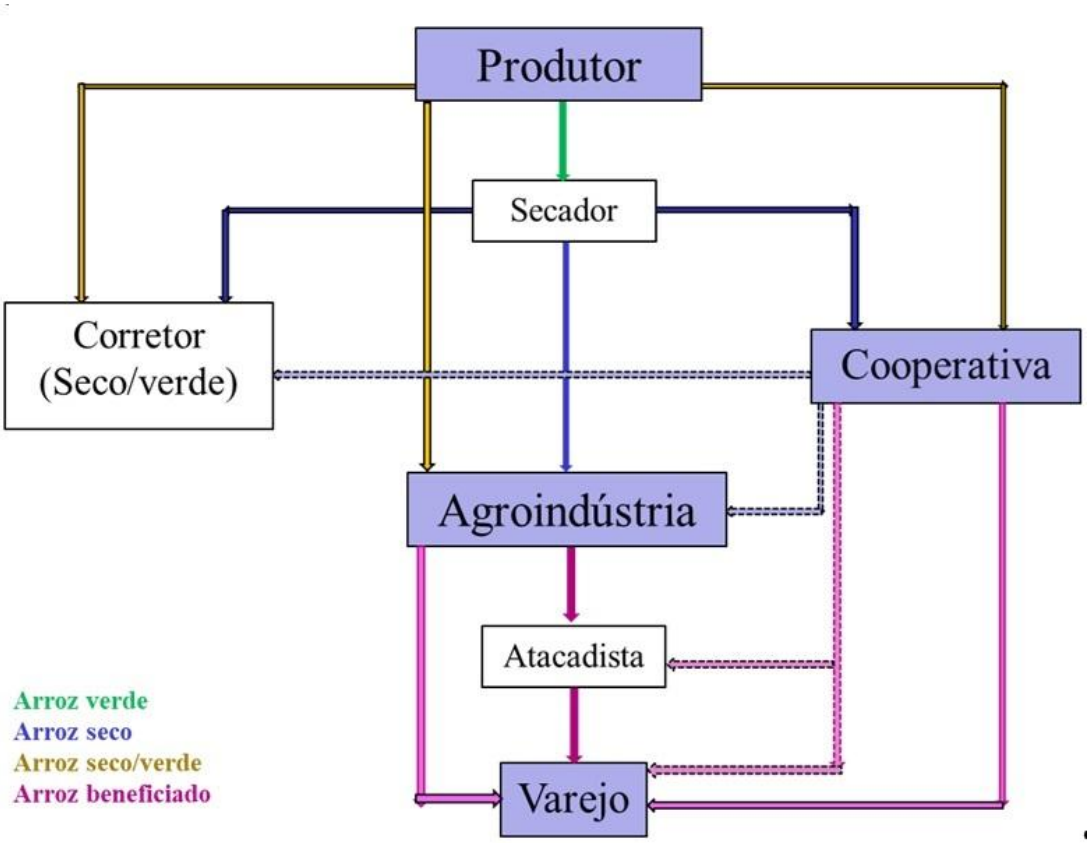
Preiss and Schneider (2020) highlight, stem from the need for family farmers to structure local agri-food systems that are more diversified and sustainable while establishing short chains as alternatives to long commodity chains. This approach also addresses the "squeeze"[2] effect, which has reduced farmers' incomes and quality of life.

Batalha (1997) defines a production chain as a sequence of dissociable transformations that can be separated yet are interconnected through linkages, complemented by commercial and financial relationships that establish an upstream and downstream exchange flow between suppliers and customers. Many studies on the global food system have addressed structural changes within it. According to Farina and Zylbersztajn (1992), a production chain is a "sequence of stages through which raw materials (inputs) pass," involving a series of intermediary actions (processes) aimed at production to meet market demands (outputs).

These processes are separate but integrated into modules, combining operations to achieve increasingly better results. However, the structure of a production chain is continuously influenced by management models, technology, and the surrounding environment. As noted by Zylbersztajn and Giordano (2015), Gurgel and Nunes (2019), and Nunes, Azevedo, and Queiroz (2023), production chain segments are critical for providing a systemic view of the modules, facilitating interpretation to identify market structures, competitiveness, and other factors. In the case of the red rice farming production chain in the Sertão do Apodi territory, its structuring demands integration through efficient management and cooperative actions, as illustrated in the flowchart in Figure 1.

Figure 1: Apodi Sertão Territory – Red Rice Production Chain Flowchart

[2] The term "squeeze" refers to the "pressure" created by agricultural modernization, in which farmers are squeezed between, on the one hand, rising costs of inputs and external technologies to their farms and, on the other hand, declining prices of agricultural commodities, leading to a consistent drop in the profitability of productive activities, as described by Ploeg (2008).



Source: Prepared by the authors.

In Brazil, the states of Rio Grande do Norte and Paraíba are the main producers of red rice. For decades, this product has been cultivated in the Apodi-Mossoró River Valley, especially in the municipalities of Apodi and Felipe Guerra. According to Nunes; Gomes Silva (2022); Gurgel; Nunes; Silva (2022), the cultivation of red rice, or "arroz da terra" as it is regionally known, has become one of the main crops, constituting an important value chain and regional agro-food system. One characteristic of this crop is that monitoring of pests and diseases carried out in large-scale commercial production areas of white rice revealed losses due to infestations of weeds, with red rice being the main one. As an invasive plant, red rice competed for water and nutrients, resulting in lower productivity in commercial production areas.

However, based on the perspectives of innovation production and novelty production, family farmers in the municipalities of Apodi and Felipe Guerra implemented endogenous processes, making socio-technical adjustments to adapt the technical standard that previously eliminated red rice, transforming it into a primary crop and increasing its production and productivity levels. According to Nunes, França, Lima, Medeiros (2018), by internalizing novelties within the rice farming value chain, family farmers in the Apodi-Mossoró Valley initiated internal processes that countered the traditional innovation production model of large-scale commercial rice. In the way they began producing and the results achieved, family farmers have built one of the main value chains by structuring a regional agro-food system. Today, red rice is one of the most important activities developed in this territory.

Most red rice cultivation areas use the flood irrigation method, with planting taking place in the floodplains of the Apodi-Mossoró River on small rural properties, relying predominantly on family labor. The first red rice seeds were introduced in the state of Maranhão in the 17th century, brought by early settlers from the Azores Archipelago. Red rice quickly spread to states in northern Brazil, where it became known as red rice, "arroz da terra," or Venice rice. In the 18th century, due to a directive from the Portuguese Crown, which was interested only in the trade of white rice, red rice — despite being highly favored by the native population of Maranhão — was banned from cultivation. Since then, red rice migrated to the semi-arid regions of Northeast Brazil, where it is still produced today. In all production areas, red rice is tied to the dietary habits of local populations.

2.2 Agro-Food Systems and Digital Food Markets

Regarding agro-food systems, the sustainable appeal of food regimes is highlighted, with contributions from McMichael (2013), Maluf & Reis (2013), Friedmann (2016), Gazolla & Schneider (2017), and Niederle & Wesz-Junior (2018). Their structuring occurs in a diversified and localized manner, as an alternative to the global[3], standard, and predominant food regime. According to Gazolla & Schneider (2017) and Nunes; Freitas (2020b), alternative agro-food systems represent what is understood about the role of short chains or short marketing circuits as a way of constructing and organizing markets within the scope of family farming.

In this sense, the cultivation of red rice is developed in the Sertão do Apodi territory by family farmers, where a diversified and sustainable regional agro-food system has been structured in a dynamic rural development process rooted in family farming. The production chain encompasses red rice production stages, integrating family farming with small-scale agroindustry and coordinating cooperative and association efforts toward market construction. Regarding markets, red rice finds demand in a niche for regional products, becoming a culinary delicacy, a special food for families, and a sought-after dish in the most sophisticated restaurants in capital cities and larger cities in the interior of the Northeast region. The most famous dish is "arroz de leite" (milk rice).

Due to its status as a family farming agro-food system, the red rice-based rice farming chain has an artisanal character. Processing via small-scale agroindustry is conducted using machines called "dehullers," most of which are made of wood. According to IBGE data, in 2016, the municipality of Apodi produced 3,000 tons of red rice, while Felipe Guerra produced 221 tons. Since 2003, territorial policies have been implemented to build markets and address food security, such as the Food Acquisition Program (PAA) and the National School Feeding Program (PNAE). (GRISA; SCHNEIDER, 2014; Nunes *et al.*, 2015; SILVA, SILVA, NUNES, 2017; NUNES, GOMES SILVA, 2022).

[3] According to McMichael (2013), regarding the predominant regimes, the first food regime, the "colonial" regime, spans the period from 1870 to 1914. The second, the "mercantile-industrial" regime, covers the years from 1947 to 1973. Finally, the third regime, the "corporate" regime, begins its hegemony in the late 1980s, driven by globalization, and continues to the present day.

To meet demand, this production chain structured the regional agro-food system for red rice in the Sertão do Apodi territory and accessed digital food markets, following the dynamics of rural development in family farming. Digital markets, according to Nunes and Freitas (2020b); Gazolla and Aquino (2021); Niederle, Schneider, and Cassol (2021), involve online commercial activities and opportunities for businesses and entrepreneurs. These include selling physical and digital products, advertising, online services, social media work, and content creation. To meet this demand, the Regional Information System for Family Agriculture (SIRAF/Northeast), created in 2020, is a Digital Platform implemented in the context of the Northeast region of Brazil. It has been used to build markets, aiming to open access for family farmers and their organizations to participate in government procurement processes and offer family farming products to other markets.

According to Nunes, Silva, Sá (2020a), the SIRAF Digital Platform is used to build digital markets to facilitate commercial transactions between family farmers and urban consumers. However, its use extends beyond this, including functionalities for strategic actions in agricultural management and mapping by cooperatives, organizing information to aid government decision-making in supporting family farmers and cooperatives. One example is the PECAFES[4] (State Program for Governmental Purchases of Family Farming and Solidarity Economy), a state-level adaptation of the PAA tailored to Rio Grande do Norte.

Through the PECAFES, a collaboration with the University facilitated the development of SIRAF, which was created within the State University of Rio Grande do Norte (UERN) and focused on family farming. This initiative, according to Nunes et al. (2015); Nunes, *et al.* (2024), supported territorial development policies, structuring agro-food systems and market access through the Rural Territories Infrastructure Support Projects (PROINF), aiming to integrate family farming with small-scale agroindustry in the red rice chain of Sertão do Apodi.

3 Methodological Aspects

This article is part of a broader research project studying the value chains of family farming in Northeast Brazil and is related to two specific projects. The first is the project carried out under the National Territorial Development Policy, titled *"Economic Dynamization and Governance Structures: Innovation and Management for the Development of Rural Territories Açu-Mossoró and Sertão do Apodi, Rio Grande do Norte."* The second is the *"Gente do Campo"* project, which represents a proposal for the development of the new Rural Technical Assistance and Extension Service (ATER), aligned with the National ATER Policy (PNATER), focusing on agroecological family farming in Rio Grande do Norte.

[4] Law no. 10,536 of July 3, 2019, established the State Program for Government Purchases from Family Farming and Solidarity Economy (PECAFES) in the state of Rio Grande do Norte. Its purpose is to ensure the procurement of agricultural, extractive, and fishing products, both raw and processed, produced by farmers or their rural socioeconomic organizations, traditional peoples and communities, and beneficiaries of family farming. The program aims to promote sustainable rural development, food and nutritional security and sovereignty, and to enhance job and income generation (see: https://www.legisweb.com.br/legislacao/?id=379252).

The *"Gente do Campo"* project encompasses a set of actions aimed at rural development, including both formal and experiential training processes conducted as part of the daily activities and experiences of the Technical Assistance and Rural Extension Institute of Rio Grande do Norte (EMATER-RN), in partnership with the State University of Rio Grande do Norte (UERN).

The research was conducted in the municipalities producing red rice, namely Apodi and Felipe Guerra, located in the Sertão do Apodi territory. This region consists of 17 municipalities: Apodi, Campo Grande, Itaú, Janduís, Rodolfo Fernandes, Umarizal, Caraúbas, Felipe Guerra, Governador Dix-Sept Rosado, Messias Targino, Olho-d'Água do Borges, Paraú, Patu, Rafael Godeiro, Severiano Melo, Triunfo Potiguar, and Upanema (see Figure 2).

Figure 2: Section of the Citizenship Territory of Sertão do Apodi, Rio Grande do Norte.

Source: Núcleo de Extensão em Desenvolvimento Territorial (NEDET/UERN, 2016)

The research was conducted in two stages: 1) In 2014, with information collected from January 1 to December 31 through the application of semi-structured questionnaires to managers of small agro-industries in the red rice-based Riziculture value chain in the Sertão do Apodi territory, between February and April.; and 2)Using information from the SIRAF platform between 2020 and 2023 to analyze the digitization processes of red rice commercialization from the supply side.

The study involved visits and interviews with three distinct types of actors and enterprises: a) Those processing red rice using "descolpadeiras" (small-scale agro-industries); b) Family farmers producing red rice; and c) Managers of cooperative enterprises (cooperatives and associations). The research universe

consists of enterprises owned and/or directly managed by family farmers producing red rice in the Sertão do Apodi territory, Rio Grande do Norte.

Although the initial intent was to gather data on all family enterprises owned or controlled by red rice family farmers in the municipalities of Apodi and Felipe Guerra, it cannot be assured that this goal was fully achieved. The selection of organizations for the study depended on the knowledge of the research coordinators in the Sertão do Apodi territory. Consequently, in a joint effort with university technicians, the research strategy and trajectory were defined according to predetermined criteria.

It is noteworthy that the research coordinators and students were trained in applying the questionnaires, leveraging the activities related to implementing the National Territorial Development Policy in the Sertão do Apodi territory.

The field data were tabulated, critically analyzed, grouped, and made available for this study. The research encompassed six small-scale agro-industries and 364 family farmers (see Tables 1 and 2) producing red rice in the municipalities of Apodi and Felipe Guerra. The data relate to the characterization of small agro-industries, family farmers, processed products, production, commercialization, management, and environmental aspects.

Table 1: Municipalities, Communities, and Red Rice Processing Units

Municipality	**Association/Community**	**Quantity**
Apodi	APAVA	1
Apodi	Baixa Fechada II	1
Apodi	Paulista	1
Apodi	Bela vista	1
Apodi	Sítio Juazeiro	1
Felipe Guerra	P. A., Lagoa de Saco	1
Total		**6**

Source: Field research, 2014. Prepared by the authors.

Regarding the use of SIRAF, the methodology employed for the commercialization of red rice is based on the belief that knowledge derived from information generated by a secure digital platform will lead to greater affirmation and consolidation of public policies, such as the Territorial Development Policy. Moreover, digital food markets, reaching technical and collective organizational capacities, are gradually being built from a sociotechnical adoption perspective by family farmers and their collective organizations, particularly involving cooperatives. The methodological approach adopted in this article considered the analysis of digitalization processes in the commercialization of family farming from the supply side—specifically in the red rice production chain in the Sertão do Apodi territory—with an analysis of digital food markets built by family farmers through digital platforms.

4 Results And Discussions

4.1 The Rice Production Chain In The Sertão Do Apodi Territory, Rio Grande Do Norte

In the Sertão do Apodi Citizenship Territory, in Rio Grande do Norte, a specific variety of rice has formed a regional agro-food system that integrates family farming with small-scale agro-industries, coordinated by cooperatives responsible for market access and development. According to research data, red rice is cultivated in 16 rural communities (14 in the municipality of Apodi and 2 in the municipality of Felipe Guerra), involving 364 family farmers over a total planted area of 920 hectares, as shown in Table 2.

Table 2: Producing Communities, Number of Producers, and Planted Area of Red Rice

Producing Community	Municipality	Number of Red Rice Producers	Planted Area per Community (ha)
Trapiá 1 e 2	Apodi	50	300
Reforma	Apodi	20	50
Baixa fechada 1 e 2	Apodi	40	80
Santa Rosa	Apodi	10	15
Cipó	Apodi	15	30
Água Fria	Apodi	5	10
Bamburral	Apodi	10	25
Rio Novo	Apodi	30	60
Pindoba 1 e 2	Felipe Guerra	40	80
P A Lagoa do Saco	Felipe Guerra	5	10
Paulista	Apodi	40	100
Carrilho	Apodi	4	10
Santa Cruz	Apodi	10	20
Bela Vista	Apodi	10	20
Boa Vista	Apodi	5	10
São Lourenço	Apodi	20	40
TOTAL		**364**	**920**

Source: Field research, 2020. Prepared by the authors.

Analyzing production from 2009 to 2020—over the last eleven years—Rio Grande do Norte produced an average of 4,873 tons of rice annually, with more than 90% being red rice cultivated in the Apodi-Mossoró River Valley, within the Sertão do Apodi territory, particularly in the municipalities of Apodi and Felipe Guerra. According to the research, the cultivation of red rice has been carried out in an artisanal manner over recent decades. From 2009 to 2020, production exhibited variations in terms of quantity, value, planted and harvested areas, and average yield, as detailed in Table 3.

Table 3: Production Quantity, Value, Planted Area, Harvested Area, and Average Yield of Red Rice in the Sertão do Apodi Territory (2009–2020)

Year	Quantity Produced (tons)	Production Value (R$)	Planted Area (ha)	Harvested Area (ha)	Average Yield (Kg/ha)
2009	10.435	15.280,00	2.606	2.586	4.035

2010	5.156	4.111,00	1.375	1.146	4.499
2011	3.177	3.377,00	1.030	1.003	3.167
2012	1.830	1.729,00	941	722	2.535
2013	3.490	4.532,00	1.397	1.396	2.500
2014	3.910	5.282,00	1.697	1.681	2.326
2015	2.432	4.000,00	933	866	2.808
2016	3.244	4.347,00	808	739	4.390
2017	3.415	4.418,00	851	811	4.211
2018	3.045	4.055,00	859	859	3.545
2019	2.870	5.129,00	780	780	3.262
2020	2.920	4.230,00	780	780	3.635

Source: IBGE, 2021.

In recent years, new techniques for cultivating red rice have been made available, including the introduction of more productive seed varieties and the use of advanced irrigation technologies. These innovations have enabled family farmers to achieve higher productivity, especially considering the significant water resource potential of the Sertão do Apodi territory. According to the research, in the red rice cultivation activity within the Apodi-Mossoró River Valley, the predominant method is flood irrigation. This technique involves maintaining water at a constant level over terraced areas, with seeds distributed either after pre-germination or by direct sowing. The activity occasionally employs chemical inputs, such as urea and herbicides, which renders the production and certification process as organic unfeasible. As shown in Figure 3, red rice plantations in the region are not certified as organic.

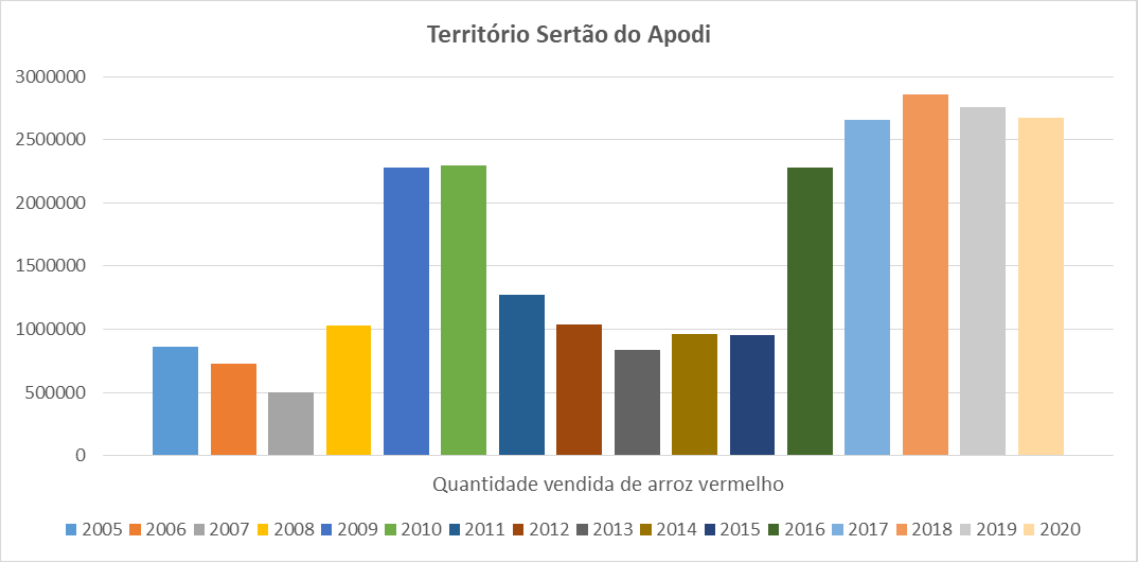
Figure 3: Red Rice Plantation in the Community of Baixa Fechada II, Apodi (RN)

Source: APAVA's collection , 2020.

Focusing solely on the cultivation of red rice in the Sertão do Apodi territory, the research revealed significant fluctuations over the years. Between 2005 and 2009, red rice production was relatively small due to the absence of incentive mechanisms, such as credit, as well as deficiencies in collective organizational structures and the provision of Agricultural Technical Assistance and Rural Extension (ATER) services. According to a leader of the Central Cooperative of Family Farming in the State of Rio Grande do Norte (COOAFARN), a secondary-level cooperative coordinating several primary cooperatives in integrating family farming with small-scale agroindustry for red rice, "the harvests of 2009 and 2010 grew significantly, responding to the demands of previous years under the public procurement programs PAA and PNAE."

However, despite access to institutional markets and encouragement through public purchases, the period from 2011 to 2015 was marked by severe droughts, which severely reduced red rice production in the Vale do Rio Apodi-Mossoró. Following five years of intense drought, red rice production in the Sertão do Apodi territory recovered to levels even higher than those of 2009 and 2010, showing a trend of high production between 2016 and 2020, as illustrated in Figure 4.

Figure 4 – Evolution of red rice production in the Sertão do Apodi territory (Tons) from 2005 to 2020.



Source: Field research, 2019. Prepared by the authors.

Although red rice has been introduced into public procurement and accessed institutional markets through the Food Acquisition Program (PAA) and the National School Feeding Program (PNAE), there are still significant restrictions on its commercialization. As it is considered an invasive plant, red rice is not listed as a product in the food catalog of the National Supply Company (CONAB) and faces entry barriers imposed by the commercial rice industry. Nonetheless, red rice was marketed to the PAA under its Simultaneous Donation (DS) modality in 2008 and to the PNAE in schools exclusively within the Sertão do Apodi territory in 2019. Another strategy involves the promotion of red rice by the government of Rio Grande do Norte, which has implemented the State Program for Government

Purchases from Family Farming and Solidarity Economy (PECAFES) and the State Program for Crioula Seeds since 2018. These initiatives enabled the acquisition of 225 tons of red rice between 2019 and 2021.

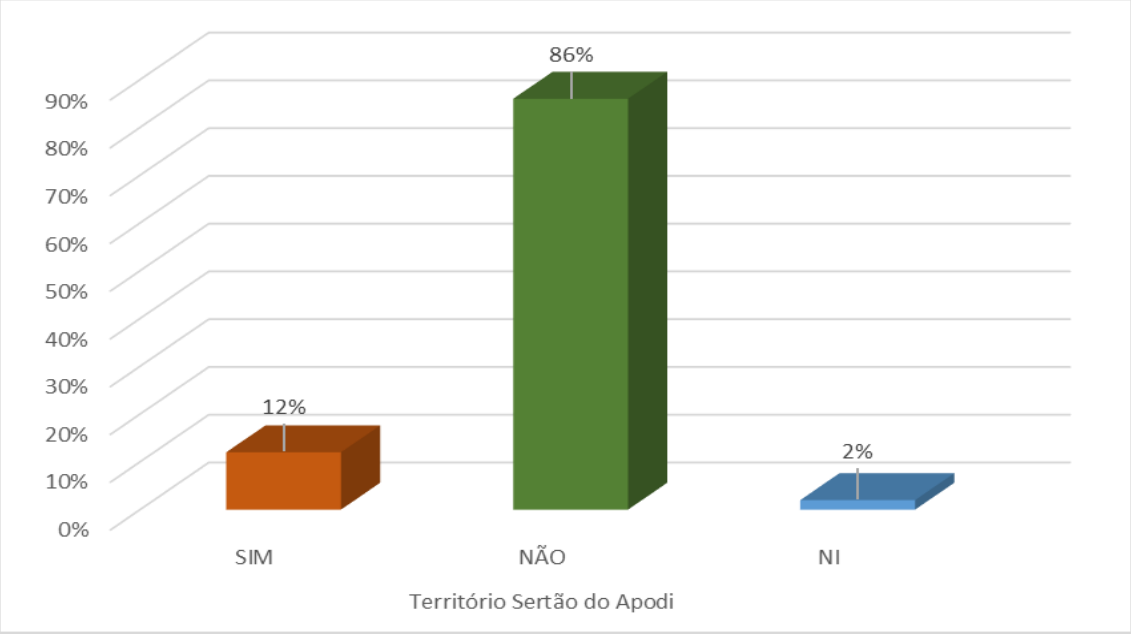
The major challenge for red rice lies in meeting all technical and legal compliance requirements, including proper facilities, health conditions for workers in small-scale agroindustries, packaging and storage standards, and registration with IDIARN. Additionally, there is a pressing need for improved qualifications among family farmers and technical advisors in integrated pest management and sustainable agricultural practices. There is also an expectation that red rice will achieve organic certification through the Xique-Xique Network, accredited by the Ministry of Agriculture, Livestock, and Food Supply (MAPA), allowing it to be marketed under proper packaging and storage conditions.

Given its formation as a value chain and its structuring within a regional agri-food system, the rice farming value chain in the Sertão do Apodi territory has been building its economic production infrastructure over the past decades. Research findings indicate that since the 1990s, public programs, particularly those financed by the World Bank, have contributed to the chain's development. Of the constructed infrastructure, 30% were funded by the National Program for Strengthening Family Farming (PRONAF Infrastructure), which aimed to meet the needs of the poorest family farmers. Subsequently, 25% was financed by the Land Bank and the Rural Poverty Combat Program (PCPR), with banks contributing 20% to the financing of red rice chain infrastructure in the Sertão do Apodi territory.

PRONAF "Infrastructure and Services" operations, as noted by Leite and Wesz Júnior (2012) and Nunes *et al.* (2015), were active between 1998 and 2002. Their objective was to finance the production infrastructure of family farming, aiming to create rural development dynamics in municipalities with precarious agricultural economies. These municipalities were defined through Municipal Rural Development Plans (PMDRs) and discussed within the scope of Municipal Rural Development Councils (CMDRs). The Land Bank, or Land and Agrarian Reform Fund, focused on financing rural properties directly to interested parties and community infrastructure. The PCPR, inspired by the Small Rural Producer Support Program (PAPP) of the 1980s and 1990s, supported by the International Bank for Reconstruction and Development (IBRD), aimed to reduce rural poverty through non-repayable financing for community-based rural projects in the poorest areas.

Regarding the provision of Agricultural Technical Assistance and Rural Extension (ATER) services within the red rice value chain, the research revealed a sharp deficiency or complete lack of technical support for family farmers. As shown in Figure 5, 86% of interviewed family farmers reported not having received any form of ATER services, while only 12% affirmed they had received support, and 2% did not respond.

Figure 5 – Received any Agricultural Technical Assistance and Rural Extension (ATER) services?

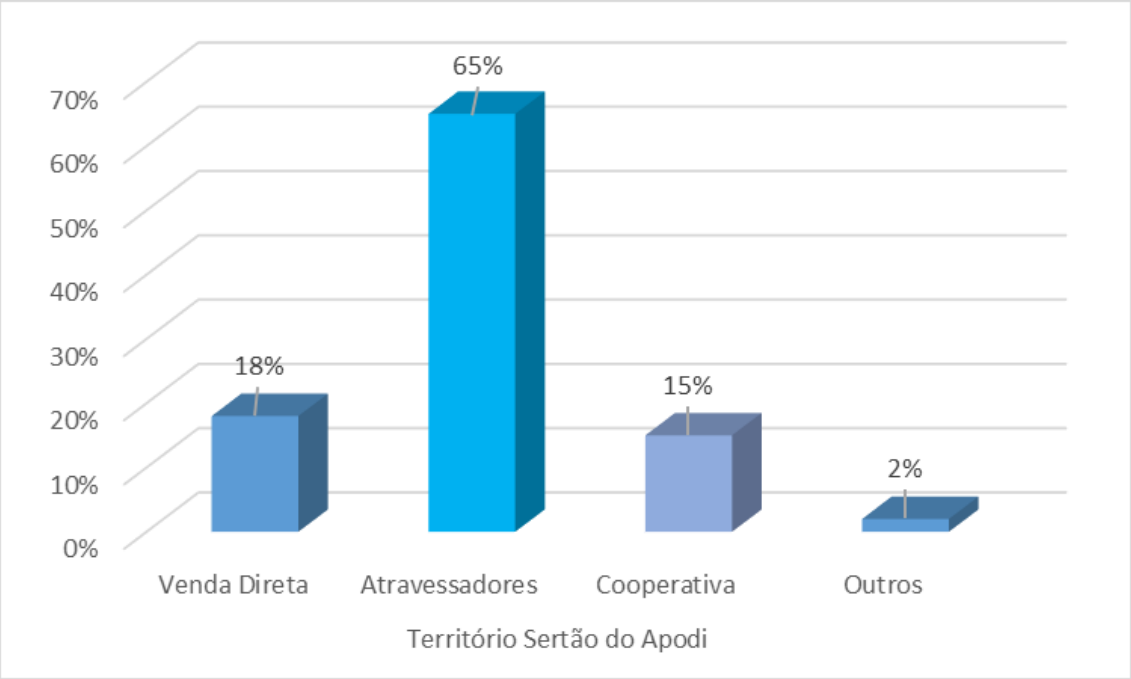


Source: Field research, 2014. Prepared by the authors.

The deficiency in the provision of Agricultural Technical Assistance and Rural Extension (ATER) services in the red rice value chain of the Sertão do Apodi territory suggests a potential need for restructuring the regional agri-food system, particularly considering the characteristics of the technological framework and the adjustments anticipated under the perspectives of innovation production and novelty production. This lack of ATER services could also impose limitations on collective management and organizational processes (cooperatives), potentially diminishing the dynamism afforded by the integration of family farming with small-scale agroindustry, and consequently restricting the development of both conventional and institutional markets.

Regarding market types or accessible commercialization channels, the research revealed that red rice is marketed regionally and reaches various consumer hubs while also meeting the demands of government programs such as PAA, PNAE, and PECAFES. However, among the markets most accessed by family farmers producing red rice, 65% are controlled by intermediaries and their well-established wholesale and retail distribution networks. The remaining portions include 18% for direct sales, 15% for cooperative transfers, and only 2% directed to other commercialization channels, as shown in Figure 6. These findings highlight the harsh realities of the Brazilian agricultural model, reflecting a suppressive pricing system that marginalizes family farmers and deprives them of the ability to access commercialization chains and build markets.

Figure 6 – Main sales channels for red rice in the Sertão do Apodi territory (in %)



Source: Field research, 2014. Prepared by the authors.

According to the research data, among the seventeen red rice producers who marketed their products between 2020 and 2023 using the Digital Platform of the Regional Information System for Family Farming (SIRAF), only 1 (6%) operated individually, while 16 (94%) marketed their products through collective organizations, particularly through family farmer cooperatives. As shown in Table 4, a total of 131,898 kg of red rice was marketed via SIRAF during this period, with 2020 being the year with the highest number of transactions, largely due to the COVID-19 pandemic.

Table 4: Quantity of red rice (annual supply) marketed by producers using the SIRAF Digital Platform from 2020 to 2023.

Group	State (UF)	Municipality	year	Unity	Annual Supply
Cooperativa de Agricultores e Agricultoras de Mossoró e Região – COOAFAM	RN	Mossoró	2020	Kg	1.500
Cooperativa de Comercialização Solidária Xique Xique - COOPERXIQUE	RN	Apodi	2020	Kg	10.003
Cooperativa de Comercialização Solidária Xique Xique - COOPERXIQUE	RN	Mossoró	2020	Kg	10.003
Cooperativa de Comercialização Solidária Xique Xique - COOPERXIQUE	RN	Apodi	2020	Kg	6.000
Cooperativa de Comercialização Solidária Xique Xique - COOPERXIQUE	RN	Apodi	2020	Kg	8.628
Cooperativa de Comercialização Solidária Xique Xique - COOPERXIQUE	RN	Apodi	2020	Kg	8.628
Cooperativa de Produtores Agropecuários de	RN	Caraúbas	2020	Kg	6.000

Umarizal - COOPAU					
Cooperativa Mista Agroindustrial dos Pequenos Produtores de Caraúbas, Ltda - COOPERUBA	RN	Caraúbas	2020	Kg	3.504
Cooperativa Mista Agroindustrial dos Pequenos Produtores de Caraúbas, Ltda - COOPERUBA	RN	Caraúbas	2020	Kg	9.996
Associação dos Agricultores e Agricultoras do Rio Novo e Comunidades Adjacentes	RN	Apodi	2020	Kg	24
Associação dos Agricultores e Agricultoras do Rio Novo e Comunidades Adjacentes	RN	Apodi	2020	Kg	50.004
Produtor individual	RN	Caraúbas	2021	Kg	5.004
Cooperativa Potiguar de Apicultura e Desenvolvimento Rural Sustentavel - COOPAPI	RN	Apodi	2021	Kg	198
Cooperativa da Agricultura Familiar de Apodi-COOAFAP	RN	Apodi	2022	Kg	2.400
Cooperativa da Agricultura Familiar de Apodi-COOAFAP	RN	Apodi	2022	Kg	2.800
Cooperativa da Agricultura Familiar de Apodi-COOAFAP	RN	Apodi	2023	Kg	4.800
Cooperativa da Agricultura Familiar de Apodi-COOAFAP	RN	Apodi	2023	Kg	2.406
Total (Kg)					**131.898**

Source: SIRAF, 2023. Organized by the authors.

As noted above, it has predominantly been through cooperatives that red rice, or "arroz da terra" as it is regionally known, has accessed institutional markets via digital platforms. Its primary destinations include the Food Acquisition Program (PAA), the National School Feeding Program (PNAE), and the State Program for Government Purchases from Family Farming and Solidarity Economy (PECAFES). These public commercialization channels are utilized to seize opportunities and introduce red rice into school meals, daycare centers, and hospitals.

5 Final Considerations

The research conducted for this study determined that the rice farming value chain in the Sertão do Apodi territory, Rio Grande do Norte, constitutes a regional agri-food system based on red rice cultivation. This system, characterized by its artisanal and localized production, suggests an alternative to the dominant global food regime. It also revealed that the value chain's structuring has achieved a certain level of integration between family farming and small-scale agroindustry, coordinated by cooperatives and supported by the creation of digital food markets. This integration represents a synergy between opportunities for productive inclusion, cooperative coordination, and the guidance of public policies, such as the Territorial Development Policy.

One notable feature is the value chain’s capacity for innovation production and novelty production, positioning it as an environment with potential for socio-technical adjustments due to its predominantly artisanal production methods. Demonstrating internalized innovations and/or novelties, the rice farming value chain in the Sertão do Apodi territory has accessed and constructed institutional markets, particularly through digital platforms. The Regional Information System for Family Farming (SIRAF/Northeast) has been integral to the operationalization of

red rice sales, a role that became especially significant during the COVID-19 pandemic. The main destination markets for the annual red rice supply from cooperatives and other producers are government procurement programs, including PAA, PNAE, and PECAFES.

However, the research also highlighted significant weaknesses in the value chain and the regional agri-food system, despite their considerable potential. These include deficiencies or a lack of Agricultural Technical Assistance and Rural Extension (ATER) services, limited access to financing, and market restrictions. The lack of ATER services undermines the overall efficiency of the value chain, jeopardizing the technical framework reversal that transformed an invasive plant into a primary crop. It also compromises the integration of family farming with small-scale agroindustry. Market restrictions are further exacerbated by barriers imposed by the conventional rice industry and the Brazilian agricultural model, which perpetuates a suppressive pricing system that marginalizes family farmers, limiting their capacity to organize and access markets. Additionally, red rice is not included in the National Supply Company's (CONAB) list of marketable food products.

In conclusion, the findings point to a value chain with significant expansion potential, especially considering the risk of red rice extinction. This highlights the need for further research agendas to identify and address challenges and propose solutions for this critical regional agri-food system. Recognizing that red rice represents a niche market, one of the key recommendations is to direct public policy actions toward fostering economic diversification, building a robust social fabric through collective organization, and increasing income levels to support a vibrant and diverse rural livelihood. This can be achieved through initiatives in small-scale rural industrialization within the rice farming value chain, aiming to establish it as a vital driver of rural development in the Sertão do Apodi territory.

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