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Agroforestry systems as a resilience factor for family farming in Portal da Amazônia (MT) during the Covid-19 pandemic

Sistemas agroflorestais como fator de resiliência da agricultura familiar no Portal da Amazônia (MT) durante a Covid-19

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Abstract: The populations most affected by the impacts of the COVID-19 pandemic include those in rural areas, particularly family farmers. In the Portal da Amazônia Territory, located in the far north of Mato Grosso, within the so-called "arc of deforestation" of the Amazon rainforest, family farming has historically faced numerous challenges arising from different shocks, making strategies to strengthen its socioecological resilience in this context both urgent and necessary. Non-governmental organizations have been working to implement agroforestry systems (AFSs) in the region to restore degraded areas, ensure food security, and revalue family farming. This research analyzed the role of these AFSs during the COVID-19 shock based on the perceptions of the farmers responsible for their implementation and management. The aim was to investigate whether these systems could contribute to strengthening farmers' resilience to new shocks. To this end, semi-structured interviews and content analysis were used. The results show that the COVID-19 crisis exacerbated several problems already experienced by farmers in the region, such as difficulties in marketing AFS products and labor shortages. On the other hand, it also stimulated adaptation strategies, such as the creation of new marketing channels. Farmers perceive AFSs as systems that have enabled them to strengthen their families' food sovereignty, diversify production, improve environmental conditions, including water quality and the local microclimate, contribute to family income, and facilitate environmental regularization. Considering the main challenges and vulnerabilities caused by the pandemic for family farming worldwide, this study identified AFSs as a resilience factor that can help family farmers in the Portal da Amazônia Territory cope with adversities arising from ecological, social, and economic factors.

Keywords: socio-ecological systems; socioecological resilience; family farmers; pandemic; food systems.

Resumo: As populações mais afetadas pelos impactos da pandemia da Covid-19 estão em áreas rurais, com destaque para a agricultura familiar. No Território Portal da Amazônia, localizado no extremo norte de Mato Grosso, no chamado "arco do desmatamento da floresta Amazônica", a agricultura familiar enfrenta, historicamente, inúmeros desafios, advindos de diferentes choques, o que faz com que estratégias de fortalecimento de sua resiliência socioecológica sejam urgentes e necessárias. Organizações não governamentais vêm atuando na implantação de sistemas agroflorestais (SAFs) na região para a recuperação de áreas degradadas, na segurança alimentar e na revalorização da agricultura familiar. A presente pesquisa analisou o papel desses SAFs, diante do choque da Covid-19, a partir da percepção de agricultores responsáveis pela implantação e manejo. O intuito foi investigar se esses sistemas poderiam se apresentar como um fator de fortalecimento de resiliência desses agricultores frente a novos desafios. Para isso, utilizou-se de entrevistas semiestruturadas e da análise de conteúdo. Os resultados apontam que a crise da Covid-19, por um lado, acentuou diversas problemáticas já vivenciadas por agricultores na região, como a dificuldade de comercialização de produtos do SAF e a escassez

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de mão de obra. Por outro lado, estimulou estratégias de adaptação, como a criação de novos canais de comercialização. Os agricultores perceberam os SAF como sistemas que permitiram fortalecer a soberania alimentar das famílias, a diversificação da produção, a melhoria das condições ambientais, como melhoria da qualidade da água e alteração do microclima, a contribuição para a renda familiar, além de auxiliar a regularização ambiental. Considerando os principais desafios e vulnerabilidades causadas pela pandemia à Agricultura Familiar a nível mundial, no contexto do Portal da Amazônia, este estudo identificou os SAF como um fator de resiliência para o enfrentamento às adversidades causadas por fatores ecológicos, sociais e econômicos.

Palavras-chave: sistemas socioecológicos; resiliência socioecológica; agricultores familiares; pandemia; sistemas alimentares.

1. Introduction

The COVID-19 pandemic has clearly affected current food systems, particularly agriculture and food supply chains, causing widespread shortages and rising prices (Altieri & Nichols, 2020). According to Bellamy et al. (2021, p. 783), the pandemic:

> […] illuminated multiple systemic injustices linked to food, including the lack of affordable, good quality and nutritious food for all; poor pay and working conditions for food system actors; concentration of power in the hands of a few actors; and limited opportunities to participate in food systems transformation. Investigating them has revealed some ways in which food systems need to transform to become more just.

The United Nations (2018) states that family farming – a sector that includes some of the populations most vulnerable to poverty and hunger worldwide – was particularly affected by the COVID-19 health crisis. The most affected populations are located in rural areas, where family farming faces various economic, social, and environmental challenges amid the expansion and consolidation of capitalist structures in the countryside.

Challenges faced by local family farming food systems during the pandemic included financial difficulties and limited access to credit, fiscal informality, a lack of human resources, the use of low-technology production methods, difficulties in adding value to products, and a lack of public policies (Cordeiro et al., 2021). Adverse effects also included disruptions to input supply chains, resulting in price increases, an oversupply of certain products, and reduced labor availability (Béné, 2020).

Furthermore, prevention measures established by the World Health Organization (WHO) – although crucial for containing the spread of the virus – created additional difficulties by disrupting key marketing channels for family farming products, such as community kitchens, public schools, and farmers' markets (Sambuichi et al., 2020). According to Béné (2020), one of the main impacts was the loss of purchasing power among these actors as consumers, resulting from reduced income available for food purchases, although this effect is sometimes conflated with rising food prices.

However, the environmental sustainability and resilience of peasant and family farming systems – which are closely integrated into their territories and communities – stand out as factors that strengthen their capacity for adaptation (Van der Ploeg, 2020). From this perspective, the pandemic may provide an opportunity to reintegrate food systems into their territories and restructure them according to the principles of agroecology and food democracy (Petetin, 2020; Altieri & Nicholls, 2020).

The pandemic had both positive and negative impacts on family farming (Duguma et al., 2021). Evidence regarding the sector's responses and adaptation strategies to pandemic-related challenges points to production diversification and the creation of new marketing channels, with an emphasis on direct-to-consumer sales and increased investment in digital marketing (Mastronardi et al., 2021; Meuwissen et al., 2021; Tittonell et al, 2021; Marusak et al., 2021; Durant et al., 2023).

Identifying resilience strategies – particularly within complex socioecological systems such as family farming – requires consideration of the specific characteristics of different local contexts, given the social, economic, and territorial heterogeneity of this sector in Brazil (Wanderley, 2009; 2019). In this regard, gathering information on the actual impacts of the pandemic, both positive and negative, across distinct locations is crucial for achieving a more comprehensive understanding of the situation.

The resilience of socioecological systems (SESs)[1] encompasses their capacity to absorb external shocks, adapt to them, and develop transformation strategies aimed at maintaining desired attributes (Folke, 2006; Nikinmaa et al., 2020). Considering the COVID-19 pandemic as another shock affecting family farming as a socioecological system, identifying the adaptation and strengthening strategies that emerged in this context can contribute to the analysis and development of sector-specific strategies aimed at enhancing resilience.

In the Portal da Amazônia Territory (TPA), located in northern Mato Grosso State, the vulnerabilities of the rural population – including specific socioeconomic, demographic, and biological factors – hindered efforts to cope with the COVID-19 crisis. Agricultural holdings in the region are predominantly family-run, accounting for 80% of rural properties (Instituto Brasileiro de Geografia e Estatística [IBGE], 2017).

Data collected during this study showed that the pandemic exacerbated existing vulnerabilities in the region due to factors such as low educational attainment among a large portion of the rural population, particularly elderly men; limited access to healthcare services because of distance, information barriers, and a lack of available hospital beds; and difficulties

1 The term "Social-Ecological Systems" was coined by Berkes and Folke in 1998 in the book *Linking Social and Ecological Systems: Management Practices and Social Mechanisms for Building Resilience*. In this work, the authors define social-ecological systems as complex, integrated systems in which human beings are part of nature.

in accessing public policies. During the pandemic, farmers faced challenges in accessing programs such as the National Program for Strengthening Family Farming (PRONAF), the Food Acquisition Program (PAA), and the National School Feeding Program (PNAE), which negatively affected family income (Weihs & Olival, 2021).

The expansion of the agricultural frontier in the region is a root cause of several historical impacts and challenges faced by family farming. Cycles of economic exploitation – including dairy farming, mining, and, more recently, the expansion of soybean cultivation – have raised concerns and affected family farmers and their livelihoods. Consequently, effective strategies are needed to strengthen the socioecological resilience of these populations and their production systems, enabling them to cope with the various challenges to which they are frequently exposed.

One such strategy was the implementation of agroforestry systems (AFSs) to restore degraded areas and revitalize family farming. This initiative was conducted primarily with the support of non-governmental organizations (NGOs). The strategy aimed to put environmental preservation and restoration policies into practice while also addressing the socioeconomic realities of rural areas (Makishi et al., 2021). According to data collected in this study, between 2014 and 2018, a single organization – the Instituto Ouro Verde (IOV) – established 1,100 agroforestry systems across eight municipalities in the TPA.

Agroforestry systems (AFSs) are not a novel arrangement, as they constitute an ancient practice among traditional peoples. According to the Food and Agriculture Organization (FAO), these systems encompass a set of land-use technologies in which trees, shrubs, palms, and other components interact with agricultural crops and/or livestock. These interactions occur in various spatial arrangements and temporal sequences and involve ecological and economic exchanges among the different components. Such systems are considered multifunctional because they integrate trees with agricultural production to create diverse landscapes, thereby generating environmental and economic benefits for local communities through diversified production (Food and Agricuture Organization [FAO], 2026).

Biodiverse agroforestry systems can provide numerous benefits, including food for humans and animals; timber for construction and fuelwood; improvements in local and global air quality; enhanced soil fertility and water availability; increased biodiversity; and natural pest control (Grosrenaud et al., 2021). Diversity is a key feature of these systems. Family farming is generally characterized by a high degree of diversification in agricultural and economic activities (Gervazio et al., 2025). Consequently, family farms may benefit from the implementation of AFSs, as this approach enables the diversification of cropping systems and, in theory, enhances socioecological resilience. More recently, agroforestry systems have been identified as a key strategy for adaptation and resilience-

building at multiple scales within the TPA rural landscape, with the aim of improving environmental conditions, increasing diversification and food production, and fostering social cohesion and rural community engagement (Oliveira et al., 2021; Gallo et al., 2024).

This research is based on this perspective and aims to analyze attributes of socioecological resilience associated with agroforestry systems implemented in three municipalities within the TPA. Given the numerous challenges already facing family farming in the region – and considering COVID-19 as an additional shock – this study evaluates the role these systems played during the pandemic and examines whether and how they can contribute to strengthening the resilience of local family farming.

2. Materials and Methods

2.1. The Portal da Amazônia Territory

The municipalities that make up what is now known as the Portal da Amazônia Territory (TPA) began to be established in the 1970s, amid the expansion of the agricultural frontier into the Amazonian region of Mato Grosso. This expansion occurred through private colonization projects, Joint Action Projects (PAC), and agrarian reform settlements. The process was part of the territorial occupation policies implemented by Brazil's military governments during the 20th century. These policies relied on subsidies and incentives for large corporations, as well as public investments aimed primarily at land acquisition and the development of activities such as cattle ranching, logging, and mining, thereby intensifying conflicts and social inequalities in the region (Domingues & Sauer, 2022).

Decades later, this territorial configuration was incorporated into the Brazilian Federal Government's rural territorial development policies through the "*Territórios da Cidadania* (Citizenship Territories) Program". Created in 2008, the program served as a strategy to promote sustainable regional development and ensure social and economic rights in rural areas characterized by elevated levels of poverty and vulnerability.

In this context, the Portal da Amazônia Territory came to encompass 16 municipalities located along the edge of the Amazon rainforest (Lovato, 2017). The region is characterized as an agricultural frontier with a history of extensive cattle ranching expanding into areas of native forest (Weihs et al., 2017). It lies within the "Arc of Deforestation", a region where environmental impacts have accumulated as a result of the advance of the agricultural frontier since the early 1980s (Paulo et al., 2015) and where areas designated for environmental conservation conflict with the expansion of agricultural production, creating intense pressure on land use (Olival et al., 2006).

According to the Executive Council for Family Farming Actions of the State of Mato Grosso (2010, p. 26),

> The Portal da Amazônia is a territory in which agricultural activities play a significant economic role, particularly dairy farming and temporary crop production. Family farming is especially important in this context, accounting for a huge proportion of agricultural establishments and representing a major source of employment in the region.

On the other hand, according to the same Executive Council, "some important constraints still need to be overcome", particularly: (1) the concentration of land ownership; (2) low family income, mainly due to the production of low-value-added products; and (3) the "serious environmental impacts caused by the advance of the agricultural frontier" (Mato Grosso, 2010, p. 26).

2.2. Study area

The research was conducted in three municipalities within the TPA (Figure 1): Alta Floresta, Carlinda, and Nova Canaã do Norte. These municipalities were selected because they are part of the study area for field data collection under the project titled "Resilience in the Face of COVID-19: Adaptations to Strengthen Family Farming in the Amazonian Agricultural Frontier Region", to which this research is linked.

According to information obtained from the Instituto Ouro Verde (IOV) during this study, these municipalities have established community leaders and strong coordination between farmers and agricultural extension agencies, as well as a long history of engagement with and activities previously carried out by the IOV.

In Nova Canaã do Norte, the study site was the Veraneio Settlement Project (PA Veraneio), located in the municipality's rural area. The settlement comprises 620 families and covers approximately 14,000 hectares. It was established on December 15, 1997, under INCRA Ordinance SR-13, with settlement code PA MT0202000 and IBGE code No. 5103205. The settlement is subdivided into the communities of Boa Esperança, Monte Sinai, Nossa Senhora de Fátima, Boa Nova, Monte Verde, São Bartolomeu, Novo Paraíso, União da Vitória, and São Camilo (Chagas et al., 2022).

In Carlinda, the selected settlement was the São Paulo Sustainable Development Project (PDS São Paulo), established on March 27, 2012, under INCRA/SR-13/MT Ordinance No. 014/12. This type of settlement has the following characteristics: (1) communal land tenure and (2) the development of sustainable activities based on the Amazonian Extractive Reserve model. The PDS covers approximately 2,390.07 hectares, of which 63.25% is designated as Legal Reserve, and is home to 47 families (Gervazio, 2019).

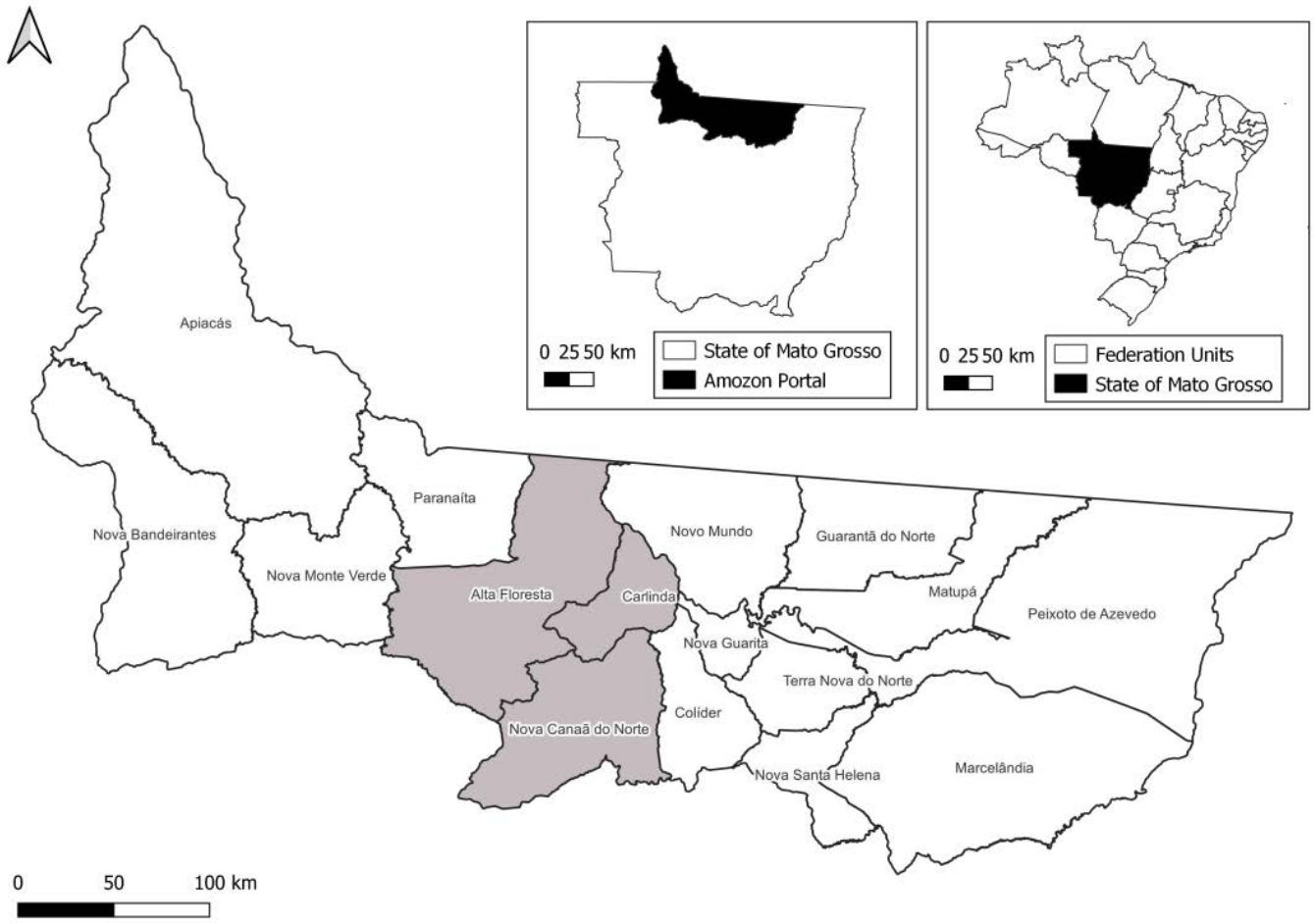


Figure 1

Municipalities selected for the study – Alta Floresta, Carlinda, and Nova Canaã do Norte – in the Portal da Amazônia Territory, Mato Grosso, Brazil.

Source**:** Julia Alves de Oliveira.

Finally, in the municipality of Alta Floresta, the settlement selected for this study was the Jacaminho Settlement Project (PA Jacaminho). Established on November 19, 1997, by the Mato Grosso Land Institute (INTERMAT) through the "Nossa Terra, Nossa Gente" program, the settlement is located approximately 94 km from the municipal seat of Alta Floresta and is home to approximately 90 families within an area of 2,477.33 hectares (INTERMAT, 2018).

Within these settlements, rural properties contained AFSs belonging to various categories, including orchard AFSs, vegetable-garden AFSs, restoration AFSs established in Legal Reserve and Permanent Preservation Areas (APPs), and silvopastoral systems. These systems were implemented through the "Sementes do Portal" project and with resources provided through initiatives carried out by the Instituto Ouro Verde (IOV) from 2014 to 2018.

2.3. Participant selection and agroforestry system (AFS) classification

Across the three settlements, family farms with AFSs belonging to two categories were selected: agroforestry orchards and restoration AFSs established in Permanent Preservation Areas (PPAs) (Figure 2). Agroforestry orchards, or home gardens, are defined here as areas of diversified and

biodiverse agricultural production, generally located near the family home, and shaped by the families' nutritional, emotional, social, and cultural needs (Duarte & Pasa, 2016).

Restoration AFSs are systems established primarily to rehabilitate previously degraded PPAs. In the study region, these areas were rehabilitated through the implementation of AFSs, a practice authorized in degraded areas on family farms under Federal Law No. 12,854 of August 26, 2013 (*Lei n. 12.854*, 2013).

Fifteen farming families were selected to participate in this study. Among the AFSs established and managed by these families, seven were restoration AFSs in PPAs and eight were agroforestry orchards. This distribution was intended to provide a balanced representation of families across the AFS categories. Accordingly, four families were selected from the municipality of Alta Floresta, five from Carlinda, and six from Nova Canaã do Norte.

Semi-structured interviews were conducted with family members responsible for managing the established agroforestry systems to understand

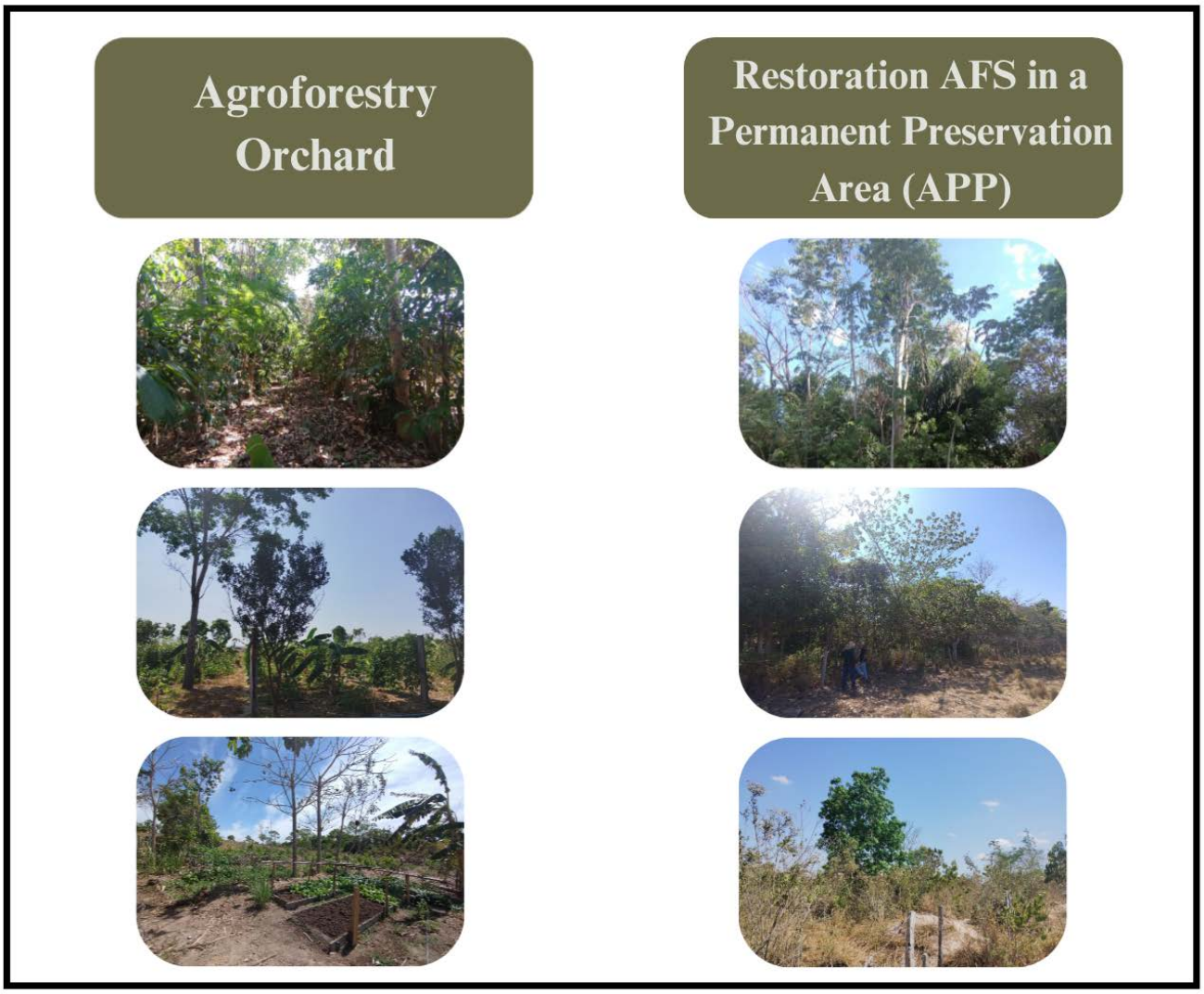


Figure 2

Schematic representation and examples of each AFS category (photographic records obtained during visits to the properties).

how these systems were maintained during the pandemic and the role they played in the families' lives during this period.

2.4. Semi-structured interviews and field visits to rural properties

Semi-structured interviews were conducted with participants during field visits, specifically at the sites where the agroforestry systems had been established, between February and March 2024. The interviews involved one or more members of each participating family and were conducted on their respective properties. The interviews were audio-recorded and subsequently transcribed. During the field visits, agroforestry systems were also photographed to document the areas visited.

Following the interviews, the audio files and photographs were transferred to a local storage device, and all data and records were deleted from virtual platforms, shared environments, and cloud storage (CONEP Resolution 1/2021).

Interview guide initially focused on characterizing the participants and their properties, including information such as age, occupation, property size, and the number of people working on the property. It also included questions specifically related to the established agroforestry systems, such as their size, initial purpose, and the marketing and consumption of products derived from them. Finally, the COVID-19 pandemic was addressed to explore the contributions of the agroforestry systems to the families during this period, as well as the associated benefits and challenges.

Information was also gathered on activities conducted on the properties during the COVID-19 pandemic, particularly those related to agroforestry system management. The study sought to determine whether community organizations remained active during this period or whether their activities had been completely suspended. Technical assistance during the same period was assessed in an analogous manner. The interviews also addressed (1) the introduction of new species and technologies into the systems, particularly to optimize labor use, and (2) the use of external inputs.

All participants received the Informed Consent Form (ICF), and the study was approved by the Research Ethics Committee of the Federal University of São Carlos under protocol number 74588723.3.0000.5504.

2.5. Data analysis

The interviews were audio-recorded, listened to in their entirety, transcribed, and tabulated according to the types of questions included in the interview guide, which comprised both open- and closed-ended questions. Responses to the open-ended questions were analyzed using an adaptation of Bardin's (1977) content analysis method and organized into categories and subcategories.

To establish the categories, a literature review was conducted to identify potential benefits and challenges associated with the implementation and

Table 1 Organization of categories and subcategories (coding elements) to support the preparation of tables for content analysis.

Category	Subcategory
Income generation	Marketing of agroforestry system (AFS) products; increased income; increased income from AFS products during the pandemic; new marketing channels for AFS products; processing and value addition to AFS products.
Food sovereignty	Household consumption of AFS products; distribution of products to family members or the community; donation of AFS products.
Social cohesion and community engagement	Organization of collective agroforestry work activities; organization of and participation in community training courses; formation of support and knowledge-sharing groups; participation in social organizations (associations, cooperatives, etc.).
Production diversification	Implementation of diversified production systems on the property; cultivation of distinct species within the same plot or across the property.
Compliance with forest legislation	Restoration of Permanent Preservation Areas (APPs) and Legal Reserves (LRs); implementation of AFSs in APPs and Legal Reserves.
Improvement of environmental conditions	Increased water quantity and quality on the property; increased biodiversity of micro- and macroorganisms; increased soil fertility; perceived changes in the microclimate.
Satisfaction with the property	AFS as a recreational space; AFS as a place for tranquility and rest; satisfaction with the area.
Management	Labor shortages; management difficulties due to the size of the area; lack of technology; lack of time for management activities.

use of agroforestry systems in family farming. The subcategories served as coding elements and were developed based on the literature and "floating reading", a technique in which the researcher conducts an initial, exploratory reading of the material to identify impressions, patterns, and potential hypotheses based on the data collected in the field (Bardin, 1977) (Table 1).

The coded transcripts were organized into tables and grouped into four themes: (i) Motivation for implementing agroforestry systems (AFSs); (ii) Contribution of AFSs to the family during the COVID-19 pandemic; (iii) Advantages and benefits of AFSs during the COVID-19 pandemic; and (iv) Challenges associated with AFSs during the COVID-19 pandemic. Accordingly, four tables were created, one for each theme. The full transcripts were coded by extracting specific statements, which were entered into the tables as "context units" and classified according to their respective categories and subcategories. Responses to the closed-ended questions were also tabulated to characterize the family farming activities of the study participants.

3. Results

3.1. Characterization of the properties and profiles of the interviewed farmers

The farmers participating in this study followed a migration pattern, with the majority originating from southern Brazilian states ($n = 8$), such as Paraná and Rio Grande do Sul. A smaller number had migrated from the Central-West region (Mato Grosso and Mato Grosso do Sul; $n = 4$), the Southeast ($n = 2$), and the Northeast ($n = 1$). The length of time they had lived in the study region varied widely, ranging from 10 to 47 years. Most participants ($n = 10$) reported having family members living in the region or in their local community.

Nine men and six women were interviewed. The men ranged in age from 40 to 72 years, whereas the women ranged from 43 to 64 years. Overall, 80% of the participants had already been engaged in agriculture before settling on their current properties.

Farm size varied according to the local settlement project, ranging from 2.4 to 168 hectares. The first agroforestry systems (AFSs) were established in 2014. Some interviewees maintained more than one AFS or AFS model on their properties and had participated in subsequent implementation initiatives. For this study, the oldest AFSs, established 8 to 10 years before data collection, were selected. Their areas ranged from 0.10 to 10.7 hectares.

Regarding community organization, seven interviewees reported that some forms of community organization remained active during the pandemic through online groups and other forms of remote interaction. This was one of the adaptations described by participants for this period. Eight interviewees reported that community organizational activities ceased completely, which hindered the resumption of activities in the post-pandemic period. Of the seven participants who remained involved in community activities during the pandemic, four managed agroforestry orchards and three managed restoration AFSs in Permanent Preservation Areas (APPs). Among those who reported no community organization during this period, three managed agroforestry orchards and five managed restoration AFSs in APPs.

Technical assistance was provided remotely to farmers on three properties, whereas the farmers on the remaining 12 properties received no technical assistance. This lack of assistance may have influenced (1) decisions regarding the introduction of new species into the systems, as 11 farmers did not introduce new species, and (2) the absence of modern technology adoption across all properties. Of the 11 farmers who did not introduce new species, six managed agroforestry orchards and five managed restoration AFSs in APPs. Among the four farmers who introduced species in addition to those already established, one managed an agroforestry orchard and three managed restoration AFSs in APPs.

Regarding the use of external inputs, most farmers ($n = 13$) reported that they did not use them, either generally or during the pandemic, opting instead for agroecological management practices and inputs produced on the property. The two properties where external inputs were used had agroforestry orchards. Reasons for not using external inputs ranged from financial constraints, because some products were considered very expensive, to the diversity of activities conducted on the properties, which allowed farmers to make use of locally available organic resources such as chicken manure.

Farmers were also asked about the implementation of other production systems on their properties, including simplified systems, such as traditional slash-and-burn plots, and diversified systems, such as new agroforestry areas and intercropping systems. Most farmers implemented simplified systems ($n = 10$), whereas five implemented diversified systems.

When asked about the contribution of agroforestry products to family income during the pandemic, seven respondents reported no contribution, six reported a partial contribution, and two reported that these products accounted for their entire family income. Among those who reported no contribution, one managed an agroforestry orchard and six managed restoration AFSs in APPs. Among those reporting a partial contribution, four managed agroforestry orchards and two managed restoration AFSs in APPs. Of the two respondents who reported that agroforestry products accounted for their entire family income, one managed an agroforestry orchard and the other a restoration AFS in an APP.

Gender-related differences were observed in the participation of family members in AFS activities, including planting, management, and harvesting, when the pre-pandemic and pandemic periods were compared. The number of men working in the AFSs decreased during the pandemic, whereas the number of women increased.

To cope with financial difficulties at the beginning of the pandemic, men from some families took on paid work on farms near their own properties because some marketing channels were slow to adapt to the new circumstances. Consequently, women assumed responsibility for activities on their properties that they had not previously performed, including tending the AFSs, carrying out management activities, and harvesting products from the agroforestry orchards.

3.2. Motivations for implementing agroforestry systems from the farmers' perspective

Interviewees were asked about their main motivations for implementing agroforestry systems on their properties. The motivations reported were compliance with forest legislation ($n = 10$), income generation ($n = 6$), food sovereignty ($n = 2$), production diversification ($n = 2$), and improvement of environmental conditions ($n = 2$) (Figure 3).

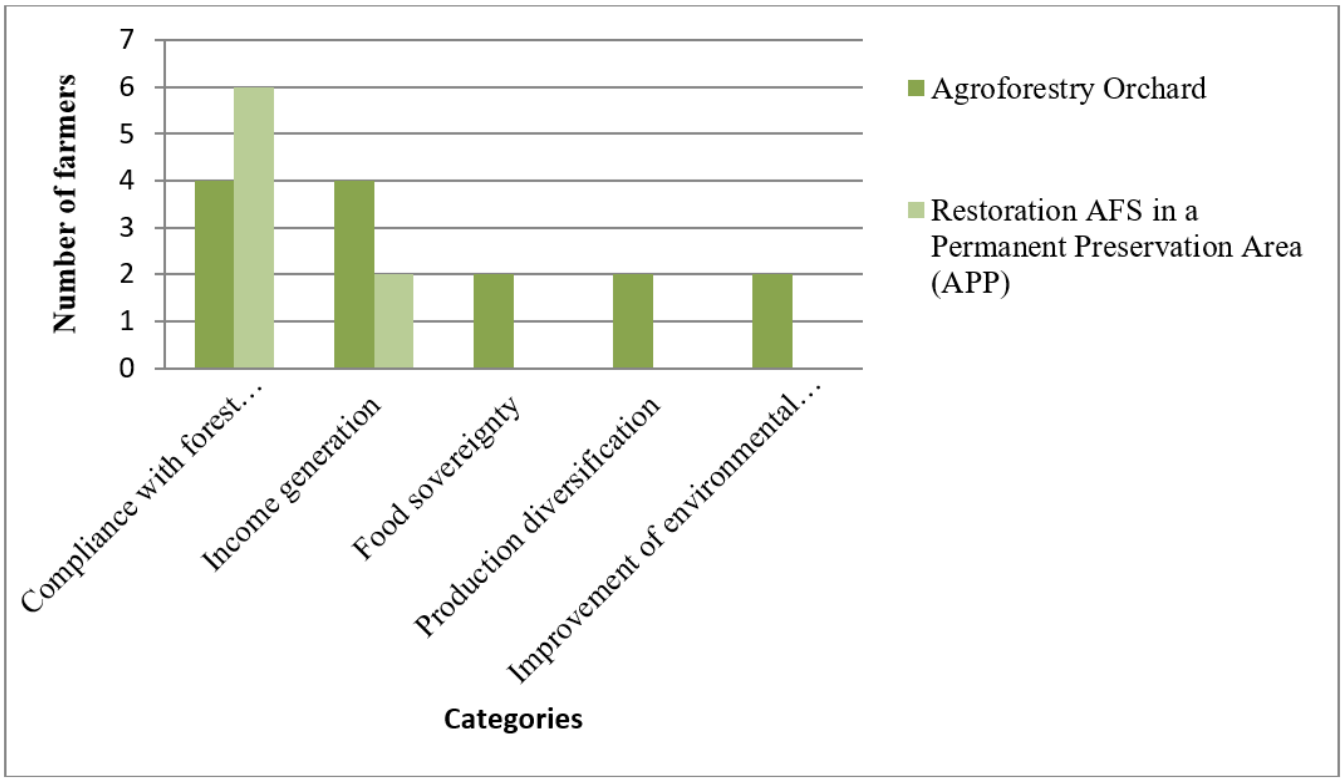


Figure 3
Motivations for implementing agroforestry systems (AFSs) on the properties, as perceived by the study participants, according to AFS category: agroforestry orchards and restoration AFSs in Permanent Preservation Areas (APPs).

Many of the properties visited contained degraded areas, primarily within Permanent Preservation Areas (APPs). In addition to concerns about compliance with environmental legislation, farmers also faced water scarcity, which constrained both agricultural and non-agricultural activities, as one interviewee explained:

> My main goal was for my small farm to have water because it didn't. You see, I dreamed of having a farm, right? Of raising my children there. I didn't think about the hardships; I just thought about getting the land. I wanted to work, just like my mother did, you know? I dreamed of having a fishpond. But I didn't think about the difficulties. I didn't know; I had no idea. Raising fish was one of my dreams, but what could I do if my farm were dry? So, the first thing we did when we took over the plots was ask for the degraded areas to be restored [...] But, you know, it was sad that my farm didn't have water. Still, I thought, 'I'm going to reforest, and there will be water,' because they always said that if you reforest, you get water. So that was my focus because I needed water. (E8)

For the participants, the concern involved not only water availability but also water quality, as they live in a region characterized by intensive pesticide use, which may lead to the contamination of watercourses.

Improving environmental conditions was a recurring topic among the farmers and included aspects related to soil fertility and microclimate modification. Because these areas were degraded, soil conditions were considered poor, and farmers expected that implementation of agroforestry systems (AFSs) would contribute to soil recovery. Regarding microclimate modification, the main concern was the provision of shade for livestock.

In addition to compliance with environmental legislation and improvements in environmental conditions, interviewees cited income generation as a motivation for implementing AFSs. They expected that the sale of products derived from these systems would supplement or increase household income. Furthermore, AFSs could contribute to cultural continuity, as some interviewees expressed a desire to cultivate particular species within the systems, both for sale and household consumption, based on their personal preferences.

Another motivation reported was household consumption of AFS products, which was associated with food sovereignty. Farmers emphasized the importance of knowing the origin of their food and how it was produced, as well as having the autonomy to choose which species to cultivate and to maintain a diverse diet for their families. This finding is consistent with the discussion by Balem and Silveira (2015) on the erosion of food culture resulting from agricultural modernization and the increasing standardization of dietary practices, highlighting the importance of diversified production systems in maintaining food autonomy and local culinary knowledge.

This topic revealed a fourth motivation: the possibility of diversifying production by cultivating different species within the same area. The production diversity of agroforestry systems (AFSs) is reflected in the range of activities and benefits they can generate, including product marketing, household consumption (Grisa & Schneider, 2008), and support for livelihoods in areas that previously had little productive diversity. This last aspect was highlighted by one of the interviewees:

> […] the recent *Sementes do Portal* projects encouraged the establishment of orchards, and today we drive by and see the plants all producing, and […] families are feeding themselves from that. So, a place that used to be entirely pasture is now feeding people. We need these kinds of incentives, right? (E1)

3.3 Contribution of agroforestry systems (AFSs) to farming families during the COVID-19 pandemic

The "Food sovereignty" category was identified in the responses of six farmers (Figure 4). Farmers reported that household consumption of products derived from AFSs was particularly important during the pandemic because it reduced the need to travel to urban centers to purchase food from supermarkets, thereby lowering their potential exposure to COVID-19. Another benefit was the reduction in household food expenses, as farmers reported perceiving increases in food prices during this period.

Regarding the "Income generation" category, farmers reported that the sale of AFS products contributed to family income. Of the four farmers who reported this benefit, three managed restoration AFSs in APPs and sold seeds collected or produced in these areas, whereas one managed an agroforestry orchard.

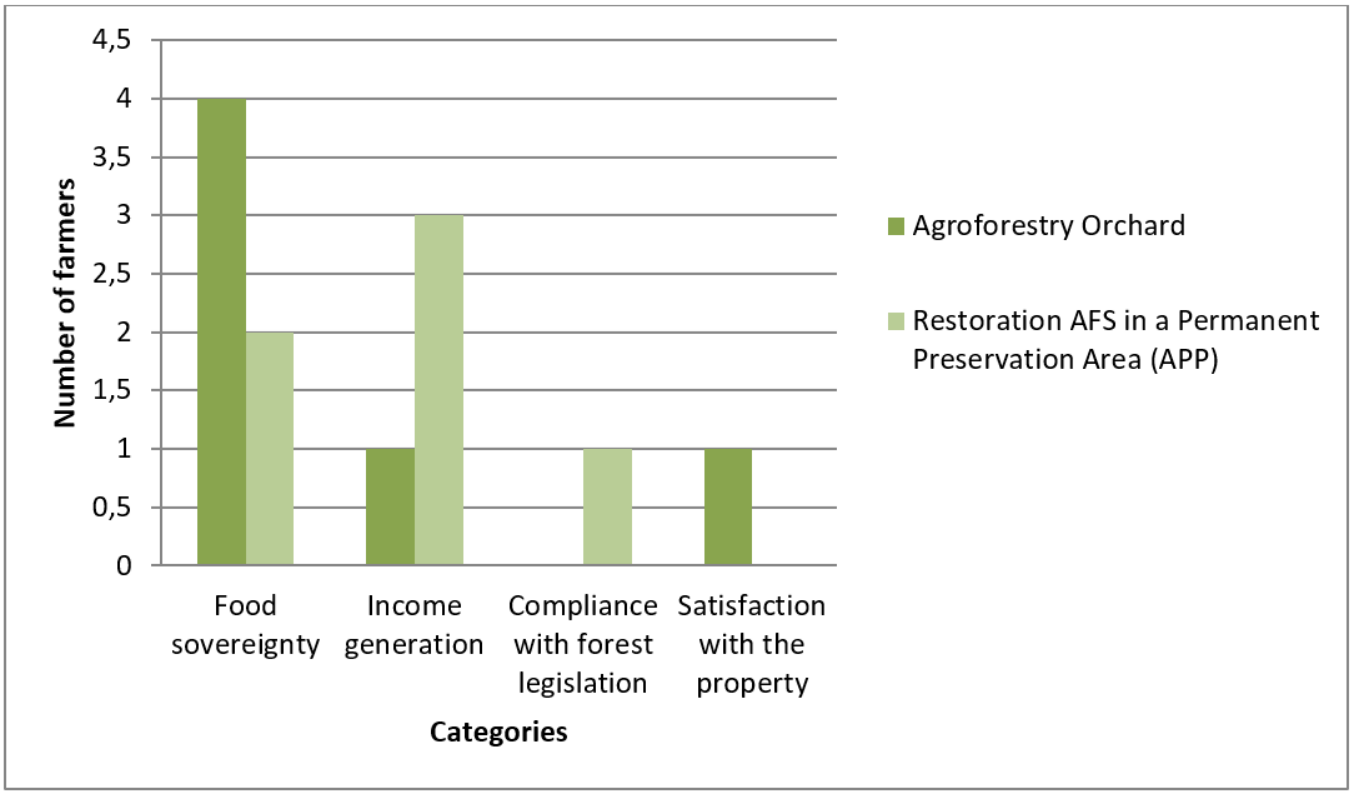


Figure 4
Contributions of AFSs to farming families during the COVID-19 pandemic, according to AFS category: agroforestry orchards and restoration AFSs in Permanent Preservation Areas (APPs).

The collection of native seeds in the region represented an important income-generating alternative promoted through the *Sementes do Portal* (Seeds of the Portal) project, complementing the main objectives associated with AFS implementation. This initiative led to the establishment of seed houses and strengthened a network of seed collectors who share both technical and traditional knowledge.

The "Satisfaction with the property" category was identified in the response of one farmer who managed an agroforestry orchard. The participant emphasized the sense of well-being provided by the system amid the difficulties experienced during the pandemic. Concerns and uncertainties, particularly those related to food availability, were partially alleviated by the ability to produce a variety of foods within the AFS for household consumption. These systems also provided food that could be shared with community members and relatives who lacked sufficient financial resources to purchase it.

> It's about satisfaction, isn't it? Having an area like this – and then there was the concern many people had about food shortages, right? We didn't face that here because we were producing food […] And the quality of life is better, isn't it? Having food right here… well, you never know what might happen, right? (E1)

Regarding "Compliance with forest legislation", this category was identified in the statement of one farmer who managed a restoration AFS in an APP. In the participant's view, the system contributed to the

restoration of degraded areas. As the interviewee emphasized, "we really dedicated it to reforestation" (E14).

3.4. Advantages and benefits of agroforestry systems (AFSs) during the pandemic

The advantages and benefits perceived by the farmers included "Improvement of environmental conditions" ($n = 4$), "Food sovereignty" ($n = 4$), "Income generation" ($n = 2$), "Compliance with forest legislation" ($n = 2$), and "Satisfaction with the property" ($n = 2$) (Figure 5).

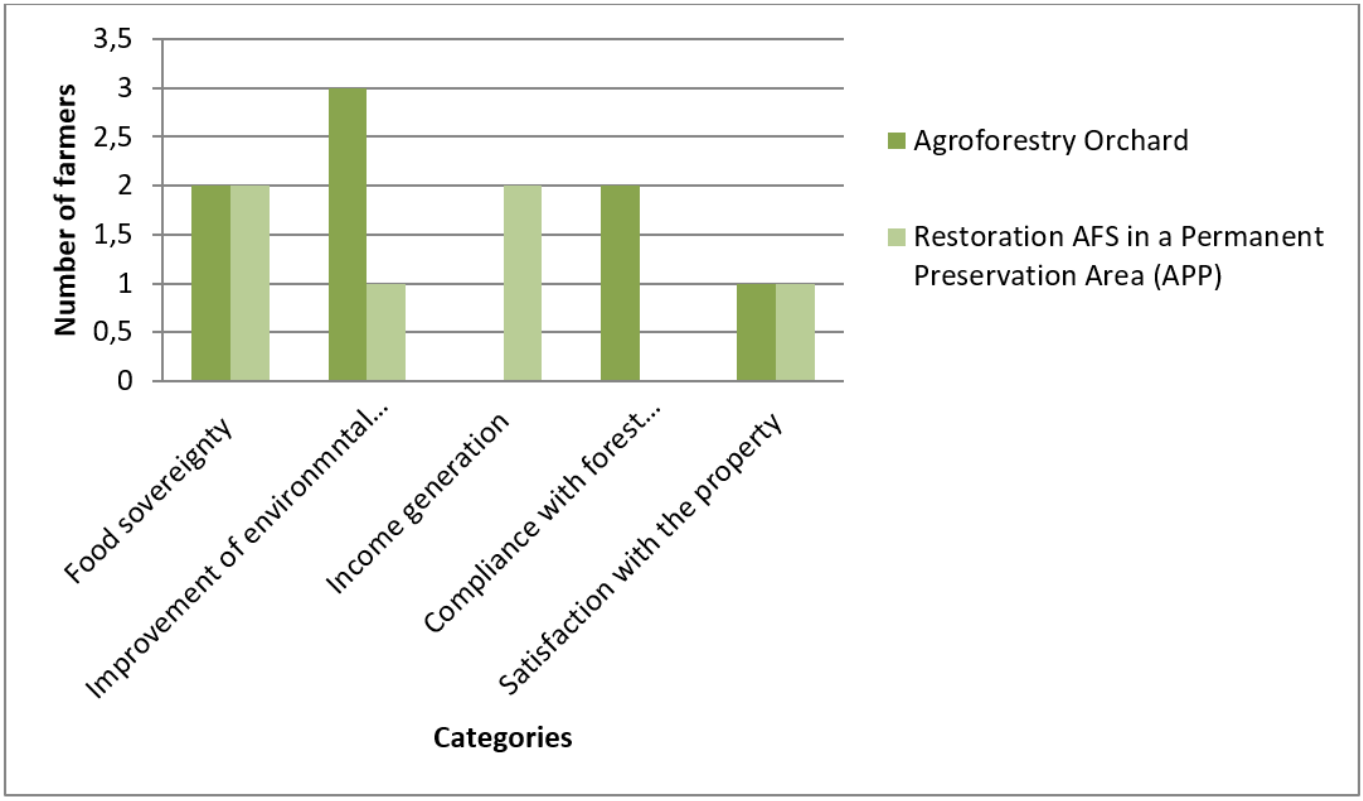
Regarding the "Improvement of environmental conditions" category, the aspects mentioned included improved air quality, increased water quantity and quality in springs and watercourses within APPs, and improved soil fertility.

Farmers also identified food sovereignty as a benefit of these systems, emphasizing household consumption of AFS products and knowledge of the origin of their food. In their view, one of the main advantages of maintaining a biodiverse agroforestry system on their properties is its contribution to meeting household food needs. They also emphasized the importance of knowing how their food is produced and, consequently, being able to assess its quality and safety. As interviewee E5 stated: "The advantage is knowing where what we eat comes from, right? [Knowing] that it is healthy food, that we don't use pesticides, that it's organic – thinking about our health; that's it".

In the study region, farmers also reported hosting family members during this period or sending food from rural areas to relatives living in urban areas, thereby contributing to household and family food security.

Figure 5

Advantages and benefits of AFSs for farming families during the COVID-19 pandemic, according to AFS category: agroforestry orchards and restoration AFSs in Permanent Preservation Areas (APPs).



Within the "Income generation" category, the subcategory "Marketing of AFS products" was identified. New marketing channels emerged during the pandemic because farmers' markets in the region were temporarily suspended due to social distancing measures. In response, farming families used the Solidarity Organization System (SISCOS), promoted and organized by the IOV, to market their products. According to some farmers, SISCOS was particularly important during this period of uncertainty:

> […] besides having food for us, there was also enough for my daughters to take with them, because things were tough out there, you know? And we didn't stop dreaming, producing, or selling, right? Because when the PAA ended, SISCOS stepped in. I think the period when we sold the most through SISCOS was during the pandemic. We produced without fear because we knew we would be able to sell". (E8)

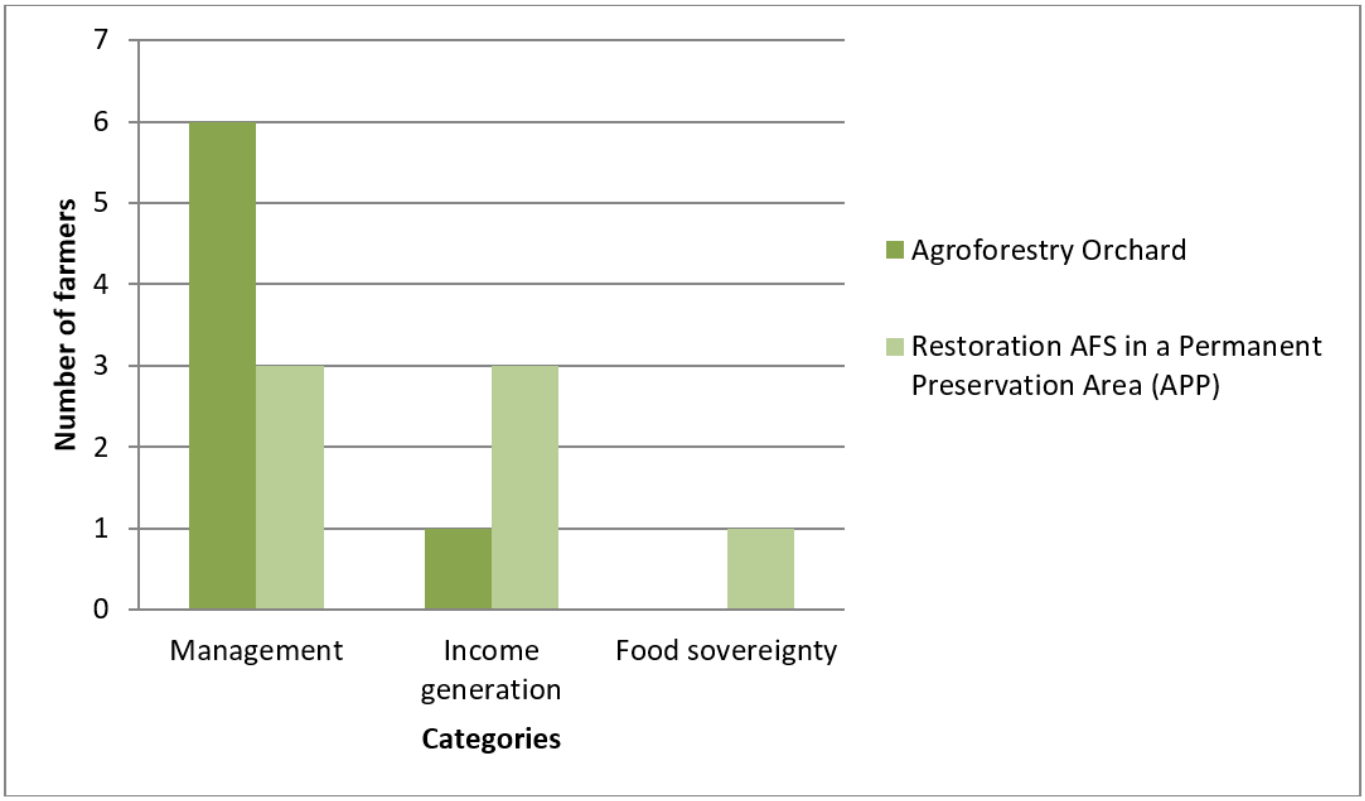
In the "Satisfaction with the property" category, farmers described their agroforestry systems as spaces for leisure and relaxation, rather than solely as areas for food production. For them, these systems also provided opportunities for recreation and tranquility, as reflected in the interviewees' comments: "[…] because here, many things serve as entertainment, right?" (E9) and "It's a good place, a peaceful place, isn't it?" (E12).

3.5. Challenges associated with agroforestry systems (AFSs) during the pandemic

Three categories were identified for this theme: "Income generation" ($n = 4$), "Management" ($n = 9$), and "Food sovereignty" ($n = 1$) (Figure 6). Three

Figure 6

Challenges associated with AFSs for farming families during the COVID-19 pandemic, according to AFS category: agroforestry orchards and restoration AFSs in Permanent Preservation Areas (APPs).



respondents reported no challenges or difficulties related to the AFSs implemented on their properties during the pandemic.

Within the "Income generation" category, farmers reported difficulties in marketing products derived from AFSs. Most interviewees had more than one source of income on their properties, including dairy farming and monoculture production, which provided easier access to established markets. This scenario highlights the persistence of production logic driven by agricultural specialization and conventional marketing chains. According to Balem and Silveira (2015), this process contributes to the homogenization of food systems and the erosion of food culture by discouraging diversified production practices aimed at strengthening the food autonomy of rural families.

Interviewees also identified other challenges related to the "Income generation" category, particularly a lack of financial resources for investment and improvements to the systems, as well as difficulties in accessing rural credit and public policies.

Within the "Management" category, interviewees discussed difficulties associated with management practices, including limited access to technologies, weed control, and damage caused by wild animals.

Another challenge concerned labor availability, which farmers associated with rural-to-urban migration. On the properties visited, management activities were generally conducted by one or, at most, two people. Collective work activities ("mutirões") were no longer organized within the communities, making management particularly labor-intensive. Farmers also reported insufficient financial resources to hire outside labor. Some participants identified the size of the area as a limiting factor. According to these farmers, expanding AFSs would require larger areas, which would increase both management demands and investment costs. In addition, the total area of some properties was considered insufficient for establishing new AFSs because farmers prioritized land for livestock production, particularly pastures, which occupied a substantial portion of the properties visited.

The production strategies observed may also be related to the socio-territorial trajectories of the settled families. In an analysis of agrarian reform settlements in Rio Grande do Sul, Sulzbacher (2015) highlights how the livestock tradition and predominance of pastures in the southern half of the state influence the socioeconomic integration of settlements and the land-use practices adopted by families.

Given that a substantial proportion of the interviewees originated from Rio Grande do Sul, this background may, on the one hand, help explain the prioritization of land for livestock production over the expansion of AFSs. On the other hand, Malmann and Bolter (2015), in their study of settlements in the northern half of the state, highlight experiences characterized by production diversification and the adoption of agroecological practices,

demonstrating how different socio-territorial contexts can influence the production strategies developed by settled families.

Within the "Food sovereignty" category, one farmer reported difficulties in dedicating sufficient time and effort to food production on the property because of health-related limitations. On properties where planting, management, and harvesting depend on only one or, at most, two family members, illness can substantially disrupt production activities, an especially relevant concern during a pandemic. This account highlights participants' concern with maintaining production systems capable of providing food for household consumption.

4. Discussion

The COVID-19 pandemic affected various sectors of agriculture. Disruptions to agricultural supply chains were a major concern, given the heavy dependence of conventional agriculture on chemical fertilizers, pesticides, and seeds. These disruptions increased input costs because of high demand and limited availability, creating additional production challenges for farmers (Rukasha et al., 2021). For family farmers, the situation was further aggravated by limited access to these inputs due to their low purchasing power.

In the Portal da Amazônia region, most of the farmers interviewed had already adopted alternative methods of fertilization and pest and disease management before the COVID-19 shock. Those who had not previously used such methods began considering them in response to rising input prices. The presence of biodiverse agroforestry systems (AFSs) on their properties facilitated this transition. These systems provided organic material that could be used for soil cover and fertilization and, through greater species diversity, could favor natural biological control and reduce pest pressure.

The substitution of chemical agricultural inputs with organic fertilizers and the adoption of production strategies aimed at reducing input costs were reported in several locations during the pandemic (Siddiqui et al., 2020; Thang et al., 2021; Landicho et al., 2024). Numerous studies have documented the lockdowns implemented to curb the spread of the virus and their effects on agri-food supply chains (Sharma et al., 2020; O'Brien, 2020; Middendorf et al., 2021; Nakat & Bou-Mitri, 2021; Luque Zúñiga et al., 2021). Agri-food supply chains encompass food production, post-harvest activities, processing, distribution, transportation, and consumption. The pandemic exposed vulnerabilities, particularly in long supply chains, and raised concerns about food security (Barman et al., 2021).

According to Kumar and Singh (2022), reduced food accessibility and availability were major concerns resulting from restrictions on movement and transportation.

In the study region, some settlements are located up to 100 km from the nearest urban market. Transportation constraints affect both the movement of agricultural products to markets and the delivery of agricultural inputs, challenges that this rural population had already faced before the pandemic. Against this backdrop, family farmers and civil society organizations have developed and coordinated short food supply chain strategies, such as SISCOS, to market their products, including those produced in agroforestry systems.

These marketing systems provide greater security by increasing the likelihood that products will be sold, an aspect of particular importance for family farming. This is especially relevant because production risks in this sector are generally high due to both environmental and economic factors, including extreme weather events and fluctuations in market prices and the cost of external input.

In biodiverse production systems, such as agroforestry, risks may be lower because of reduced expenditure on external inputs for fertilization and pest and disease management. Greater biodiversity can enhance system resilience and promote internal nutrient cycling, thereby reducing dependence on external inputs (Gliessman, 2014).

Alternative marketing strategies have also been reported in other regions (Kolodinsky et al., 2020; Fardkhales & Lincoln, 2021; Levidow et al., 2022). Notably, Bui et al. (2021) identified economic, social, and environmental benefits associated with short food supply chains among family farming communities in Vietnam. During the COVID-19 pandemic, the authors observed increased adoption of this marketing model among farmers. This shift was also accompanied by growing interest in organic production and in production systems with lower dependence on synthetic agricultural inputs. According to the authors, these changes also contributed to improvements in local environmental conditions, particularly through reductions in soil and water contamination associated with pesticide and synthetic fertilizer use. In the area covered by the present study, however, practices and strategies related to community organization around agroforestry production were already in place before the pandemic and were further strengthened during this period.

Farmers interviewed in the Portal da Amazônia region highlighted the importance of agroforestry systems (AFSs) for income generation and food security among participating families. Moreover, the range of activities involved in managing these systems has integrated AFSs into the families' daily routines. Through the agroforestry systems established on their properties, interviewees cultivate a wide diversity of plant species.

The pandemic indeed affected food security worldwide, with particularly severe consequences for vulnerable populations (Stephens et al., 2020). Certain strategies proved important for coping with these challenges in the context of family farming. According to Maraseni et

al. (2022), agroforestry practices represent an important alternative for supporting rural livelihoods during the pandemic, a finding consistent with the results of the present study.

In contrast, other studies have reported challenges faced by agroforestry farmers, particularly difficulties in marketing their products associated with declining prices during the pandemic (Pieter et al., 2022). This problem was less pronounced in the study area, however, because alternative marketing strategies had already been established in the region before the health crisis.

Landicho et al. (2024) reported that the agricultural income of agroforestry farmers was affected by the pandemic. In response to declining agricultural income, farmers relied on agroforestry systems for household consumption, which helped support their food security. This experience also increased farmers' awareness of the importance of crop diversification during the pandemic.

The farmers interviewed identified agroforestry system (AFS) management as a major challenge during this period. These difficulties were compounded by limited access to credit and public policies, which may have constrained further investment in these areas, particularly in the acquisition of machinery and product processing.

Some farmers reported no challenges related to their AFSs during the pandemic. This finding may be interpreted in three distinct ways. First, these farmers may have prioritized other agricultural or livestock activities, leaving the AFSs in a secondary position within the economic activities of the property. Second, the systems may have required less maintenance because they were already well established, approximately 10 years after implementation. As a result, farmers may have perceived more benefits than difficulties associated with these systems or may not have readily identified specific management challenges. Third, the challenges they faced may have remained relatively unchanged during the pandemic. In other words, these difficulties may have been similar to those experienced in the pre-pandemic period, given that family farming in the region has long been exposed to a range of environmental, social, and economic shocks.

The agricultural sector was indeed negatively affected by the pandemic; however, family farming in the region had already faced numerous challenges and had developed adaptation strategies over time, such as using on-farm inputs for fertilization, diversifying crops, and adopting other management practices. In this context, it is understandable that some farmers did not perceive specific challenges arising directly from the pandemic.

5. Conclusion

Family farming in the study region has a long history of coping with economic, social, and environmental shocks. Agroforestry systems (AFSs)

implemented with the support of civil society organizations, together with the various initiatives associated with these projects, played a key role in strengthening the socioecological resilience of local family farming systems. The COVID-19 pandemic therefore affected a context that was already vulnerable, exacerbating pre-existing challenges.

The emergence of innovative marketing channels and the production diversification enabled by AFSs served as resilience strategies in the region, helping to support household food security during this period. Interviewees also emphasized concerns related to livelihoods and food autonomy, reflecting the importance of food sovereignty for farming families. In this context, AFSs emerged as an important production strategy.

Thus, AFSs represent an alternative to more conventional family farming production models. In addition to their environmental benefits, they can contribute to income generation and food security for farming families, as demonstrated by the biodiverse AFSs implemented in different settings across the study region. Government incentives and public policies are essential to support the implementation, management, and long-term maintenance of these systems in rural communities. Such measures are particularly important in areas vulnerable to multiple shocks, including those associated with climate change and economic or public health crises, such as the COVID-19 pandemic.

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