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Cultivating sustainability: challenges and opportunities in agroforestry systems of the Pampa biome

Cultivando sustentabilidade: desafios e oportunidades nas agroflorestas do bioma Pampa

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Abstract: This study aims to characterize agroforestry systems in the Brazilian Pampa Biome, highlighting their potential, weaknesses, demands, and limitations while considering their relevance to family farming as well as to environmental preservation and restoration. Although focused on the Pampa Biome, similar challenges are observed globally. Farmers express the need for dedicated markets for agroforestry products, greater social recognition, technical support, and access to rural credit. Among the main strengths of agroforestry systems are product diversity, enhanced quality of life, reduced dependence on conventional agricultural inputs, and environmental improvement. Targeted policies, even at the municipal level, have the potential to address a substantial portion of the challenges faced by agroforestry farmers.

Keywords: family farming; agroecology; agroforestry systems; SWOT matrix; environment; sustainability; rural extension.

Resumo: Este estudo visa caracterizar as agroflorestas do Bioma Pampa brasileiro, destacando suas potencialidades, fragilidades, demandas e limitações, considerando sua relevância para a agricultura familiar e a preservação e restauração ambiental. Embora focado no Bioma Pampa, observa-se que desafios semelhantes são enfrentados globalmente. Os agricultores manifestam a necessidade de mercados específicos para produtos agroflorestais, reconhecimento social, apoio técnico e crédito rural. Entre as principais forças das agroflorestas, destacam-se a diversidade de produtos, a qualidade de vida proporcionada, a independência de insumos agrícolas convencionais e a melhoria ambiental. Políticas específicas, mesmo em nível municipal, têm o potencial de solucionar grande parte dos problemas enfrentados pelos agricultores agroflorestais.

Palavras-chave: agricultura familiar; agroecologia; sistema agroflorestal; matriz FOFA; meio ambiente; sustentabilidade; extensão rural.

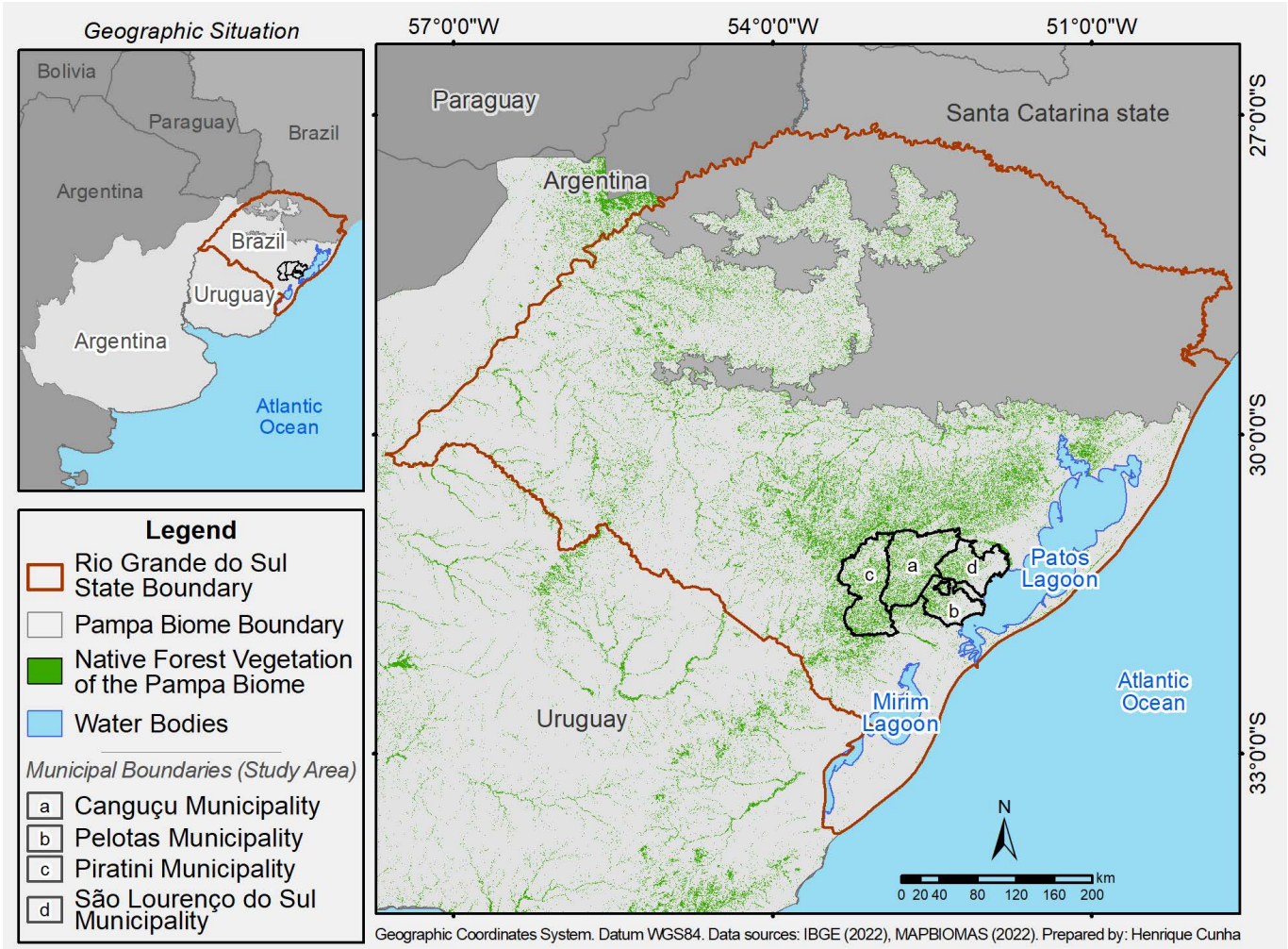
1. Introduction

Brazil is a territorially large country, the fifth largest in the world in area, occupying 47% of South America; however, it presents markedly distinct climatic conditions across its regions. In the South of the country, a subtropical climate predominates, in which the seasons are well defined, with no dry period, hot summers and cold winters, marked by polar fronts and sub-zero temperatures, and it may even snow in some places. In the far

south of the country lies the Pampa Biome (Figure 1), which occupies – in addition to Uruguay and part of Argentina – 2% of the Brazilian national territory, covering 63% of the state of Rio Grande do Sul. This region is characterized by plains with gently or slightly undulating topography, with a predominance of native grasslands, where shrub formations, forests, and woodland patches (*capões*) occur. In Brazil, the vegetation types of the Pampa Biome are classified as Semideciduous Seasonal Forest, Deciduous Seasonal Forest, and Areas of Pioneer Formations (*Restingas* and alluvial areas); that is, the Pampa is not made up of grassland alone (Instituto Brasileiro de Geografia e Estatística [IBGE], 2008).

The largest concentration of forest area in the Brazilian Pampa occurs in the Serra dos Tapes (Figure 1), where Indigenous peoples lived during the pre-Columbian period and where Portuguese, Spanish, German, French, Italian, and African settlers later arrived. This colonization process resulted in a landscape mostly occupied by family agricultural production units, where the use of the family's own labor predominates in economic activities (Salamoni et al., 2021). Currently, the Semideciduous Seasonal Forest, which before the arrival of European immigrants covered practically the entire Southeastern Slope (Encosta do Sudeste), is reduced to fragments

Figure 1
Location map of the study area



with varying degrees of disturbance embedded within small agricultural production units.

Because the characteristics of this region differ greatly from the rest of Brazil, agriculture must be approached in a particular way. The state of Rio Grande do Sul (RS) itself is divided between the Atlantic Forest and the Pampa, and thus not everything that is good or productive in the northern half will yield the same response in the southern half, since these are different environments that may respond distinctly when subjected to the same forms of agriculture. The southern half of RS has a fragile economy compared with the other half of the state, since for decades it depended almost exclusively on livestock farming and rice production (Salamoni et al., 2021).

Felipe et al. (2023) present a general overview of agroforestry throughout Brazil and highlight that Agroecological Agroforestry Systems (AFS) in Brazil exhibit distinct trajectories and characteristics according to the country's regions. In the Amazon, these systems have ancestral roots, integrating traditional Indigenous and colonial practices that promote diversity, environmental resilience, and food security. In the Northeast, they stand out for their capacity to adapt to conditions of water scarcity and climate change, favoring diversified family production. In the Center-West, AFS gain strength in rural settlements and traditional communities, also incorporating syntropic agriculture. In the Southeast, they range from biodiverse urban home gardens to complex agroforestry systems on family landholdings, supported by social movements and universities. In the South, initiatives seek to value native species and local practices, strengthened by coordination among farmers, institutions, and public policies – such as agroforestry certification in Rio Grande do Sul, which provides technical and legal support to producers, consolidating AFS as a strategy for conservation, sustainable production, and regional cultural strengthening.

About 50% of Brazil's native vegetation occurs on private properties. The native forests and savannas on these lands store billions of tons of CO2 and play a vital role in maintaining a wide range of ecosystem services. Therefore, the proper management of these private landscapes is critical to the success of global efforts to mitigate climate change (Soares-Filho et al., 2014). In accordance with the Native Vegetation Protection Law (Lei nº 12.651, 2012), agroforestry emerges as an attractive alternative for family farmers who have the possibility of bringing their properties into environmental compliance while also obtaining direct economic benefits

from their Permanent Preservation Areas (APP)[1] and Legal Reserve[2] (*Lei nº 12.651*, 2012).

However, when creating agroforestry systems in the Pampa, one cannot reproduce the agroforestry models developed in other parts of Brazil, in regions close to the tropics. The species intercropped in those regions do not always adapt to the local climate. Being aware that restoring is more expensive than conserving, the need becomes evident for public policies that encourage the profitability of more efficient and sustainable production systems – systems that make it possible to integrate grassland and forest ecosystems while at the same time burdening and limiting the expansion of production systems that degrade natural resources. Therefore, given the importance of agroforestry for family farming and for environmental preservation and restoration, this study aims to characterize the agroforestry systems of forest areas of the Pampa Biome, discussing their strengths and weaknesses, demands, and limitations.

2. Materials and Methods

Traditional knowledge related to the forest is fundamental to sustainable forest management. In this regard, we sought to characterize and to understand the limiting factors, demands, and strengths of the agroforestry systems of southern Brazil, from the perspective of five rural extension agents who are enthusiasts of agroforestry implementation and ten farming families with agroforestry experience in the Pampa Biome. The analyses are conducted holistically and without in-depth theoretical treatment of the topics addressed, with the aim of presenting these points so that they may be addressed more incisively in the future.

2.1. Research site

The study was carried out in the Serra dos Tapes, in the municipalities of Canguçu, Pelotas, Piratini, and São Lourenço do Sul, in the south of Rio Grande do Sul. These municipalities are located within the Pampa Biome, in the region where the Semideciduous Seasonal Forest occurs (Figure 1).

1 Permanent Preservation Area: a protected area, whether or not covered by native vegetation, whose function is to preserve water resources, the landscape, geological stability, and biodiversity, to facilitate the gene flow of fauna and flora, to protect the soil, and to ensure the well-being of human populations (*Lei nº 12.651*, 2012).

2 Legal Reserve: an area within a rural property whose function is to ensure the economic and sustainable use of the property's natural resources; to promote the conservation and rehabilitation of ecological processes and biodiversity, and to shelter and protect wild fauna and native flora (*Lei nº 12.651*, 2012).

2.2. Interviews

The present work began with contact and interviews with rural extension agents from the Empresa de Assistência Técnica e Extensão Rural (Emater) and the Associação Sulina de Crédito e Assistência Rural (Ascar), Emater-Ascar/RS, who subsequently indicated farmers in the region engaged in agroforestry production. These farmers indicated other farmers, following the precepts of the snowball technique (Goodman, 1961). Semi-structured interviews were administered to those who agreed to participate in the research and signed the Free and Informed Consent Form (TCLE). A voice recorder and written notes were used to record the interviews.

The interviews were divided into two stages: i) doubts and ii) demands. In the first stage, the farming families and the extension agents were asked about their main doubts concerning agroforestry. For the farmers, the doubts were raised throughout the conversation. The extension agents, in turn, were asked directly what their main doubts regarding the topic were. The reported doubts were transcribed and listed in an Excel spreadsheet and subsequently grouped into three categories:

1 – Establishment, design (*croqui*), and management;

2 – administration and legislation; and

3 – concept of the Agroforestry System (AFS).

In the second stage, demands, the farming families and the extension agents were asked about their main demands regarding agroforestry. For the farmers, the demands were raised throughout the conversation, and the extension agents were asked directly what the main demands they had identified for the development of agroforestry in the region were. The reported demands were transcribed, listed in an Excel spreadsheet, and subsequently discussed. This totaled 15 interviews: ten with farmers, who are identified in the order in which the interviews were conducted as Family 1; Family 2 ... Family 10; and five with extension agents, identified in the order in which the interviews were conducted as Ext. 1 ... Ext. 5.

2.3. SWOT matrix

The information obtained in the interviews was analyzed and organized in the format of the SWOT matrix (Strengths, Weaknesses, Opportunities, and Threats). This instrument, widely used in the field of planning and management, facilitates the systematization and visualization of the strengths (Strengths and Opportunities) and the fragilities (Weaknesses and Threats) of a social collective, allowing the assessment of its structure, performance, and/or contexts, since it distinguishes what is internal (Strengths and Weaknesses) – and over which there is governability – from what is external (Opportunities and Threats), whose characteristics and particularities need to be identified (Gomide et al., 2015). Based on the interviewees' narratives, the authors highlight these points, not in order of importance.

3. Results and Discussion

The families interviewed indicated that up to four people, including adults and children, reside on the same property. The production units have an area of between three and twenty-four hectares, of which, on average, 30% of the space is dedicated to agroforestry. Two families sell their products at farmers' markets, another two process their products in their own agro-industries, and the remainder produce for self-consumption, selling only the surplus.

Research on agroforestry in the Pampa Biome began in 2010 (Cardoso et al., 2018). However, ensuring the family's livelihood from the resources derived from agroforestry is a reality experienced by few farmers in the Brazilian Pampa (Henzel et al., 2021). There are numerous doubts and limitations that hinder agroforestry development in the region.

3.1. Main doubts regarding Agroforestry Systems

When asked about their main doubts regarding agroforestry, the farmers raise questions related to the choice of species, mainly concerning the relationship among these plants when intercropped.

> *I don't know which plants adapt to the shading conditions beneath those that are already more grown. Which plants are friends and which do not get along so well... I wanted to let the AFS advance, and then I keep asking myself which plants I can put there (Family 1).*

Management also raises doubts among farmers my doubts are about the pruning season, perhaps, the first treatments that have to be carried out in the first years... what is the correct type of cut (Family 9).

The farmers show uncertainty regarding the concept of the Agroforestry System, an issue that may be related to the area converted into agroforestry, as evidenced in statements such as *We don't know whether this, whether this system I made here is an agroforest. Down below there is an agroforest, but up here I'm not sure.* (Family 4) or related to the choice of species

> *we don't know whether this, whether this system I made here is an agroforest... because I think an agroforest is native and fruit species that will give you a return. I'm afraid that in the future a group of people will come and look and 'ahh this here is not an AFS'; we know we are doing something wrong (Family 4).*

The extension agents present doubts about implementation, *How do we begin?* (Ext. 1); about legislation, *my main doubt today would be the legislation. I am not familiar with AFS legislation* (Ext. 2). With respect to the administration of agroforestry systems, the extension agents express doubts related to implementation costs and financial return, as evidenced in phrases such as *What return will the farmer get?* (Ext. 1).

It is evident that practically the same doubts that afflict the farmers are also cited by the rural extension agents (Figure 2). With respect to

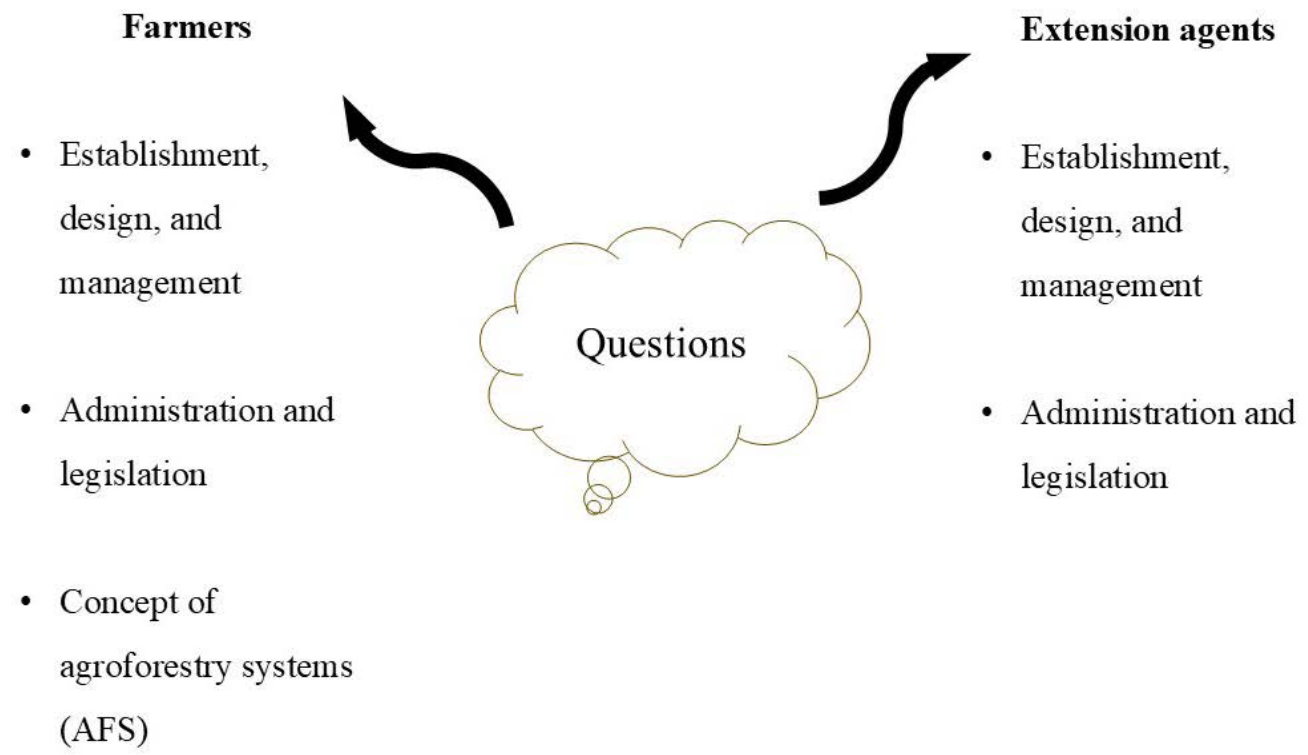


Figure 2
Cognitive map representing the doubts expressed by farmers and rural extension agents in the Brazilian Pampa Biome

establishment, design, and management, the farmers present doubts about the choice of species for composing the agroforestry systems; in this regard, questions arise such as which plants adapt to shading conditions, which plants establish a favorable symbiotic relationship and which are incompatible when cultivated together, and which species will perform well in agroforestry systems at this location, including exotic ones. The extension agents, in turn, have doubts about which forest and fruit varieties to recommend for planting and which species serve a cover function.

Within the broad concept of agroforestry (Nair, 1985), biodiverse successional agroforestry systems (Miccolis et al., 2016) are those that most closely resemble natural ecosystems in terms of biodiversity conservation and the provision of environmental services. They are therefore recommended for the recovery of degraded forest landscapes and as an ecologically sound agricultural model (Santos et al., 2019). However, the high species diversity and functional heterogeneity of these complex, successional, and biodiverse systems require intensive management, which implies the availability of labor as the main input and a great deal of knowledge about management practices (Miccolis et al., 2019).

Most agroforestry experiences in Brazil occur in tropical regions; therefore, the Pampa farmers who today dedicate themselves to agroforestry are pioneers, since the models developed in other biomes are not a reference for the agroforestry systems of southern Brazil. After all, species respond in different ways to the climate and soil in which they develop. The cold temperatures of the *gaúcho* winter require other types of management.

> *At the beginning of the AFS I also had to put a bag over the seedling because of the frost. So, when it rained during the day and the night improved, it would frost even more, and then the water in the soil would freeze and kill all the plants; even so, some plants died because the wind tore off the bag. I spent two years doing this (Family 7).*

The Pampa lies entirely within the subtropical climate zone and is therefore subject to major climatic variations, including the occurrence of frost. It is known that temperature is one of the main factors influencing the establishment of forest species in the field and that the occurrence of frosts represents an important constraint on the trajectory and continuity of ecological processes; moreover, it is important to use species native to the region, especially because the native vegetation of the Pampa is the most threatened and least protected on the American continent and has been undergoing changes in land cover and land use at alarming levels (MapBiomas, 2023). In this regard, studies are needed on the management and intercropping of these native species with other species, identifying the viable arrangements (Turchetto, 2020).

Farmers demand answers, instruction, and consultancy, and this assistance is normally provided by rural extension; however, in the case of Pampa agroforestry, the extension agents present the same concerns, doubts, and insecurities as the farmers. Research in the region is very recent, so the technicians have little material to guide them. Some information is obtained through experiences from other locations, such as the Cerrado (Martinelli et al., 2019; Miccolis et al., 2019); the Atlantic Forest (Santos et al., 2019); the Caatinga (Miccolis et al., 2019); and the Amazon (Rodríguez, 2021). However, agroforestry models for the Pampa Biome are still scarce (Soares et al., 2020; Bierhals et al., 2020).

The farmer is afraid of making mistakes, losing time, money, and land, while the extension agents do not feel confident and have neither the tools nor sufficient technical knowledge about agroforestry to provide guidance. Although agroforestry systems have been developed by traditional populations throughout history (Cunha et al., 2021), today, in the face of the simplification of monoculture agriculture and dependence on agrochemicals, managing biodiverse systems has become a novelty that leaves the farmer insecure (Shiva, 2018). In light of these issues, the importance of tools that assist technicians and farmers in choosing species for the restoration of native vegetation in different biomes, in a correct and simple manner, is emphasized. One example of a digital tool to support farmers and rural extension agents in selecting species for agroforestry implementation is the WebAmbiente platform, an interactive information system whose function is to provide the list of recommended plant species according to the particularities of each location in Brazil and to assist decision-making in the process of environmental adaptation of the rural landscape (Embrapa, s.d.).

Agroforestry sketches (croquis) can serve as a model for other farmers interested in producing fruits from native species in the Pampa (Soares et al., 2020). However, it is essential that the system be adapted in advance according to the families' objectives, since the farmers desire not only financial return but also healthy food, ecological restoration, and living in an environment with a pleasant landscape (Henzel et al., 2021).

Owing to a lack of knowledge of the current environmental legislation, farmers in the initial process of conversion and less experienced extension agents claim to feel fear and insecurity regarding the management of native species. They also claim not to know how to proceed with the documentation. In this sense, the Native Vegetation Protection Law (Lei nº 12.651/12, popularly known as the New Brazilian Forest Code) establishes rules for the protection of native vegetation combined with sustainable agricultural production; that is, it not only sets limits on productive activities in the rural environment but also promotes opportunities for farmers to benefit from the natural resources present on their properties, exploiting native vegetation in a sustainable manner and enabling the productive use of the land and the preservation of water, soil, and vegetation (*Lei nº 12.651*, 2012).

In an innovative way, the *Secretaria do Meio Ambiente e Infraestrutura do Rio Grande do Sul* (SEMA) has shown itself to be a partner of the agroforestry farmer, and this rapprochement is considered very important by the farmers. Those who adopted the model longer ago and whose agroforestry systems are certified today feel proud and satisfied with the support of the environmental agencies. In this sense, the importance of acting through partnerships, and not only in the form of command/control, is emphasized.

With respect to administration, farmers and extension agents report being unable to make projections of costs and financial return. Because it is an unstable market, with high diversification and no specific industry to which they can direct the sale of their products – as occurs with tobacco, soybeans, and milk, which are considered easy to project in terms of short- and long-term returns – the quantifications and projections for products of agroforestry origin become more complex. In agroforestry, this will depend on the diversity, the processes, the logistics, and the farmer's objectives.

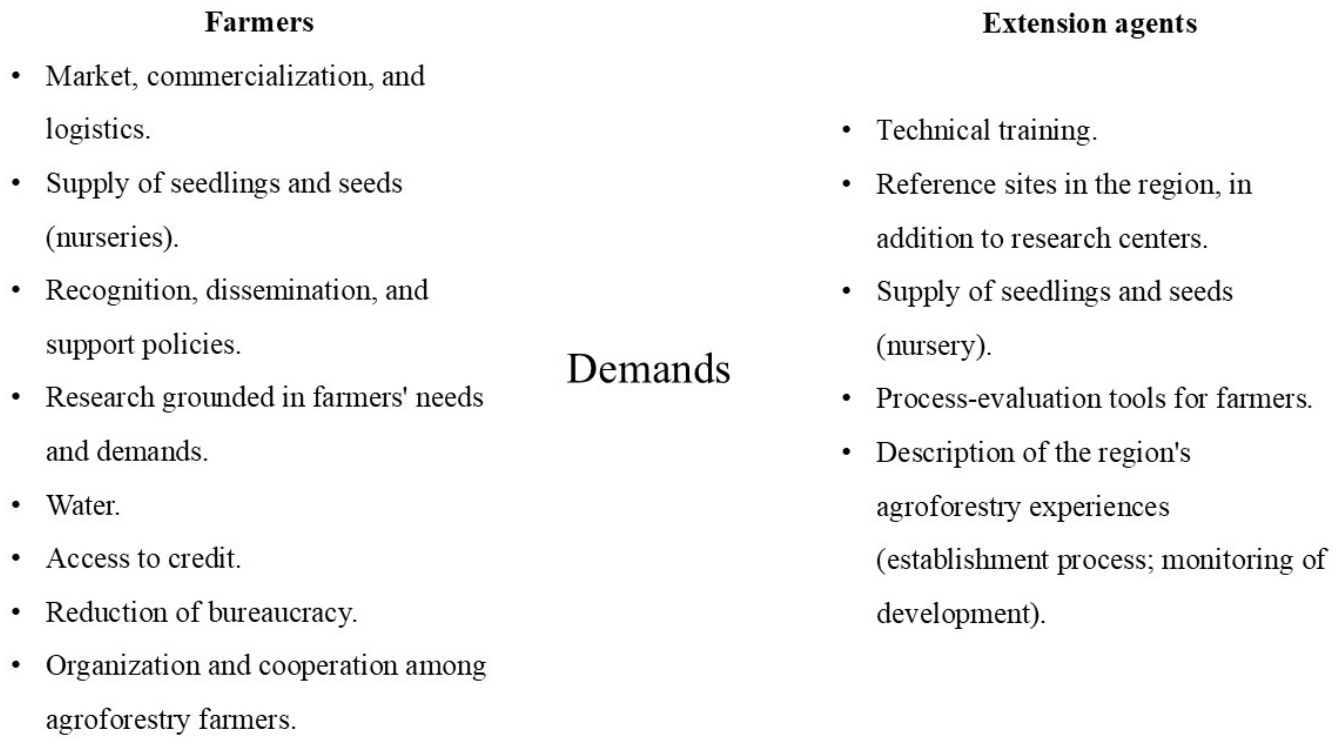
Regarding the concept of the Agroforestry System (AFS), the farmers raise questions such as: Is what I did an agroforest? Is there a minimum limit of size and diversity to be considered an agroforest? On this point, the extension agents did not present doubts. Defining an AFS is a complex task, because it depends on the concept one has of a forest. Silviculture appropriated the term forests, using it to name tree monocultures. It is not appropriate to discuss this issue here; however, the inadequate use of the term may end up generating confusion. Nair (1985) states that it is possible to classify and group Agroforestry Systems using as criteria the structure of the system (composition and arrangement of components),

function, socioeconomic scale, level of management, and/or ecological distribution. However, he emphasizes that each of these criteria has merits and applicability in specific situations, but also limitations, so that no classification scheme can be accepted as universally applicable. Sinclair (1999), in turn, proposes the use of the term 'agroforestry practice' instead of 'agroforestry system' as the unit of classification, focusing on forms of land use. And Torquebiau (2000) writes that the term 'agroforest' only makes sense for the category of agrosilviculture in which the tree component is dense and mixed, with different strata, and, in addition, the crop component must be diverse; otherwise, the association will bear no resemblance to a forest, and therefore the use of the term is not appropriate. In the interviews, two farmers felt uncomfortable with this. In their statements they reiterated the need for greater clarity in the definition. They did not know whether what they were building could be called an agroforest. They feel hesitant to use the term agroforestry. They questioned how diverse the planting needs to be in order to be considered an agroforest. This insecurity is intensified when one intends to introduce agroforestry into Permanent Preservation Areas (APP) or Legal Reserve.

3.2. Main demands regarding agroforestry systems

The demands are diverse, both on the part of the farmers and of the extension agents (Figure 3).

Figure 3
Representation of the demands expressed by farmers and rural extension agents in the Brazilian Pampa Biome



The families call for improvements to rural roads, for means of transport that make it possible to bring products to consumers, but mainly for a consumer market. The farmers report the need to create municipal markets specifically for agroforestry products, as well as the creation and maintenance of a market share exclusively for agroforestry products destined for school meals. It is necessary to organize the market and the logistics so that the agroforestry farmer can fulfill their role. After all, they report having nowhere to sell their products. The conventional market does not serve them; it does not value the origin and form of production, much less the environmental service they provide. Since legal certification already exists, granted by SEMA (Rio Grande do Sul, 2024), why not create a market specifically intended for agroforestry production? Schneider et al. (2016) point to nested markets as a strategy for rural development. According to these authors, nested markets need to be associated with, or continuously coexisting with, broader agri-food markets, yet rooted in a social network and in a set of social norms, rules, and conventions that allow their distinction. In this sense, nested markets allow greater resilience and autonomy of farmers vis-à-vis conventional markets and their forms of management, regulations, and global standards of food production, commercialization, and consumption.

The families report difficulty in buying and finding seedlings and seeds of species of agroforestry interest. The importance of municipalities maintaining a forest nursery where farmers can meet this demand is emphasized. In the municipality of Piratini (RS), the nursery already exists and stands out for its potential for seed collection, seedling production, and appropriate planting and management information. In addition, it is a space for the production of scientific-practical knowledge and for the exchange of seeds and seedlings, knowledge, and experiences (Henzel et al., 2022). The extension agents highlight the necessary establishment of nurseries for seedlings and seeds of species of agroforestry interest, mainly native species.

The lack of knowledge on the part of society about agroforestry is notable. In this sense, the media has a very important role to play, helping to raise awareness of the consumer's role and of the benefits of agroforestry agriculture.

> *When we started, the neighbors around us would say, 'this is for crazy people,' 'you're going to waste your time, you're working for nothing.' Now they have already changed their opinion; in fact, people do not know about it, so publicizing this is a very interesting thing. Because when you say that Embrapa and Emater are taking part, people already believe a little more (Family 5).*

The interviewees talk about how advantageous it would be if this type of dissemination existed, especially in this region, where agroforestry systems are still few. They emphasize the importance of promoting courses and

lectures on the subject so that other farmers become acquainted with it. In addition, consumers would become aware of the differentiated form of production, and this adds value to the products. Once again, the need for specific markets, combined with dissemination in the media, is emphasized.

The farmers also complain about the sanitary legislation, which in some cases becomes an obstacle when commercializing agroforestry products, especially those of animal origin, such as eggs and honey.

> *There is so much bureaucracy to sell that people opt for easier things like tobacco. To sell tobacco, the buyer comes to your house, whereas to sell 1 kg of honey we have to take it to the city, and if they catch you with 10 jars of honey you are incriminated as if you were a criminal. So it is quite complicated (Family 4).*

Bureaucracy is another limiting aspect, as it prevents access to credit. Although in theory there are specific credit programs for sustainable agroforestry systems (Banco do Brasil, 2024), the farmers report their inaccessibility. They relate the difficulty to the bank's lack of interest, since the process is more bureaucratic and different from what is done for agribusiness.

It is worth reflecting on the urgent need to foster public policies that finance sustainable agriculture initiatives. Between April and May 2024, Rio Grande do Sul suffered the largest climate disaster ever recorded in the state, which affected 298 of the 497 municipalities of Rio Grande do Sul; hundreds of people died and thousands were left homeless (Fonseca et al., 2024). Specialists relate these phenomena to climate change arising from global warming and warn of an increase in the frequency of climatic events of these proportions in the coming years, noting that of the four largest floods recorded in RS, three occurred between 2023 and 2024 (Ministério da Ciência, Tecnologia e Inovação, 2024). In this sense, encouraging and financing the development of more resilient agricultural systems with lower environmental impact, such as agroforestry systems, is a fundamental and urgent measure.

The farmers express the need for research that addresses their specific demands and ask that such studies be guided by their own realities and needs, rather than being driven by the market or by industry. It is mentioned that most of the research and technologies developed for agriculture come *from the top down* (Family 1); that is, from the needs of industry, without truly helping the producer. The farmers demand projects built from them, from what they need. The extension agents, in turn, demand technical training, such as courses, practical activities, and visits that qualify them to guide the farmers who wish to establish agroforestry systems. They also point to the need to create reference units in agroforestry in the region, in addition to research centers: agricultural units, managed by farmers, where technicians can take other farmers for technical visits. And the production of a document reporting the agroforestry experiences of the Pampa Biome

to serve as a guide for those who wish to "agroforest". They also call for the establishment of indicators for the assessment and monitoring of agroforestry systems, created in a participatory way by the actors involved with agroforestry, so that the extension agents, in the face of the dimensional complexity these systems reach, can assist beginning farmers.

Although in the South region the rains are regular, weather adversities do occur. The farmers report the lack of irrigation as one of the greatest problems they face in establishing agroforestry systems. For this reason, they cite support for the construction of reservoirs and artesian wells as one of their main demands. Another aspect strongly emphasized concerns the importance of cooperation among the farmers themselves, considered by them fundamental to the advancement of agroforestry systems. This cooperation is demanded for commercialization; knowledge exchange; the exchange of seeds and seedlings; collective work efforts (*mutirões*) for management; and brand creation.

3.3. SWOT matrix – factors internal and external to the community

Based on the narratives, the strengths and weaknesses, as well as the opportunities and threats, for the agroforestry systems of the Pampa Biome are identified and presented in the form of a matrix (Figure 4).

Figure 4

SWOT matrix representing the strengths and weaknesses, as well as the opportunities and threats, for the agroforestry systems of the Pampa Biome

3.3.1. Strengths quadrant (internal factor)

Agroforestry provides farmers with the economic benefit of agriculture while at the same time helping with compliance with legal environmental requirements, since it can be implemented in Legal Reserve and APP. The farmers interviewed report improvements in soil quality resulting from the infiltration and temporary storage of water in the soil, which prevents erosion and leaching. In addition, tree barriers prevent wind erosion of soils by reducing wind speed and shading the land, conserving moisture (Carpanezzi, 2000). In the same sense, when the environment is healthy, the use of chemical inputs becomes unnecessary and is replaced by green manure. This is a point highlighted by the farmers, since one of the greatest liabilities of conventional agriculture concerns dependence on fertilizers and pesticides.

> *We haven't been in this AFS for long and it's going really well; when we pass by there and see those plants growing, it gives us pleasure, it gives another zest for life. And there you work, you don't work with any poison, so that part – no fertilizer is added – so in a short time you walk on the land and the soil is already so soft that you sink your feet in, and this was land where I used to plant corn, soybeans, and tobacco, but the land was not like it is now (Family 5).*

In the study region, soybean, tobacco, and peach crops predominate. However, investing in a single product generates greater risks for farmers, because the likelihood of weather adversities and market fluctuations can easily place the farmer in a situation of uncertainty and risk. Product diversity is one of the greatest advantages for those farmers who opt for agroforestry systems, since, in addition to expanding the diversity of food and raw material for the families' consumption, it enables income from different products, minimizing the risk of losses due to problems in the production or commercialization of a single product (Santin et al., 2024) – the reality of those who opt for monoculture. Moreover, when harvest staggering in the agroforestry systems is well planned, income flows in throughout the year, as does the distribution of the necessary labor.

Living in an aesthetically pleasant environment, in contact with nature, is the dream of many and the reality of few. The farmers cite quality of life as a decisive factor when opting for agroforestry systems. *In fact, all we want is to work for a better quality of life; the food we produce is primarily for our own consumption and for the family members who are in the cities* (Family 6). Agroforestry farmers of the Serra dos Tapes report that among the reasons that led them to choose to establish agroforestry systems on their properties is the quality of life it provides – because they want to live amid nature, to work in the shade, listening to the birdsong (Henzel et al., 2021).

Because what I really want is to stay in the middle of the woods, to live in the woods. The intention is to stay in the woods, and I myself am making the woods; it's what I like. And I think that's everything – I think that's good (Family 7). The study developed by Santos et al. (2024) draws attention to the human need for contact with nature. The authors report that during the COVID-19 pandemic people seek natural refuges in order to improve aspects related to stress, anxiety, and depression.

3.3.2. Weaknesses quadrant (internal factor)

If, on the one hand, diversity is an advantage, on the other it is a fragility. Monoculture generates high specialization on the part of farmers, focused on the performance of a single species. Managing a biodiverse agroforest is complex and demands a great deal of labor. Diversity also affects the logistical issue: agroforestry systems produce more varieties of products, but smaller quantities of each product individually. In order to commercialize small quantities of various products, proximity to consumer centers that enables direct sale to the final consumer is vital; and for those in rural areas, often far from urban centers, this becomes unfeasible, unless they have an agro-industrial process, as is the case for two of the interviewees. In the study region, the properties are far from urban centers and also from one another, a fact that hinders the link for joint commercialization.

In addition, the agroforestry systems established in the region are biodiverse and composed especially of native vegetation species; however, difficulties in acquiring seedlings and seeds of these species are reported. Municipal forest nurseries would be perfect to meet this demand of farmers and extension agents (Henzel et al., 2022). There are several uncertainties regarding the management of agroforestry systems in the Pampa, a region where the lack of prior references requires innovative approaches. The extension agents' inexperience with agroforestry intensifies these doubts, highlighting the need for greater technical training to meet the specific demands of these farmers. Among the weaknesses, it is worth highlighting the lack of clarity and the indefiniteness regarding objectives and goals, which becomes a limiting factor when one considers the formation of groups. When everyone has the same objective in commercial terms, it facilitates the formation of strategies; however, when one wants only a pleasant place to live, another wants to industrialize, and others want to sell products *in natura* in baskets or at markets, it becomes more difficult. In addition, when agroforestry becomes secondary in income generation, it may end up falling into neglect.

Low financial return is also among the weak points. What happens is that farmers generally select the best sites for annual agricultural crops, leaving the worst soils for the agroforestry systems, which results in the financial and environmental failure of the undertaking (Galvão, 2000). In addition, managing agroforestry systems requires knowledge and demands

a great deal of labor, occupying many work-hours for each activity. This happens because there are no specific tools that facilitate agroforestry management. However, Santin (2023), based on an economic-ecological analysis of AFS in the Serra dos Tapes (RS), shows that even in periods of unfavorable climate, AFS produce and have generated revenue.

Although in theory there are credit means for agroforestry farmers, in practice they become inaccessible. Agricultural financing is intertwined with conventional agricultural models, since farmers must present invoices for chemical inputs and industrialized seeds – even to gain access to agricultural insurance. Being prevented from accessing credit means is one of the obstacles that hampers the development of agroforestry systems. In addition, not all farmers are organizing to certify their property; of those interviewed, only two achieved agroforestry property certifications with the Secretaria do Meio Ambiente do Rio Grande do Sul (SEMA-RS).

3.3.3. Opportunities quadrant (external factors)

During COP 26, held in November 2021, agroforestry systems were cited as the best alternative for food production. And Brazil stands out as the perfect country to be a leader in this segment. In addition, the opportunities lie in consumers who want agroecological products, in rural tourism, in the farmers' power of association, and in the availability of universities and centers of research and rural extension that have professionals interested in and dedicated to the sustainable development of the Pampa Biome.

Rural tourism emerges as an option for income generation for farmers who wish to conserve the environment, although not all rural tourism is ecological. More and more people seek leisure spaces amid nature. Using these spaces in pursuit of conservation, income generation, and environmental education is an important step among the options with faster return and lower investment. In addition, consumers aware of the benefits that agroforestry systems bring may be willing to opt for these ecologically sound products over others. To this end, it is necessary to reach these consumers (Schneider et al., 2016).

The union of farmers in groups for the exchange of experiences and support in management is a consolidated practice in Canguçu. In this municipality, a group composed of farmers, extension agents, and researchers maintains active communication through a social network, where they schedule meetings and share information and seeds. Additionally, three interviewed families find commercialization opportunities in a solidarity-economy group. Complementarily, the southern region of Rio Grande do Sul stands out for the presence of renowned research institutions, such as the Universidade Federal de Pelotas (UFPel), the Fundação Universidade Federal do Rio Grande (FURG), the Instituto Federal Sul-rio-grandense (IFSul), and Embrapa Clima Temperado. Alongside these entities,

institutions dedicated to rural technical assistance operate, such as Emater/Ascar – RS and the Centro de Apoio e Promoção da Agroecologia (CAPA).

3.3.4. Threats quadrant (external factors)

The threats identified reside in the market itself and in the lack of policies to support farmers, as one of the interviewees reports about the process of entering the school sales market.

> *It is very difficult today, and it was much worse before, because the nutritionists do not prioritize healthy eating in schools, most of the time opting for industrialized products. I lost a lot of production, including stored food, for lack of a market. There was no awareness of the importance of the organic, and the most practical[3] was always prioritized (Family 1).*

In this sense, the market may present itself as a threat to agroforestry systems as society's demand for more practical food grows. Consumers who seek convenience tend to prefer processed and convenient foods, such as ready meals and packaged products, which are generally produced on a large scale by conventional agriculture. In addition, the foods produced by family farming are generally sold locally and have a shorter distribution chain. Consumers who seek convenience often shop at large supermarkets and store chains that rarely offer space for local products.

The Programa Nacional de Alimentação Escolar (PNAE) establishes the obligation to allocate at least 30% of resources to the acquisition of family-farming products, including organic and agroecological ones; however, the interviewee's statement shows that the technical mediation, represented by the nutritionists, does not always act in accordance with the principles of adequate and healthy eating provided for in the policy, sometimes prioritizing the logic of convenience and food standardization.

The Programa de Aquisição de Alimentos (PAA) constitutes an important mechanism for creating a market for family farming, by promoting public food procurement with exemption from bidding. However, operational limitations, discontinuity of resources, and bureaucratic difficulties frequently reduce its reach and predictability, weakening its capacity to structure stable markets for agroforestry systems. Thus, both programs, although potentially strategic, have not been sufficient to overcome the structural barriers identified in the study.

Institutional procurement, such as that promoted by the PNAE and the PAA, can be understood as potential forms of nested markets, insofar as they create protected spaces for the inclusion of family and agroecological-based farming. According to Ploeg et al. (2012), these markets are socially constructed on the basis of relationships of proximity, trust, differentiated quality, and reconnection between production and consumption. Unlike

3 "Practical" is understood to mean ultra-processed, pre-prepared, and quick-to-cook foods.

conventional markets, oriented toward scale and standardization, nested markets value territorial attributes, sustainable practices, and short commercialization circuits.

Another important aspect relates to prices and accessibility, since agroecological products tend to be more expensive owing to production methods that are more labor-intensive and less chemical-intensive, making the consumption of these products elitist. These factors, combined with the lack of awareness of the benefits of agroforestry agriculture, may lead consumers not to recognize the importance of choosing sustainable products. Agroforestry production still suffers from a lack of political, technical, and economic credibility; in reality, the lack of support policies presents itself as a threat. The lack of recognition, even by close people such as family members and neighbors, also discourages farmers.

> *The resistance of family and neighbors regarding the agroforest is great; to this day people think that it is a patch of scrub and that it will not manage to produce anything, that the field is untidy, that I am careless – these are things that people still think today and that I hope to change (Family 10).*

Lack of a specific market; lack of awareness on the part of society; logistical issues; difficulty in complying with fiscal and sanitary regulations; a shortage of qualified agricultural technicians; dependence on technological packages; and inaccessible agricultural credit are reported as the main structural limitations for the development of agroforestry systems in the Caatinga and Cerrado Biomes (Miccolis et al., 2016) – the same ones identified for the Pampa Biome in this research, showing that the problems are very similar throughout Brazil.

Agroforestry systems contribute positively to the mitigation of greenhouse gases; they contribute to the food security of families; and they provide ecosystem services (Martinelli et al., 2019). Governments worldwide know the urgency of changing the way food and energy are produced; however, policies and actions are needed that truly develop equitable market opportunities, emphasizing local commercialization and distribution schemes, fair prices, and other mechanisms that connect farmers with the urban population. In this sense, the greatest challenge lies in dismantling and transforming the institutions and regulations that currently hold back sustainable agricultural development on the planet (Altieri & Toledo, 2010). An analysis of existing public policies leads us to understand that these are not able to respond to this challenge:

The analysis of the public policies active in 2026 (Table 1) shows that the promotion of Agroforestry Systems in Brazil depends predominantly on indirect instruments, especially rural credit, institutional markets, and climate policies which, although operational, present structural limitations regarding their suitability to the biophysical and economic specificities of these systems. In this context, the advancement of AFS requires the

improvement of existing policies and the construction of more suitable instruments, including credit lines compatible with long-term production cycles, the expansion and qualification of specialized technical assistance, the strengthening of differentiated markets, and economic mechanisms that internalize the ecosystem services generated by these systems.

Table 1 Active and operational public policies (2026) related to the promotion of Agroforestry Systems (AFS) in Brazil

Analytical category	Policy / Program	Nature of the instrument	Central objective	Interface with AFS	Mechanism of action	Structural limitations
Credit and financing	Programa Nacional de Fortalecimento da Agricultura Familiar (PRONAF) – Agroecologia, Floresta and ABC+ credit lines	Financial instrument	To finance family-farming production	Main source of financing for the establishment and management of AFS	Subsidized credit with specific lines for sustainable practices	Low suitability to the long cycle and complexity of AFS
	Plano Safra (Agricultura Familiar)	Annual macroeconomic policy	To provide rural credit and productive incentives	Indirectly enables AFS via sustainable lines	Interest equalization, subsidies, and rural credit	Predominance of conventional production models
Market and commercialization	Programa Nacional de Alimentação Escolar (PNAE)	Food security policy	To ensure school meals and foster family farming	Encouragement of diversified and agroecological production typical of AFS	Mandatory public procurement (minimum of 30%)	Logistical and organizational barriers to access
	Programa de Aquisição de Alimentos (PAA)	Institutional market policy	To promote access to food and support family farmers	Absorbs diversified production originating from AFS	Direct public procurement	Budgetary limitations and operational instability
Climate and environmental	Plano ABC+ (Agricultura de Baixa Emissão de Carbono)	Climate sectoral policy	To mitigate emissions and promote adaptation in agriculture	Recognizes AFS as a low-emission technology	Integrates credit, targets, and technical assistance	Low specific adherence to AFS
Technical assistance	Política Nacional de Assistência Técnica e Extensão Rural (PNATER)	Operational policy	To promote ATER with a sustainable focus	Dissemination and training in agroforestry systems	Public calls and extension services	Limited coverage and low technical specialization in AFS
Science, technology, and innovation	Public research (Embrapa and associated institutions)	ST&I policy	To develop and transfer agricultural and livestock technologies	Scientific and methodological basis for AFS	Applied research and technology transfer	Low integration with market and credit instruments

4. Final Considerations

Based on the results of this research, some recommendations are pointed out regarding necessary and urgent actions for the maintenance and expansion of the agroforestry systems of the Pampa Biome. One of them concerns the promotion and dissemination of agroforestry, with the aim of raising consumers' awareness, as evidenced among the demands highlighted by the farmers. They desire recognition, dissemination, and support policies. It is important for people to visualize what an agroforest is like; the benefits it provides to the environment; and the quality of the food produced.

In addition, as identified among the farmers' demands, market and logistical support is needed for agroforestry products. In this sense, research and extension should point to strategic actions and differentiated public policies for the construction of markets that can meet the diversity, quality, and sustainability of the products generated by AFS. These would be necessary measures until the point at which the market itself creates the conditions to continue on its own. In this sense, targeted policies, even at the municipal level, are capable of promoting the solution to a large part of the problems faced by agroforestry farmers.

Among the weaknesses identified by the research, issues related to labor and the management of AFS stand out. Considering that the agroforestry farmer – mostly represented by family farmers – is expected to have adequate conditions to serve a broader market, it becomes imperative to provide them with appropriate equipment for production. The management of agroforestry systems requires a significant amount of labor owing to the need for pruning and various types of management resulting from the diversity of plants involved. While conventional agriculture advances toward the technological era, with the use of drones and autonomous equipment, in agroforestry the farmer is expected to manually carry out activities such as sawing branches, cutting, pruning, cleaning, and harvesting, perpetuating an artisanal model of production.

Finally, it is evident that there are still numerous doubts and uncertainties regarding Agroforestry Systems, possibly one of the causes of the low adherence of farmers to the model. Therefore, with the identification of these bottlenecks, it is necessary to develop projects and research in order to reduce doubts and generate information that allows farmers greater confidence in decision-making.

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