Pinhão agroforestry system in the Planalto Serrano Catarinense, Brazil: Characterization of practices and local knowledge

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Research

Abstract

Background: Pinhão Agroforestry System (PAS) is a distinctive socioecological legacy from Santa Catarina state, southern Brazil, centered on pinhão extractivism (the nut-like seeds of *Araucaria angustifolia*) and cattle ranching. This study aimed to characterize the management practices and knowledge associated with the PAS and to discuss their implications for the conservation of the Araucaria Forest.

Methods: An ethnobotany survey was conducted with 26 families in the municipalities of Painel, Urubici, Urupema, Bom Jardim da Serra and São Joaquim (Serrano Plateau of Santa Catarina) to document the management practices and production arrangements within the PAS. Additionally, an exploratory temporal analysis was performed to compare land-use dynamics in the study area with those observed across the rest of Santa Catarina.

Results: Pinhão extraction is the primary source of income for 65% of informants, who self-identify as pinhão extractivists. The PAS is mainly characterized by family labor (77%), smallholdings (73%), and low levels of technification. It encompasses traditional climbing techniques for pinhão harvesting and strategies for storage, threshing, processing and marketing. The system is also characterized by shared informal norms that promote low-impact harvesting. In areas where PAS occurs, forest-cover reduction was smaller than that observed across Santa Catarina as a whole.

Conclusions: The Traditional Pinhão Agroforestry System (PAS) is maintained by family farmers who identify themselves as pinhão extractivists and is characterized by shared ecological knowledge, intergenerationally transmitted management practices, and a long-standing relationship with the Araucaria Forest. These elements contribute to both sustainable pinhão harvesting and the long-term forest conservation.

Keywords: Araucaria Forest; Atlantic Forest, Highlands; Non-timber forest products

Background

Araucaria Forest is a unique ecosystem within the Atlantic Forest in South America, characterized by the prominent presence of a native tree known as Araucaria (*Araucaria angustifolia* (Bertol.) Kuntze), found at elevations above 500 meters of sea level in the southern region of Brazil, northern Argentina and eastern Paraguay (Hueck 1953, Klein 1960).

Throughout history, a myriad of human communities have actively engaged with the Araucaria Forest resources and landscape (Reis *et al*. 2014). Historical and ecology studies (Bitencourt & Krauspenhar 2006, Robinson *et al*. 2018, Vasconcellos *et al*. 2024) combined with genetic evidence (Lauterjung *et al*. 2018) suggest that the Taquara/Itararé indigenous people -ancestors of the Kaigang and Xokleng groups- played a significant role in the expansion of Araucaria Forest between 2000 years and 1400 years before the present. For these groups, pinhão (Araucaria nut-like seeds) was a vital food source, while the Araucaria tree fulfilled multiple purposes, including marking territories, attracting game for hunting, and an element in religious rituals (Reis *et al*. 2014, Robinson *et al*. 2018, Ladio *et al.* 2026).

The Araucaria Forest originally covered an estimated area of 272.970 km², however, during the 20th century, Araucaria logging combined with urban expansion and deforestation resulted in a dramatic loss of 95.66% of the original range, decreasing to 11.850 km² (Zorek *et al*. 2024). Consequently, Araucaria Forest is now one of the most endangered forest ecosystems within the Atlantic Forest domain, and *A. angustifolia* is listed as a critically endangered species in the International Union for Conservation of Nature (IUCN) Red List (IUCN 2023).

After the decline of Araucaria populations, especially after 1980, local communities in the southern region of Brazil have reframed their relationship with pinhão extraction (Reis *et al*. 2014, Ladio *et al.* 2026). Pinhão is a highly nutritious food, and its commercialization has become the primary source of income for many rural (Vieira da Silva & Reis 2009, Adan *et al*. 2016) and traditional communities (Magnanti 2016), and it has become one of the most significant non-timber forest products in Brazil (IBGE 2023). In 2022, pinhão sales in Brazil totaled R$ 51.8 million (approximately $8.4 million), with the state of Santa Catarina standing out as the country's largest producer.

In the Serrano Plateau of Santa Catarina (Planalto Serrano Catarinense), Brazil's main pinhão-producing area (Magnanti 2019, IBGE 2023), family farmers developed a traditional management system rooted in agroforestry practices (Magnanti & Rover 2019). By adapting indigenous practices, they developed local landscape management systems based on pinhão extractivism, an approach that significantly contrasts with the exploitative logic perpetrated by the timber industry (Magnanti & Rover 2019). This system, referred to by Magnanti (2019) as "Sistema Agroflorestal Tradicional para produção de Pinhão", translated into English as "'Pinhão Agroforestry System (PAS), centers on pinhão extraction and extensive cattle ranching (Adan *et al*. 2016, Magnanti 2016). Beyond cattle ranching and pinhão extractivism, the PAS encompasses a diversified portfolio of agricultural, livestock and extractive activities, including cultivation of vegetables, agricultural crops, exotic fruits (Magnanti 2016), as well extraction of other non-timber-forest products (Bogoni *et al*. 2018), such as yerba mate (*Ilex paraguariensis* A.St.-Hil.) (Reis *et al*. 2014) and native fruits (Magnanti 2016). Additional activities, such as tourism and the production of bracatinga honey (*Mimosa scabrella* Benth.), further diversify household income sources and enhance the economic resilience of the system (Magnanti 2016).

PAS pinhão extractivists share a strong sense of belonging to their territory, reflected in the cultural importance attributed to *Araucaria angustifolia*: the most emblematic species of the Araucaria Forest and a recognized cultural keystone species for communities in southern Brazil (Wilson *et al*. 2019, Bogoni *et al*. 2020). Over generations, these communities have accumulated extensive knowledge related to pinhão production, including management practices that have shaped the landscape while maintaining forest resources. Together, these practices and knowledge systems underpin a distinctive traditional agricultural system in the highlands of Santa Catarina (Magnanti 2016, Adan *et al*. 2016, Tagliari *et al*. 2023).

The understanding of the Pinhão Agroforestry System as a system composed of multiple elements (services and products, material and immaterial dimensions), has received limited attention in the scientific literature. Furthermore, the practices involved in the activities that constitute the productive basis of this system (pinhão extractivism and livestock farming) have not yet been adequately characterized or described. Accordingly, this study aimed to characterize the management practices and knowledge related to the Pinhão Agroforestry System, particularly those linked to pinhão extractivism and, based on evidence derived from the analysis of forest-cover dynamics over time, to discuss the potential implications of this system for the conservation of the Araucaria Forest.

Materials and Methods

This study combined two methodological approaches: ethnobotanical fieldwork to characterize management and production practices associated with the Pinhão Agroforestry System, and a temporal analysis of changes in Araucaria Forest cover.

Study area

Ethnobotanical fieldwork was conducted from January 2022 to March 2023 in the Serrano Plateau region of Santa Catarina, Brazil, locally known as Planalto Serrano Catarinense, located within the geographical microregion of Lages (Thomé 1999). The study was conducted in five municipalities (Fig. 1) that comprise the main pinhão-producing areas in the state of Santa Catarina (Magnanti & Rover 2019), accounting for more than half of the state's total production in 2023, with 1.600 tons (IBGE 2023).

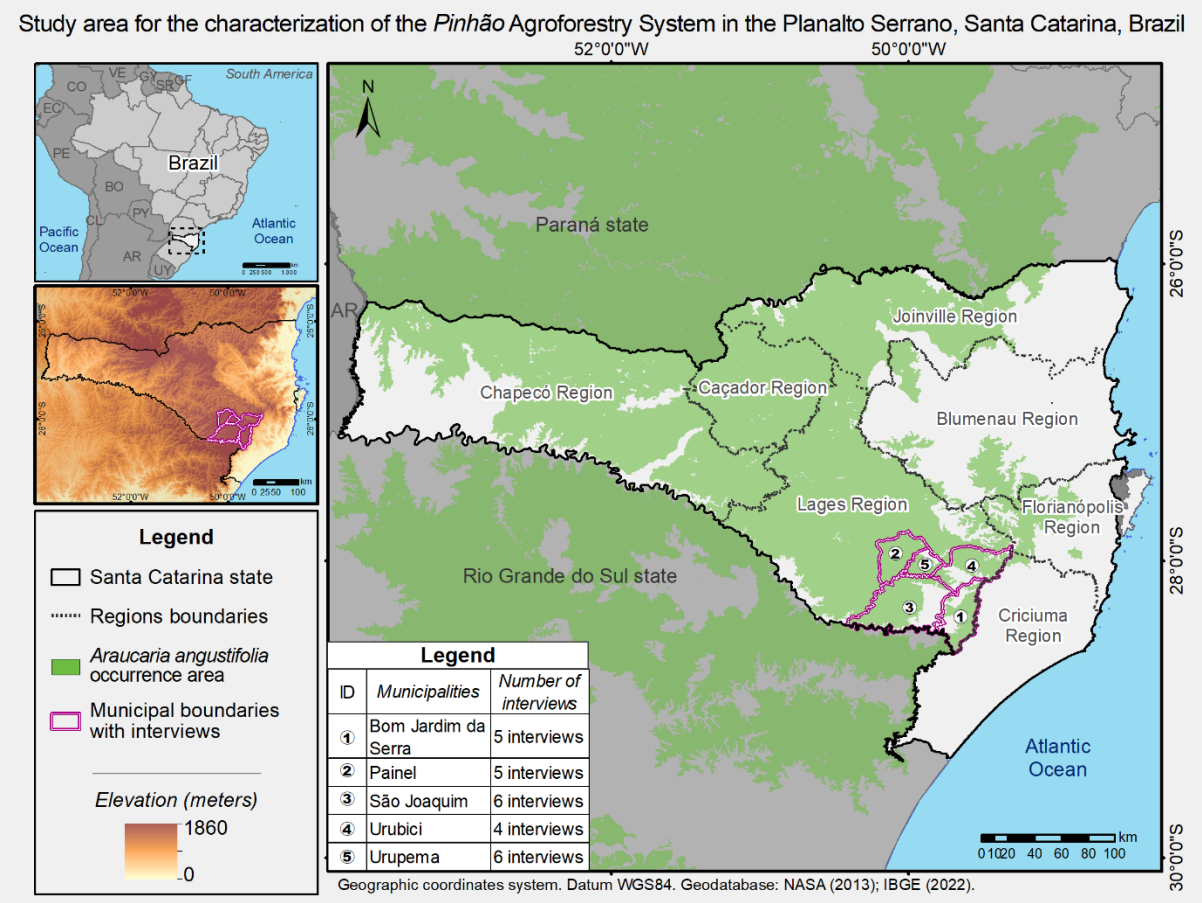


Figure 1. Geographic coverage of the ethnobotanical survey on the Pinhão Agroforestry System (PAS) in the Serrano Plateau of Santa Catarina/Brazil

The region has a Cfb climate (temperate with mild summers) according to Köeppen (Alvares *et al*. 2013), with average annual temperatures ranging from 13.8ºC to 15.8ºC (EPAGRI 2002), and harsh winters (Magnanti & Rover 2021). Annual rainfall varies between 1,360 mm and 1,700 mm (EPAGRI 2002), while altitude ranges from 800 to 1820 m (Thomé 1999). The landscape features Araucaria Forest interspersed with native grasslands (Magnati & Rover 2021).

Colonization in these areas, which were home to the Xokleng and Kaigang indigenous groups (Brandt & Campos 2014), began around the 18th century by bandeirantes and tropeiros from São Paulo (Machado 2011). Agricultural activities form the economic base of the municipalities addressed in this study (IBGE 2024), which are in a region predominantly characterized by family farming (IBGE 2017).

Data collection and analysis

Ethnobotanical survey

An ethnobotanical study was conducted to understand practices related to pinhão extractivism, as well as general characteristics of the system's management and production arrangements in the Pinhão Agroforestry System in the Serrano

Plateau of Santa Catarina. The research adhered to the ethical guidelines established by Brazilian Law No. 13.123 of May 20, 2015, which regulates the access to traditional knowledge, registered in the Brazilian System for the Management of Genetic Heritage and Associated Traditional Knowledge (SiSGen) under registration No. A406E70. It was approved by the Ethics Committee of the Universidade Federal de Santa Catarina (UFSC), under protocol No. 53895221.8.0000.0121.

Semi-structured interviews (Bernard 2006) were conducted. The main topics included knowledge and practices related to pinhão harvesting, storage, and threshing; commercialization pathways; productive organization and farm-level characteristics; and other activities associated with the system and their economic relevance. Direct observation and guided tours (Albuquerque *et al*. 2010) in areas of interest and harvesting areas were also made to complement the interviews' information.

The family unit was considered the informant unit. Interviews were generally conducted with the household member primarily responsible for pinhão harvesting, however in some cases, both members of the couple participated in the interview. Regardless of the number of participants, the family unit was treated as a single informant in the analysis (Netting 1993).

The first informants were identified through the Participatory Rural Diagnosis carried out between 2016 and 2017 by Magnanti et al. (2017). Purposive sampling was employed, and the inclusion criteria were families who identified themselves as pinhão extractivits, possessed traditional knowledge transmitted across generations, and whose livelihoods depend on this activity. To expand the sample, the snowball technique (Bailey 1994), a non-probabilistic sampling method, was employed based on the principle of self-identification, whereby self-declared pinhão extractivists referred peers whom they recognize as belonging to the same social group. Sample saturation was achieved when participant referrals no longer resulted in the identification of new informants (Bernard 2006).

Thematic analysis was conducted to examine the data, identify patterns, and interpret findings, following the method proposed by Braun & Clark (2006), with adaptations by Souza (2019). The analysis involved the following phases: familiarizing with the data, systematizing it, grouping the data into relevant themes, reviewing themes using a thematic map, refining them, and analyzing the research question in relation to literature.

Plants specimens mentioned in this study were collected with guidance from local informants, processed through pressing, drying and deposited in different herbaria as voucher specimens. The respective voucher accessions numbers are provided alongside the species names in the Results section. Plant specimens were taxonomically validated by comparison with previously identified specimens deposited in the respective herbaria.

Contemporary Analyses of Araucaria Forest coverage in Santa Catarina

To investigate landscape changes in the Araucaria Forest, a temporal land-cover analysis was conducted for the state of Santa Catarina and the five pinhão producing municipalities examined in this study, where the Pinhão Agroforestry System was characterized. Land-cover patterns in 1985 were compared with those observed in 2023, allowing the assessment of changes over a 38-year period.

The Araucaria Forest domain was delineated on the definitions provided by Klein (1978) and Vibrans *et al*. (2021) in the Phytogeographic Maps of Santa Catarina. The temporal assessment of forest cover included natural grasslands and natural forests as integral components of the Araucaria Forest.

Satellite images from 1985 to 2023 - a span of 38 years - were analyzed, using data from MapBiomas digital platform (version 9.0), which processes Landsat satellite images at a 30 x 30-meter resolution. Land cover changes were assessed at the pixel level dominance using Google Earth computing platform. These transformations over time were visualized through Sankey diagrams, which were generated using QGis 3.16.13 software for land use and Power BI for organizing the spatio-temporal information.

Table 1 presents the vegetation physiognomy and land use designations defined by MapBiomas (column 1) alongside the classifications adopted in this study (column 2). The land use classifications adopted by the authors were designed to enhance visualization and interpretation, facilitating the identification of patterns and changes in the Araucaria Forest over time.

Table 1. Correspondence between Mapbiomes land cover class and the classification adopted in this study.

MapBiomas class	Reclassified class
Forest formation	Forest
Grassland formation	Grassland
Rice Land use mosaic Other temporary crops Pasture Soy	Agriculture and pasture
Silviculture	Silviculture
Urban	Urban
Rock outcrop Aquaculture Mining Other non-vegetated areas	Other categories

Source: the authors (2024).

Results

Informant profile and overview of the Pinhão Agroforestry System (PAS)

A total of 26 family units were interviewed, comprising 36 informants, including 10 married couples and 16 male extractivists. The participants' ages ranged from 23 to 84 years, with an average of 56. The most common age group was 58 to 70 years, representing 31% of the informants. Interviews were conducted across four municipalities: Urubici (4 interviews), Bom Jardim da Serra and Painel (5 each) and São Joaquim and Urupema (6 each).

In all family units, the system integrates pinhão extraction with extensive livestock farming, whether for meat or dairy production. Additionally, according to the informants, the system may include yerba mate (*I. paraguarensis*), fruit trees (both native and exotic species), and medicinal plants, with a predominance of species of cultural relevance and potential for income diversification. The system's structure is characterized by *A. angustifolia* trees (voucher CTBS9518) forming the upper canopy, trees and shrubs occupying the understory, and native or naturalized grasses constituting the herbaceous layer, where cattle are often present (Fig. 2).



Figure 2. Composition of the Pinhão Agroforestry System (PAS) in the Serrano Plateau of Santa Catarina

Half of the informants mentioned fruit trees as part of the system, including native fruits such as **feijoa** (*Feijoa sellowiana* (O. Berg) O. Berg; voucher LUSC012730) (n=8) and **araçá** (*Psidium cattleyanum* Sabine; voucher FLOR0078016) (n=2) as well as naturalized ones. Twenty-three percent of informants reported selling fruits, either processed (in the form of jams, jellies or juices) or fresh. The native species most frequently mentioned for fresh fruit sales was **feijoa** (*F. sellowiana*) (n=3), followed by exotic species. The other informants reported using fruit solely for household consumption. Additionally, medicinal plants are cultivated and/or maintained for domestic purposes. The cultivation and extraction of yerba mate (*I. paraguariensis;* voucher LUSC013390) in these systems is carried out by seven informants, five of whom utilize it for their own consumption and two of whom engage in direct sales to regional yerba mate industries (n=2). Honey production was only referred to by one informant.

The pinhão extractivism involves various steps and strategies (Fig. 3), ranging from knowledge of determining the point for harvesting the pinecones to marketing pinhão and its by-products. Throughout these stages, different strategies and tools are employed for climbing the trees to harvest the pinecones directly from the pine tree – a practice aimed to guarantee a better quality of the pinhão and ensure a longer post-harvest life (according to the informants)–, as well as strategies for storage, pinhão threshing, processing and commercialization.

Productive organization structure of PAS and its socioeconomic significance

Among the properties surveyed, ten reported that income from pinhão accounts for up to 60% of their annual earnings. It was identified as the main income source for 65% of informants, followed by livestock production (31%), annual crops cultivation (15%), and rural tourism (8%). The integration of pinhão extraction with livestock production is essential, because while pinhão production is concentrated in the period between April and June, livestock provides income throughout the year.

The pinhão extraction is conducted primarily on informants' properties (73%) or through partnerships (27%) on others' properties. In Painel and São Joaquim, all informants (100%) reported extracting pinhão exclusively from their own land. In contrast, Urupema had the highest number of informants engaged in partnership arrangements, with four out of six informants following this practice. When partnership arrangements, payments to landowners often involve a share of the harvest or bartering, such as exchanging sacks of pinhão for sacks of corn, with an exchange ratio of approximately six sacks of pinhão for one sack of corn. This modality is defined by informal agreements that outline not only the distribution method, but also the designated areas, harvesting points, and management precautions.

Property size ranged from 3 to 460 hectares, with a majority (73%) being smaller than 100 hectares. Most informants were family farmers, with 73% of the properties classified as smallholdings of up to 4 fiscal modules (1 fiscal module corresponding to 20 hectares). This finding aligns with the regional profile, where family farming predominates (74%) (IBGE, 2017). Production activities are predominantly organized around family nuclei (77%), often involving collaboration with family members and neighbors.

Identification of practices and local knowledge in PAS

Agroforestry management practices were reported by 66% of the extractivists, with most of the cited practices (7 out of 10) aimed at enhancing pinhão production. These practices included liming (n=6), fertilization (n=5), cleaning pruning (n=3), control of competing plants (n=2), grafting (n=1), inducing lesions in the plant's trunk to boost productivity (n=1), and incorporating Araucaria sterile bracts into the soil to enhance organic matter and control competing plants (n=1) (Table 2). However, such interventions are carried out in small areas of the property sporadically, usually on female trees close to the residence or recognized for their high productivity, and fertilization is often made with tanned manure.

Two practices are carried out to benefit livestock production: the collection of the Araucaria branches (n=3), a relevant activity according to informants to prevent animals from inhaling the needle-like leaves (acicles) of the Araucaria, and pasture maintenance (n=2). In addition, fire control, mentioned by 5 informants, was regarded as an important management practice benefiting the whole agroforestry system.

The main characteristics of the Pinhão Agroforestry System identified in this study are summarized in Fig. 3, which provides a visual guide to its productive structure, management practices, and the strategies and activities associated with pinhão production:

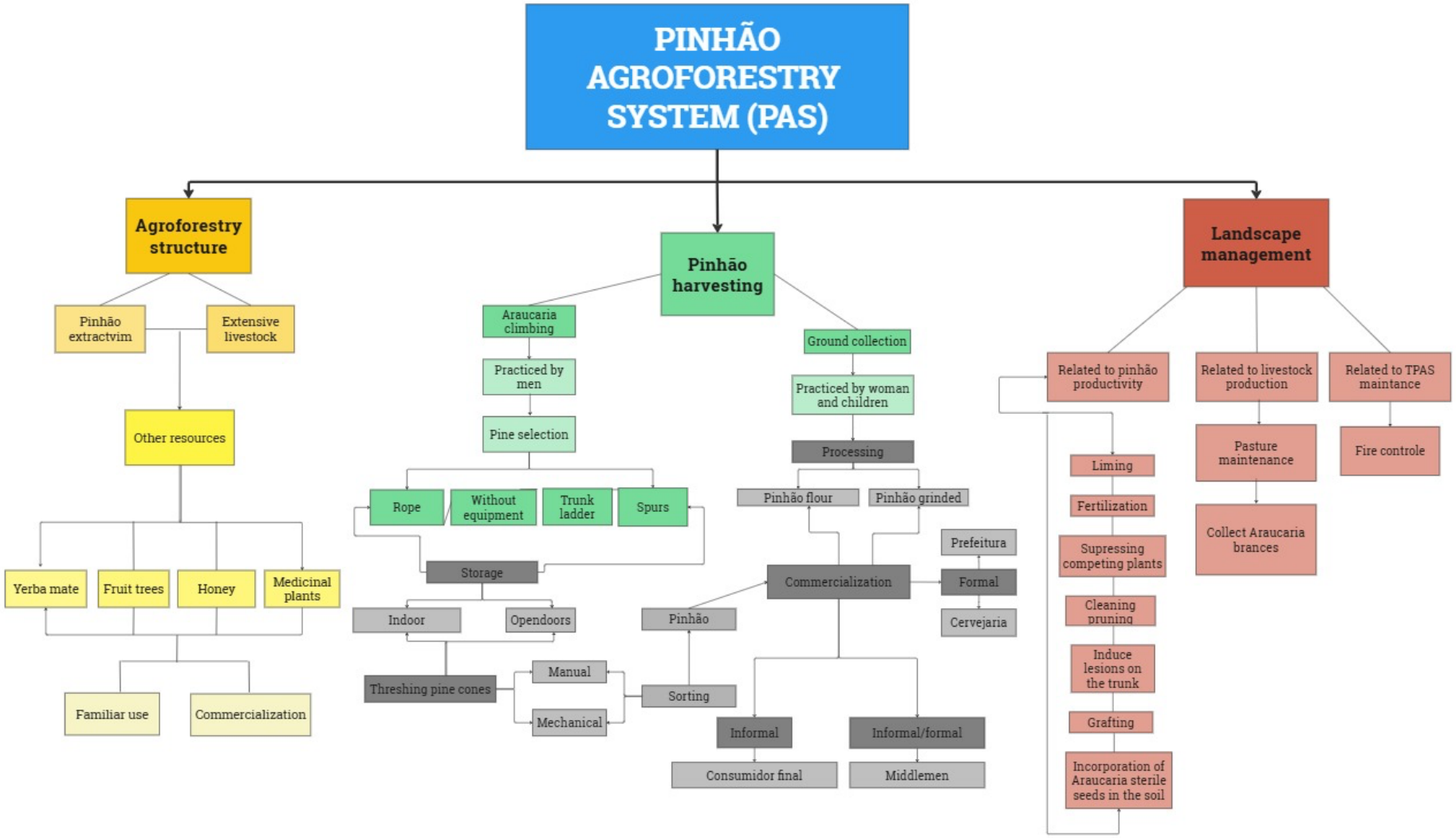


Figure 3. Flowchart of the elements and stages that make up the PAS

While management practices within the system are diverse and not universally adopted, all informants reported employing knowledge and strategies associated with pinhão harvesting, encompassing activities from determining the appropriate harvest time to the commercialization of pinhão. The pinhão is harvested selectively, favouring areas with lower density of Araucarias and less rugged topography, which makes it easier to access and move around. In addition to not harvesting the entire area, immature pinecones are avoided, and care is taken to prevent damage to the plant and immature pinecones. The harvesting point is defined by the change in coloration of pinecones, from completely green to points with shades of brown and purple, which indicate the presence of ripe seeds. Harvesting strategies are deeply rooted in tradition, involving four climbing methods to harvest pinhão directly from the tree. Climbing is done using a rope, climbing spurs, carving a makeshift ladder into the tree trunk, or without any equipment (Fig. 4, A1-C2). This practice is exclusively performed by men, shaped by social, cultural and physical factors, and the knowledge associated with it is passed down orally from generation to generation.

Table 2. Frequency [n] of citations of practices and processes employed by extractivists in different aspects of the Pinhão Agroforestry System (PAS), according to 26 informants participating in the ethnobotanical survey in the Planalto Serrano Catarinense.

Category	**Practices and strategies used in PAS**				
Pinhão harvesting method	Climbing with a rope n=16	Climbing with spurs n=16	Makeshift ladder into the trunk n=6	Without equipment n=2	Ground collection n=2
Pinhão harvesting tools	Protection belts n=3	Aluminum pole n=2	Bamboo pole n=5	Pole with hook n=1	-
Threshing[1] and Storage[2]	Manual[1] n=18	Mechanized[1] n=10	Indoors[2] n=22	Outdoors[2] n=4	-
Processing	Pinhão flour n=1	Pinhão grinded n=3	-	-	-
Management practices	None employed n=11	Liming n=6	Fire control n=5	Fertilization n=5	Cleaning pruning n=3
	Control of competing plants n=2	Inducing lesions on the plant's trunk n=1	Grafting n=1	Incorporation of Araucaria sterile bracts n=1	Pasture maintenance n=2
	Collection of Araucaria branches n=3	-	-	-	-
Marketing channels	Informal n=13	Formal n=8	Sporadically formal n=5	-	-
Channel type	Through middlemen n=22	Direct sale n=9	Markets and restaurants n=3	Breweries n=2	National School Feeding Program n=1

Climbing with ropes and spurs is practiced by 61% of informants (Figure 4, A1 and A2), climbing with a ladder carved into the trunk by 23% (Figure 4, C1), and without any equipment by 8%. The same extractivist may use different techniques. In rope climbing, the extractivist throws a rope with a counterweight at the end, securing it to the second or third branch. After checking the branch's stability, the rope is used as support for the climb. The spur is a tool, typically made of iron or aluminum, attached to footwear (usually rubber boots) with a sharp point that is inserted into the tree trunk. The ladder carved into the tree consists of notches made diagonally at regular intervals, creating steps that facilitate climbing.

Trees are selected for climbing based on specific characteristics, such as a straight trunk, a high number of reproductive branches, lower heights (20 to 30 meters), and a diameter that allows extractivists to wrap their arms around the trunk (Figure 4, C2).

The use of belts to enhance the safety of climbing techniques was reported by 11% of the informants. Although this practice reduces risk it is rarely adopted, according to the extractivists it requires additional time for harvesting. After climbing to harvest the pinecone, extractivists use poles made of bamboo, aluminum or other materials. These poles are either attached to the climber's waist or lifted by a support person (usually a familiar) and used to bring down the pinecones.

After being felled by the extractivists, some pinecones open naturally, and their seeds are selected in the field, whereas closed cones are transported to storage area using animal or mechanized transport. Pinhão is also gathered from the ground after pinecones have naturally fallen, a task primarily carried out by women and children. This activity is often associated with areas near homes and is typically intended for domestic consumption. Pinecones are stored indoors (n=85%) (Fig. 4, E1, E2) or outdoors (n=15%) (Fig. 2, D1, D2) before being threshed, a process typically carried out near the marketing period.



Figure 4. A1-C2. Equipment and corresponding climbing strategies used for pinecones harvesting in the Pinhão Agroforestry System on the Serrano Plateau of Santa Catarina /Brazil. A1. Rope equipment. A2. Rope/loop climbing technique. B1. Spur equipment. B2. Spur climbing technique. C1. Makeshift ladder carved into the tree. C2. Demonstrations of ladder climbing. D1-E2. Storage methods. D1-D2. Storage outdoors. W1-E2. Storage indoors. F1-G2. Threshing methods. F1. Mechanized threshing. F2. Semi-mechanized threshing. G1. Manual threshing. G2. Manual seed sorting

The main form of threshing is manual (69%) (Figure 4, G1, G2), in which the pinecones are opened with a wooden stick. Women and children assist in sorting viable seeds suitable for consumption from sterile bracts, which are inedible. Semi-mechanized (23%) (Figure 4, F2) and mechanized methods (15%) (Figure 4, F1) have been incorporated into the system in the last five years, the former requiring the pinecones to be broken by hand and the machinery helping to separate the seeds. For instance, mechanized methods break and separate the pinhão using a vibration or an impact process, with the seeds being separated using sieves.

Only a few families are involved in processing pinhão, primarily due to the high costs of equipment, infrastructure, and labor, as well as the higher demand for raw pinhão. Among the four family units that process pinhão (15%), it is the women who

carry out this activity, reporting that it significantly contributes to their financial autonomy. The processing typically involves boiling the pinhão before grinding it (n=3), mainly for the preparation of a traditional regional dish known as “paçoca de pinhão”. Another marketing avenue is pinhão flour (n=1), which presents an appealing option for those following gluten-free diets.

Raw pinhão is the primary product sold, with the most transactions occurring informally (50%). Formal sales with invoices account for 31% of transactions, while 19% are sporadically formalized. Informal sales are more common because they are straightforward, requiring no strict standards, contractual obligations (such as minimum quantities), or the issuance of invoices. The process of issuing invoices poses a significant barrier to entering the formal market, as many sellers lack the knowledge or access needed to issue them.

Those who sell informally sporadically do so when the volume is small. The formal sellers emphasize several advantages, including access to formal markets (supermarkets, restaurants), easier access to financing, and exemption from tax on the Goods and Services Tax, as eligibility for the Minimum Price Guarantee Policy (Schwantes & Bacha 2019).

Most of the informants sell through middlemen (85%), direct sales were mentioned by 35% of the informants and other forms were mentioned less, such as sales to markets and restaurants (11%), breweries (8%) and sales to the National School Feeding Program (4%).

Landscape transformations in PAS

Through satellite image analysis, it was possible to compare the reduction in the total area of the Araucaria Forest in Santa Catarina with the area covered in the study where the PAS is located. Comparison of land-cover data from 1985 and 2023 revealed a 17.7% decline in Araucaria Forest cover in the state of Santa Catarina, a reduction linked to the expansion of silvicultural activities and the cultivation of annual crops such as soybeans and rice (Fig. 5).

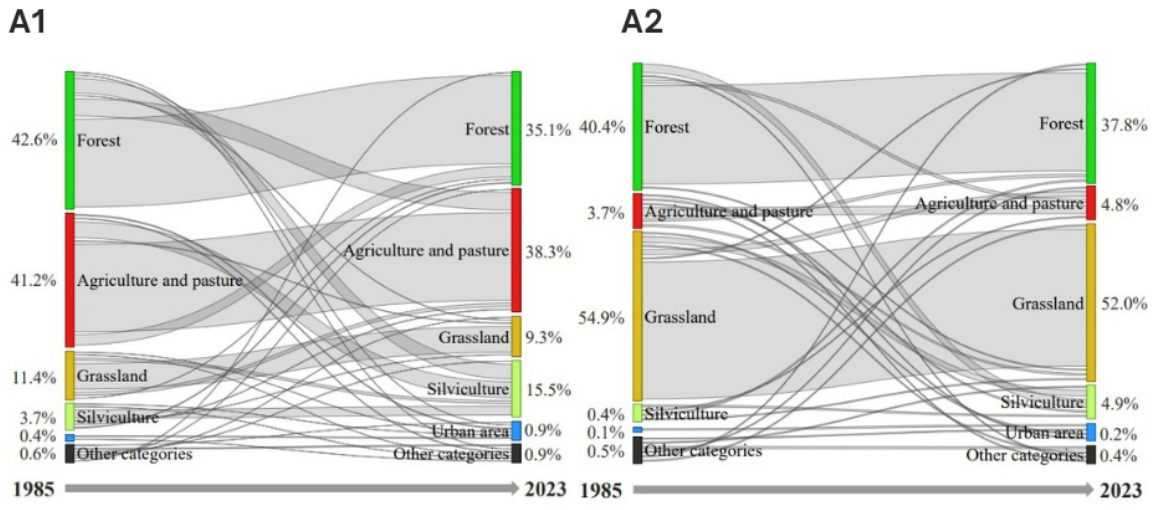


Figure 5. A. Transformation of land cover in the Araucaria Forest of Santa Catarina between 1985 and 2023. B. Change in the landscapes of Bom Jardim da Serra, Painel, São Joaquim, Urubici, and Urupema between 1985 and 2023

In contrast, the five municipalities analyzed showed a 6.09% reduction in Araucaria Forest cover, representing a less pronounced loss compared to the state-level trend, in areas with a traditional agroforestry system for pinhão production. Furthermore, the maintenance of native grassland areas is also higher in the area covered by the study (94.71%) than the average for Santa Catarina (81.57%) over the period in question.

Discussion

The use of *Araucaria angustifolia* in the Serrano Plateau of Santa Catarina has undergone three distinct phases in recent history. Between the 1920s and 1950s, the species was primarily used for household consumption, including pinhão and

timber, as well as for pig fattening within the economic context of the tropeirismo cycle[1]. Between the 1950s and 1970s, timber extraction became the dominant use of **araucária**, driven by the logging cycle, which led to the species being classified as threatened (Magnanti & Rover 2021, IUCN 2013). Since then, pinhão have undergone a process of increasing economic valorization (Guerra *et al*. 2002; Vieira da Silva & Reis 2009, Adan *et al*. 2016; Reis *et al*. 2018). This process is reflected in the current status of pinhão, as one of the most important non-timber-forest products in southern Brazil, with Santa Catarina leading national production and accounting for 34.9% of the country's total output in 2022 (IBGE 2022).

Among the different arrangements associated with pinhão harvesting that emerged in this context, PAS represents a distinctive socio-ecological system developed by communities with a long-standing relationship with the territory. It is important to note that the structure of the PAS has changed over time in response to broader economic transformations and shifts in the system's main products (Magnanti & Rover 2021). However, the importance of the pinhão as a food resource has remained constant through this period. This enduring relevance has fostered the accumulation of knowledge associated with pinhão extractivism and the management of other plant species, enabling intergenerational transmission of practices and skills (Magnanti 2016).

In the current configuration, the PAS is structured around pinhão extractivism and cattle ranching, which together constitute the primary sources of household income. The system structure reflects the long history of social and cultural reproduction in the Serrano Plateau of Santa Catarina (Magnanti & Rover 2021). Pinhão have historically constituted an important food resource for indigenous peoples, while cattle production is associated with the tropeirismo tradition, which is central in shaping patterns of settlement, economic development and territorial organization in the Serrano Plateau of Santa Catarina during the post-colonial period (Magnanti & Rover 2021). Furthermore, the system encompasses several species that are embedded in local food traditions. Many of these species, including *A. angustifolia*, yerba mate (*I. paraguariensis*) and **feijoa** (*F. sellowiana*) were already culturally important and actively managed by indigenous peoples (Reis *et al*. 2014, Ladio *et al*. 2026), and continue to be recognized by the informants as part of PAS. This continuity suggests that ecosystem management in this region is not a recent innovation, but an ancestral practice from indigenous peoples that have actively shaped these landscapes through the management of culturally and ecologically significant species, including those mentioned above as well as **butiá palm** (*Butia eriospatha* (Mart. ex Drude) *Becc*), **caraguatá** (*Bromelia antiacantha* Bertol.), and others (Reis *et al*. 2018ab, Clement *et al*. 2021).

Although much of the knowledge associated with indigenous uses and management of the forest has been lost over time, some of it has persisted through processes of adaptation, incorporation and reinvention by the communities that have inhabited the territory across generations. The communities' long-term experience, combined with the continuous observation and reinterpretation of locally available resources, has led to the accumulation of a wide range of knowledge and to the development of diverse agroforestry systems (Miller & Nair 2006).

The PAS is one of the agroforestry systems developed within the Araucaria Forest, where the accumulation of extensive local ecological knowledge has been documented among the pinhão extractivists. This knowledge encompasses the ecology and reproductive biology of species of interest, including the dynamics of *A. angustifolia* cone development and the fauna associated with seed dispersal (Silva *et al*. 2015, Adan *et al*. 2016), the identification of pinhão ethnovarieties (Adan *et al*. 2016), ecological interactions within the system, such as competition, stand density, and seed predation; as well as perceptions of the impacts of climate change on the territory (Tagliari *et al*. 2023).

In addition, as demonstrated in this study, PAS extractivits have developed strategies related to pinhão extractivism, encompassing the determination of harvesting timing, as well as techniques for harvesting, storage, threshing, and sorting. Among these, tree-climbing techniques stands out as a distinctive feature of the system as, to our knowledge, no other agroforestry system has been documented in which it constitutes the primary method for pinhão collection.

Pinhão extractivists share management norms and practices aimed at ensuring both the quality of the harvested pinhão and long-term maintenance of the system. Harvesting is limited to selected portions of forest fragments, and particular care is taken to avoid damaging immature cones and Araucaria trees. In addition, extractivists harvest only mature pinecones and intentionally leave a portion of them on each tree. Together with the low level of technological intervention and minimal

[1] An economic activity that emerged during the colonial period, characterized by the long-distance movement of livestock, particularly cattle and mules, as well as the transport of goods on pack animals. The activity was central to integrating Southern Brazil with other regions of the country, especially the Southeast (Lemos 1977).

interference that characterize the system (Magnanti & Rover 2021), these practices contribute to a sustainable management regime that ensures food resources availability for wildlife while allowing natural regeneration of Araucaria and associated plant species (Reis *et al*. 2018a).

These low-impact harvesting practices are transmitted orally across generations. Although they have not been formally established or collectively negotiated among extractivits from different families or localities, remarkably similar norms and practices are observed throughout the territory. This suggests the emergence of a shared understanding of appropriate harvesting behaviour, rooted in generations of experience with pinhão extractivism and the continued use of the resource.

In that regard, self-identification as "pinhão extractivist" reflects more than engagement in harvesting activities, it denotes shared knowledge, rules and and ongoing relationship with the *A. angustifolia* tree, distinguishing these individuals from those who collect pinhão only occasionally for household consumption or when it is economically advantageous to do so. It is important to emphasize this point, as the concept of "extractivism" varies across the international literature. Even in Brazil, the term has historically been associated with the predatory use of natural resources, characterized by overexploitation leading to resource depletion or even local extinction (Vieira da Silva & Miguel 2014). However, in Brazil the concept has undergone a process of reformulation, expanding beyond the mere extraction of natural resources to encompass knowledge, practices and cultural values associated with the activity (Vieira da Silva & Miguel 2014). Moreover, sustainability has become a central element in defining extractivism, as reflected in Federal Law Nº 9.985 of July 2000, which established the Brazilian National System of Conservation Units (SNUC) (Brasil 2000).

In the temporal land-cover analysis conducted in this study, the areas examined (those encompassing the main pinhão-producing region of Santa Catarina) showed a higher prevalence of forest cover than the state of Santa Catarina as a whole. This finding lends support to the argument that the maintenance of Araucaria Forest cover, which is predominantly located on private rural properties (Reis *et al*. 2010, Reis *et al*. 2018a), is favored by family farmers who depend on the products and ecosystem services provided by these forests (Bittencourt & Sebbenn 2009, Tagliari *et al*. 2021).

In the context of PAS, pinhão is central to household livelihoods and constitutes one of the main sources of family income. Notably, forest remnants, where the PAS is located, represented the predominant land-cover category on participants' properties. This finding highlights the strong interdependence between local communities and the biodiversity conservation within this socio-ecological system (Tagliari *et al*. 2023).

This positive reinforcement of agroforestry systems for landscape conservation within the Atlantic Forest (and the biodiversity associated with it) is also observed in caívas (Mello & Peroni 2015, Zechini *et al.* 2018, Reis *et al*. 2018b, Hanisch *et al*. 2019, Marques *et al*. 2019, Lacerda *et al*. 2020, Hanisch & Pinotti 2024) and bracatingais systems (Steenbock *et al*. 2011, Moreira *et al*. 2011, Steenbock & Reis 2013, Silva *et al*. 2016). In this context, the study by Medina-Macedo *et al*. (2016) highlights the importance of preserving forest remnants to ensure the evolutionary persistence of Araucaria populations. Even on small properties, existing fragments reduce functional isolation, enable gene flow and play a critical ecological role. It enhances connectivity among forest patches, potentially providing refuge for wildlife and preventing extreme changes in the landscape, especially when considering the effects of climate change, and the increasing prevalence of other types of domesticated landscapes (Reis *et al*. 2018b, Marchioro *et al*. 2020, Ferreira *et al*. 2022, Levis *et al*. 2024, Ladio *et al*. 2026).

The PAS is an example of a forest-based livelihood that, by providing economic incentives to local rural communities, can help curb pressures for land-use change (Ticktin 2004). This is particularly relevant in the context of ongoing monoculture expansion, which has contributed to the loss of approximately 95% of the original forest cover (Tagliari *et al*. 2021, Bastos *et al*. 2023, Zorek *et al*. 2024).

Due to its distinctive relationship with the environment, which allows for the sustainable extraction of forest resources, this production system has been recognized in Brazil as a food production model based on good agricultural practices for Traditional Agriculture Systems (IPHAN 2019). Traditional Agricultural Systems are rooted in the use of natural resources by communities who coexist with and rely on nature, passing on their knowledge orally from one generation to the next (Diegues 2002).

Based on the available literature (Adan *et al*. 2016, Magnanti 2016, Magnanti *et al*. 2017, Magnanti & Rover 2019,Magnanti & Rover 2021), as well on the analysis and systematization of data obtained from interviews, guided tours during this study, and direct field observations accumulated over more than two decades of research on this agricultural system and related

cultural landscapes of the Araucaria Forest (e.g., bracatingais and caívas), the following classification criteria for the PAS are proposed:

1. Demonstrate a long-standing relationship with the territory, marked by extractivist activities and the prevailing use of family-based labor;
2. Adopt landscape-level management practices that support pinhão production, without compromising the native forest-grasslands structure or promoting land use change;
3. Combine pinhão production with extensive, pasture-based livestock farming in the same area, generally incorporating other resources derived from native or naturalized species;
4. Follow good management practices for araucaria trees, especially regarding the time of pinecone harvesting;
5. Have a significant share of household income derived from the PAS and seek to strengthen the pinhão value chain.

By sustaining cultural practices, reinforcing social meanings, and ensures both nutrition and income generation for local communities, while also conserving nature, the PAS exhibits characteristics consistent with those recognized by the Globally Important Agricultural Heritage Systems (GIAHS) program (FAO 2022). GIAHS is initiative from the Food and Agriculture Organization (FAO) of the United Nations Organization (ONU), that seeks to identify and safeguard sustainable agricultural practices that support food and nutritional security, preserve agrobiodiversity, and promote cultural heritage (Koohafkan & Altieri 2011, FAO 2022). This perspective may enhance the visibility and valorization of the PAS, thereby contributing to its continuity and resilience in the face of contemporary and future challenges. Encouraging younger generations to continue promoting the resilience of Araucaria Forest through their adaptative management practices is particularly urgent, given projections that climate change may result in the loss of up to 70% of the remaining forest cover by 2070 (Tagliari *et al*. 2023).

In this study, we sought to contribute to the conceptual foundation of the PAS by identifying and describing the structural and organizational characteristics that distinguish this system. However, much remains to be understood about this productive system and its multiple dimensions. Future research should investigate not only production practices associated with market-oriented activities, but also the system's contribution to food security, including the practices and knowledge associated with crop cultivation, livestock raising, and the extraction of other plant species for household consumption. Additional attention should be given to cultural expressions, such as handicrafts and traditional architecture, native fauna, water resource management, the use of medicinal plants, the roles of women within this system, value systems, forms of social organization, and other socioecological dimensions. Advancing knowledge in these areas is essential for safeguarding the PAS, ensuring the continuity of the traditions and cultural identity associated with it, and supporting future efforts towards its recognition as a Globally Important Agricultural Heritage (GIAHS).

Conclusion

The Traditional Pinhão Agroforestry System (PAS) is a distinct system embedded within the remnants of the Araucaria Forest from the Serrano Plateau of Santa Catarina. It reflects the historical socio-cultural and economic relations that shaped this territory. In its current configuration, the system is centered on cattle ranching and pinhão extractivism, the latter representing the main extractive activity among diverse set of culturally significant plant species. The family farmers who maintain this system identify themselves as pinhão extractivists, a designation that reflects more than engagement in harvesting activities, it denotes shared body of knowledge, informal management norms, and an enduring relationship with forest. PAS extractivists have developed strategies for harvesting, storage, threshing, and sorting that have been passed down and refined over generations. The extractivists also share a set of management practices aimed at ensuring the quality of harvested pinhão while supporting long-term maintenance of the system. These norms have not been formally established or collectively negotiated but have emerged as a common understanding rooted in generations of experience with pinhão extractivism and the continued use of the resource. In this sense, the PAS constitutes an important cultural heritage of the Serrano Plateau of Santa Catarina, grounded in a careful and sustainable management relationship that reconciles food security, livelihood generation, and the conservation of the Araucaria Forest.

Declarations

List of abbreviations: FAO- Food and Agriculture Organization; GIAHS – Globally Important Agricultural Heritage Systems; IUCN - International Union for Conservation of Nature; ONU - United Nations Organization; PAS – Pinhão Agroforestry Sistem; SC - Santa Catarina State.

Ethics approval and consent to participate: The development of the study followed the ethical and legal guidelines for the development of research on traditional knowledge. The project was approved by the Ethics Committee for Research with Human Beings of the Federal University of Santa Catarina (CEPSH) under the number: 82427718.0.0000.0121 de 18/06/2018. The participation of healers was subject to the acceptance of the Free and Informed Consent Form. The project was registered with SISGEN under the number A011D4A.
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