

Article

Evaluating Sustainability in Traditional Silvopastoral Systems (caívas): Looking Beyond the Impact of Animals on Biodiversity

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Abstract: Caívas are traditional silvopastoral systems that occur in the Araucaria Forest biome, Southern Brazil, in which animal production and erva-mate extraction are integrated. Participatory research was conducted in caívas in the Northern Plateau, Santa Catarina State, to identify strategies to intensify pasture use and increase animal productivity. To better understand the outcomes of these strategies, a sustainability assessment was conducted in properties that participated in the research (improved caívas; IC) and those that did not (traditional caívas; TC). The Sustainability Assessment of Food and Agriculture Systems (SAFA) tool 2.0.0 for smallholders was chosen as it evaluates the productive unit as a whole using environmental, social, economic, and governance indicators and is tailored for small-scale production. All evaluated indicators showed higher scores for IC properties in relation to TC. In general, the SAFA analysis showed that when evaluated as productive systems, TCs are a strategic option for rural development, as 65% of their indicators were evaluated as good. With the support of rural outreach and research and the adoption of appropriate technologies, this percentage increased to 86% in ICs. These results confirm that with adequate support caívas can significantly contribute to the development of more sustainable livestock farming in Southern Brazil.

Keywords: agroforestry; sustainability indicators; SAFA; traditional ecological knowledge

1. Introduction

As a response to global challenges stemming from population increase and a changing climate, alternative agricultural systems are necessary to obtain social, economic, and environmental sustainability [1]. Agroforestry, a system as old as the practice of cultivating land, is a sustainable agricultural practice [2] whose benefits include carbon sequestration and soil protection [3,4], nature conservation [5], poverty reduction and food security [6], and environmental resilience [7]. Due to its economic, ecological, and sociocultural benefits, agroforestry is an important land-use strategy that has been implemented worldwide [8]. Despite its recognition as a sustainable agricultural practice, measures and metrics related to assessing the sustainability of agricultural systems often give greater weight to environmental and economic indicators to the detriment of social dimensions [9–11], which are an essential aspect of many traditional agroforestry systems. This oversight can lead to incorrect interpretations about the sustainability of agroforestry systems [12], further threatening their continuation in the face of ‘modern’ agricultural practices.

Over generations, communities have developed traditional ecological knowledge (TEK), enabling them to implement forest management practices that combine sustainability of food resources and healthy forests with various crops, trees, and animal husbandry [13]. TEK has been defined as “a cumulative body of knowledge and beliefs, handed down through generations by cultural transmission, about the relationship of living beings (including humans) with one another and with their environment” [14] (p. 3). Although it is often used to refer specifically to Indigenous knowledge paradigms, TEK can also include settler communities that have continual, historical resource-use practices [14] as this knowledge is “both cumulative and dynamic, building upon the experience of earlier generations and adapting to the new technological and socioeconomic changes of the present” [15] (p. 281). Even though traditional agroforestry systems are often essential to biodiversity conservation, some antagonism towards traditional knowledge and management remain as they are seen as in conflict with nature conservation [16]. Environmental policies have concentrated conservation efforts mostly on establishing protected areas [17,18], overlooking the role of traditional systems in landscape, habitat, and species conservation [13,19]. The intense degradation of some ecosystems, combined with a resistance to incorporate TEK into environmental policies, have prevented or even prohibited small-scale farmers from managing forests through agroforestry systems [13,20].

The disfranchisement has been remarkably intense in Southern Brazil where communities are legally restricted from managing native forests (see for example, [21,22]), which in turn puts at risk the conservation of cultural landscapes and the species protected within. In the region’s plateaus, traditional forest management has provided land owners with a source of food, firewood, wood, medicine, fruit, pasture, and erva-mate, all of which support household food security and income [23–25]. Traditional systems known as caívas in Santa Catarina State [26] and faxinais in Paraná State [23] have been used for approximately a century to manage regional subtropical forests for multiple products; the latter system is based on productive commons, while the former is implemented in private properties. Both faxinais and caívas are strong cultural symbols to the families that have continued to maintain these systems with knowledge passed down through several generations and families perceiving an important link between the forest environment, traditional knowledge, and management practices [25].

Caívas are an agroforestry system based on the production of erva-mate (*Ilex paraguariensis*; a tea consumed locally and produced for export) and bovine husbandry that occur in the Araucaria Forest biome in Southern Brazil. In these systems, animals are rotated between areas to allow pasture to re-grow after intense grazing (especially in the winter) and erva-mate is left to re-sprout and produce foliage after harvesting (generally a three-year cycle). Caívas consist of an intermediate to open forest canopy that is maintained by pruning, favoring the development of erva-mate trees and pasture [27,28]. Because the management of forests is integral to caívas and faxinais, landowners have maintained a forest cover that varies in terms of canopy cover, forest structure, and diversity, depending on the production objectives [24–26]. Several authors have suggested that the remaining forest fragments found in Southern Brazil continue to exist because traditional systems and TEK have protected the forests; these landowners did not necessarily take part in the intense process of land conversion that occurred in Brazil throughout the 20th century [28,29].

As an agroforestry system, caívas are poorly understood, although the presence of animals is generally regarded as having a negative impact on the maintenance of forest biodiversity as they are considered a vector of ecosystem destruction [29–31]. The long-term sustainability of these systems has yet to be formally assessed despite their use for generations. Aiming to contribute to the understanding and valuing of these systems, in 2014 we began a participatory research project assessing strategies to increase animal productivity in caívas in the Northern Plateau region, Santa Catarina State, Brazil. Low levels of natural pasture productivity have led to lower levels of animal production and thus income, and many farmers are transforming traditional caívas into eucalyptus or pine plantation to improve revenue. Therefore, the strategies developed through the participatory research focused on the intensification and improvement of natural pasture to increase animal productivity and economic

security. An important aspect of this project was to assess the impact and sustainability of the strategies used with tools that integrate social, economic, and environmental factors.

Over the last several years, a range of measures and tools to assess agricultural sustainability have been developed along with the corresponding comparative assessments of these tools and their applicability to a range of contexts and purposes [12,32–34]. The tool chosen to conduct this analysis is the Sustainability Assessment of Food and Agriculture Systems (SAFA) [11]. Based on guidelines generated from fair and sustainable practices in food production, trade, and agriculture, the tool provides protocols to assess sustainability across the four dimensions of environmental integrity, economic resilience, quality of life (social), and good governance (institutional framework). Seeking to adapt to the particularities of family agriculture, a more compact, easy-to-apply version of the program was created, called SAFA Smallholders (SAFA-SH), which includes 44 indicators [35]. This paper presents the results of the diagnosis using the SAFA-SH tool in caívas. Specifically, we sought to assess the potential benefits of the strategies developed through the participatory research, compare the results for caívas managed by farmers that had participated in the project with those managing traditional caívas in the region, while also validating the use of the SAFA-SH tool for assessing the sustainability of traditional systems. The results are discussed in the context of sustainable rural development.

2. Materials and Methods

The research was carried out in the Northern Plateau region, Santa Catarina State, Southern Brazil, on rural properties in the municipalities of Três Barras, Canoinhas, Irineópolis, and Porto União (Figure 1).

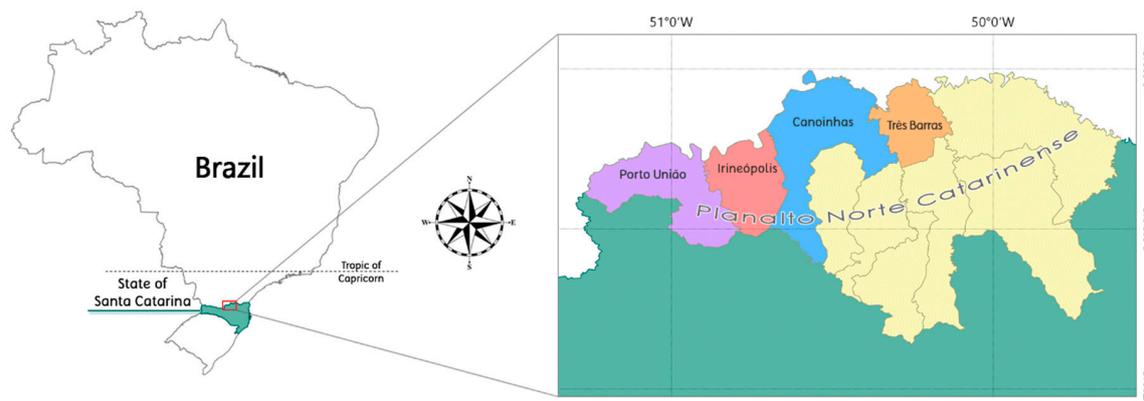


Figure 1. Northern Plateau region of Santa Catarina State, Brazil, showing the municipalities involved in the research: Porto União, Irineópolis, Canoinhas, and Três Barras.

Seventeen rural properties were selected that include areas of caíva in flat to gently undulating terrain within the Araucaria Forest region [31]. The caívas systems presented a range of different tree densities and spatial distribution, management practices of the understory, and animal load, but all occupied an area of at least two hectares. Forests were subject to historic selective harvesting while current use is limited for domestic fuel for over the last 50 years. Dairy farming is the main economic activity of 70% of the families, while the others mainly use caívas for beef cattle and erva-mate production.

Of the families selected, seven were involved in a participatory research project that occurred from 2013 to 2017, focused on developing techniques for improving production in the caíva silvopastoral system. Along with the establishment of experimental plots in these properties, productive planning activities were also carried out, and the properties were monitored periodically by the research group. In addition, the families agreed to participate in various activities, such as meetings, technical visits, and training sessions related to the production system. The participatory research project did not provide financial resources to the families involved, but all successfully accessed resources from

other government programs to implement improvements on their properties (for further information, see [24]). The remaining 10 families have maintained traditional caívas and were selected based on the recommendations from rural outreach workers from Epagri (Agricultural Research and Extension Company of Santa Catarina) and by technicians from partner organizations. For the purpose of analysis, the systems are referred to as improved caívas (IC—properties participating in the participatory research) and traditional caívas (TC—other properties). Participation of the families in the sustainability assessment was voluntary. Site visits were conducted to clarify the aims and outcomes, present the procedures, and establish an agreement governing the use of the collected information.

Data collection took place in February 2017 and included visits to evaluate the agricultural practices of properties and semi-structured questionnaires. Of the SAFA-SH tool's 21 themes, 44 indicators, and 100 guiding questions, our questionnaire included 20 themes, which were analyzed using 34 indicators (Table 1) based on 77 guiding questions. (More detailed information about the SAFA Smallholders App can be accessed here: <<http://www.fao.org/nr/sustainability/sustainability-assessments-safa/safa-app/en/>>). The selected set of indicators and questions excluded those that fall outside the context of the studied properties, such as fish farming and fishing activities. To avoid bias in the responses by participants, the evaluation was carried out by a team from the Federal University of Paraná (UFPR), without the direct involvement of researchers and rural outreach agents who led the participatory research project.

Table 1. Dimensions, themes, and indicators of sustainability selected from the Sustainability Assessment of Food and Agriculture Systems Smallholders (SAFA-SH) tool [35].

Dimension	Theme	Indicator
Social well-being	Fair trade practices	Fair price and transparency in contracts
	Human health and safety	Safety in the workplace, in operations and facilities
	Decent life	Capacity building
	Equity	Gender equity
	Cultural diversity	Food sovereignty Indigenous knowledge Quality of life
Good governance	Corporate ethics	Knowledge of the mission
	Social accounting	Social accounting
	Participation	Participation
	Holistic management	Sustainable management plan
Environmental integrity	Legal aspects	Right of ownership and use of land
		Greenhouse gas (GHG) mitigation practices
		Practices for prevention of air pollution
		Soil improvement practices
		Nutrient balance
	Atmosphere	Practices for conservation and recovery of areas
	Materials and energy	Water conservation practices
	Soil	Water pollution prevention practices
	Water	Pesticides
	Product quality and Information	Diversity of the ecosystem
Biodiversity	Species conservation practices	
Animal welfare	Genetic conservation of seeds and breeds	
	Renewable and recycled materials	
	Energy use and consumption/renewable energy	
	Loss of food/reduction of waste	
	Animal health and welfare	
Economic resilience		Profitability
		Production diversification
	Investment	Market Stability
	Vulnerability	Liquidity
	Product quality and Information	Safety nets
		Power quality Certified products

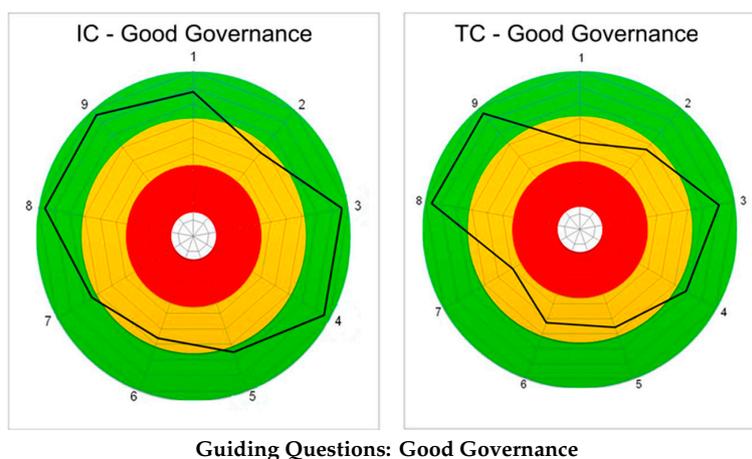
The information collected was analyzed by the SAFA-SH software version 2.0.0, which provides a guided metric for the definition of performance levels for each evaluated indicator. Thus, each score is derived from the processing performed by the tool, which correlates the primary information entered in its database (from the current scenario) and the standard defined by the tool. The SAFA-SH performance assessment uses three sustainability scores: good (green, >80%), limited (yellow, 50–79%), and unacceptable (red, <49%) (Table 1) [11].

The SAFA-SH tool was created as an easy-to-use application for use with cellular smart phones, that allows producers to quickly visualize specific critical points of sustainability in their agricultural activities. For this, the results of the analyses are presented individually, as bar graphs, and are made available directly on the screen of the cell phone at the end of the interview. Although the study was carried out with the support of a cell phone in the field, all outputs of the application were transferred to Microsoft Excel to assess the average score for each group and develop the polygon graph, as recommended in [11]. The graphs were prepared based on the average score for each of the 77 guiding questions and presented according to the indicators defined for each dimension.

3. Results and Discussion

3.1. Good Governance

The focus of good governance indicators is on family-farm organization and strategic planning. For both evaluated groups, no unacceptable values were observed for any of the indicators (Figure 2). However, in the traditional caívas (TC), five out of nine questions presented limited values, including those related to farm planning and record keeping.



- Guiding Questions: Good Governance**
-
- (1) Do you have a statement about the farm's goals and values that you follow and that everyone on your farm understands?
 - (2) Do you keep records of the production processes?
 - (3) Do you participate in any producer organization?
 - (4) Do you believe that being part of a producer organization adds value to your property?
 - (5) Do you have a property management plan to ensure long-term production?
 - (6) How successful has been this plan?
 - (7) What elements are part of your plan? (Finances; soil fertility management; environmental management; profitability; expansion/staff; health and safety; marketing; quality; processing or adding value; green for 3 choices or more, yellow for 2 choices, red for 1 choice or less).
 - (8) Do you feel secure with your land ownership situation of where you live?
 - (9) Have you been unable to invest/obtain funding due to a property or right of land use issue?

Figure 2. Performance and guiding questions for good governance in properties with caívas in the Northern Plateau region, Santa Catarina, 2017. Bold lined polygon reflects each indicator performance evaluated through guiding questions; colors represent indicator performance (good ● >80%; limited ● 50%–79%; unacceptable ● <49%). TC: traditional caívas; IC: improved caívas.

While both groups showed good levels for participation in producer organizations, this participation seems to have been more effective for the IC group as reflected in increased scores for the importance of the organization in adding value to properties, better understanding the intersection between research, outreach, and production (items 1 and 4), and property planning (items 5, 6, and 7). These results confirm the importance of technical/scientific participation and follow-up through farmers' organizations for greater property sustainability and knowledge sharing.

Considering that the seven properties that participated in the research project (IC group) had developed, presented, and discussed their management plans during participation in the farmers' organization, higher scores were expected for items 5, 6, and 7. However, among the IC group we found that this indicator was lower for the properties that received fewer technical guidance visits and therefore may be related to insufficient follow-up. Lack of planning is common in rural properties in the region, as can be confirmed in the TC group, and it is part of the farming culture. Nevertheless, changing this behavior requires commitment from the farmers and increased engagement by the outreach institutions involved.

The high values observed for all properties in relation to the "right of ownership and use of land" (items 8 and 9) across both groups represents a positive social and environmental aspect of caívas. The majority of farmers who use a caíva system are owners and very often heirs of these properties that are continuing the traditional system developed by their ancestors, many of whom migrated to Southern Brazil in the late nineteenth and early twentieth centuries. As such there is a strong sense of belonging and appreciation of the property, which is connected to cultural and ethnic heritage and deep understanding of the forest environment. This is an important consideration for supporting sustainable production and forest conservation among caíva producers as the sense of belonging and knowledge of the land and forest can be leveraged to develop feelings and practices around environmental stewardship. By supporting these small-scale producers in continuing and optimizing their traditional practices, they become defenders of these productive forest environments which will likely help to ensure their continuation into future generations.

3.2. Social Well-Being

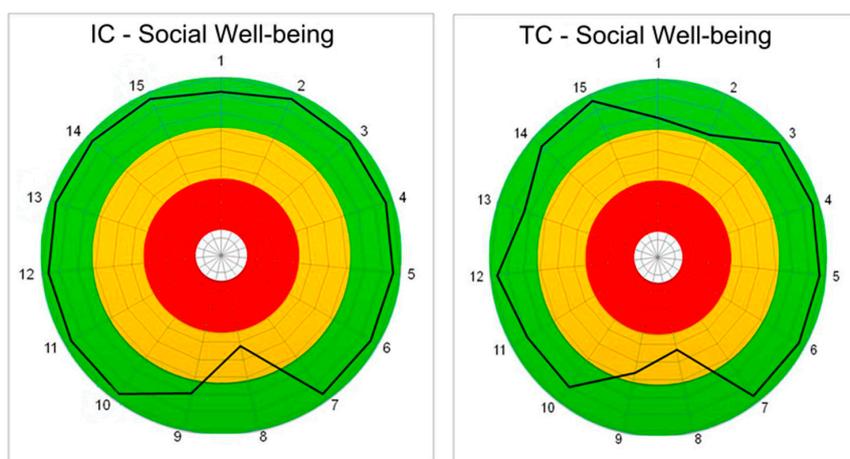
The results observed under theme of social well-being were a pleasant surprise, since it is the category with the least difference between the two groups and the majority of the results are almost all positive (Figure 3).

Once again, these graphs demonstrate the importance of the participatory project, but also engagement with farmer's organizations and outreach agencies through technical assistance and training. All IC families received information about the market for their main products (dairy and *erva-mate*), through the various training events in which they participated. TC families also showed good performance in terms of understanding of the market, but the improved results for the IC families suggests that greater engagement with outreach institutions and knowledge sharing across families increases market awareness.

Indicators for work health and safety (items 3 to 6) show that the majority of households have access to healthcare and clean water, as well as sufficient training on the use of agrochemicals. Item 8, regarding the use of personal protective equipment (PPE) during pesticide use, had the lowest score for both groups. This result indicates that despite advances in relation to the use of agrochemicals in rural areas, there are still requirements that are not being met, mainly due to cultural conceptions of masculinity; for example, many farmers do not use PPE because they think it is only necessary for those who are weak or frail, and its use could be seen as threatening their manhood.

A very positive indicator of social well-being was the high value for gender equity (items 10 and 11). All interviews were conducted with the participation of the family unit (generally the male and female heads of the household). In the IC group, field visits, training, and knowledge exchange that occurred throughout the project always involved both men and women. While the participation of both genders was a requirement of the project, it was accepted very naturally by all families, as it is one

of the defining characteristics of family agriculture in Brazil, in which all family members participate in property activities.



Guiding Questions: Social Well-Being

- (1) Do you understand how the prices paid for your product are calculated or established?
- (2) What type of market information did you have access to in the last productive year?
- (3) If you need medical help, how far must you travel for assistance?
- (4) How much assistance does the nearest medical care center provide to farmers and their families?
- (5) How long should farmers leave their workplace to access the nearest source of drinking water?
- (6) Do members of your household have access to adequate drinking water?
- (7) Do any of the following rural workers or family members apply pesticides in the property? Pregnant women (red); minors (red); persons not trained for such activity (red); none of the above (green).
- (8) What PPE (personal protective equipment) are used when applying synthetic pesticides?
- (9) What kind of training did you participate in during the past year?
- (10) Are both men and women active/participating in farm activities?
- (11) Do women and men have equal rights with regard to access to the training offered?
- (12) Do you agree with the following statement: I have the right to choose what I will produce on my property.
- (13) Do you consider that your product has higher value-added thanks to traditional knowledge?
- (14) Do you have a connection with communities from which traditional or indigenous knowledge originated?
- (15) What is your opinion of the overall quality of life (e.g. in terms of time, money and lifestyle) on the farm compared to the previous year?

Figure 3. Performance and guiding questions for social well-being in properties with caívas in the Northern Plateau region, Santa Catarina, 2017. Bold lined polygon reflects each indicator performance evaluated through guiding questions; colors represent indicator performance (good ● >80%; limited ● 50%–79%; unacceptable ● <49%).

As this project aimed to evaluate a traditional production system, the very positive result for items 12 to 14 related to “indigenous or traditional knowledge” is encouraging. It is evident in the region that the production of erva-mate in natural forests and the knowledge associated with the management of caívas is a source of pride and is a culturally significant tradition. In terms of sustainability, it is important that this knowledge is valued by governmental and academic research and outreach institutions and incorporated into technical models and training, particularly through participatory research similar to the caíva improvement project implemented in the region. By valuing and building on this knowledge in a participatory manner, traditional producers become active participants in developing sustainability strategies and are therefore much more likely to implement and continue these practices [32].

Another important aspect of the social well-being indicators is that in addition to supporting women’s participation in technical training courses, especially those related to dairy production activities in the context of the caívas, specific courses should be made available for women and youth around other productive activities (i.e., medicinal plants and gardens) and promoted by institutions such as Epagri. These outreach and training activities must actively seek the participation of younger

generations to encourage intergenerational knowledge sharing and further underscore the value of traditional knowledge and practices in the region.

The high score for quality of life is an important point to emphasize, as it reflects satisfaction in living and working conditions, with the availability of decent markets for their products and an acceptable infrastructure. This does not mean, however, that social well-being does not need to be further addressed, as these indicators must be seen as a starting point from which further discussions, reflection, and learning can develop [36].

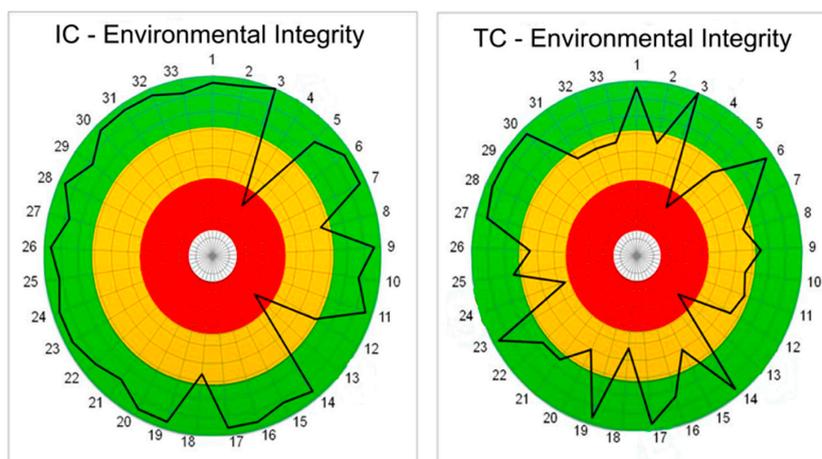
3.3. Environmental Integrity

In terms of environmental integrity, the objective of the SAFA tool is to evaluate the entire productive unit, and not only the caívas. As such, the results show a marked difference between the two groups (Figure 4), which is likely related to the fact that the IC group received technical support for property planning and training activities, rather than differences in caíva management strategies. All the indicators that had a higher score in IC in relation to TC are the result of the adoption of practices indicated through strategic property planning and training events, and direct support through investment projects for the families participating in the research project.

The environmental integrity dimension of the improved caívas was excellent. In four questions where the IC were classified as intermediate, we found interpretive conflicts with the SAFA-SH App. Item four, for example, only accepts “yes” or “no” and its interpretation is that livestock production on a rural property is automatically considered unacceptable. In items 8, 13, and 18, related to the use of synthetic fertilizers and agrochemicals, we must consider that these systems are not characterized as organic, and as such it is not surprising that the scores are low. There is a need for re-evaluation over time, combined with technical assistance focused on the proper and reduced use of agrochemicals and the integration of agroecological practices.

The improvement of environmental integrity in productive systems requires qualified technical assistance and monitoring of the properties. An example of this is the indicators related to soil improvement practices and nutrient balance (items 5, 8, 9, 10, and 11) that were positively altered in IC farms due to the introduction of sustainable practices such as soil analysis, pasture height control, organic fertilization, and intercropping with legumes. The same was observed for the animal welfare indicators, which improved significantly in IC (items 31 to 33). All of the practices suggested and implemented were improved with technical training and outreach rather than new investment in the farm. This is an important consideration as many small-scale, family-owned farms lack the economic capital to make large investments, and slight improvements that build on the systems and traditional knowledge already in place are more likely to be adopted.

Indicators related to caívas that were high in both groups (items 1 and 17), confirm that properties with caívas have greater forest cover and are able to adapt more easily to changing legal requirements such as areas of permanent preservation (APP, which in this context is mainly the protection of riparian forests) and legal forest reserves (% of property required to be covered by forest). While the current legislation in the Forest Code [22] is meant to protect native vegetation and support sustainable development, it severely restricts management within forested areas and in so doing is threatening the continuation of caívas as agroforestry systems. As Mello and Peroni [25] note, management is inherent in these systems, through cattle grazing and exploitation of non-wood forest products, and without management these systems would no longer exist. Caívas should be understood as cultural landscapes [37] within the Araucaria Forest, and based on agroforestry system classifications [13,38], they should be classified as traditional silvopastoral systems. With the exception of the questions regarding tree cover, the SAFA-SH App did not address the characteristic advantages of caívas in relation to biodiversity or other ecosystem services. Thus, despite the important environmental benefits that are maintained through these systems, it was not possible to use these criteria to evaluate the sustainability of these systems in terms of the services they provide.



Guiding Questions: Environmental Integrity

- (1) Which of the following statements best describes the area covered by trees on your property? More than 20%; less than 20%; there are no trees on my property.
- (2) During the last 3 years of production, was there any changes in the number of trees in the property?
- (3) What is your main method of cultivation? Conventional; minimal cultivation; direct seeding?
- (4) Is most of the production of the property ruminants (cattle, sheep, goats)? Yes/No
- (5) What is the main manure management system used on the property?
- (6) Is smokeless fuel used in your property (e.g., kitchen gas) or do you have an exhaust hood?
- (7) Do you practice field burning? Yes/No
- (8) What is the main type of fertilizer used on the property?
- (9) What strategies are used to improve soil quality on the property? (Cover crops; perennial or annual legumes; intercropping; crop rotation; none)
- (10) How do you determine how much fertilizer needs to be applied to crops?
- (11) Which of the following soil management options are used in the property? Maintain a permanent soil cover through mulch, planted soil cover; terracing or contour planting on areas of significant slope; hedgerows (e.g., trees and shrubs); soils are often bare between cropping cycles (red).
- (12) Do you use any synthetic chemical pesticide?
- (13) Do any of the pesticides used on your property have a red stripe on the label?
- (14) Do the pesticides used on the property come with clear instructions for use?
- (15) Do you mix pesticides in the tank/backpack?
- (16) Have you converted any native vegetation area into a production area in the last 3 years?
- (17) Among the following alternatives, is any of them used on your property to recover or conserve native species: areas of permanent preservation (APPs); recovered or reclaimed areas; area of permanent vegetation?
- (18) What are the pest and disease management practices used in the main crops in the last productive year?
- (19) What is the diversity of your production system?
- (20) Do you use any locally adapted variety or breed for the main crops and livestock produced on the property?
- (21) What is the main source of local seeds or breeds?
- (22) Do you use water conservation practices on your property?
- (23) Do you irrigate your crops?
- (24) What care do you take with any source of natural water on your property?
- (25) How do you handle crop residues, processing residues, and organic matter?
- (26) Do you either take for recycling or reuse metals, plastic packaging, or bags?
- (27) If you use electricity, coal, wood, or other sources of energy, have you been improving your efficiency?
- (28) If wood or coal was used on the property during the last year of production, which one was used the most?
- (29) Do you use any of the following renewable energy sources in a significant proportion of the total energy used in the property? Solar (green); hydropower or geothermal (green); wind (green); biofuel from farm or household waste (green); none of the above (yellow).
- (30) Are there preservation measures used to prevent pre- and post-harvest losses on the property?
- (31) Does the herd have veterinary access/monitoring?
- (32) How is waste managed on your property?
- (33) Which of the following best reflects the animal welfare conditions on the property? Animals have adequate space, shelter is kept clean and not crowded, there is sufficient and balanced diet, and unnecessary distress (green); Animals have adequate living conditions, sufficient feed, and I try to prevent unnecessary distress, but there is room for improvement (yellow); Animals are kept in unsanitary or inadequate shelter conditions, are limited in expressing natural behaviors, do not have access to adequate feed, or measures are not taken to keep animals from experiencing unnecessary distress (red).

Figure 4. Performance and guiding questions for environmental integrity in properties with caívas in the Northern Plateau region, Santa Catarina, 2017. Bold lined polygon reflects each indicator performance evaluated through guiding questions; colors represent indicator performance (good ● >80%; limited ● 50%–79%; unacceptable ● <49%).

On the other hand, we identified a negative aspect of traditional caíva management related to water conservation practices, which is animal access to naturally occurring water sources (item 24), a practice at odds with current legislation. Although this practice has been used for almost 100 years in the region, it was very easy to change in the ICs through the introduction of techniques such as pasture picketing and water distribution in paddocks, as well as fencing around rivers and springs to avoid animal access.

The participatory research project with caíva farmers focused on improved and intensified use of pasture and increased animal production, including perennial pasture, forage intercropping, water conservation for distribution in paddocks, among others, yet the elevated scores for all environmental integrity indicators observed for the IC group strongly counters the perception of the role of cattle as a vector for ecosystem destruction. Depending on the approach, cattle can have both negative and positive impacts, where “in some places with a long history of livestock grazing, a unique biodiversity has specifically adapted to habitats associated with the presence of domestic herbivores” [39]. In Southern Brazil, cattle are one of the central components in socioeconomic production strategies of families using caíva, faxinal, and other traditional silvopastoral systems. While the presence of animals may be responsible for the degradation and fragmentation of forest landscapes in some contexts, in the case of caívas it has contributed to forest connectivity because of the continuation of native tree cover. Meanwhile, the production of dairy products is clearly linked to local identities and practices that are grounded in the shared histories and ethnicities of the families in the region. However, the negative perception of cattle in terms of environmental integrity is so entrenched in current discourse that even the SAFA-SH tool considers the presence of cattle on rural properties as “unacceptable”. Given the importance of diversity in productive activities for the greater stability of a productive system [40,41], as well as the importance of organic fertilizers such as manure, a sustainability evaluation tool that disregards the importance of animals in the rural environment needs to be more finely-tuned. Clearly, sustainability assessment methodologies should reflect the different weight of these impacts on the evaluated system [12].

3.4. Economic Resilience

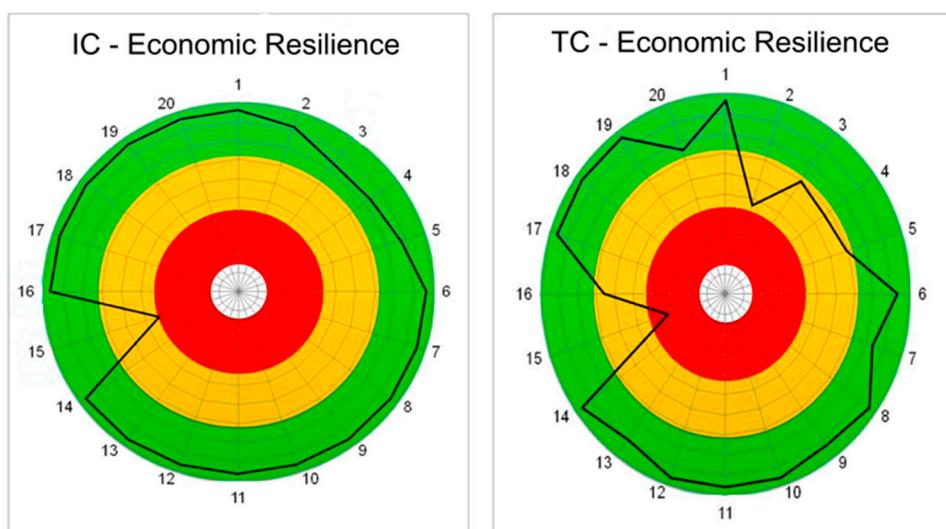
Similar to environmental integrity, the economic resilience showed excellent performance for the IC group (Figure 5) which reflects the successful integration of participatory research, technical follow-up, regional traditions, and public policies.

The indicators of profitability (items 2 to 5) were high for IC and are characteristic of properties with technical monitoring and assistance, where the acquisition of inputs and product commercialization is integrated into strategic planning. An important indicator for economic resilience is product diversification (item 6), which was high in both groups, and reflects another characteristic of family agriculture in Brazil [28].

The market stability indicators (items 7 to 10) were high in both groups and are correlated with the two main products that are produced in the evaluated properties: milk and erva-mate. In both cases, there is high market demand, which promotes a sense of stability on the part of the farmers in relation to commercialization.

Regarding the “safety net” indicators, the high values for both groups (items 11 to 14) confirm the positive impacts of public policies related to family agriculture that have been implemented over the last decade, including greater access to credit, agricultural insurance, financing, agricultural product pricing policies, and marketing support programs [42]. These policies were also reflected in the financial savings item, which was high for all properties. The improvement of risk reduction (item 16) in the IC group also supports the positive impacts of the integration between public policies and the participatory project, as participants received resources to build water reservoirs on their property. Clearly, participatory projects and local-level implementation of national policies must be expanded through the various government research and outreach institutions, such as Epagri, Embrapa, and Emater. However, government policies that support family agriculture are embroiled in political and ideological debates

which threaten their continuation. Policies grounded in sustainability assessments, such as the one produced herein, can help to mitigate these political divides by demonstrating clear outcomes of policies and practices in terms of economic sustainability of rural producers.



Guiding Questions: Economic Resilience

- (1) Do you market your crops, animals or agricultural products?
- (2) Do you know the financial income of your last year's production?
- (3) Do you know the costs of fertilizers, pesticides, and seeds/seedlings in the last year of production?
- (4) Do you know the costs of feeding animals, veterinary care, and animal replacement?
- (5) In the past three years, how often were the property's profits higher than the costs?
- (6) How many crops, products, or services are sold by your property?
- (7) Do you do any processing or value adding in order to increase revenue from services or the sale price of your crops or agricultural products (e.g., tourism, butchered meat, drying coffee or fruit, processing jam)?
- (8) How many selling options do you have for the crops or products produced on your property?
- (9) How is your relationship with your primary buyer?
- (10) Do you believe you have a choice of where to sell your products?
- (11) Where can you get a loan if necessary?
- (12) If you took out a loan last year, how much did you receive compared to the amount requested?
- (13) Do you have financial reserves?
- (14) Do you have agricultural insurance?
- (15) Do you have a risk management plan that guarantees the minimum costs of production or support in case of loss?
- (16) Have you implemented any agricultural measure to reduce the risks arising from variation in natural production conditions and inputs (e.g., the construction of a water reservoir)?
- (17) Do you take any action to maintain a high quality of your crops and products?
- (18) In the last three years has there been any technical analysis of the quality of your crops or products?
- (19) Is any product produced on the property under any specific production or certification standard?
- (20) How many of your products or crops are sold under a specific production or certification standard?

Figure 5. Performance and guiding questions for economic integrity in properties with caívas in the Northern Plateau region, Santa Catarina, 2017. Bold lined polygon reflects each indicator performance evaluated through guiding questions; colors represent indicator performance (good ● >80%; limited ● 50%–79%; unacceptable ● <49%).

The high scores for the certified products indicator (items 17 to 20) are due mainly to the commercialization of erva-mate produced in natural forests. In the current market, erva-mate that is grown in shaded conditions and native forest stands following traditional practices provide a level of quality that is recognized by both middle-men and the industry and as such commands a slightly higher price. Nevertheless, knowledge about erva-mate in traditional systems and the quality implications are not yet part of the commercialization of the product and as such producers are often left at the mercy of current market demands and prices. More work needs to be done by both producers, co-operatives, family farmers' unions, and research and outreach agencies to educate consumers not only about the quality differences between different types of mate production, but also the socioenvironmental

impacts that traditional production systems provide, such as the continuation of cultural practices and the maintenance of native forest cover. To date, several initiatives have been implemented to recognize native erva-mate production and quality, such as the geographical indication IG-Mathe, but many are top-down initiatives from industry that lack benefit sharing with small-scale producers. While these indicators showed positive results for both IC and TC farms, much work still needs to be done to improve market conditions that ensure the sustainability of these traditional systems in the long-term.

3.5. Overall Indicators of Sustainability

The results showed an increase in the number of responses with good scores in IC in relation to TC, indicating that the strategies developed in the participatory research had a positive impact in terms of caíva sustainability (Figure 6). In IC, 86% of the 77 guiding questions reached a level considered good, compared to 65% for traditional caívas.

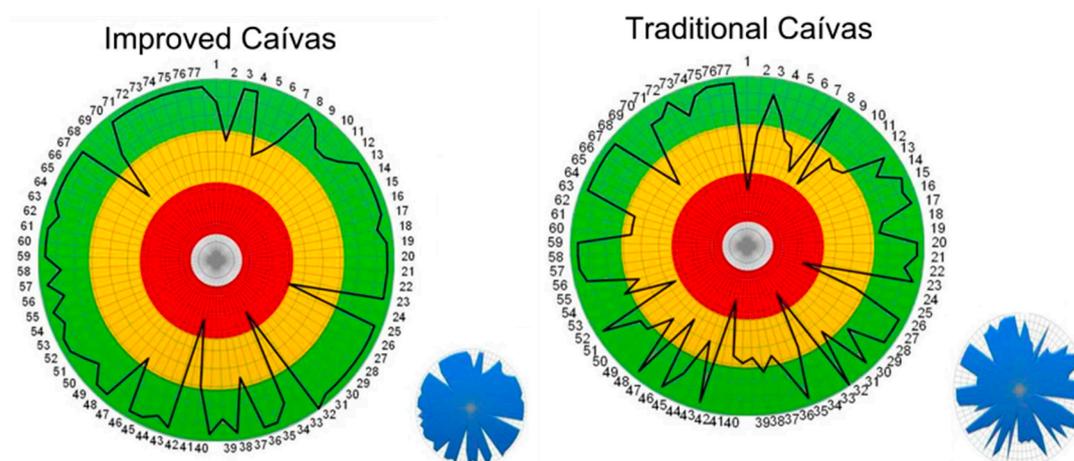


Figure 6. Overall performance of the sustainability analysis of properties belonging to the groups improved caívas (IC) and traditional caívas (TC), in the Northern Plateau region, Santa Catarina, 2017. Bold lined polygon reflects each indicator performance evaluated through the guiding questions; colors represent indicator performance (good ● >80%; limited ● 50%–79%; unacceptable ● <49%).

The results of the SAFA-SH assessment confirm that innovation and the development of technologies based on traditional systems such as caívas can help to increase their sustainability. The improved performance of the farms that participated in the research compared to those that did not demonstrates the benefits of valuing traditional systems and building on them through the development of adapted technologies [43–45]. Many of the improvements in the IC farms for economic and governance dimensions relate to improved management and planning in terms of production and a better understanding of the financial aspects of their farming systems. Meanwhile, environmental integrity indicators were generally lower for TC due to the use of synthetic pesticides and fertilizers and the management of waste and on farm resources, such as water. Participation in the project included training and management planning assistance which clearly had a positive impact on the IC farms, suggesting simple solutions can be used to help improve sustainability across the region.

The multidisciplinary approach of the participatory research project that included agronomists, ecologists, and traditional knowledge practitioners, was another strong advantage of the research as it brought several different perspectives of the landscape to bear on the practices and strategies developed. Meanwhile, the participation of different stakeholders in the process of evaluation and discussion is an important strategy as it tends to promote almost immediate acceptance or rejection of results generated [46]. Such projects, however, require the commitment of several different individuals and institutions and a re-imagining of current top-down approaches in scientific and agriculture research and outreach.

4. Conclusions

Many attributes of traditional silvopastoral systems are consistent with sustainable agriculture and provide a variety of socioenvironmental services to farmers and their surrounding communities [47]. Our analysis demonstrates that incorporating environmental, social, governance, and economic factors into assessments of sustainability enable a more nuanced understanding of not only traditional practices but also the important institutional indicators that can play a key role in supporting sustainable development. In this case, approaching institutional indicators through good governance guidelines is an important contribution of the SAFA-SH App, since it is understood that organizations and farmers committed to sustainable development require governance structures where values and responsibilities are clearly established and transparency, accountability, process legitimacy, and rigorous sustainability management are supported [11]. Furthermore, commitment of not only the families but also government research and outreach institutions through participatory research are essential to ensure that proposed strategies and practices have relevance and buy-in at the local level.

The SAFA-SH analysis shows that traditional caíva (TC) productive systems should be considered as important opportunities for rural development, since 65% of the indicators were evaluated as good. Indicators with excellent scores such as quality of life, good relationship with the market, appreciation of traditional knowledge, gender equity, and the evident sense of belonging and pride in all families are important factors that confirm their importance among small-holder farmers. With the support of rural outreach and research and the adoption of appropriate technologies, such as the intensification of pasture use, this percentage increased to 86% as shown in the improved caívas (IC). Considering that recent work by the United Nations Food and Agricultural Organization (FAO), the International Union for Conservation of Nature (IUCN), the World Resources Institute (WRI), and a range of other institutions and countries around the world are working together to develop flexible and affordable frameworks for countries to rapidly identify and analyze potential areas for forest landscape restoration (FLR) (see for example the Restoration Opportunities Assessment Methodology (ROAM) methodology outlined in [48]), this analysis suggests that caívas as traditional agroforestry systems have significant potential to contribute not only to the sustainable development of the rural landscape in Brazil, but also forest restoration strategies that address many of Brazil's national and international commitments (i.e., the Bonn Challenge, 20x20 initiative).

Nevertheless, our results highlight the need for further discussion and analysis on the presence of animals in productive systems in terms of sustainability, especially those that involve agroforestry systems, such as caívas. In both traditional and improved caívas, scores for environmental integrity were lower because of cattle production, which is an integral part of the system and the farms' economic production. Finding a solution to this conflict requires a larger number of context-specific indicators that consider that animals can be part of conservation strategies when properly managed. An interesting proposition is to integrate tools that evaluate the impact of livestock on biodiversity, such as Life Cycle Analysis (LCA) and Pressure-State-Response (PSR), into sustainability analyses such as SAFA [1,31].

This evaluation makes clear that all families, independently of the group, consider caívas as part of their productive systems and as such they should be considered as cultural landscapes that have been transformed through management practices, especially with animal husbandry and the extraction of natural resources such as *erva-mate*. However, current legislation and dominant conservation ideologies in Brazil define these systems as forest fragments, bringing with this definition the associated strict legal restrictions in terms of management and antagonism between government institutions and traditional small-scale producers. By devaluing the important socioenvironmental aspects of these traditional systems in the Northern Plateau of Santa Catarina and requiring strict conservation, families that have used these systems for generations may no longer see their value. If the historical, cultural, and environmental heritage embodied in these systems were no longer highly valued by these small-scale farmers, the caívas would likely no longer exist and the damage to the region's environmental integrity would be vast. By supporting the continuation of these traditional systems through participatory research, outreach, and innovation, we are supporting not only the continuation

of traditional knowledge and culture, but also sustainable economic and environmental practices that offer significant benefits for society as a whole.

Current legislation that is meant to protect the remaining forest fragments has inadvertently antagonized small-scale traditional farming practices. This sustainability assessment makes clear that the knowledge and care of the forest among caíva producers can be leveraged to develop practices around environmental stewardship that will likely have much greater success in preserving biodiversity and ecosystem services than the current prohibitive policies. And these practices can be built upon through innovative approaches to develop context specific strategies for forest landscape restoration and sustainable rural development. Nevertheless, it is fundamental to understand that valuing caívas as areas of socioenvironmental use and conservation through strategies for their productive improvement does not negate the need and importance of maintaining areas of strict forest preservation in properties (i.e., APP) nor the creation of areas exclusively for the purpose of forest landscapes preservation.

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