

Opportunities and challenges for the development of the Cerrado bioeconomy: an analysis from the agents of the baru supply chain

Oportunidades e desafios para o desenvolvimento da bioeconomia do Cerrado: uma análise a partir dos agentes da cadeia do baru

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ABSTRACT

Strengthening sociobiodiversity production chains plays a little-understood role in supporting the transition into bioeconomy. This article explores the strengthening of sociobiodiversity chains through the case study of the baru supply chain. Data from semi-structured interviews (n = 114) with various agents involved in the supply chain underwent thematic analysis to understand their perceived opportunities and challenges for strengthening the chain and its contributions to promoting a sociobiodiversity-based bioeconomy in the Cerrado. Results suggest that despite existing opportunities for strengthening the chain, they face numerous challenges to trigger development processes aligned with the sustainable goals of the bioeconomy.

Keywords: Bioeconomy. Sociobiodiversity. Agroextractivism. Supply chain. Baru. Brazilian Cerrado.

RESUMO

A forma como o fortalecimento das cadeias de produtos da sociobiodiversidade apoia a transição para a bioeconomia é pouco compreendida. No presente artigo, realizou-se uma aproximação ao fortalecimento das cadeias da sociobiodiversidade com base no estudo de caso da cadeia produtiva do baru. Os dados de entrevistas semiestruturadas (n = 114) a diversos agentes da cadeia produtiva foram analisados a partir da análise temática visando compreender as percepções dos agentes sobre oportunidades e desafios para o fortalecimento da cadeia e suas contribuições para promover a bioeconomia do Cerrado baseada na sociobiodiversidade. Os resultados sugeriram que, apesar das

oportunidades para fortalecer a cadeia, ainda são inúmeros os desafios enfrentados por ela para desencadear processos de desenvolvimento com o viés sustentável que a bioeconomia persegue.

Palavras-chave: Bioeconomia. Sociobiodiversidade. Agroextrativismo. Cadeia produtiva. Baru. Cerrado.

1 INTRODUCTION

Sociobiodiversity-based bioeconomy represents a promising opportunity for sustainable development based on processing and commercialising products from Brazilian biomes associated with the territories of traditional peoples and communities. Strengthening sociobiodiversity product chains constitutes a key path to promote bioeconomy and biodiversity conservation, as well as food security, well-being, and maintenance of the way of life of agroextractivist communities.

The Cerrado biome presents several possibilities for insertion in the bioeconomy by means of sociobiodiversity product chains. Their relevance in the biome stems from the economic, social, and environmental importance of the Cerrado as the second largest biome in Brazil, home to a high biodiversity and subsistence ensurer for several traditional agroextractivist communities. Among the various sociobiodiversity product chains existing in Cerrado, the baru production chain has recently gained prominence. Baru went from a product virtually unknown to consumers and ignored by the market ten years ago to being considered a promising product with great sales potential and increasingly appreciated and sought after in the national and international markets.

However, with a few exceptions (Bispo *et al.*, 2021; Magalhães, 2019; Monteiro; Carvalho; Vilas-Boas, 2022; World Wide Fund for Nature – Brasil; Instituto Conexões Sustentáveis, 2021), few studies have inquired about the opportunities and challenges linked to the baru production chain or analysed these aspects aimed at strengthening the chain from the viewpoint of a broad representation of the various agents involved.

Considering this context, this article explores the perceptions of the various baru production chain agents on the opportunities and challenges for strengthening the chain and their contributions to promoting the sociobiodiversity-based Cerrado bioeconomy. Besides this introduction, this paper has four sections. In the second section, we present the theoretical framework of the research. The third section of empirical character outlines the methodology for data collection and analysis in the case study. In the fourth section, we present the results and discuss the perceptions of the production chain agents. The fifth and last section offers some final considerations on this exploratory study.

2 THEORETICAL FRAMEWORK

2.1 BIOECONOMY AND SOCIOBIODIVERSITY IN THE CERRADO

Bioeconomy is an emerging and dynamically developing paradigm in contemporary economy that aims to create, develop, and revitalise economic systems through the sustainable use of renewable biological resources (Aguilar; Twardowski; Wohlgemuth, 2019). It created high expectations for its potential to lead the way into a sustainable future, simultaneously searching for the ecological and economic harmony that fosters the creation of innovative value chains and protecting the environment (Barañano *et al.*, 2021; von Braun, 2014).

Bioeconomy's roadmap distinguishes three main visions (Bugge *et al.*, 2016): (i) biotechnology vision, centred on the research, application, and commercialisation of biotechnology; (ii) bioresources vision, focusing on research, processing and valorisation of biological raw materials; (iii) bioecological

vision, emphasising the importance of ecological processes that promote soil, water, and biodiversity conservation and calls for the inclusion of local populations in discussions about an ideal bioeconomy.

Bioeconomy, as a transition from a fossil-based economy to a bio-based economy, constitutes a relevant strategy to address the main global challenges of the 21st century, including food and water security, climate change, resource scarcity and global pollution (Dietz *et al.*, 2018; Lewandowski *et al.*, 2018). Although bioeconomy is a developing concept with different views on how the transition it advocates should be achieved, there seems to be a consensus regarding sustainability as its objective and guiding principle (Gawel; Pannicke; Hagemann, 2019; Lima, 2022; Pfau *et al.*, 2014). Consequently, bioeconomy is a common ideal for reconciling the economy, the environment, and social objectives. Due to its transverse nature, bioeconomy plays a key role in achieving the Sustainable Development Goals (Food and Agriculture Organization of the United Nations, 2021).

In recent years, many countries and regions have developed bioeconomy strategies, especially the most industrialised countries, but also including transition economies and developing countries (German Bioeconomy Council, 2020). In Brazil, the term bioeconomy was first introduced into public policies in 2018 with the Action Plan of Science, Technology and Innovation in Bioeconomy (Brasil, 2018).

In the most widespread strategies for implementing bioeconomy, as well as in current research on this field, biodiversity does not feature as a factor that can contribute to economic development (D'Amato *et al.*, 2017; Meyer, 2017). These approaches to bioeconomy prioritise technologies in the monoculture-based production of biofuels and biomass (Wohlfahrt *et al.*, 2019).

In Brazil, the emerging discussion linking biodiversity to bioeconomy moves between two poles: biodiversity economics and sociobiodiversity (Costa *et al.*, 2022; Queiroz-Stein *et al.*, 2024). Biodiversity economics focuses mainly on generating profits associated with ecosystem conservation (i.e., potential for biodiversity industrialisation). Sociobiodiversity aligns with the concept of bioecological bioeconomy, focusing on social, political, and economic inclusion, combined with biodiversity conservation (i.e., potential for biodiversity integration) aiming at the creation of biodiversity-based production chains that are of interest to Indigenous peoples, traditional communities, and family farmers.

Under sociobiodiversity, a core element in production chain structuring is the appreciation of traditional practices and knowledge to ensure the cultural and ecological sustainability of the ways in which biodiversity is used, fighting poverty and improving the quality of life and the environment of local communities (David; van Els, 2021; Diniz; Cerdan, 2017; Guéneau *et al.*, 2020a). In this approach to bioeconomy, the concept of sociobiodiversity products emerges as a political strategy of the Brazilian government with the National Plan for the Promotion of Sociobiodiversity Products Chains aimed at strengthening production chains and consolidating sustainable markets for sociobiodiversity products and services (Brasil, 2009).

Developing the bioeconomy of sociobiodiversity products in the Cerrado biome shows great potential due to the great number of derived products one can obtain from native species and the wide diversity and distribution of species of economic interest present in its different environments (Diniz; Afonso; Lima, 2020). Agroextractivism is a concept often used in the literature to describe production systems based on the sociobiodiversity products from the Cerrado and developed by families in rural areas of remaining native vegetation. Such systems are diversified and based on pluriactivity, combining several activities such as subsistence agriculture, small-scale livestock farming, fishing, hunting, and plant extractivism (Bispo; Diniz, 2014; Guéneau *et al.*, 2020b; Nogueira; Fleischer, 2005).

2.2 SOCIOBIODIVERSITY PRODUCT CHAINS IN THE CERRADO: THE PROMINENCE OF BARU

Strengthening sociobiodiversity product chains within agroextractivist systems can potentially foster conservation and sustainable development in the Cerrado (Diniz; Nogueira, 2014; Guéneau *et al.*, 2019). Production chains emerge from the interaction of different social actors and production processes within a network of relationships (Galaskiewicz, 2011; Vurro; Russian; Perrini, 2009). Well-structured production chains are strategic to achieve sustainability in all its dimensions (Kumar *et al.*, 2019; Linton; Klassen; Jayaraman, 2007).

Several studies in the last decade have shown the richness, importance, and socioeconomic potential of the sociobiodiversity products from the Cerrado (Afonso; ngelo, 2009; Campos *et al.*, 2023; Carvalho Ribeiro *et al.*, 2020; Diniz *et al.*, 2013). Besides its intrinsic value, sociobiodiversity can provide vital services in terms of food production. Agroextractivist communities in the Cerrado use or manage dozens of species of native fruits for their own consumption, contributing to food security through low-cost food with high nutritional properties. Additionally, agroextractivism represents a fundamental source of employment and income for the traditional populations of the Cerrado, as sociobiodiversity products are also commercialised.

Among the sociobiodiversity products from the Cerrado, the use of baru (*Dipteryx alata* Vogel.) contributes to food security and the well-being of populations in the biome and its production chain is intricately linked to the Cerrado conservation agenda and local communities' lifestyle. The *baruzeiro*, a baru fruit tree, is a legume of the Fabaceae family, native to the Brazilian Cerrado and occurring in the Federal District and in the states of Bahia, Goiás, Maranhão, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Piauí, São Paulo, and Tocantins (Sano *et al.*, 2004). Baru is mainly processed and marketed *in natura*, roasted, or as a flour. Baru agroextractivism promotes income generation and preservation of the local way of life and helps to keep families and youth in rural areas (Azevedo *et al.*, 2022; Candil; Arruda; Arakaki, 2007). Baru demand, appreciation and acceptability have increased in recent years thanks to its nutritional and functional potential associated with health promotion benefits and has been included in the gastronomic circuit (Fernandes *et al.*, 2010; Monteiro; Carvalho; Vilas-Boas, 2022; Zaneti; Balestro, 2015).

In addition to its financial importance for agroextractivist communities and applicability in the agrifood, microbiological and energy industries, the *baruzeiro* is associated with an important fauna of pollinators and seed dispersers, which makes its protection of great relevance for the ecosystems of the Cerrado (Ribeiro *et al.*, 2000; Sano *et al.*, 2004). From an environmental perspective, the baru production chain contributes directly to preserving this species and the biome as a whole.

3 METHODOLOGY

3.1 STUDY POPULATION

Study sample consisted of individuals who represent different agents involved in the baru production chain and who make up the “base list of baru agents,” a consolidated inventory of agents in the Cerrado baru production chain which was prepared based on the registration of guests and participants in the “1st Workshop for the fair and solidarity trade of the baru chain”, organised by the Sustainable Family Agriculture Cooperative Based on Solidarity Economy (Copabase, for the acronym in Portuguese) and held in Brasília during the IX Cerrado Peoples' Meeting and Fair, on September 12, 2019. The record of guests and participants (n=72) was examined in depth by FM and AB and confronted, in exploratory conversations, with four key actors, prominent representatives of cooperatives and civil society organisations involved in the baru production chain. This allowed the identification of other

agents active in the chain and the inclusion of new individuals (n=159) in the “base list of baru agents.” Thus, the consolidated list totalled 231 individuals who constitute a sample of the population involved in the baru production chain.

3.2 DATA COLLECTION

Data were collected by semi-open interviews conducted by FM and AB with 114 individuals between October and December 2020. Except for baru consumers, who were directly identified by the interviewers in commercial establishments, the other participants were selected from the “base list of baru agents.” Of the total 231 individuals in the consolidated list, 50 were not interviewed because they belonged to the same organisations or performed the same functions. Additionally, 58 people on the list were contacted but not interviewed, mainly because they no longer worked in institutions or activities related to the baru chain or verbally expressed their willingness not to participate. Finally, 26 people initially included in the list could not be contacted. No more interviews were conducted after noticing clear redundancy in the information provided by the interviewees.

Most interviews were conducted by videoconference (62), through Google Meet (53) or video call using WhatsApp (9). For individuals who lacked an internet signal or the signal coverage was deficient, the interviews were conducted by telephone (2). Individuals who were in Brasília at the time of the interview and expressed the desire to talk in person (50) were interviewed face-to-face in the outdoors, usually in places indicated by the interviewees and following all Covid-19 prevention guidelines released by competent health agencies.

A semi-structured interview script was prepared from a broad literature review that included pre-readings, selection, analytical readings, and extraction of relevant information on the state of the art of the baru production chain. In addition to initial questions aimed at collecting data on individual characteristics, practices, and the roles assumed as agents involved in the baru chain, the script dedicated a broad specific section to questions about the interviewees’ view of opportunities and challenges associated with strengthening the chain and its contributions to the Cerrado bioeconomy. Interviewees were informed that the research assured the anonymity of both individuals and organisations in all documents presenting the study results, and verbal consent was requested before conducting the interview.

Study participants (n=114) were characterised based on common attributes and grouped into nine agent categories according to the functions performed in the baru production chain (Figure 1). Agroextractivist comprises family farmers and small rural producers who work with the extractive exploitation of baru. Intermediary corresponds to marketing agents that act between producers and consumers, transporting and reselling the baru to a processing or retail company. Cooperative involves associations of rural producers and family farmers with common interests. Cooperatives association represent groups of cooperatives articulated around a shared objective, equivalent to federation or union of cooperatives. Small business/micro-industry comprises several business, industrial and artisanal entrepreneurs linked to the agrifood sector that transform baru into derived products and sell them. An exporting company is primarily engaged in the commercial activity of baru exports, eventually including baru purchase and processing centres. Retailer encompasses both the small baru trade (emporiums, food trucks, shops, markets, and itinerant fairs) as well as large food distribution and marketing companies with national or international reach. Consumer corresponds to those who buy or use baru products for their own consumption. Support is a heterogeneous category of development and promotion organisations that includes development agencies, government organisations, technical assistance and rural extension institutions, higher education institutions, socio-environmental organisations, and business support services.

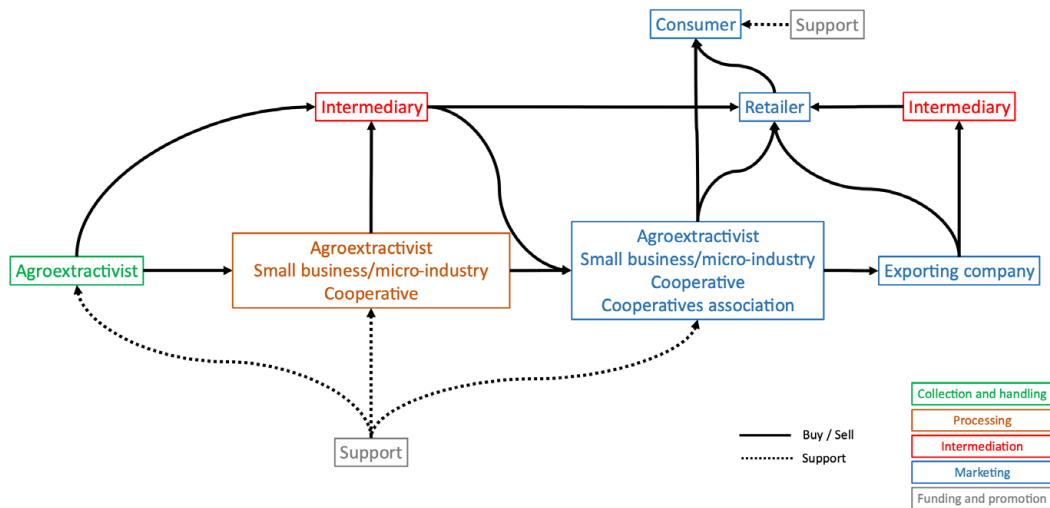


Figure 1 – Simplified general model of the baru production chain. Boxes correspond to the main categories of agents involved in the chain according to the functions performed (collection and handling: green; processing: brown; intermediation: red; marketing: blue; funding and promotion: grey). Arrows indicate the relations between the agents (solid line: buy/sell; dashed line: support).

Source: The authors.

3.3 DATA ANALYSIS

Interview data were systematised in a Microsoft Excel spreadsheet and analysed using a constant comparison method. First, the contents of the collected responses were organised into the following two topics: (1) challenges and threats associated with the production-marketing activities of the production chain; (2) opportunities and advantages associated with the production-marketing activities of the production chain. Second, the answers within each of these two topics were grouped according to the nine categories of agents interviewed. After this classification, the answers were compared with each other to identify redundancies and the main issues related to strengthening the baru chain to promote the Cerrado bioeconomy. An interactive process of systematic comparisons between similarities and differences found in the data allowed the creation of descriptive themes under which the subjects were aggregated. Finally, the themes were explored and organised within the three basic sustainability dimensions emphasised in the bioeconomy.

4 RESULTS AND DISCUSSION

4.1 CHARACTERIZATION OF THE PARTICIPANTS

Table 1 presents the participant characteristics per the categories of baru production chain agents. Most interviewees are retail agents (27%), support (21%), and consumers (15%), whereas the lowest percentage works as an intermediary (4%), is linked to an exporting company (4%), or works in a cooperatives association (2%). At an intermediate point are those who work in a cooperative (11%), small business/micro-industry (10%), or as agroextractivists (6%). We interviewed a similar number of men (55%) and women (45%). Most individuals interviewed are under 50 years old. About 50% of the participants are technicians or have a bachelor's degree, and 21% have graduate education.

Table 1 – Individual characteristics of the study participants by baru production chain agent categories.

Characteristics	Total (n=114)	Cooperative (n=13)	Cooperatives association (n=2)	Agroextractivist (n=7)	Intermediary (n=4)	Exporting com- pany (n=4)	Small business/ micro-industry (n=11)	Retailer (n=31)	Consumer (n=17)	Support (n=25)
Gender										
Female	44.7	38.5	50.0	85.7	25.0	0.0	36.4	35.5	58.8	52.0
Male	55.3	61.5	50.0	14.3	75.0	100.0	63.6	64.5	41.2	48.0
Age										
18-35	28.1	7.7	0.0	0.0	0.0	0.0	45.5	32.3	35.3	40.0
36-49	36.0	46.2	50.0	28.6	25.0	50.0	45.5	32.3	35.3	32.0
50 +	36.0	46.2	50.0	71.4	75.0	50.0	9.1	35.5	29.4	28.0
Education level (in years)										
0-5	3.5	23.1	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0
6-9	14.0	46.2	0.0	42.9	0.0	0.0	0.0	22.6	0.0	0.0
10-12	13.2	7.7	0.0	28.6	0.0	0.0	0.0	35.5	5.9	0.0
13-17	48.2	15.4	100.0	14.3	100.0	25.0	90.9	35.5	58.8	56.0
18 +	21.1	7.7	0	14.3	0.0	75	9.1	3.2	35.3	44

Source: Work by authors (2024).

4.2 PERCEPTIONS OF THE BARU PRODUCTION CHAIN AGENTS

4.2.1 ECONOMIC DIMENSION

Our analysis unveiled opportunities for the economic development of the production chain, mainly mediated by the growing demand for baru and obstacles to its strengthening that hinder access to product markets and achieving fair economic benefits for the entire chain, especially small producers.

Its economic opportunities revolve around the promising investment scenario for new products and businesses geared towards sustainability and socio-environmental issues by means of activities with less impact on ecosystems and agroextractive communities. However, these opportunities are unequally distributed among the agents of the various chain stages. Agroextractivists and cooperatives benefited the least from the product's recent economic expansion despite their key role in the chain. Conversely, the present context of a specialising chain favours agents that have more capital, knowledge, and technology.

From the data collected, we established price ranges for the purchase and sale of raw and roasted fruits and nuts in the various production chain stages, referring to the 2019 harvest, which shows the sharp increase in sale prices along the chain (Figure 2). Such increase reaches a factor of almost 100 between the minimum price (\$ 8 BRL) for 20 kg of fruits (equivalent to 1 kg of nuts) sold by an agroextractivist in a cooperative and the maximum sale price (BRL 780) for 1 kg of roasted nuts to the final consumer in stores abroad. Without information on the costs associated with each production chain stage, we cannot identify how the economic benefits are distributed between the various agents. Nevertheless, these wide price variations speak to the challenge of organising the chain around a fair price policy that integrates the Cerrado conservation and the agroextractivist culture, embedding the socio-

environmental value of the agroextractivist activity applied to the various local and producer realities. The prices practised in the baru commercialisation also point to the challenge faced by agroextractivists in gaining greater control over the production stages and fully using the fruit as a recognised way to increase economic return for families (see, e.g., Pimentel, 2008).

Cooperatives encounter several difficulties in ensuring economic benefits. According to the interviewees, the low-value aggregation to baru products through diversification and processing hinders making greater payments to agroextractivists and strengthening long-term relationships of trust with them. Lack of working capital hinders job stability, price guarantees, cash and advance payments to cooperative members, and inventory maintenance—essential aspects to ensure regularity in baru supply. Lack of credit (and bureaucratic obstacles in obtaining it) has multiple impacts, such as limiting technological advancement in production processes and promoting new markets and distribution and sales channels. Low public investments in the baru chain, compared with other agricultural activities, also limit the possibilities of chain structural transformation, from production, processing, and commercialisation to social and productive organisation processes.

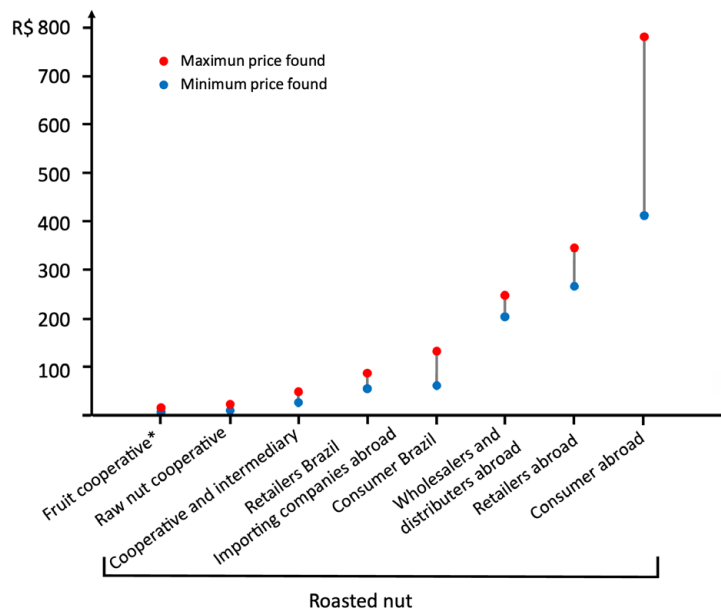


Figure 1 – Sales prices (\$ BRL) of 1 kg of nuts along the baru production chain. Exchange rate used: BRL 5.2 / 1 U\$, BRL 4.1 / 1 CAD (Brazilian Central Bank 01/01/2021).

Source: The authors. *Price of 20 kg of baru fruits equivalent to approximately 1 kg of nuts (after breakage).

The lack of Brazilian food culture on sociobiodiversity products threatens the production chain, causing the devaluation of baru agroextractivism and negatively impacting market access. Interviewees pointed to some certification options (socio-environmental and fair trade) and labels (protected designation of origin, geographical indication and fair trade) as relevant dissemination strategies for accessing markets that would foster trust and credibility, help to value agroextractivist work and add value to the product. These mechanisms would also promote more sustainable and fair production systems, helping agroextractivist producers organised in associations or cooperatives to achieve a differentiated market position as a guarantee for the consumer in relation to competing companies that do not usually stand out for socio-environmental care. Despite the opportunities presented by these marketing devices, the interviews highlighted several challenges for their successful implementation. Among these

stand-out aspects related to being equitable, inclusive and accessible to the producer / cooperative; integrating the sustainability values associated with the baru chain and the conservation of the Cerrado sociobiodiversity; banning dishonest and fraudulent practices on the origin and type of product; and ensuring principles such as gender equality, healthy working conditions and environmentally friendly agroextractivist practices.

Market access is also conditioned by logistical and flow aspects of the baru chain. Results showed that the informality of most agroextractivist producers hinders potential buyers from acquiring baru directly from producers (except when they are organised in cooperatives), pushing them to buy it from an intermediary, either a distribution company or a middleman. For most agroextractivists, the lack of articulation for product commercialisation and the difficulty of alternative flow routes encourage the middleman's role, who usually presents themselves as the only alternative for selling the product using opportunistic practices and causing great instability in the chain. Another logistical and flow aspect that impacts market access is the lack of guarantees both in the sale and in the supply and quality of baru. On the one hand, sellers (agroextractivists and cooperatives) complain about the lack of long-term commitment from buying companies and dependence on a single customer. Besides weakening trust relationships, these planning difficulties lead sellers to serious financial problems due to the limited availability of working capital. On the other hand, buyers draw attention to the difficulty in finding suppliers, their high turnover, and the variable quality standards of the baru supplied by producers or cooperatives. Faced with this distrust, companies usually seek to diversify their suppliers to ensure marketing requirements, especially in the international market, where signing long-term contracts with distributors and large retailers requires product quality and quantity stability for long periods of time.

Another element that offers good market access opportunities for agroextractivists is public policies for food procurement. However, the main challenge here lies in the administrative and bureaucratic difficulties generated by public procurement programs which hinders access to the institutional market for agroextractivists not organised in cooperatives. Additionally, the dismantling of public policies aimed at strengthening family farming as a result of the interruption of assistance programs for family farming and food security under the Bolsonaro administration also emerged as a challenge associated with public procurement policies.

Finally, to improve access to markets, the interviewees highlighted the need for support actions on three fronts. First, by training agroextractivists and cooperatives to improve financial education and develop new opportunities for baru commercialisation and promotion. Second, by assisting in the organisation of agroextractivist communities and in strengthening their networks to create cooperatives that help in designing channels and improving production flow. Third, by helping to develop short marketing circuits and baru direct sales spaces through the organisation of producers for sales in fairs and institutional purchases and by assisting in the promotion and implementation of collective purchasing groups.

4.2.2 SOCIAL DIMENSION

In the social sphere, our results highlighted the importance of the baru chain for the socio-productive inclusion of agroextractivist families in the countryside and revealed several challenges for chain strengthening, associated with the conditions and structural problems that characterise agroextractivism, and the role of science and technology in chain sustainability.

Despite the great potential for baru commercialisation, the precarious production conditions and high dispersion of *baruzeiros* make the agroextractivist activity extremely tiring and inefficient, frustrating producers' expectations and limiting the full development of the production chain. Lack of training and qualification on the agroextractivists' part and of activity mechanisation, added to logistical and infrastructure deficiencies, prevent producers from executing the different production process stages with minimum hygienic-sanitary guarantees and in safe and health conditions. This negatively impacts

product quality and, consequently, the possibility of selling it at a better price. Generally, producers prioritise direct sales *in natura* to both companies and intermediaries with little or no processing, which increases their vulnerability and weakens the first link in the production chain, as this agent risks becoming a mere fruit supplier without access to consumer markets or the possibility of adding value to the product.

For many interviewees, the land issue in the countryside puts the agroextractivist practices of families who depend on the baru at risk, if not directly excluding producers from developing their own activity. Many agroextractivists collect baru on third-party land, especially farms, which generates anxiety, uncertainty, and insecurity about the future of the activity. All this causes difficulties in obtaining support or credit for chain development while causing growing conflicts between agroextractivists, cooperatives and farmers.

Developing the baru production chain emerged as a good option for reducing rural exodus and, particularly, as an opportunity to foster women's autonomy, emancipation, and empowerment in the countryside by expanding their role in the rural economy. Such female leadership manifests itself in the organisation of women's collectives managing enterprises around the baru and the role of women as "guardians of the Cerrado" as the main workforce of baru agroextractivism. However, the interviews highlighted the need to advance in the social mobilisation of the actors involved, promote social cohesion, and create social capital centres and horizontal relations to overcome the individualism and competition that threaten the chain and the common good. Results pointed to the lack of collaborative or participatory culture among chain agents, especially agroextractivists, as a threat to structuring associations or cooperatives since they are often guided more by a competitive spirit than a collaborative or cooperative one. Likewise, local enterprises require more diluted competencies to avoid their collapse when leadership figures who concentrate power and information leave.

Historical processes and specific conditions of poverty and inequality among agroextractivists were also identified as social challenges of the baru chain. These contexts translate into geographic and cultural isolation of the communities, causing great socioeconomic vulnerability for families, which hinders their full insertion in the rural labour market and ensures labour rights and social protection. Additionally, high product demand would affect the sociocultural context and evolution of baru agroextractivism, as many families would no longer extract the fruit as a complementary activity to other agricultural activities, assuming extractivism as their main or even only activity.

Regarding knowledge, science and technology, most respondents believe that developing applied research and outreach projects in different fields of knowledge linked to the baru production chain (e.g., nutrition, technology, social sciences, anthropology, economics, administration, ecology, biology) is fundamental for strengthening the production chain. Effective research should offer answers to specific bottlenecks in the chain to facilitate the work and rural permanence of these populations by means of sustainable and economically profitable management practices. Academic research should, therefore, involve the communities and be conducted in collaboration with the private sector and technical assistance organizations. Likewise, research would offer integrated perspectives aiming at promoting the sustainability of the baru chain if developed with an interdisciplinary approach. Finally, the interviewees emphasised that developing technologies or improving innovations that facilitate baru collection and processing without stripping away what makes agroextractivism a highly specialised, artisanal and unique work is necessary for strengthening the production chain while adding value to the product and reducing the negative impacts baru extraction has on the agroextractivists' health and safety. Technical knowledge, mechanisation, and the development of economically accessible equipment for agroextractivists (e.g., breakers, pulpers, classifiers, dryers) would also help to achieve large-scale production in the chain.

4.2.3 ENVIRONMENTAL DIMENSION

Environmentally, interviewees pointed out several threats to strengthening the baru production chain at three levels: local, regional, and global. These arise mainly from the reductionist approach adopted by chain agents regarding the baru, which disregards both the ecological interactions of the species and the ecosystem services generated from this sociobiodiversity product. However, the interviews also cited some alternative management strategies that offer opportunities for environmental improvements in the chain.

At the local level, they highlight the possible negative environmental impacts associated with the cutting of *baruzeiros* to exploit wood and produce charcoal, as well as the lack of adoption of good management practices by agroextractivists at the time of collection (e.g., dropping the fruits from the tree, not leaving fruits on the ground or on the tree for germination or dispersion). This inadequate management results from the lack of technical training and the unbridled greed of many agroextractivists to collect as many fruits as possible in the short term. Consequently, the low replacement of young individuals may cause a sharp decline in the population of *baruzeiros* in the coming years.

At the regional level, interviewees highlighted three environmental threats with significant impacts on the future baru production chain. First is the accelerated deforestation in the Cerrado. The advance of agribusiness and regional development projects is leading to the clearing of many baru forests and the transformation of old collection farms into large soybean plantations or areas for photovoltaic and wind projects. In office at the time of this research, the Bolsonaro administration's political will to intensify agribusiness activities, including on the territories of traditional communities, aggravates this threat to the baru in the near future. Additionally, the mass use of pesticides would be contaminating areas of *baruzeiros* adjacent to soybeans, corn, or cotton plantations. Second, is the expansion of large-scale *baruzeiro* plantations to meet the growing demand for the product. For many interviewees, large-scale planting would exclusively favour exporting companies in their objectives of controlling all production and commercialisation stages of the chain. Despite being a native species, the exponential growth of *baruzeiro* plantations risks increasing deforestation of the Cerrado to make way for baru monoculture farms, resulting in loss of biodiversity in the biome and contamination by agrochemicals to increase productivity. Such productivist logic would negatively impact the role of the *baruzeiro* as a protection umbrella for other species of the Cerrado biodiversity and its role in generating income from preserving a biodiverse landscape. The third regional environmental threat concerns the invisibility of the Cerrado in relation to other Brazilian biomes, especially the Amazon. In this perspective, the Cerrado is considered less valuable and is consequently less protected, becoming a preferred space for development projects with large environmental impacts that end up affecting the conservation of the baru and its provision of ecosystem services.

At the global level, the main environmental threat to the baru production chain is climate change which would be affecting its seasonality and causing a drop in productivity. As an example, interviewees highlighted the consequences on production resulting from the lack of rain in September/October (a critical period for floral development) and periods of high temperatures in January/February, which cause the abortion of fruits that fall without reaching maturity.

In addition to challenges, the interviews revealed several environmental opportunities to strengthen the baru production chain. Often cited was the high potential of *baruzeiros* to develop integrated baru crops, diversifying and intensifying productive activities without needing to deforest. This integration can be achieved using several possible strategies, such as agroforestry backyards, consortia with crops, and integration with livestock farming. Other environmental opportunities highlighted included the potential of the *baruzeiro* tree to develop rational crops, seedlings and plantations in backyards and small properties; silvicultural use of the *baruzeiro* (reforestation); use of *baruzeiros* in the ecological restoration of watersheds, legal reserves and permanent preservation areas; baru planting in livestock farming areas, providing shade and food for the cattle; and contribution to climate change mitigation

through the baruzeiro's ability to sequester carbon. Besides fostering a regenerative culture that cares for the natural systems and life in the Cerrado, these uses of the baru would generate new collection areas or production reserves for future agroextractivism, helping producers' income and allowing gains in production efficiency, scale, and quality.

5 FINAL CONSIDERATIONS

Sociobiodiversity-based bioeconomy involves exploring native fruits as assets to generate new services and products, forming production chains for valuing traditional peoples and communities. In the Cerrado, sociobiodiversity product chains meet a contextualised vision of bioeconomy which adheres to the political, cultural, and social reality of the biome, bringing real benefits to the development and autonomy of agroextractivist families as users and caretakers of the Cerrado's resources. Focusing on biodiversity through the inclusion of local populations and making production technologies available so they can transform primary products into items with higher added value, we can foster a Cerrado bioeconomy by achieving economic prosperity, respecting the knowledge and ways of life of agroextractivist communities, and keeping the Cerrado standing.

Qualitative analysis of the exploratory interviews conducted with different agents involved in the baru production chain allowed us to identify several opportunities to strengthen the chain, mainly via growing demand for the fruit. However, the results suggest that the chain faces numerous local and regional challenges in the three sustainability dimensions that hinder its strengthening and constitute obstacles to developing a sociobiodiversity-based Cerrado bioeconomy. Access to markets and obtaining fair economic benefits for small producers (economic dimension), the precarious conditions and structural problems of agroextractivism (social dimension), and the lack of knowledge or consideration about the dynamics of the baru agroextractivist production chain as a complex socio-ecological system that generates ecosystem services in the Cerrado from this sociobiodiversity product (environmental dimension) stand out among these challenges.

Overall, this study offers relevant information for strengthening the baru production chain based on the perception of several agents involved in it. However, future analyses of this, as well as other sociobiodiversity chains, could incorporate the view of external agents such as representatives of public or private support institutions who can influence both the organisation of production chains and their functionality. Other elements omitted in this analysis which can affect production chain performance include contextual aspects, such as the role of regulatory and institutional bodies surrounding the chain that condition its development.

We expect these results can contribute to building and consolidating integrated actions intended to strengthen the baru production chain, jointly considering alternative forms of economy based on this sociobiodiversity product, assurance of sustainable livelihoods in agroextractivist communities and the biodiversity conservation and maintenance of ecosystem services in the Cerrado.

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