Beyond the Superfood

An overview of the environmental sustainability of açaí *(Euterpe oleracea*) cultivation across the management spectrum on the floodplains of Pará

(Carneiro, 2023)

Graduate School of Life Sciences Research Report

Ilse Marijke Annaïs Passchier
6475760

Utrecht University

01-03-2024

Examiner: Dr. Pita Verweij   Daily supervisor: Dr. Anna Duden
Second examiner: Dr. René Verburg

“ The Amazon, in all its enigmatic grandeur, embodies the paradoxes of existence. It is a place of untamed beauty and unfathomable complexity, where the fragility and resilience of life intertwine.”

- Ryan Gelpke

Abstract
This paper outlines an overview of the current state of the environmental sustainability of açaí (*Euterpe oleracea)* cultivation on the Amazon floodplains in the state of Pará, Brazil. Currently under the threat of becoming a global resource frontier, Pará shows an increasing expansion of areas with unsustainable land use practices such as cattle ranching and soy cultivation, being the main drivers of deforestation. Due to the increased international demand for this recently coined superfood, cultivation of açaí has increased. Along with this increase, a shift from traditionally extractivist harvest towards more intensive management and monoculture cultivation of the fruit is currently observed. This paper addresses two central questions, first assessing to what extent current açaí cultivation is sustainable on the floodplains. Secondly, evaluating the potential role of certification as a tool for sustainable development of the sector. This paper uses a combination of literature research, database searches and semi-structured stakeholder interviews, and structured outputs along the most prominent environmental sustainability themes of the Sustainable Intensification Metrics Framework (SIMeF). Key findings show a variety in sustainability impacts across the currently existing management spectrum. Ranging from positive ecological impacts in extractivism to negative impacts of monocultures, driving deforestation rates over time and weakening ecosystem functioning and climate resilience. The agroforests, representing the intermediate on the management spectrum, present a gradient themselves, including high- and low- intensity agroforests, of which the latter emerge as a sustainable cultivation method while the prior poses significant ecological risks such as impacts on biodiversity and increased emission levels. Gaps in the current research landscape critical to overcome regard traceability and distributions of management intensities within the industry. Beyond policy, certification could emerge as a tool to overcome some of the sustainability challenges, though context- and species-specific redefinition of their requirements ought to take place.

Key words: Açaí *, Amazon, Pará, Brazil, environmental sustainability, certification, SIMeF*

Layman's Summary
Products containing açaí berries, which are currently gaining a lot of popularity as a trending superfood in western countries, originate primarily on the floodplains of the Amazon rainforest of Pará, a Brazilian state. The state is currently facing high deforestation rates as a result of unsustainable land use practices such as cattle ranching and soy cultivation. As global demand for açaí is growing, so is the need to produce larger quantities, which is why more local farmers are shifting to açaí cultivation. To boost production, intensive management practices are emerging, which are turning diverse forests into monocultures. This paper describes the sustainability risks of these monocultures on their environments and compares them to traditional extractivist methods and an intermediate management practice, agroforestry. This is done by combining literature and national database searches, with semi-structured stakeholder interviews. This shows that more intensive management practices also carry more negative environmental impacts with them, threatening ecosystem functioning and increasing deforestation rates. Agroforests could be a sustainable alternative, though there is a need to ensure that they do not become increasingly managed over time, becoming near-monocultures themselves. Policy and certification could be tools to promote such sustainable agroforests, especially in light of a changing political agenda in recent years, but only if their methods and requirements are revised to the specific context of açaí cultivation in the floodplain area. In doing this, this research sheds light on how the emerging industry can balance meeting global demands with protecting the Amazon floodplains of Pará.

Table of contents

1. Introduction

Açaí bowls, shakes, powders, juices, smoothies, and supplements, among many other forms; when searching for nutritious foods, this recently coined "superfood" is rapidly gaining popularity, especially among urban consumers in the US, Western Europe, and Japan (Nascimento et al., 2008; Salo et al., 2013; Sato et al., 2020). The health benefits and therapeutic effects of the berries on illnesses are evident due to their rich content of micronutrients and essential fatty acids, antioxidant capacity, and anti-inflammatory properties (De Cássia Rodrigues Batista et al., 2016; Salo et al., 2013). Yet, as the global appetite for these berries increases, so do concerns regarding the sustainability impacts of their cultivation within the Amazon region (Freitas et al., 2015).

In recent years, the Amazon region has been at the forefront of several global discussions that have presented tradeoffs between socio-economic development and sustainable land use. Such examples are the expanding soy and cattle-ranging sectors, which have significantly expanded their operations in response to incentives provided by development policies and an increased demand from regional and international markets (Salisbury & Schmink, 2007). This has boosted local economies, but has also been the major driver of deforestation (Gollnow & Lakes, 2014; Walker et al., 2009). Within this changing landscape, farmers who have been practising traditional agricultural methods such as extractivism of Non Timber Forest Products (NTFPs) are showing a transition towards such high-rewarding sectors to generate income and increase their family's security (Brondízio et al., 2002; Salisbury & Schmink, 2007). These shifts have several implications for land use and forest cover and present challenges to many regional conservation and developmental projects, such as sustainable settlement projects and extractive reserves seeking to develop forest-based livelihood alternatives to limit deforestation (Salisbury & Schmink, 2007). Despite national efforts to promote socio-biodiversity chains and the introduction of Payment for Ecosystem Services (PES) systems such as the *bolsa floresta*, NTFP profits are frequently outpaced. Açaí is currently one of the only emerging exceptions to this trend (Lopes et al., 2019). Since it has the highest revenues of any NTFP in the Brazilian Amazon, açaí has gained the interest of many local farmers (Lopes et al., 2019). Cultivating, harvesting, or transporting açaí has become and proven to be the most lucrative livelihood option to rural communities (Bourscheit, 2022). Especially in the fight against the transition to becoming an unsustainable global resource frontier, açaí cultivation could offer an opportunity to a more sustainable model for farmers in the region, providing an alternative livelihood model which could be a driver of sustainable change in the Amazon region, focusing on balancing socio-economic development and protection of ecosystem services. Furthermore, as an alternative livelihood model to other emerging sectors, açaí cultivation could have significant impacts on ensuring the future of NTFP markets and their entwined traditional extractivist livelihoods.

More than 95% of the world's açaí (*Euterpe oleracea*) is produced in the northern regions of Brazil, particularly on the amazon forests' floodplains in the state of Pará (Carneiro, 2023; De Oliveira et al., 2018). Pará's state production has increased by 40% in just 6 years, from 1 million tons to 1.4 million tons, between 2015 and 2021. Furthermore, it involves 130,000 producers (Bourscheit, 2022). The industry's increase, yielding nearly 1.7 million tonnes in 2022, has generated a value surpassing 1,15 billion euros for the state's economy in 2022 alone (IBGE, 2022). In the space of a few decades, it has become Brazil's main forest food product by value with the fastest growing markets (Lopes et al., 2019).

This rising trend is expected to continue its course in the upcoming years, and has been stated as being currently in the midst of growth and not yet having reached the point of maturity. The market is expected to continue its growth, with demand rising especially in Europe (Sabbe et al., 2009). Between

2022 and 2027, the açaí market is expected to expand by USD 370.87 million (Lima, 2023). This also means production numbers of the fruit will have to increase significantly to meet this demand.

Açaí is traditionally mainly produced by manual harvest of the clumps of berries from home gardens and secondary forests surrounding households in Amazon floodplain forests (also called várzeas) (Muñiz-Miret et al., 1996). However, due to the rising market value and demand from other countries, a trend towards commercial crops has been emerging. This commercialisation means management decisions are increasingly based on profit maximisation, causing a vast variety of management practices to have emerged. In some cases, to such an extent that it is becoming an intermediary between a wild and a domesticated resource, with an increasing number of monoculture plantations emerging in recent years (Albiero et al., 2012; Nascimento et al., 2008).

Given the current developments in which cultivation grounds are quickly becoming more managed, it is especially relevant to review the sustainability of different cultivation practices now (Shanley et al., 2016). The current period presents a potentially transformative moment for the industry, in which economic opportunities are rising due to international demand, but alongside this, questions regarding the ecological and socio-economic sustainability of more intensive management practices also arise (Neumann & Hirsch, 2000). The current period therefore presents a crossroad at which the trajectory of development in the açaí industry can be shaped. By researching the sustainability of the current industry now, there is still time and an opportunity to guide the developments of this industry in a sustainable manner. This is especially important given the location in which these developments take place, as the Amazon rainforest region is a critical ecosystem for regulating the earth's climate and reducing global warming, containing 40% of the world's remaining tropical forest and is currently threatened by deforestation. (Peng et al., 2020; Salisbury & Schmink, 2007). Nevertheless, it is also becoming increasingly developed as a result of political agendas and an expanding agricultural sector within the region (Gabbatiss, 2022). Given this trend of development, it is critical to look for ways in which these developments can be done sustainably.

This paper addresses the following two questions; 1. To what extent is the current açaí industry on the floodplains in the state of Parà environmentally sustainable across the management gradient? 2. Could certification emerge as a tool for sustainable development in the sector? These questions are answered by combining literature research with stakeholder interviews and structuring outputs along the Sustainable Intensification Metrics Framework (SIMeF) (Mouratiadou et al., 2021). The results show an overview of the key factors of sustainable açaí production in the Brazilian Amazon. It supplements this literature review with stakeholder input from interviews, and indicates gaps. The findings can inform stakeholders along the chain about the sustainability of açaí cultivation. On the farm-level, these insights can help with improvements of management practices. For policymakers and certifiers, it can assist in creating a roadmap to sustainable development of the industry. It does this by providing focal points of action towards sustainable production.

Section 2 first describes traditional models and theories on developing NTFP markets within the Amazon region and discusses açaí's place in the context of such models to analyse the current situation in which the industry resides. Subsequently, section 3 provides contextual information on the açaí industry in the Brazilian Amazon, and describes the output of the interviews and literature research into the environmental sustainability of açaí production that has been done, as well as identifies gaps in literature and opportunities for sustainable development. Lastly, this paper analyses current certification practices and explores the potential role of certifiers in ensuring sustainability in the future of this developing sector.

2. Theory and methods

This section first describes two models; the first on NTFP management gradients and secondly Homma's traditional model on developing NTFP markets in the Amazon. For both, it will place the current açaí sector in the given model. Placing açaí in these models provides the context on management gradients necessary to answer the question regarding to what extent the current sector is sustainable. Furthermore, considering historical cycles of developing NTFP markets in the Amazon enables the possibility of drawing a comparison between the açaí market and historical developments of other commodities, and drawing lessons from those other sectors.

2.1. Theory

2.1.1. NTFP management gradients

Within tropical forests around the world, local communities employ many different management systems that encompass a variety of ecosystems and management strategies, such as agriculture, semi domestication and fallow management, secondary forests, and home gardens (Shanley et al., 2016). NTFPs are harvested from a range of habitats and management regimes, existing along a gradient. This gradient, ranging from domestication to wild harvesting, is visualised in figure 1.

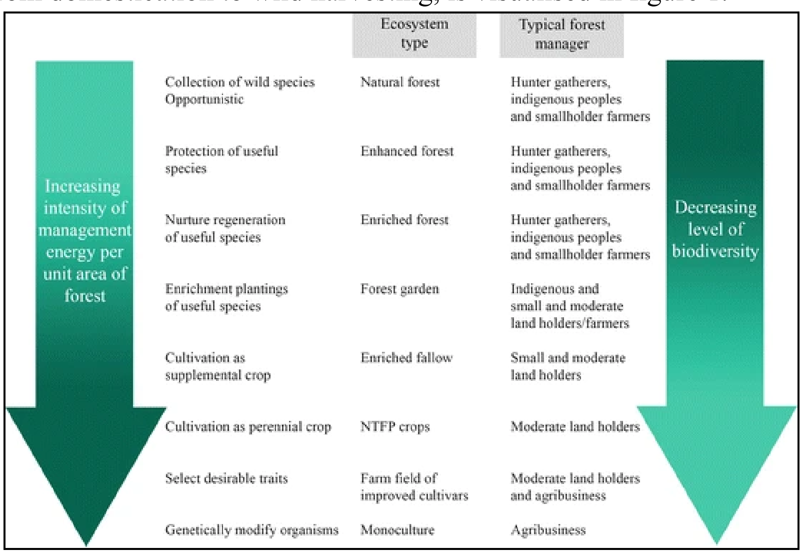

Figure 1: The gradient of intensity of NTFP management

This figure shows an overview of the gradient from NTFP domestication to wild harvest from primary forests, with management practices described in the left column. Reprinted from (Shanley et al., 2016)

In the case of açaí as an NTFP, the system also exists along this gradient, ranging from extractivist systems in which açaí is gathered from the wild, to an increasing number of monocultures emerging that heavily manage the crop. The traditional gradient of management according to Shanley's model applied to açaí is visualised in figure 2.

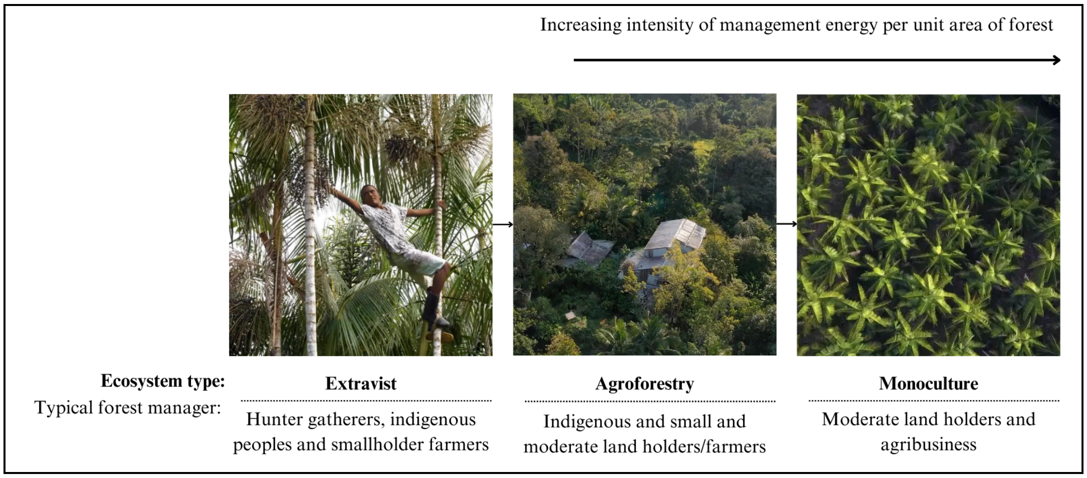

Figure 2: The gradient of intensity of açaí management
This figure shows an overview of the gradient from açaí domestication to wild harvest from primary forest. Based on the model of Shanley et al., 2016, applied to açaí cultivation.

2.1.2. Traditional models of NTFP developments

Homma's model of the economic dynamics of extractivism outlines four developmental phases for NTFPs in the Amazon. These phases are visualised in figure 3. Throughout the expansion stage, there is a noticeable increase in extraction levels from the forest. Then, prices start to climb in the stabilisation phase once supply and demand have balanced out. During this period especially, there is a focus on the implementation of policies to safeguard and/or promote the developing sector. In the decline phase, a progressive failure of extraction results from the declining resource and the increasing costs of harvesting. Lastly, during the stabilisation phase, domestication starts to emerge as long as cultivation equipment is available, replacements are nonexistent, and prices are high.

According to this model, there are four drivers which can lead to a decline in the extraction of forest products. First, an inflexible supply of the product. Second, if a point is reached where harvest rates exceed the regeneration rates of the product. Third, if domestication of the product takes place. And fourth, as a result of industrial alternatives rising on the market (Neumann & Hirsch, 2000).

By comparing recent developments in the expanding açaí sector to this traditional model of developing NTFP markets in the Amazon forests, the açaí sector shows a move through similar phases as described. Just as is described within Homma's model, a shift in producers is currently observed in the açaí sector as a result of the increasing global demand and profitability of the berries. This means the sector is increasingly moving from extractivist harvesting, to production by small land owners, as well as a rise in large scale intensive production systems (monocultures). Thus, when comparing the observed trends with this traditional model and placing it in its context, the sector could be classified as being in the 'declining phase'.

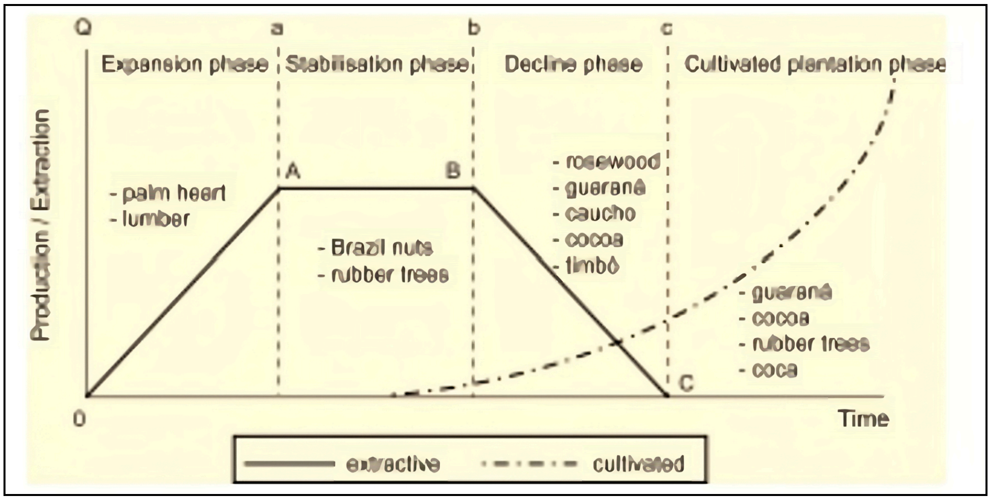

Figure 3: The historical cycle of forest production in the Amazon
This figure shows Homma's 1996 model of the historical cycle of forest production in the Amazon. Reprinted from (Neumann & Hirsch, 2000)

By analysing the current açaí industry in the context of the historical cycle, a parallel can be drawn with other forest products that have already gone through this full cycle. An example of a product that shows similarity to açaí in its historical developments is the rubber industry, a well documented case.

During the 19th century, the development of the automotive industry led to a quickly growing global demand for rubber. This in turn drove a rapid expansion of the rubber sector in the Brazilian Amazon, where rubber was extracted by traditional rubber gatherers who gathered the latex from the rubber trees naturally occurring in the Amazon forests by making cuts in the bark and collecting the runny sap in cups (Brüning, 2015). The expanding industry led to significant economic growth and attracted a lot of investment and labour to the area. Although this extraction increased during the rubber boom and brought about economic success for the area initially, development eventually ran into problems. Unchecked growth of the rubber sector led to increased negative environmental as well as economic and social sustainability impacts for the Amazon forest (Barham & Coomes, 1994; Resor, 1977). The landscape had been transformed: areas had been cut and land cleared for cultivation. Monoculture farms and unsustainable extractive methods spread, driving native communities deeper into the upland forests. Eventually, the industry began to decline due to an inability to sustain high extraction rates and competition from Southeast Asian farms (Perkins & Weinstein, 1985). Now, in the post collapse era, new studies argue managed agroforests provide opportunities for sustainable land use in the region. They emphasise how Amazon's traditional rubber agroforests have been mostly neglected in favour of low-tech extractive use and high-tech rubber clones, but that opportunities for sustainable development have been present all along. Studies on rubber agroforests in the Brazilian Amazon's eastern Pará State state production in agroforestry rather than attempts to monocultures with improved tapping techniques and tree health management could enhance profitability and could even give significantly higher yields than monoculture practices (Schroth et al., 2004).

Mirroring the rubber boom, the açaí industry is currently in the midst of rapid growth driven by global demand, which here too has social, economic, and environmental implications. A comparison between the two commodities makes it clear that guiding the current açaí industry towards sustainability is essential to preventing the dangers of past fast-growing extractive industries from being repeated in the açaí sector. The rubber industry collapse should serve as a warning about the dangers of increasing numbers of systems relying too much on a single resource, moving towards unsustainable monoculture systems to meet the demand, and disregarding sustainable methods. A simplified overview of the parallel between these two NTFPs is depicted in table 1. By providing further insight into the environmental sustainability aspects, this paper broadens insight into the current state of the industry and explores the potential of certification as a sustainable development pathway.

Table 1: Overview of the parallels between the açaí and rubber industries in the Brazil Amazon.
In this table, key developments, obstacles, and effects of the rubber and açaí industries are visualised in this table.

Aspect	Rubber industry	Acai industry
Time period	Throughout the late 19th and early 20th centuries	from the late 20th century until the present
Key events	Rapid expansion brought on by the world's need for rubber, particularly for tires for cars (Barham & Coomes, 1994).	Demand surges globally as a result of açaí's status as a superfood (Salo et al., 2013).
Main sustainability challenges	Rubber plantation deforestation, an excessive dependence on a single resource, and competition from Asia (Resor, 1977).	Shifting tendency towards unsustainable monoculture cultivation systems causing environmental, social and economic implications (Freitas et al., 2021)
Economic impacts	Economic boom at first, then decline as a result of competition and unsustainable practices (Barham & Coomes, 1994).	Present economic expansion, together with possible concerns , environmental, social and economic impacts (Freitas et al., 2015).
Conservation measures	Limited in the early stages, causing harm to the environment	Growing focus on sustainable practices, but in urgent need of active measures
Lessons	Significance of resource management that is sustainable and diversified.	A reiteration of the importance of diversification, biodiversity preservation, and sustainable cultivation methods
Policy interventions	Conservation methods and policies regarding sustainability were introduced belatedly (Salisbury & Schmink, 2007).	Possibility of early adoption of policy focusing on sustainable development of the emerging sector.

This table visualises and structures a comparison between developments and key events in the developing markets of both the rubber and açaí industries. It highlights some significant differences and similarities between the two sectors. This table serves as a comparative tool to understand trends within the industry and possible future developments and avoid historical pitfalls of other NTFP sectors.

2.1.3. Defining sustainability

Given that this research is focusing on analysing the current environmental sustainability of the Brazilian Amazonian açaí industry, it is important to first describe the concept of sustainability and define how it is regarded in this paper.

In the early 1990´s, an examination of the possibility of sustaining industrial civilization was constructed using concepts from physics, ecology, evolutionary biology, anthropology, history, philosophy, economics, and psychology; in this, sustainability was defined as preserving "utility" (average human wellbeing) over the very long term (Pezzey, 1992).

Following this period, the term has become widely used and can encompass many different definitions in different contexts, making it an inherently multidimensional concept that can differ in meaning across disciplines. For example, in the environmental sciences, it primarily focuses on preserving ecological balance. Socially, the focus shifts more to cultural preservation. In this sense, every discipline brings with it its own priorities, leading to diverse interpretations and strategies to achieve sustainability. Nevertheless, in all cases, and in this paper as such, it can be defined as an objective concept, revolving around the use of our biophysical surroundings in such a way that they remain indefinitely available (Hueting, 1998).

In this paper, the main focus lies on environmental sustainability, which adopts the following definition by Morelli, 2011:

"Meeting the resource and services needs of current and future generations without compromising the health of the ecosystems that provide them, …and more specifically, as a condition of balance, resilience, and interconnectedness that allows human society to satisfy its needs while neither exceeding the capacity of its supporting ecosystems to continue to regenerate the services necessary to meet those needs nor by our actions diminishing biological diversity."

Nevertheless, this paper does not disregard other disciplinary definitions and will point to socio-economic dimensions, as these are integral to the acai industry.

2.1.4. Framework structuring tool

Assessing and quantifying the sustainability of agricultural systems has been a remaining challenge over the past few years due to its multiple dimensions and potential associated tradeoffs (Mouratiadou et al., 2021). To provide structure in the analysis of the environmental sustainability of açaí cultivation, the recently developed Sustainable Intensification Metrics Framework (SIMeF) is used. This framework is composed of an integration of academic- policy indicator-frameworks, expert opinions, and Sustainable Development Goals. Given this broad consideration of environmental sustainability, SIMeF is especially fitting to analyse the current sustainability of the açaí industry across the management gradient. Its use allows ex-ante assessment of different production system types and encompasses their sustainability (Mouratiadou et al., 2021).

2.2. Methods

This research is a combination of literature and database research that has been done. In addition, semi-structured interviews with stakeholders have taken place. This section provides further information on the methods that were used.

2.2.1. Literature research

First, to limit the number of themes to consider in analysing environmental sustainability, six themes were selected from the SIMeF framework. SIMef presents these six themes as the prominent and mentioned consensus in workshops, SDGs, and the reviewed frameworks that make up the basis of SIMeF. The selected themes are visualised per category in figure 4.

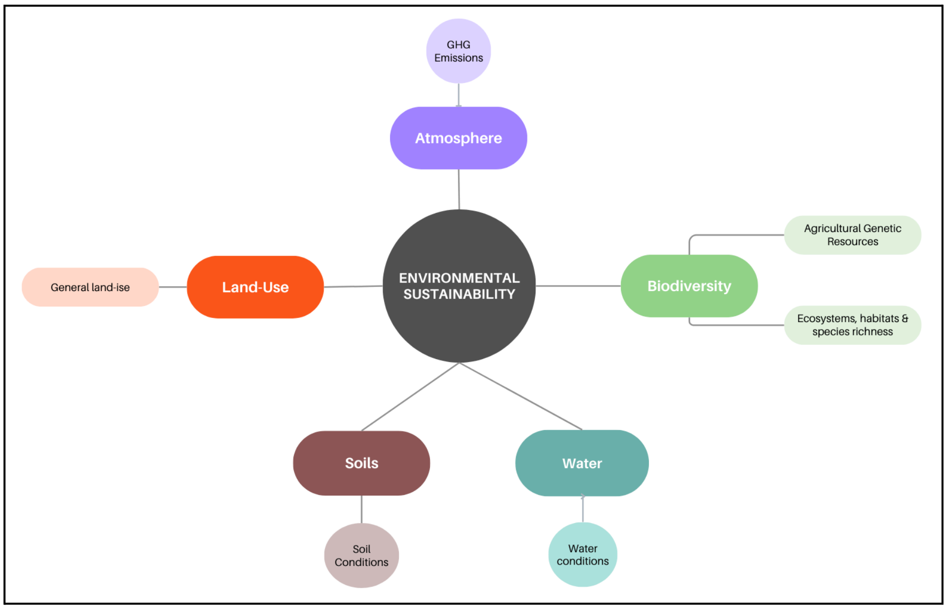

Figure 4: Environmental sustainability themes
This figure shows an overview of the themes that were selected from the SIMeF framework.

For each theme, metrics provided by SIMeF were searched using scholar databases such as Google Scholar, JSTOR and Scopus with search items. Articles that offered details regarding the given metric/theme were researched in more detail and used as the foundation for snowballing. In addition to the analysis of scientific papers found via Google Scholar, a body of grey literature was gathered, such as government reports and policy documents, NGO reports, industry reports, technical reports, working papers, and policy briefs. For all the literature that was found, a categorization took place in a constituted online notion database, tagging each data source regarding its contents on location and management system. Each source was tagged as either focusing on extractivism, agroforestry, or monocultures, so it could be easily found when structuring findings. Furthermore, it was tagged on its location as 'pará', 'brazil', or 'other' based on the geographical context of the given research. This served as a method to hinder findings from Pará from getting mixed up with findings from other regions. Furthermore, to analyse the potential role of certification, online available standards as pointed to by Fairtrade Netherlands were analysed.

Database research
To find out more about the distribution and presence of different açaí management systems, a number of Brazilian databases (e.g., IBGE, EMBRAPA) were researched, as well as the organizations behind the databases contacted. Furthermore, researchers in the field were contacted with the question of whether they had accessible data to answer this subquestion.

The next step of data collection involved doing interviews with stakeholders and researchers that have worked on açaí research guided by the themes selected from the SIMef framework. The objective of conducting these interviews was to enrich this paper with real-life examples and insights coming directly from experts in the field. In doing this, this paper aimed to get a more practical understanding of the dynamics within the industry. Furthermore, the interviews served as a tool for the verification of literature findings. Lastly, the goal was to use these interviews to complement findings in the literature by identifying and addressing gaps.

2.2.2.Interviews

Selection of participants
The selection of interview participants is based upon literature and web research for experts in the field. The aim was to approach as many different stakeholder groups as possible, such as policymakers, NGO's, researchers, farmers, and sellers. Interviews with researchers as well as stakeholders from all levels within the production chain enable the capture of insights and perspectives from different stakeholders working within the production system, especially insights that might not yet be prevalent in scientific literature. The starting point was reaching out to authors of recently published papers on açaí and asking each of those for contacts that might be open to interviews. In total, 46 stakeholders were reached out to. These methods resulted in a total of 6 semi-structured interviews, all held as video calls lasting between 38 and 77 minutes.

Interview process
The next step of data collection involved doing interviews with stakeholders that were open to it. A semi-structured approach was employed, in which the themes selected from the SIMef framework served as a guideline. The themes from this framework were translated into open questions that formed the basis of the interviews. An interview guide with the questions that were asked can be found in appendix I. Informal pilot testing was done multiple times to refine the interview questions and approach. The interview itself consisted of two separate phases. First, after asking for prior consent and addressing any ethical considerations, interview partners were questioned per theme about their insights on the sustainability of different management strategies and their impacts on the given theme. If the given interviewee had no experience or knowledge of the given theme, the theme was skipped, and the interview moved onto the following theme. The second phase of the interview moved to questioning the partners their own future perspectives on the industry. Each interview was recorded and saved in private online databases. Interview partners were also asked to provide contacts to other farm owners, governmental institutions, certification organisations, and NGOs.

Post-interview process

After the interviews were conducted, each of the audio recordings was transcribed by hand. Then transcriptions were compared to findings from the literature. Literature was used to contextualise the interview findings.

3. Results

Table 2 provides an overview of the interviews that were conducted as part of this research.

Table 2: Overview of interviews

This table provides an overview of the interviews that were conducted as part of this research. For each interview, the length is noted, and for each person, the stakeholder category they can be categorised within in the açaí industry.

	Interview overview			
Number	**Description of current function**	**Interview partner (in-text-reference)**	**Date (2024)**	**Length (min.)**
1	Trainee at ministry of foreign affairs on agriculture in brazil: working on açaí projects now	Interviewee 1	23.01	38
2	Agricultural Officer at the Embassy of the Kingdom of the Netherlands. Brasilia: working on açaí projects now	Interviewee 2	23.01	38
3	Professor at Universidade de Brasília and working at CIFOR: history in açaí research	Interviewee 3	23.01	77
4	CEO and regional director of NGO	Interviewee 4	26.01	62
5	Postdoctoral researcher analysing agency in amazonian forests: history in açaí research	Interviewee 5	08.02	58
6	CEO and founder of european trader of Bazil Amazonian açaí	Interviewee 6	08.02	55

3.1. The açaí industry in the Brazilian Amazon: context

This first chapter provides an overview of the Brazilian açaí industry, focusing on key themes to understand its dynamics based on literature research, supplemented by interviews.

3.1.1. Botanical description

The *Euterpe* genus, belonging to the *Arecaceae/Palmae* family, consists of eight palm tree species native to Central and South America. Their distribution is particularly prominent in the north of South America, concentrated within the Amazon estuary floodplains (Heinrich et al., 2011). Several of these species, such as *Euterpe edulis Mart.* are well known for their use in the production of 'palm hearts'. This means that the açaí tree (*Euterpe oleracea Mart*.) produces two products; palm hearts and the açaí fruit. Though palm hearts hold a considerable part in the market, most focus is on the harvest of the fruits, with palm- hearts sold as a by-product (Muñiz-Miret et al., 1996).

Açaí, obtained from two palm species, *Euterpe oleracea* (mainly) and *Euterpe precatoria* (secondarily), being the most well known members of this genus, are palms characterised by their slender and tall stems that can reach heights of up to 25 metres (Lee and Balick, 2008). The main difference between the two species is the growth pattern of the palms. *E. Precatoria* is single-stemmed and native to the state of Amazonas, also referred to as "açaí-do-amazonas" or "açaí-solteiro" (Ribeiro et al., 2020). It is distributed across the Amazonas River Basin, a region of mixed upland and lowland terrain. It is most frequently observed south of the equator, particularly in western Amazonia. Secondly, *E. oleracea*, better known as "açaí-do-pará," is multi-stemmed and mostly found in the lowland and flooded forest land of the estuary of the Amazon River in the state of Pará, but also in other Brazilian estates, Guyana and Venezuela. A distribution of the two species is visualised in figure 5 (De Lima Yamaguchi et al., 2015). Due to the greater use of its fruit pulp worldwide and the fact that 94% of açaí production takes place in the state of Pará, this paper, focuses on the cultivation of *E. oleracea* in the state of Pará.

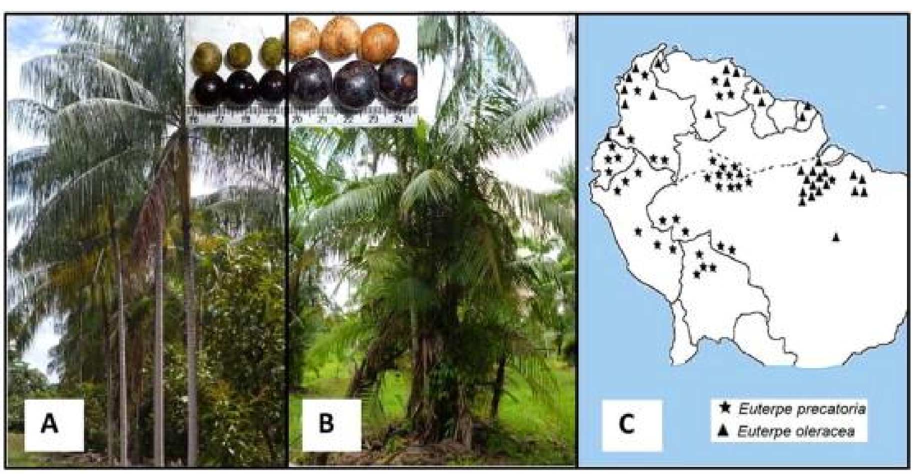

Figure 5: Two Euterpe palms used for Acai fruit production
This figure shows the seeds and palm trees of (A) *E.precatoria*, (B) *E.oleracea* and (C) a distribution of the two species. Reprinted from De Lima Yamaguchi et al., 2015.

oleracea is characterised as a fast growing palm tree that grows in clusters of up to 20 stems, which, when combined, can yield 120 kg of fruits a year or more. They are mainly abundant in riparian forest or pluvial forest in the Amazon region. Because of the root system's ability to adapt to yearly flooding, it is known as a pneumatophore. The unisexual flowers, which range in colour from yellow-brown to purple and are arranged in composite panicles, bloom all year, reaching their peak in February and July (Da Luz Freitas et al., 2020). During its immature stages, the *Euterpe Oleracea* fruit clusters show a green colour, eventually transforming into a deep purple colour when fully ripe, comparable in size to a grape (Pompeu et al., 2009). Each individual berry consists of a relatively large seed measuring 7–10 mm in diameter (Sabbe et al., 2009). This seed makes up about 80-95% of the overall volume of the fruit. The fruit's external structure is made of a delicate, hard, purple epicarp, while the mesocarp is thin, ranging from 1 to 2 mm (Pompeu et al., 2009; Sabbe et al., 2009).

3.1.2. Site description: The Amazon estuary

94% of Brazil's açaí is produced in Pará and is produced in municipalities like Igarapé-Mirim, Cametá, and Abaetetuba, which are all close to the network of islands along the Amazon River delta, making up the palm forests of the floodplains, also known as varzéas (Bourscheit, 2022; Muñiz-Miret et al., 1996). The areas in which production is concentrated are depicted in figure 6.

The Amazon estuary consists of a maze of islands and surrounding regions that have floodplain forests and are influenced by the ocean. There are two daily cycles of floods and ebbs in this area (De Bito Lima Soares et al., 2023). Açaí development is favoured by these ecological conditions because the frequent floods supply moisture and nutrients to the soil, enabling fruit production even in immature fallows. Although açaí is well suited to the estuary's daily floods, it does not grow well in locations that are never flooded or are continuously wet (Muñiz-Miret et al., 1996).

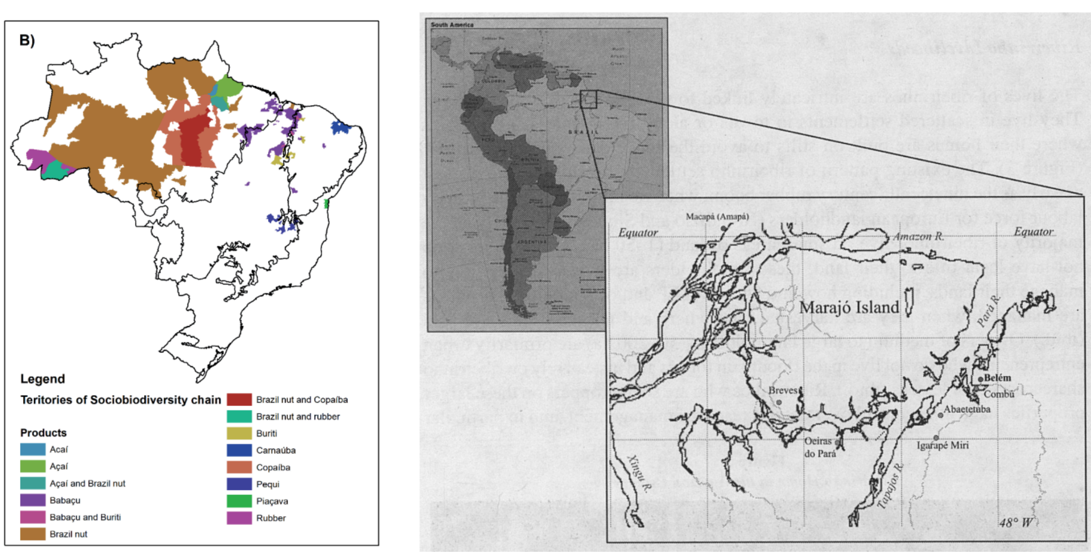

Figure 6: Spatial distribution of Acai

This figure shows the spatial distribution of NTFP product chains in Brazil based on municipal reports combined in an IBGE dataset (left). And a map of the Amazon estuary, extending from the western edge of Marajó Island and the mouth of the Xingu river over 250 km to where the Amazon and Pará rivers empty into the Atlantic Ocean (right). Reprinted from (Ribeiro et al. ,2020; Weinstein & Moegenburg, 2003)

3.1.3. History and traditional use

Açaí is widely consumed in Brazil's tropical regions and has been a staple in the diets of local communities throughout history, making up to as much as 42% of their diet's dry weight (Heinrich et al., 2011; Lee & Balick, 2008). The fruit is typically macerated in water and then filtered before consumption. The purple juice resulting from this process is typically paired with a meal (De Oliveira et al., 2018). In Pará specifically, the fruit juice is traditionally consumed as a "chilled soup" with tapioca or manioc flour and often served with shrimp or fish, as depicted in figure 7 (De Oliveira et al., 2018). Consumers in other states generally prefer açaí when it is combined with cereal, bananas, guarana, and condensed milk (De Oliveira et al., 2018). Furthermore, açaí has been used medicinally in traditional medicine in addition to being consumed as food (De Lima Yamaguchi et al., 2015).

Figure 7: Açaí market and consumption
This figure shows a picture of vendors selling freshly harvested açaí berries on a market in Belem on the left and an example of a traditional serving of açaí puree with fried fish and manioc flour on the right. Reprinted from (Carneiro, 2023)

3.1.4. Journey to global prominence and current use

In the Amazonian states, açai was primarily consumed locally until the 1990s. Back then, it was even referred to as "food of the poor." An important moment in its history took place in the 1990s, when surfers along the coastline noticed that juices made from the berries provided them with higher and longer lasting energy levels. This led to açai juice gaining popularity and becoming a staple beach beverage in Brazil (Lee and Balick, 2008). It was only in the late 20th century that açai started gaining popularity beyond the borders of Brazil. Urbanisation, increased consumer awareness and more focus on health and wellness, and the global trend toward incorporating natural and functional foods into daily diets have all played key roles in growing the açai industry to its current proportion (Heinrich et al., 2011).

Açaí is often described as being one of the first examples of the Internet's marketing potential and how local goods can be promoted globally via the World Wide Web (Heinrich et al., 2011). The rise in popularity in western countries is thought to have begun when the world-famous talk show host Oprah Winfrey in 2004 spoke about the berry's potential health benefits, which included anti-aging qualities, immune system boosts, and increased energy levels. Following this period, açai products such as tablets, juices, energy drinks, powders, and smoothies have been marketed increasingly by a number of manufacturing companies, mostly in the United States, Europe, and Japan (De Lima Yamaguchi et al., 2015; Lima, 2023). This trend is an example of a wider process in which local products become global commodities (Heinrich et al., 2011).

Thus, in the span of just a few decades, the açaí sector transitioned from only having to supply a small local market to emerging as Brazil's foremost forest-based food product in terms of total economic value (IBGE, 2022). Subsequently, engaging in the industry by means of cultivating, harvesting, or transporting açaí, has become the most lucrative livelihood option for many individuals in rural communities along the estuary's riverbanks and islands (Bourscheit, 2022).

When exported, the berries are processed to create pulp, which serves as the basis for a number of different products (Lima, 2023). Fresh açaí is only sold at the regional level in Brazil due to its perishability. Frozen açaí pulp however, is also traded abroad (Sabbe et al., 2009). Freezing or processing açaí helps reduce the seasonality of its prices and increases the overall revenues of the industry, as well as permitting the entry into international markets (Muñiz-Miret et al., 1996). The process of mechanically extracting the açaí juice involves using either machinery or human labour.

3.1.5. Trends and distribution

This section presents findings from database searches regarding the trends and distribution of the açaí industry in the state of Pará. Data on the açaí industry was found in two of the researched databases, IBGE and Painel da floresta. Findings within both of these databases will now be presented.

<u>IBGE findings</u>
Searching available data from IBGE regarding trends and distribution of the industry within the state of Pará resulted in data regarding the production value of the cultivated açaí sector within the state, as visualised in figure 8. This production value shows a growing trend in recent years. Data on the spatial distribution of the industry showed the harvested area in 2022 was 244.044 ha, as is visualised in figure 9. Data on previous years has not been found; therefore, no trends over time can be calculated.

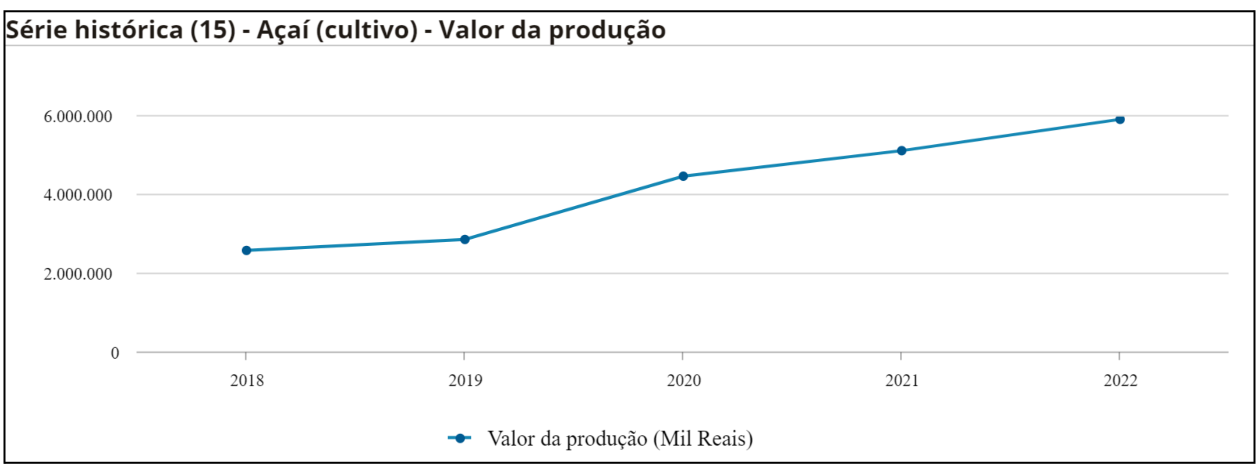

Figure 8: Value of açaí production in the state of Parà between 2018-2022
This figure shows a graph illustrating the trend of production value between the years 2018-2022. Reprinted from (IBGE, 2022)

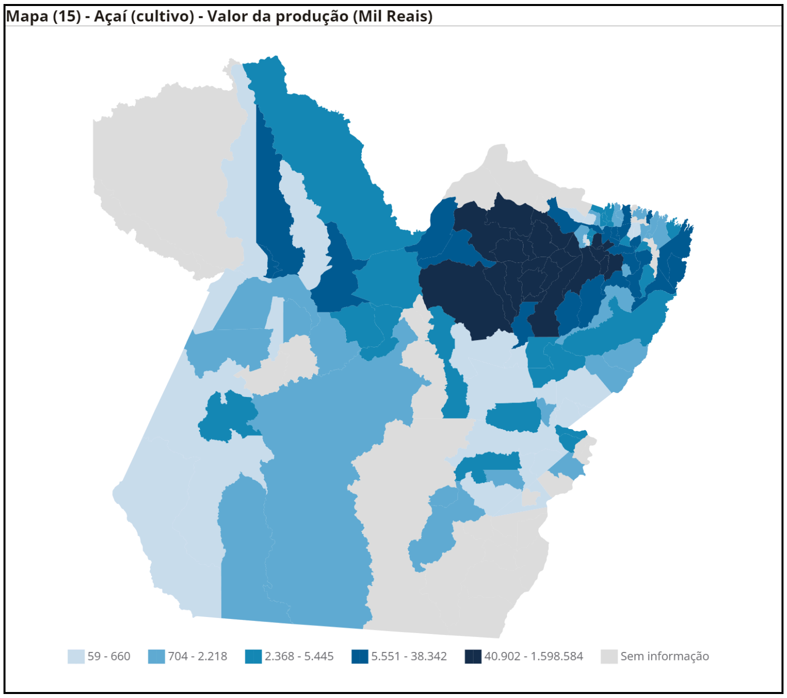

Figure 9: IBGE data on açaí cultivation in Pará
This figure shows data from the IBGE database regarding the spatial distribution of açaí cultivation in the state of Pará in 2022 based on the IBGE database. Blue tones reflect the production value of the area. Reprinted from IBGE, 2022.

<u>IBGE Gaps</u>
The data underlying figures 9 and 10, according to the IBGE website, are based on statistical and territorial surveys. Nevertheless, no information was found regarding the methodologies for gathering this data. More importantly, it is not clarified what is meant by ‘cultivated açaí’. Criteria for a system to be regarded as such are not described. Therefore, it is unclear whether this information includes data on agroforestry systems or what systems they regard as ‘cultivated’ look like. Furthermore, a lack of data on previous years regarding the area of the industry hinders visualisation of trends over time and the calculation of numbers on the expansion (rates) of the industry, nor can a comparison between different production systems be made.

The given lack of data and specifications impacts the assessment of the sector within this paper, specifically the ability to answer questions regarding the trends and market share of different types of cultivation systems. On a wider scale, this lack could also have implications for effective certification practices, policymaking, and conservation efforts. Furthermore, it could lead to misguided decisions that do not address the specific challenges associated with different types of cultivation systems.

<u>Painel da floresta findings</u>
The only database identified in this research that provided some comparable data regarding the distribution and occurrence of açaí cultivation on the floodplains of Pará is Painel da floresta, which was not able to be found by means of literature and browser research, but was recommended by one of the interview partners. This online panel is a project as part of a collaboration between several institutes that

gather data on bio-economic chains in Brazil. This database distinguishes two categories, being extractivist (extrativismo) and planted (plantado).

Painel da floresta provides quantity concentration maps, as depicted in figures 10 and 11. These show the highest production quantities for both planted and extracted açaí on the floodplains near Pará’s capital city, Belem, which is situated along the river home to the main trading post for açaí , known as the ‘feira do açaí ‘(Brondízio et al., 2002).

The credibility of these numbers is called into question by findings in recent literature pointing to the fact that formal records often do not correspond to reality and that production could be much higher than is reported (Bourscheit, 2022). Given the lack of accurate data, initiatives like those of the French Development Agency, Ipam, who are working together with the Pará government and with resources from the French Development Agency, are currently working to detail the quantities and quality of the açaí production chain in the state.

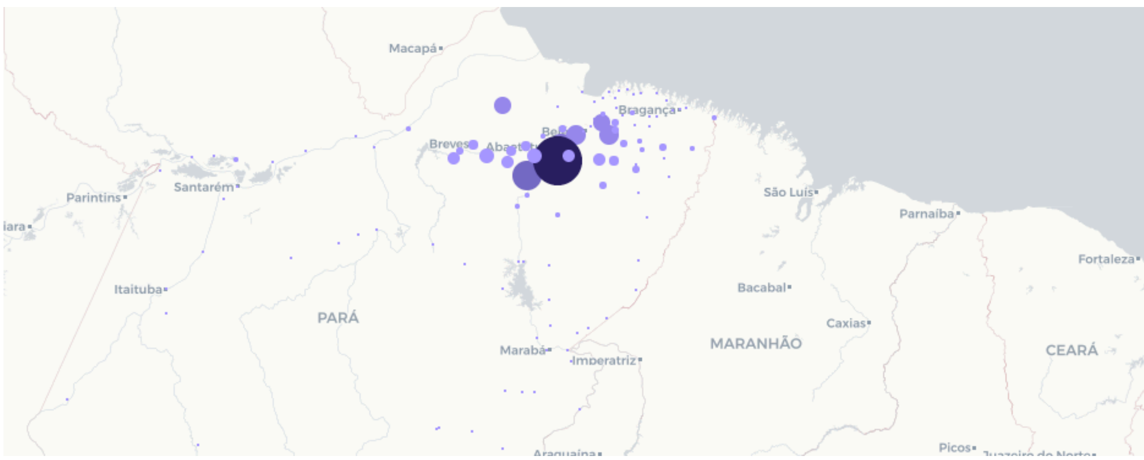

Figure 10: Quantity concentration map of planted açaí in Pará
This figure shows the quantity and concentration of planted açaí in the state of Pará in 2021 based on the painel da floresta database. Reprinted from (Painel da Floresta, n.d.)

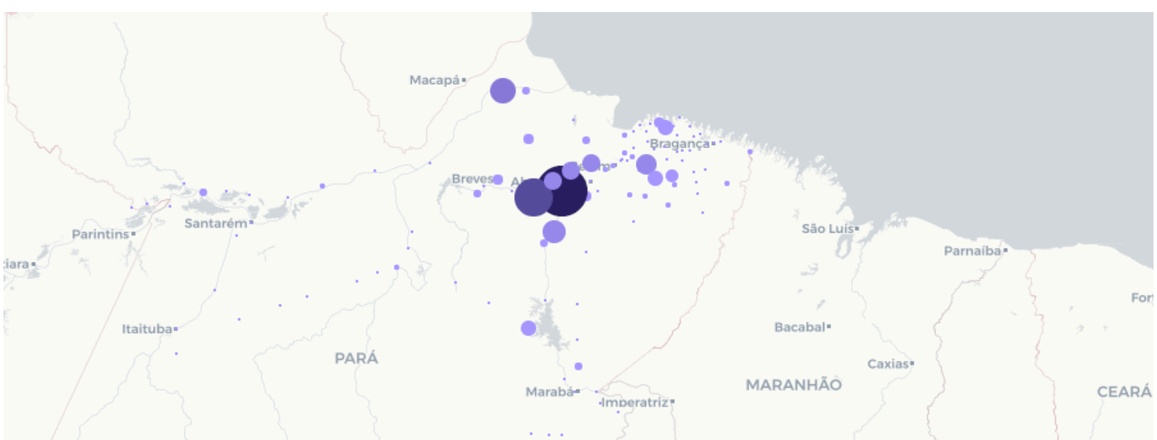

Figure 11: Quantity concentration map of extractivist açaí in Pará
This figure shows the quantity concentration of extractivist açaí in the state of Pará in 2021 based on the painel da floresta database. Reprinted from (Painel da Floresta, n.d.)

Painel da floresta also provides data on the harvested area. This is depicted in table 3.

Table 3: Comparison between quantity and area of production

This table shows a comparison between the quantity and area of açaí production in the state of Pará based on data from painel da floresta. (Painel da Floresta, n.d.)

	Extractivist (extrativismo)	**Planted (plantado)**
Quantity produced (Quantidade produzida)	2015: 126 million tons 2017: 141,9 million tons 2021: 154,4 million tons 2015-2021 change: + 28.4 million tons	2015: 1 billion tons 2017: 1,3 billion tons 2021: 1,4 billion tons 2015-2021 change:+ 0,4 billion tons
Harvested area (Área Colhida)	2015: x 2017: x 2021: x 2015-2021 change: N.A.	2015: 135,7 thousand ha 2017: 157,7 thousand ha 2021: 199 thousand ha 2015-2021 change: + 63.3 thousand ha

There is no data available regarding the area of extractivism. An explanation as to why this data is not available is absent. It could potentially be attributed to the difficulty of measuring areas of extractive reserves and tracing back harvested fruit, yet this remains unclear.

<u>Painel da floresta gaps</u>

Numerous data gaps were identified in the Painel da floresta database. First, while in contrast there ís data availability in two cultivation categories, the database does not provide information on the basis of its categorization, nor does it provide data sources. It is unclear on what basis systems are qualified into either category and how this data is gathered. Furthermore, in a similar manner as the IBGE case, binary categorization does not capture the gradient of management practices, specifically overlooking agroforestry systems and not providing information as to what category this is considered in the database. The missing data on agroforests presents a gap in the research landscape.

<u>Mapping açaí systems</u>

A major gap regarding trends and distribution of the sector, which causes an inability to analyse land use trends, is the fact that it is challenging to identify changes in floristic composition using satellite data. Satellite imagery, a common tool for large-scale environmental monitoring, is limited in accurately distinguishing between different management systems and therefore hinders the tracking of land use changes over time (Homma et al., 2006). The main obstacle is that Açaí stands and the surrounding vegetation have similar spectral signatures, which makes it challenging to distinguish variations in composition just from space-based observations. This issue is especially noticeable when attempting to distinguish between Açaí systems that differ little in terms of tree density and understory diversity. Therefore, in order to gain a more accurate overview, ground surveys could be an alternative. Though labour intensive, direct observation and recording of understory species, tree density, and other ecological factors that are difficult to consistently capture with satellite imagery are made possible by these surveys. This would help in collecting more data on not only spatial management gradient distribution but also diversity levels. This in turn facilitates making well-informed policy and implementing efficient land-use planning.

3.1.6. Cultivation and management

In traditional cultivation practices, açaí is gathered through an "agro-extractive" approach with minimal intervention on the forest ecosystem. On the opposite end of the management continuum, more intensive practices are responsible for the prevalence of near-monospecific stands, as visualised in figures 1 and 2 (Muñiz-Miret et al., 1996; Tamboracai, 2017).

While the spread of açaí cultivation does usually not entail direct deforestation, it does involve intensive management techniques that gradually supplant native tree species. This is achieved through practices such as thinning or planting more palms in the understory to boost productivity (Anderson 1988; Anderson and loris 1992). Furthermore, management practices usually entail the gradual elimination of other indigenous trees in close proximity to açaí palms. This encourages the opening of the canopy and diminishes overall competition for sunlight and nutrients (Damasco et al., 2022). Throughout the gradient of existing systems, management practices vary widely (Da Luz Freitas et al., 2020).

Because açaí production grounds vary significantly in terms of management intensity, they often blur the line between what is considered forest and what is agroforest. Depending on the extent of their production, small-scale farmers in várzea regions frequently manage for higher tree densities, with the result that density is maximum in the immediate surroundings of their homes and decreases as one moves further into the forest. In other situations, the "açaízal" might only be a quick canoe trip away. This makes it challenging to draw boundaries between cultivation and extractivism (Pepper & De Freitas Navegantes Alves, 2017).

3.1.7. Harvest

The açaí harvest season in Pará spans a three-month period every year, starting in July. During this time, the fruits clustered on broom-like inflorescences at the top of each açaí stem gradually deepen in colour to a rich purple. Farmers possess the expertise to assess the ripeness of fruit bunches high up in the subcanopy. This assessment is crucial in determining the quality. Fruit that retains a greenish tint is unsuitable. To ensure high quality and flavour, açaí at harvest must be, in the words of many farmers, "bem preto" (very black). Even more highly prized are fruits that have progressed beyond glossy purplish-black to develop an ashy "bloom" on their skin. Known as "açaí tuíra," this is the best harvest (Tamboracai, 2017).

The optimal time for harvesting is early in the morning. During the peak season, it's a rare sight to find anyone at home during these hours. Every able-bodied family member joins the açaí harvest, either climbing the palms to harvest the fruit clumps or waiting below to collect the fruit into baskets. Harvesting açaí fruit requires cutting the ripe raceme and climbing the trunks. While there are professional harvesters, most of the time local youngsters or the children of the producers are employed to harvest, which has recently gotten increasing media attention (*Documentary: The Children of the Açaí Industry | Brut.*, 2022; Muñiz-Miret et al., 1996). Families emerge again from the forest around ten or eleven in the morning. These early morning harvest practices serve a dual purpose. First, açaí fruits exhibit higher moisture content in the morning before the sun's full intensity, resulting in better quality harvest. Second, after around 10:00 AM, the palm stems heat up enough to risk burning the arches of bare feet during the descent (Muñiz-Miret et al., 1996).

Throughout the harvest season, river communities have many annual açaí festivals, and local ports are active around the clock with boat traffic. These boats arrive heavily loaded with baskets açaí harvests. Dockworkers unload the wicker baskets overflowing with açaí, which are the standard transport container and unit of trade on the rivers. The açaí is then transferred to crates and loaded onto trucks destined for local markets, nearby processing facilities, or Castanhal, where the majority of Pará state's açaí processing plants operate (Tamboracai, 2017). Middlemen often play a crucial role in this transport process by ensuring fast transport by boat to Belem. Here, the berries are quickly sold to avoid spoilage. The perishability of the fruit is a critical factor in the industry. Once gathered, açai berries don't last long and need to be processed within 24 hours. Thus, transportation must be done carefully and quickly to preserve the quality (Lima, 2023).

3.1.8. Annual cycle

The season with the most rainfall, which falls between January and August, is when fruit production takes place. Peak output takes place in May and April (Schauss et al., 2006). Figure 12 illustrates an example of such a cycle

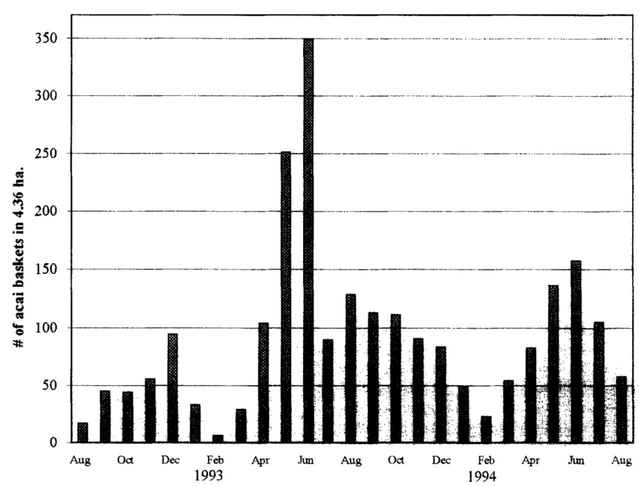

Figure 12: Monthly açaí production on a farm in Pará, Brazil
This figure shows an example of the monthly production of a single farm in the state of Pará in the months from august 1992 to august 1994. Reprinted from Muñiz-Miret et al. (1996).

3.2. Findings on environmental sustainability

This section describes the most prominent themes, as described by SIMeF, to analyse the environmental sustainability aspects of the current açaí industry in the Brazilian amazon. Using this structured framework approach, it goes by the selected themes one by one, presenting insights which draw upon literature research and stakeholder interviews. Each theme concludes with a short overview of identified gaps within the current research landscape and identification of ingredients towards sustainable development

3.2.1 General land use

In extractivist systems, the sustainability perspective on general land use trends is currently marked by the potential risk of existing extractivist reserves evolving into more managed landscapes over time, displacing and reducing natural undisturbed forest and becoming cultivation grounds (Damasco et al., 2022). While harvesting from naturally occurring populations without management has little impact on land use changes, the growing demand may drive the gradual use of more intensive management techniques, such as has happened throughout recent years (Tamboracai, 2017).

A similar is posed to existing agroforestry. Based on theory, the diversity of species cultivated in agroforestry systems ensures year-round income for farmers, which limits the need to venture into pristine forests to gather extra NTFP’s to support income (Rahman et al., 2016). However, what has been observed in recent years is that many producers have been extensively expanding their açaí agroforestry into pristine and unmanaged forests, which can be attributed to boom in global demand and drastic price increases (Damasco et al., 2022; Freitas et al., 2015) Establishing or expanding agroforestry systems by means of management practices such as thinning, can impact the natural forest (Damasco et al., 2022). It is predicted that this spreading trend, if continued in the current manner, would lead to "empty forests" when native dicotyledonous tree species are gradually replaced with açaí (Homma et al., 2006). The need to take action now is emphasised: *“Their (small scale producers) window of opportunity may soon disappear with the internationalisation of açaí plantations, even in other parts of Brazil.” (*interviewee 4).

A crucial factor to consider for each of the systems is their geolocation. Depending on the location of cultivation grounds, the push for expansion could create a number of obstacles to sustainable land use. However, if cultivation is encouraged on degraded or abandoned lands rather than in previously forested areas, it could also arise as a strategy to restore degraded or abandoned lands. Nevertheless, no literature on research regarding the cultivation of specifically açaí on degraded grounds could be found in literature or by means of interviews.

<u>Driver of land use change</u>

An examination of the policy framework for the last 20 years by CIFOR shows a clear movement in favour of laws focused on climate change and conservation in Brazil. Effective cooperation at the highest governmental levels, together with the use of incentives and penalties to promote environmental governance, have been hallmarks of this transition (Miccolis et al., 2014). Despite these encouraging developments, there are still big differences between economic development-oriented policies and those centred around climate change mitigation and conservation. An example of this became especially apparent when the state of Pará, proposed the ‘best practice’ management for açaí cultivation in the varzéa forest with a mean density of 200 stems/ha. which involves gradually thinning out wooded regions and predicts a 50% loss of tree species diversity (Freitas et al., 2015). Policies as such increase production rates and boost the economy, but they fail to align this development with environmental goals (Miccolis et al., 2014).

The future of land use changes in the Amazon region will likely be closely related to the formulation of policies and their enforcement. As legislation in Brazil, particularly for conservation units, plays a crucial role in determining land use practices, mitigating the risks of expansion would necessitate a proactive approach through policy-making (Rezende et al., 2018). Uncertainty over land tenure continues to be a major barrier. To address this issue, several initiatives, such as the Arco Verde Terra Legal program, concentrate on attempts to regularise in the Amazon and promote sustainable productive models (Miccolis et al., 2014).

Thus, the main obstacle going forward will likely be incorporating important elements of conservation- and climate change-focused policies into more comprehensive rural development and economic plans (Miccolis et al., 2014). This needs to be combined with a focus on enforcement and implementation to overcome Pará's often poor capacity and difficulties coordinating between state, federal, and local governments Overcoming these obstacles in order to bring about significant and long-lasting change will determine how effective land use regulations are in the Amazon region (Miccolis et al., 2014).

Gaps

No information on the potential of açaí cultivation on degraded land has been found. Research into this could explore the possibility of cultivation on degraded lands as a sustainable alternative to production in forested areas, contributing to restoration efforts, as it has shown to be for açaí cultivation in Colombia ("Corpocampo: Scaling-up Açaí Production in Colombia," 2023). This would be especially promising if such cultivation systems could be introduced to depleted areas of loggers, cattle ranchers, and soy farmers, which is currently a major issue in the region (Watts, 2023).

Emerging ingredients to sustainable production

- **Integrated land use policy and strengthened enforcement**
  The development and implementation of land use policies that balance environmental sustainability with socio-economic development of the region (Damasco et al., 2022; Schroth et al., 2005). In addition, a focal point should be strengthening of enforcement practices to ensure effectiveness of such policies.
- **Improved spatial mapping techniques** combined with monitoring and
  The development of accurate spatial mapping techniques with an ability to distinguish different management systems should be a second focal point. This should provide clear, accessible data on land use distribution and trends over time. This assists in creating more targeted solutions.
- **Establishment of monitoring and reporting systems**
  Establishing accurate reporting and monitoring systems could help measure the effects of land use strategies and policies, as emphasised by Homma et al. (2006).
- **Location-specific policy requirements**
  Policies should be adapted to their local context to ensure relevancy.

3.2.2 Greenhouse gas emissions

Literature points to açaí agroforestry as a possible low-cost carbon sequestration option, as well as capacity to retain 60-80% of the capacity for methane absorption (Allen et al., 2009; Coelho, 2017). Soil alterations observed in agroforestry are similar to those seen in secondary spontaneous succession. Mixed species agroforestry systems including açaí show positive total emission reduction potential when compared to monocultures. For instance, lowering methane emissions as a result of soil physicochemical changes, which are promoted by tree presence (Coelho, 2017).

The September 2021 study by Lira-Guedes et al. shows monocultures of açaí palm trees on estuarine floodplains are showing high levels of CO2 emissions when compared to more diversified systems. Furthermore, monocultures of açaí can contribute to greater susceptibility to environmental variations and, consequently, variability in CO2 emissions over time (Lira-Guedes et al., 2021).

<u>Pathway potentials</u>

The National Biofuel Policy, or RenovaBio, is an important part of Brazil's energy strategy which was implemented in 2007. This plan includes a long-term strategy on the expansion of the energy sector. It seeks to enhance the energy matrix's utilisation of bioenergy, while assisting a fair trade-off between energy efficiency and greenhouse gas (GHG) mitigation (*National Energy Plan 2050 - Climate Change Laws of the World*, n.d.). In addition to this policy similar policies have emerged on an international scale, such as the EU approval of Directive EU 2018/2001, which mandates that renewable energy account for at least 32% of total energy consumption until 2030 (Ferreira et al., 2020). With the approval of such national and international laws, there is increasing attention being given to the production of renewable fuels from biomass for bioenergy production.

Literature research shows a growing body of research on the bioenergy potential of the current açaí sector. It states the current açaí sector holds substantial bioenergy potential that, with careful management, might help in meeting energy needs and reduce overall carbon emissions (Ferreira et al., 2020). The same subject was mentioned as one of the most hopeful developments in the sector by an interview partner, who stated, "*The pits could even become more valuable than the fruit itself.*" (interviewee 4). The pits which are the fruit waste from açaí processing,t has been shown to be a viable source of lignocellulosic biomass, which, when converted, produces biogas from anaerobic digestion (AD), organic acids, reducing sugars, bioethanol, and bioactive compounds. The production of biogas and subsequent conversion into electrical and thermal energy is possible with the use of AD for the management of açaí waste. Furthermore, it can be refined into biomethane for use in heavy-duty cars, lights, and gas ovens.

Cases of improper disposal have led to several problems in the region, such as the clogging of waterways or growing number landfills with rotting pits (Carneiro, 2023). "*The residue is the main hurdle towards sustainable production"* - according to Lina Bufalino, a forest engineer in Belem. Recent developments on the use of these pits to produce biogas, could be a pathway towards both establishing a circular economy, while also tackling waste problems (Ferreira et al., 2020).

<u>Gaps</u>

No data has been found regarding the emission impacts of specific management practices, which hinders the identification of best-practices that could be recommended.

.

<u>*Emerging ingredients to sustainable production*</u>

- **Diversity of species in production systems**
  To increase carbon sequestration levels and lower total emissions. Furthermore, it helps retain moisture in grounds and retain litter and sediment (Allen et al., 2009; Coelho, 2017)
- **Use of açaí waste products for biogas**
  Further research into the potential of açaí waste to produce energy and effective ways to implement such strategies could be promising. Especially focusing on making such waste management practices accessible to small scale farmers.
- **GHG measurements and comparisons**
  To aid development of targeted mitigation strategies, more research and accessible data is needed regarding emission impacts of different management practices.

3.2.3 Water Quality & Quantity

Cultivated açaí in agroforestry systems present high levels of soil porosity and water retention, promoting sustainable use of water resources (Coelho, 2017). These systems often rely on natural water sources such as rivers and floodplains, minimising the impact on water quantity. In contrast, more intensive management has led to erosion and consequently the siltation of rivers (Da Silva Barbosa et al., 2022).

In the case of diverse enough systems of agroforestry that can host pest controllers and insects, there is no need for pesticides. However, with less diversified systems, pesticides and herbicides are sometimes used, impacting water quality (Pepper & De Freitas Navegantes Alves, 2017).

According to the interviews and recently published studies, pesticide use in açaí cultivation is a rising concern, especially for monocultures (interviewee 5; Ratnadass et al., 2011). This concern is reflected in certification developments, which show the topic has also been incorporated by a number of certifiers, such as Sambazon, who no longer certify açaí when it is cultivated with a use of pesticides. But as monoculture systems spread, herbicides and fertilisers with added nitrogen are increasingly being used. These chemical inputs have negative impacts on the soil and groundwater. Furthermore, they are argued to cause lower-quality and less abundant açaí fruit production (Tropical Acai, 2022).

Furthermore, the spread of monocultures has increased the number of pests due to higher vulnerability (Ratnadass et al., 2011). From the seed stage to the adult plant, a variety of insects can damage palms; control can be especially challenging given the height of the palm (CABI Compendium, 2019). This increases the usage of pesticide and other agricultural inputs (Pepper & De Freitas Navegantes Alves, 2017).

<u>*Gaps*</u>

No data was found on water stress under different management intensities. Furthermore, there is no available information regarding the use of irrigation in systems which are expanding further into pristine forest, which could be especially disrupting. Furthermore, detailed information on the type of pesticides, herbicides and fertilisers used was not found, nor information regarding their methods of application and impacts of these substances on animals.

Emerging ingredients to sustainable production

- **Disposal of byproducts to prevent blockages and use of byproducts for bioenergy**
  Byproduct disposal, especially pits, should be focused upon to avoid negative effects on water systems such as blockage (Carneiro, 2023). If efficiënt strategies to collect these byproducts are established, they could contribute to a more sustainable production system by being used for production of bio-energy, as described in section 3.2.2.
- **Limit pesticide, herbicide and fertiliser use, and promote diversification**
  Diverse enough systems showed to have limited need for use of pesticide, herbicides and fertilisers. Therefore, limitation on usage of such products should be focused upon by promoting diversification on cultivation grounds (and thus agroforestry practices), as well as more research into natural remedy strategies against newly emerging pests and diseases (Pepper & De Freitas Navegantes Alves, 2017; Ratnadass et al., 2011).

3.2.4 Soil Conditions

Agroforestry could help in soil conservation (thus preventing soil erosion) (Béliveau et al., 2017). Improved soil structure and chemical composition are major benefits of agroforestry practices, particularly those that incorporate plant diversity in space and time. This diversity strengthens the soil's ability to carry out its natural activities by enhancing the retention of organic compounds by means of the accumulation of plant biomass, energy, and edaphic biota. It also improves the nutrient cycle due to the increased output of litter and increased carbon cycling (Lira-Guedes et al., 2021; Selecky et al., 2017). Some research stresses the short term value of adopting agroforestry as a practice for soil conservation because of its ability to buffer the effects of rainfall variability, which will become an increasingly unpredictable factor due to expected increases in meteorological variability (De Aguiar et al., 2010; Béliveau et al., 2017).

The absence of forest and understory in a monoculture system, kept clean by management practices such as frequent weeding and cleaning, facilitates the inflow and outflow of water from an area when tidal flooding occurs, facilitating the loss of moisture through evaporation. This also contributes to a lower accumulation of litter and sediment, which are carried away by the tides that invade the area. Overall, monocultures cause the depletion of organic matter. Reduced soil organic content is caused by nutrient imbalances and soil deterioration. The monoculture systems' homogeneity and minimal litter contribution diminish the biochemical nutrient recycling's contribution, leading to soil erosion and, subsequently, river siltation (De Azevedo, 2010; Lira-Guedes et al., 2021).

Recent developments to improve soil conditions

The pits, forming waste products of the sector, are starting to be used to produce biochar. This biochar is a product of a thermochemical breakdown process known as pyrolysis, which turns organic material (açaí pits or other biomass) into a solid that is carbon-rich, porous, and highly recalcitrant (Sato et al., 2020). This biochar produced from açaí seeds has been suggested to improve soil structure in recent research (Sato et al., 2020). Furthermore, its use can promote microbial activity (Sato et al., 2020). This development is especially promising given how easy it is to acquire pits in large quantities without being mixed with other materials. Though the use of biochar is currently still in its beginning phase and it is unclear how widespread its use currently is, research suggests it has positive potential as a soil conditioner, especially for soils in the Amazon (Biederman & Harpole, 2012; Sato et al., 2020).

Emerging ingredients to sustainable production

- **Diversified systems for soil health**
  Diversification of cultivation grounds could contribute to a more healthy and future-proof soil under changing climatic conditions (Béliveau et al., 2017; Lira-Guedes et al., 2021).
- **Biochar production from açaí residues**
  Use waste products to make biochar as a way to combat soil erosion (Sato et al., 2020)

3.2.5 Agricultural genetic resources

In extractivist systems, where açaí is collected from naturally occurring populations in the wild, the impact on agricultural genetic resources is notably positive given the species' organic evolution and dispersal throughout its natural habitat (interviewee 3). This could especially be promoted by extractivist practices, which according to interviews involve consciously of leaving a portion of the fruit when harvesting (interviewee 3). Information on prevalence of such practices, nor if there are more of such practices, were not found in literature. Nevertheless, the one mentioned in an interview aligns with the açaí palms' natural lifecycle, allowing for the maintenance of genetic diversity through ongoing evolutionary processes. Enabling natural genetic adaptation in this sense helps to preserve the genetic resources of the species.

In agroforests, heavy management could result in dominance by pioneer and disturbance-tolerant species, which may contribute to a decrease in diversity and cause homogenization (Freitas et al., 2015). Such taxonomic homogenization associated with land-use change has been documented previously in upland regions (Freitas et al., 2015). Nevertheless, studies on várzea forests are lacking.

Emergence of breeding progams

Currently, a number of breeding programs are focusing on enhancing different characteristics of the açaí palm, particularly focusing on producing high-yielding and lower-canopy hybrids, making harvesting easier and production levels higher (interviewee 5, Oliveira et al. 2010). Literature indicates that such efforts to enhance its genetic features are still in their early stages of development, providing only sporadic or preliminary results (De Farias Neto et al., 2018; Da Silva Azêvedo et al., 2019; Yokomizo et al., 2016). Due to this species' long life cycle and the lack of conventional methods for vegetative propagation, breeding programs are complicated and take too long (De Farias Neto et al., 2020). Seed has been the traditional method of propagating the açaí palm, but it presents challenges because seedlings grow slowly and are therefore especially susceptible to mortality, lose viability quickly, and do not preserve well (Scherwinski‐Pereira et al., 2012).

Pathway potentials

Developments in the breeding of açaí seeds brings forth both advantages and challenges. Positively, breeding could create opportunities for the development of açaí with desirable characteristics such as increased fruit yield (limiting expansion need) and lower canopy heights, which facilitate harvesting, improved resistance to pests and diseases, which would limit the use of pesticides and other chemical inputs. Furthermore, it could aid in the development of açaí that demonstrates resilience in the face of climate change, especially relevant given the palms are currency very susceptible to climate change (De Carvalho & Nascimento, 2018; Tregidgo et al., 2020). This would ensure more long-term viability of açaí palms on cultivation grounds in the floodplain. Risks include a loss of genetic diversity, making the crop more susceptible to new pests and diseases. Furthermore, unintended repercussions of modification of characteristics could occur. For example, manipulation of height could affect how the plant interacts with its surroundings, such as, for example, the pollinators of the palm or avian fauna.

Gaps

An identified gap in the research landscape is information regarding the presence and effects of modified seeds in various açaí cultivation systems. It is currently unclear to what extent modified seeds are used and what the effects of their usage are on their physical environments.

Ingredients to sustainable production

- **Breeding**
  While possibly having risks, breeding could also play a role in moving towards more sustainable production systems. That is, if it could contribute to more frequent and/or higher yields, limiting the need to expand into forests, or promote climate-resilience. However, such advantages must be carefully weighed against the risks of decreased genetic variety, increased susceptibility to diseases and pests, and other ecological impacts, on which more research is needed (Scherwinski-Pereira et al. 2012)

3.2.6 Ecosystems, habitats and species richness

Furthermore, the International Union for Conservation of Nature has recognized numerous vulnerable species as being present in dense concentrations in certified harvesting sites (Damasco et al., 2022). Literature shows that extractivist practices support high diversity levels on the floodplain at both high and low extraction intensities (Freitas et al., 2015; Santos et al., 2004; De Jesus Batista et al., 2011). The effects of agroforestry systems are heavily dependent on their management intensity and diversity levels (P. Z. F. Santos et al., 2019). High-intensive açaí management shows a reduction in the (functional) richness of forest stands, as well as disrupting interconnectedness (Freitas et al., 2021). The altered structure and composition of the vegetation as a result of "cleaning" management techniques (such as the removal of vines, lianas, canopy trees, and understorey vegetation) cause the most significant effects (Weinstein & Moegenburg, 2003). Two such systems differing in management intensities are depicted in figures 13 and 14. The systems that are dominated by high-intensity management practices show to be impoverished in terms of understory, canopy, and emergent tree species (Campbell et al., 2018; Freitas et al., 2021). The same goes for pollinators, which is especially critical given that açaí is dependent on pollination services, and açaí flower visitors include 200 distinct taxa (Campbell et al., 2018). Intensive management practices and monoculture tendencies reduce the number of antagonistic interactions (such as high ant densities) on inflorescences and weaken pollinator communities in floodplains (Campbell et al., 2018). Research specifically into, for example, avian diversity strongly highlights an existing trade-off between açaí production and the biodiversity levels of managed várzea forests (tidal floodplain forests). For example, Moegenburg and Levey (2002) reported a reduction of 22% in avian diversity in more intensively managed açaí systems, where over 70% of fruit was removed. In contrast, low intensity harvests had no effect on diversity. Low-intensity management in agroforests show high levels of biodiversity, including a variety of understory plants, insects, and mammals (P. Z. F. Santos et al., 2019).
According to Freitas, a decline in diversity also has a detrimental impact on açaí production levels themselves, decreasing productivity. Some farmers take action on this notion, and implement management

practices to encourage diversity. An overstory is important to provide shate to the forest floor and habitat for animals. There are farmers who state such a shaded system is good for production, and leads to higher quality yield because it dries out less prior to its harvest (Pepper & De Freitas Navegantes Alves, 2017).

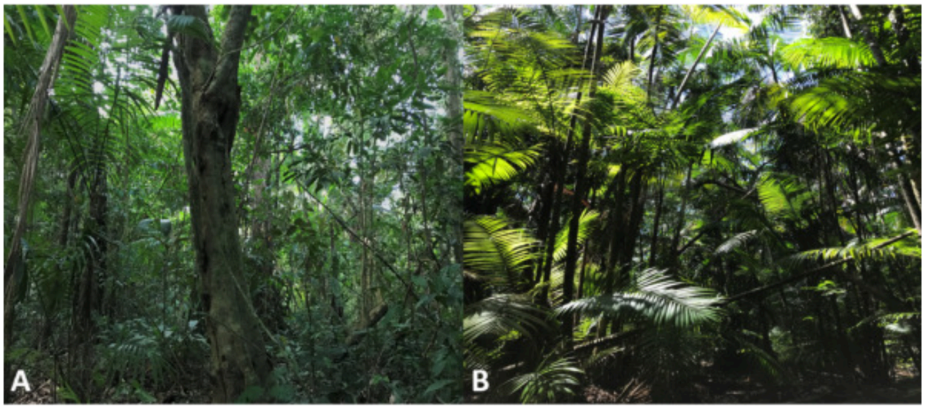

Figure 13: Estuarine açaí forest stands under different management intensities
This figure shows a comparison of estuarine forest stands under low-intensity açaí management (A) and high intensity management (B). Reprinted from (Freitas et al., 2021)

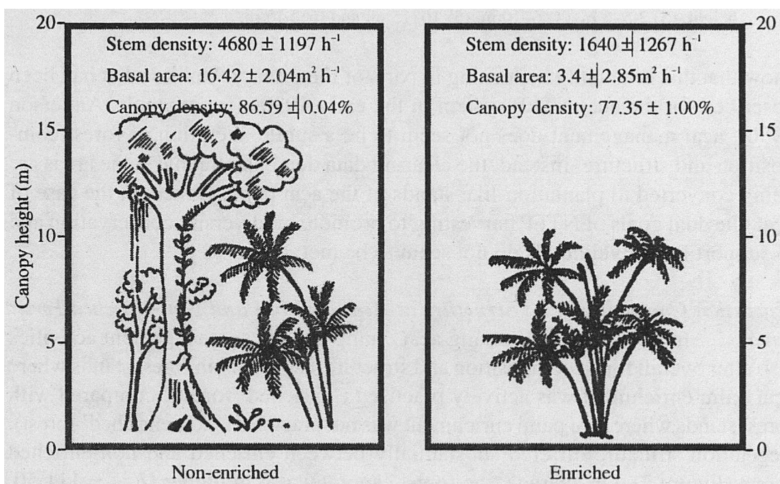

Figure 14: Vegetation profiles of stands not-enriched and enriched with acai
This figure shows a schematic comparison of estuarine forest stands under low-intensity açaí management, which does not involve enrichment (left) and high intensity management, which involves enrichment (right). Reprinted from (Weinstein & Moegenburg, 2003)

Pathway potentials

The açaí sector in Brazil is stated as lacking clear and uniform policies which regulate the promotion of biodiversity conservation in harvesting areas (Damasco et al., 2022). Recommendations in regards to management practices that should be adopted should include a focus on promoting biodiversity levels. Specific practices that could be promoted were not found in the literature. However, the aforementioned practices of extractivists who leave a portion of the fruit, which were mentioned in an interview, could be ones that can support the maintenance of biodiversity levels.

Another note that became apparent in interviews is the potential agroforests hold in conservation in comparison to extractivist practices. As agroforests are managed systems, they can also be implemented as a tool with the intention of improving species diversity levels where extractivist practices do not hold such potential. It could be especially promising if agroforests are implemented as such a tool, for example under the Law of Protection of Native Vegetation, which allows the use of agroforestry to recover environmental debts on rural properties. Such policies, however, ought to be specified to include biodiversity level requirements so they only cover biodiverse agroforestry systems instead of near-monoculture stands (P. Z. F. Santos et al., 2019).

Gaps

There is a lack of research on the impact of açaí cultivation within or near protected areas. Furthermore, no information could be found regarding the effects of cultivation in species rich hotspots. In addition, impacts on threatened or key species are not described in literature and impacts on habitat connectivity/fragmentation are underexplored, particularly in terms of how açaí cultivation might disrupt or support ecological corridors essential for species movement and genetic exchange. Furthermore, apart from less weeding and more diversity, there's a lack of available information regarding specific biodiversity-enhancing management practices

Emerging ingredients to sustainable production

- **Diversification:** Agroforestry systems can host high levels of diversity. Policies like the Law of Protection of Native Vegetation could be refined to specifically promote biodiverse agroforestry systems, distinguishing them from near-monoculture agroforests (P. Z. F. Santos et al., 2019).
- **Ground surveys:** According to Freitas et al. (2015), satellite imaging presents a challenge in monitoring ecological parameters such as understory species and tree density. Surveys and field visits could have the ability to better map this.
- **Biodiversity-focused management practices:** diversity levels can be enhanced by management techniques that specifically focus on promotion of biodiversity, such as leaving a portion of the fruit. More studies on such methods could confirm their efficacy and suitability for inclusion in standards of certification or policy (Moegenburg & Levey, 2002; Damasco et al., 2022).

3.2.7 Summary

As described in previous sections, Pará's açaí sector presents a number of risks and opportunities. Since extractivist systems rely on naturally occurring Açaí populations, they are regarded as typically more environmentally sustainable, promoting natural dispersal, genetic variety, and high levels of species richness. Nevertheless, they are also limited in their production capacities, which are critical to meeting the rising global demand. On the other side of the spectrum, monocultures, characterised by their high production quantities and intensive management, present several risks to their environment, causing soil erosion, decreasing genetic diversity, increasing emissions levels, lowering biodiversity levels, and negatively impacting water sources. Within this cultivation spectrum, theoretically, agroforests emerge as the most promising pathway to sustainable development of the sector. This notion was underscribed by all interviewees (interviewees 1-6).

Nevertheless, in practice, these agroforests present another gradient of management intensities within themselves. In some cases they can harbour high levels of biodiversity and increase soil health, yet the opposite proves true if it considers an agroforest showing near-monoculture characteristics. Several concerns arise when near-monoculture systems are labelled as agroforestry, such as misguided policy and resource allocations, as well as consumer misinformation (Ollinaho & Kröger, 2021). This calls for redefinition of requirements on what it means to be considered an agroforest producing açaí in Parà.

Thus, there are significant differences in the environmental sustainability of Açaí cultivation throughout the management gradient, but also a number of shared risks among them, mostly risks regarding trends of expansion and more intensive management. A number of ingredients to sustainable production and development arise, such as diversification of systems and usage of waste products in lowering emissions and improving soil conditions. In combination with current data gaps, such aspects could be focal points for future research, policymaking, and possibly certification. A summary of findings is presented in table 4. Furthermore, identified gaps are outlined in table 5.

Table 4: A summary of findings

This table presents a summarised overview of findings on each of the themes discussed in this chapter.

Theme	Extractivism	Agroforestry	Monoculture
General land use	Minimal impacts on land use changes, but a risk of becoming more managed systems	Current risk of expansion into pristine and unmanaged forest	Current risk of expansion into pristine and unmanaged forest
GHG emissions	Traditional harvesting methods show minimal impacts	Shows potential as low-cost carbon sequestration option	Higher levels of GHG emissions compared to diverse systems.
Water quality & quantity	Traditional harvesting methods show minimal impacts	Could promote sustainable use of water resources. However, in near-monoculture systems, the need for pesticides and fertilisation pose risks to water quality.	Increased pesticide, herbicide and fertiliser usage pose risks to water quality.
Soil Conditions	Traditional harvesting methods show minimal impacts	Could be a wayto promote soil conservation, but depends on management practices and plant diversity within the system.	Management practices facilitate loss of moisture from the ground, cause depletion of soil organic matter over time and cause soil erosion which could lead to river siltation
Agricultural genetic resources	Supports natural genetic diversity	Intensive management could lead to homogenization Use of breeding programs could lead to loss of genetic diversity	Breeding programs could lead to loss of genetic diversity
Ecosystems, habitats and species richness	Support a high variance diversity indices on the floodplain at both high and low extraction intensities	High-intensive açaí systems show a reduction in the species richness and disrupt interconnectedness Low-intensive systems show high levels of biodiversity, including a variety of understory plants, insects and mammals	Significant negative impacts on biodiversity levels

Table 5: Gaps
This table presents a summarised overview of gaps emerging from this chapter

Theme	Identified gap in research landscape	Possible implications	Areas for future research
General land use	Lack of data on the distribution and proportions of different cultivation methods/management intensities No information on the potential of cultivation in degraded areas. Loose definition of agroforestry.	Hinders understanding of general land use trends and policy making Potential misinformation	Research into improvement of current mapping methods or exploration of alternatives Research into the potential cultivation on degraded lands Define species-, location- and context-specific requirements agroforestry definition
GHG emissions	No data regarding emission impacts of different management practices	Hinders policy making for mitigation regarding recommendations on best-practices	More research and accessible data on emission impacts of specific management practices
Water quality & quantity	Lack of data on depth of water tables, irrigation water usage, extent of water stress across management gradient Lack of data on specific pesticide/herbicide/fertiliser that are used	Hinders policy making and setting of certification standards	More data collection on water quality & quantity across gradient needed Reporting on pesticide/herbicide/fertiliser use needed + impact assessments.
Soil conditions	No data regarding soil impacts of different management practices.	Hinders policy making	Research into soil impacts of different management actions
Agricultural genetic resources	Lack of available data on use of modified seeds	Potential loss of genetic diversity.	Impact assessments on use of modified seeds
Ecosystem, habitats and species richness	No information available regarding: protected areas, Cultivation in species rich hotspots, Ecosystem and habitat connectivity, fragmentation, Impacts on of key species, Impacts on threatened species Lack of information on management strategies specifically targeted towards biodiversity promotion	Hinders policy making and certifier development	Distribution of cultivation within protected areas and hotspots Impact assessments of high/low intensity management on habitat connectivity and fragmentation, abundance of key and threatened species Research on specific management strategies that could be used to promote diverse systems

The shift towards more intensive management and expansion presents a contradiction to the definition of management itself, which can be defined as follows by Soares et al. 2020:

"The goal of management is defined as preserving and replenishing productive resources. Its guiding principle is to provide production for an extended period of time, hence providing sustainable production."

The presented findings show how the 'sustainable production' part of this definition is currently called into question. While the emerging intensive management practices may indeed ensure production for an extended period of time in the context of that given cultivation system, their sustainability is questionable when considering impacts on a wider scale, highlighting the need to reevaluate current practices and align them more closely with species- and context-specific sustainable principles, beyond just an assurance of yields.

3.3 On certification

Given the fact that certification is a market-driven approach, it has the potential to go beyond policy in ensuring sustainability of a sector by setting specific requirements lacking in policy. For many well documented cases in literature, certification has proven a tool to promote sustainable land use practices and be a driver of sustainable development (Mikulková et al., 2015). Within the body of research on açaí making up this paper, several papers also mentioned certification as a tool to promote sustainable practices within this sector, especially given the current lack of efficiënt policies (Damasco et al., 2022; Weinstein & Moegenburg, 2003).

The previous sections of this paper have described a number of sustainability concerns linked to açaí production. The question arises: Could certification be a method to overcome these challenges and hereby be a tool to sustainable development of the sector? By means of analysing the current certification landscape, evaluating research on effects of certification, and a case study that assesses coverance of standards, this section reflects on the utility of certification in promoting sustainable açaí cultivation.

3.3.1 Current certification practices

In recent years, açaí food companies (especially from North-American, and European markets) have invested in a number of certification systems as a response to the growing demand for sustainable and organic products worldwide, which could be promising if it means small-scale producers can enter and gain competitive advantage in global markets (Damasco et al., 2022; Pepper & De Freitas Navegantes Alves, 2017). These new certifications, which include USDA Organic, Regenerative Organic, Biodynamic, Fair Trade, and Fair for Life, are stated to tell consumers whether a product complies with human rights, environmental conservation, and health regulations (Damasco et al., 2022). "Fair for Life", an example of one such certificate, developed and managed by the EcoCert Group, is a fairtrade certification standard. The certificate is a combination of three different standards, covering standards at municipal and corporate levels, with a focus on fair labour practices, biodiversity conservation, human rights, sustainable agroforestry methods, and positive community effect. As is for most of the certifiers, adherence to standards is checked by means of conducting annual audits (Damasco et al., 2022).

The increasing number of certification schemes in the açaí sector arguably marks a positive development, reflecting a growing commitment towards sustainability. Nevertheless, it also brings forward some concerns regarding the significance of certification. These concerns are reflected in recent studies which highlight that, in a number of cases, different certifiers have such a diverse list of objectives and standards, that they do not address all relevant aspects of sustainability for the commodity they certify (Perrigo, 2020). This presents a trade-off between specificity in requirements and coverance of certification: The more commodities/systems/area a certifier wants to include, the less context-specific their requirements can be.

Literature research, database research and interviews showed a lack in available data regarding the percentage of produced açaí that is currently covered by certification, nor does it provide a concise list of all certifiers that are present within the sector currently. More importantly, no data is available regarding the distribution along the management gradient of such certification stating details about what proportion of monocultures are covered in comparison to agroforests. A recently published study does mention that large-scale individual producers or cooperatives of industrial farmers currently are the ones that benefit the most from certification schemes such as fair for life as well as other third-party certifiers, as most of the certification schemes are directed to such systems (Damasco et al., 2022). However, research also pointed to a new trend in which a small number of recent initiatives are currently seeking to make certification practices available to more small-scale açaí producers (Pepper & De Freitas Navegantes Alves, 2017). Table 6 visualises a few of the options to small-producers are offered by three leading certifying entities in Brazil.

Table 6: Certification options

This table presents a few of the current options of certification for international markets offered by three leading certifying entities in Brazil. Reprinted from (Pepper & De Freitas Navegantes Alves, 2017)

Certifier	Certification	Target sector	International standards
ECOCERT Brasil	Organic agriculture	Production: organic products	Various
	Fair trade	Supply chain: fair trade and organic products	Various
IBD certifications	Organic	Production: organic products	Various
	EcoSocial all fair	Production: fair trade and organic products	ILO[a], IFOAM[b], quality insurance international
	Sustainable agriculture network	Production, supply chain: agriculture	Rainforest alliance
IMAFLORA	Small-Scale Low Intensity Forest Management (SLIMF)	Production: small-scale forest extractivism	FSC[c]
	FSC supply chain	Supply chain: forest products	FSC
	Sustainable agriculture network	Supply chain: agriculture	Rainforest alliance

3.3.2 Environmental impacts of certification

Studies on effects of certification on extractivism and monocultures of açaí are not present. However, recent studies show several promising results in regards to the ecological effects of certification of açaí agroforestry. An example of such are the impacts of "Fair for life" certification in the varzéas. A 2022 study shows that this certification effectively promotes higher species richness as well as more intact forest structures compared to non-certified areas (Damasco et al., 2022). Results of this study are depicted in figure 15. Certified açaí agroforests harbour 50% more tree species than the non-certified counterparts, as well as hosting trees with significantly higher mean basal areas, suggesting that older and larger individuals are protected (Damasco et al., 2022). Furthermore, the International Union for Conservation of Nature has recognized numerous vulnerable species as being present in dense concentrations in certified harvesting sites (Damasco et al., 2022). Based on available data, it is suggested that certification helps safeguard endangered species in açaí habitats in addition to promoting environmental conservation. Not only do species richness levels as well as forest structure impacts prove positive, another promising finding shows that fruit clump production retains the same levels in certified and non-certified sites.This shows certified managed sites can thus maintain fruit production at similar rates to non-certified agroforests, countering the common worry of a trade-off existing between fruit level production and sustainable cultivation practices (Damasco et al., 2022).

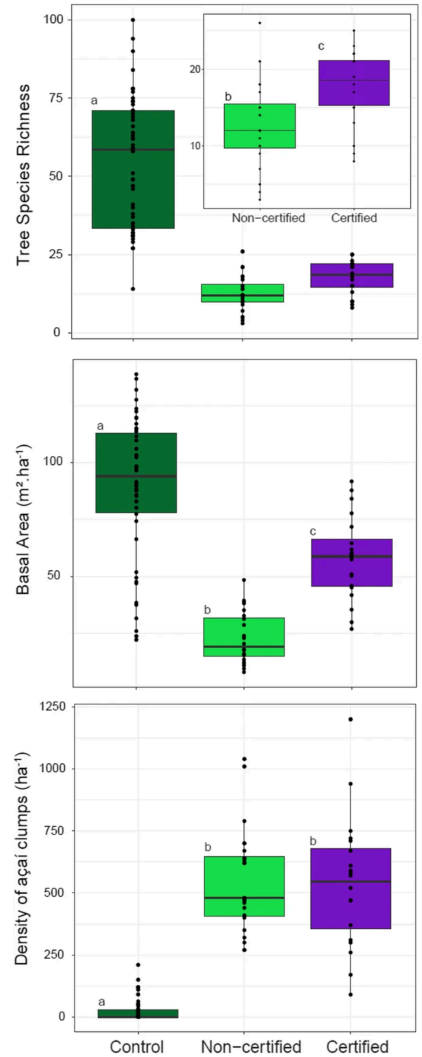

Figure 15: Comparisons of tree species richness, basal area, and density of acai clumps among certified, non-certified and control plots.
This figure shows comparisons of tree species richness, basal area and density of acai clumps among certified, non-certified and control plots. Reprinted from (Damasco et al., 2022)

3.3.3 Challenges and limitations of certification

Interviews as part of this research and gaps in literature pointed to challenges the current certification landscape is facing with regards to açaí cultivation. These findings will now be discussed.

A first important finding is the fact that for many of the certified producers, the aforementioned yearly audit to check adherence to requirements is announced (Interviewee 6). According to personal observations of an interview participant, many producers prepare extensively in the time leading up to such visits to make sure certification is continued and adherence will be scored as being sufficient. However, the time spanning the rest of the year when such visits are not planned, it is very well possible that farmers do not attain the requirements set in place by certifiers. This brings into question the utility and most of all validity of these certificates. A possible way to overcome this would be implementation of more frequent and unannounced monitoring practices set in place by certifiers.

Furthermore, based on literature, farmers report that for some cases of certification, mainly the açaí factories are the ones that benefit rather than the producers who supply them with açaí, due to high costs of implementation and low monetary benefit to doing so (Pepper & De Freitas Navegantes Alves, 2017). According to these studies, certification is beneficial, but only if a factory is prepared to pay a premium for açaí from small farmers. If not, there is no financial benefit for producers, and they are more inclined to sell to middlemen by which their açaí batches get mixed with batches from other farms (Pepper & De Freitas Navegantes Alves, 2017). This tendency highlights another challenging factor in the sector in which more sustainable cultivated fruit gets mixed with other batches of açaí from monoculture systems (interviewee 6). A manner in which certification could play a role in combating this issue would be by putting more focus and resources into methods of traceability. Interviews pointed to emerging techniques to improve traceability such as the implementation of QR codes on açaí baskets which trace back to farms as well as scanning techniques currently being developed which could lead to being able to tell apart açaí grown from different types of cultivation systems (interviewee 1, interviewee 2). If certifiers invest in such traceability systems, certification that recognizes the qualities that set this açaí apart would give the producers a way into international specialty markets (Pepper & De Freitas Navegantes Alves, 2017). An overview of challenges and opportunities is visualised in table 7.

It remains unclear what portion of açaí that is currently produced is certified and by which certifier. It is not reported which proportion of cultivated açaí is currently certified or the distribution of certified practices across the management gradient. Meaning; it is unclear to what extent monocultures are certified and how these numbers compare to agroforestry cultivation systems. Furthermore, the cooperative's size and available capital may determine the accessibility of to certification, as annual renewals and certification fees may be out of reach (Pepper & De Freitas Navegantes Alves, 2017). To combat such deterring involvement of certification, this paper argues certifiers should actively engage in facilitating aggregating harvest from small producers through investments in producer cooperatives.

It is important that certifiers focus on certification on farm/agroforest cooperation level and adopt context- and species-specific requirements that can make a distinction between management intensities of production systems, such as requirements on density of açaí palms, thereby ensuring more sustainable cultivation practices and promoting environmental sustainability such as presented in research on agroforests (Damasco et al., 2022). In addition to this, themes such as traceability, costs to engagement, frequency of audits, and higher payment to certified producers ought to be included in programs.

Table 7: Challenges and opportunities
This table provides an overview of challenges and opportunities identified in this review of certification.

Challenge	Opportunity
Management intensity: Certification standards could fail to distinguish between management intensities, hereby shifting to increased certification of monocultures rather than small scale sustainable systems	Certification should adjust requirements and include species-specific to distinguish between cultivation systems. Such requirements could include species-density.
Legitimacy: Adherence to certification standards throughout the year is often disregarded and only followed up on when an audit is planned	Implementation of unannounced frequent audits throughout the year
Benefit sharing: Farmers will not sell to factories certifiers if prices are lower	Increase consumer awareness and willingness to pay more for sustainably cultivated açaí Make sure certification provides monetary benefits to producers instead of just to processors of the fruit
Traceability: Sustainably cultivated açaí often gets mixed with other açaí from the region not adhering to sustainable practices	Invest in traceability systems
Costs: Small farmers deter from certification due to costs	Actively engage in facilitation of aggregating harvest through investment in cooperatives

3.3.4. Case study

The Netherlands has been a country showing increasing import numbers of açaí products in recent years, being one of the EU countries pushing the international demand (Sabbe et al., 2009). Fairtrade, aforementioned as one of the leading entities in the certification of açaí, is a certifier that currently certifies açaí based products within the Netherlands, and does this based upon international standards. In attempting to get a deeper understanding of the complexities of açaí certification, speaking with Fairtrade Netherlands as part of this research illuminated the fact that açaí certification of imported açaí within the Netherlands by Fairtrade currently is based upon two international standards: being SPO (Small-scale Producer Organizations) and Fresh Fruit requirements. SPO is based on the following three principles; 1. Members must be small-scale producers 2. Democracy and 3. Enabling strong producer organisations (FairTrade International, 2017) The latter is an addition to the former to include standards specifically focused on the sale of fresh fruits, including both for export and for further processing (FairTrade International, 2019). Together, these two standards encompass a list of criteria which are designed for a broad group of fruits. Therefore, they do not specifically focus on açaí (or NTFPs in general). This raises questions regarding the efficacy of this standard in capturing relevant sustainability aspects and thereby promoting sustainable açaí cultivation. By means of analysing the requirements of these two standards and comparing them to the results of the literature research in this paper, certification of açaí by fairtrade netherlands is analysed as well as the efficacy of the international standards fairtrade uses. Especially relevant given their position as a leading certifier in the sector.

Table 8 provides an overview of the fairtrade criteria corresponding to each of the themes discussed in this paper. SIMeF discussed in this paper as well as the specific challenges that have been identified. Furthermore, it shows whether a monoculture could be certified based on that given criterion. Solely criteria relevant to these themes are described to ensure focus on environmental sustainability aspects. The full set of standards however, encompasses requirements on a scope beyond these themes and includes socio-economic dimensions.

Table 8: Dutch Fairtrade certification of açaí

This table provides an overview of the SPO & Fresh Fruit standards that were identified as corresponding to the themes and challenges discussed in this paper. Requirements are reprinted from (FairTrade International, 2017) and (FairTrade International, 2019)

SIMeF Theme	Identified challenges in this paper	SPO	Fresh Fruit standard	Can monocultures be certified under these requirements?
General land use	Risk of expansion into pristine and unmanaged forest		The maximum size of the land where each of your members cultivates Fairtrade fruit is equal to or below 30 hectares.	Yes
GHG emissions	High levels of GHG in the case of monoculture stands	You implement measures on adaptation to climate change.		Yes
		You as an organization or your members take measures to reduce Green House Gas (GHG) emissions and increase carbon sequestration.		
Water Quality & Quantity	Pesticide, herbicide and fertiliser usage poses risks to water quality in more intensively managed systems	You train your members on integrated pest management. You ensure that this training includes: The monitoring of pests and diseases Alternative ways to control pests and diseases Preventive measures against pests and diseases Measures to avoid that pests and diseases build up resistance to pesticides	If you and / or your members use herbicides in the production process, you implement the following elements of an integrated weed management approach: Gain knowledge of the weeds that affect the productivity of the crop and of the conditions that favour and hamper the development of the weeds Gain knowledge of the parts of the fields where the crop is affected by the weeds	Yes
		Your members are able to demonstrate that pesticides are applied based on		

		knowledge of pests and diseases.	Prevention of the spreading of the weeds by non-chemical means (labour, mechanical or thermic means) Use of alternative control techniques, mulches or cover crops in order to control and reduce the weeds Application of herbicides focused on areas where the weeds are present and affect the crop No use of herbicides in canals, in buffer zones protecting rivers or watersheds, in protected or high conservation value areas or in buffer zones intended to protect people's health	
		You minimise the amount of herbicides used by members through other weed prevention and control strategies		
		You train your members on the appropriate use of fertilisers. You ensure that this training includes: Measures to ensure that fertilisers (organic and inorganic) are applied in amounts that respond to the nutrient need of the crop Measures to store fertilisers separately from pesticides in a way that minimises risks of polluting water		
		You list sources of water used for irrigating and processing fairtrade crops		
		You are informed about the situation of water sources in your area. In case local environmental authorities or other entities consider that your water sources are being depleted, or are in a critical situation , or under excessive pressure, you engage in a dialogue with the authorities or local existing initiatives in order to identify possible ways to be involved in research or solution finding.		
		You train your members on measures to use water efficiently. You ensure that this training includes: estimating how much water is needed to irrigate and/or process Fairtrade crops; measuring (or estimating)		

		how much water is extracted from the source; water quality for irrigation or processing; measuring how much water is used for irrigation and/or processing; providing maintenance to the water distribution system; adopting, as applicable, methods to recirculate, reuse and/or recycle water.		
		Your members follow practices that improve water resources management.		
		You handle waste water from central processing facilities in a manner that does not have a negative impact on water quality, soil fertility or food safety.		
		You train your members on waste water and the health risks it bears as well as on the prevention of risks and treatment methods of waste water and their implementation		
Soil conditions	High-intensity management practices facilitate loss of moisture from the ground, cause depletion of soil organic matter and could lead to soil erosion and river siltation	You train those members of your organisation where risk of soil erosion or already eroded land has been identified on practices that reduce and/or prevent soil erosion		Yes
		Your members implement measures to enhance soil fertility		
Agricultural genetic resources	Use of seeds from breeding programs could lead to loss of genetic diversity Intensive	You and your members do not intentionally use genetically engineered seed or planting stock for Fairtrade crop(s). You implement practices to avoid Genetically modified		Yes

	management could lead to homogenization	(GM) contamination in seed stocks		
Ecosystems , habitats and species richness	High-intensive management practices and near-monoculture tendencies have significant negative impacts on biodiversity levels Though no direct deforestation, gradual thinning can lead to negative impacts on the environment over time and decrease areas of natural forest.	Your members avoid negative impacts on protected areas and in areas with high conservation value within or outside the farm or production areas. The areas that are used or converted to production of the Fairtrade crop comply with national legislation in relation to agricultural land use.		Yes
		Your members do not cause deforestation and do not destroy vegetation in carbon storage ecosystems or protected areas.		Yes, but requirement would hinder expansion
		You have a procedure in place to ensure that your members do not cause deforestation or degradation of vegetation.		Yes, but requirement would hinder expansion
		You and your members take measures to protect and enhance biodiversity.		Yes
		You and your members maintain buffer zones around bodies of water and watershed recharge areas and between production areas and areas of high conservation value, either protected or not. You do not apply pesticides, other hazardous chemicals and fertilizers in buffer zones.		Yes
		You and your members that carry out wild harvesting of Fairtrade products from uncultivated areas assure the sustainability and survivability of the collected species in its native habitat.		
		You raise awareness among your members so that no collecting or hunting of rare or threatened species takes		Yes

		place.		
		You raise awareness among your members so that alien invasive species are not introduced.		Yes
Additional challenges	Legitimacy; adherence to standards could be disregarded due to planned and infrequent audits	You accept announced and unannounced audits of your premises and subcontracted premises and provide any information in relation to Fairtrade Standards at the request of the certification body		Yes + partly does overcome challenge in terms of planned audits. Frequency unclear.
	Benefit sharing: farmers will not sell to factories if benefits are lower.			Yes
	Traceability: sustainably cultivated açaí gets mixed with other açaí from the region		You indicate the packing station, date of packing and the identification of the individual member on each box.	Yes + could overcome challenge
	Management intensity: risk of no distinguishment between management intensities			Yes

On the efficacy of standards

This comparison shows that Fairtrade Netherlands in its certification includes requirements for each of the themes appointed as most prominent in environmental sustainability by SIMeF. In this sense, the certifier seems successful in covering a wide scope in its requirements, reflecting the most prominent themes identified on a wider scale in frameworks, SDG's and models on sustainability. Furthermore, maximum sizes of cultivation grounds incorporated in requirements can ensure the fact that large monoculture plantations cannot be certified if exceeding beyond requirement limits. However, an important risk arises, since the comparison shows that small scale monocultures could be certified under these standards. A risk especially relevant now given the following issue described by interviewee 4: "*At the moment, most of the agroforests, they are just small pieces of monoculture."* Thus, even though fairtrade does include requirements on maximum area, this does not eliminate certification of unsustainable monoculture or near-monoculture stands.

Furthermore, there are two key aspects arising which raise questions regarding the efficacy of truly promoting sustainable cultivation. First, this comparison shows that a large number of requirements are centred around training. However, there is a lack of specificity regarding the details of such training. Specific information lacks on for example:

- Frequency of training
- Audience of this training
- Repetition of training
- Follow ups on trainings to ensure long term impact of the training,
- and most critically, the specific contents of such training.

Secondly, the majority of requirements are very generic. An example of this genericness: "Your members follow practices that improve water resources management." (FairTrade International, 2019). Such broad requirements are expected given the fact that these are developed to certify a whole group of fresh fruits, rather than just açaí. On one hand, creating such generic and broad criteria allows these certifiers to cover a wider range of commodities. However, this generality also has a downside, being the risk of overlooking the unique sustainability challenges of each individual product, such as the case of açaí. This one-size-fits-all approach raises particular concerns since with these certification standards, monoculture cultivation systems of açaí can be certified too, which have been shown to carry several ecological risks with them. Therefore, certificates developed for açaí specifically might be more suitable. An opportunity to tackle such issues for fairtrade specifically could be development of a set of species-specific standards for different products, as has also been suggested for a number of other NTFPs (Shanley et al., 2008). In the case for açaí such requirements could for example entail minimum species diversity levels, maximum density of palm stands, prohibition of pesticide usage and mandating sustainable management practices such as leaving portions of the fruit, including these in education programs. The aforementioned challenges on a wider scale within the certification landscape in section 3.3.3 and table 7 are also reflected in this case study, as a lack of species-specific requirements can not entail the species-specific challenges management intensity and benefit sharing. Some requirements are in place that could tackle issues related to legitimacy and traceability the sector is currently facing.

3.3.5. On the potential of certification as a pathway to sustainable development

Research from the past few years has pointed out that in numerous cases, certification can show positive impacts on ecology. For example, the case of certified coffee agroforestry in Costa Rica or plantations in Colombia (Willemen et al., 2019; Pico-Mendoza et al., 2020). This bears the question whether the same case could hold true for the expanding açaí industry. The current açaí market in Brazil is stated to show a lack in clear and uniform policies that regulate the promotion of biodiversity in harvesting areas (Damasco et al., 2022). Particularly in situations where policy impacts are lacking, such as Brazil, certification has shown to be able to play a major role in shaping the industry's future developments (Gibbs et al., 2010).

The need to go beyond national policy has become especially clear in recent years in which president Bolsonaro continuously cut budgets on many environmental institutions and implemented measures that undermined established environmental safeguards and granted legitimacy to unlawful practices (Gabbatiss, 2022; Salazar, 2021). Despite making a commitment to eradicate illegal deforestation by 2030, Bolsonaro's actions focused on facilitating the road for the expansion of the agricultural industry, enabling it to operate unhindered and encroach upon indigenous territories without restrictions and open them to commercial exploitation. In addition to approving the 24 percent cut to the 2021 environment budget, Brazil's Congress passed several measures that reduced citizen representation on environmental policy counsels and replaced environmental policymakers with military officials. This had drastic impacts on the Amazon region. It takes time to rebuild what Bolsonaro has cut, especially with Lula facing more opposition in congress than before (Roy, 2022). This example of changes in the political landscape reinforce the notion that there is a need for practices that strengthen sustainable development which go beyond the borders of the national political landscape which can change quickly with elections that can shift political agendas. Certification therefore emerges as a potential tool worth looking into.

Consumers in this sense can become powerful agents of change by influencing the sector to adopt sustainable practices by expressing a market preference for certified products. This consumer-driven demand could create incentive for açaí producers to adhere to sustainability standards, reducing dependence on policy developments. For example, in addition to strengthening its standards based on aforementioned recommendations that make certification species- and context-specific, certification could be a means to develop place-based branding of Açaí of the varzéa region. Such developments could facilitate driving consumer demands in the direction of sustainable production systems. To do this, the list of emerging ingredients towards sustainable cultivation that have been identified in this paper could be used as a starting point, providing focal points to identify context- and species-specific requirements.

Literature research has shown effects that support the notion of beneficial ecological impacts for the case of agroforestry, therewith the possibility of certification appearing as a possible pathway to sustainable development of the açaí industry. If executed well, by means of proper guidance and training, impacts could go beyond being a stamp of approval but be a mechanism for building knowledge, promoting sustainable behaviour, and ultimately contributing to a more informed and sustainable industry (Damasco et al., 2022). Social support for such developments is present, as 92% of producers who have heard of certification regard it as a beneficial avenue for reaching a better valuation for their açaí, as visualised in figure 16 (Pepper & De Freitas Navegantes Alves, 2017).

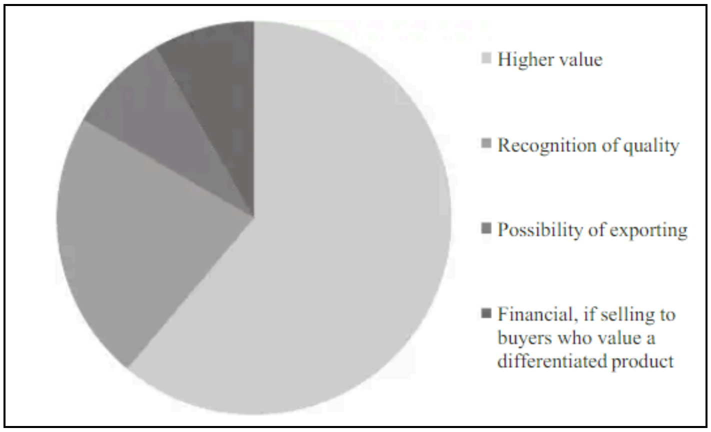

Figure 16: Farmers perspective on certification
This figure shows benefits perceived by farmers of securing certification for açaí. Reprinted from (Pepper & De Freitas Navegantes Alves, 2017)

Nevertheless, this chapter has also described a number of risks and potential pitfalls of certification, for example infrequency and expectation of audits and generality of certification requirements, and most importantly, the possibility of monocultures becoming certified. Furthermore, an often hindering factor are the certification fees and annual renewals. This can sometimes keep this certification out of reach for small farmers (Pepper & De Freitas Navegantes Alves, 2017). A gap in data hinders providing insight into certification across the existing management spectrum. Though recent initiatives seem to point to the fact that a focus towards accessibility of certification to small producers is emerging, concise data on the current proportion of small producers that are certified in comparison to large monoculture operations is unclear. If it is the case that accessibility to certification for small farmers is much more difficult than it is for large operations, a counterproductive pathway to sustainability could be taking place, in which monocultures are boosted. Place-based certification could help in this. Furthermore, certification applied to complete land areas which are under management rather than focusing on specific commodities could support farmers to diversify sources of income. This type of certification could promote biodiversity conservation within production systems by enabling producers to market a variety of locally grown goods as organic and sustainably managed (Pepper & De Freitas Navegantes Alves, 2017).

The case study of FairTrade raises challenges regarding the ability to distinguish among different management intensities. Therefore, the most prominent need currently is a development among certifiers that allow for this distinction. Lastly, this paper argues an important driver of change could be employment of a more tactical approach of certification where the frontiers of expansion become the focal point for certifiers to safeguard forests.

In conclusion, the journey towards sustainable development in the açaí industry presents certification as a possibly promising route, but with hurdles on the way to becoming such, as it currently fails to distinguish between management intensities. Recent studies highlighting the positive correlation between certification and biodiversity conservation adds weight to the argument of it emerging as a possible avenue to sustainable cultivation in the future, yet more research and developments are necessary to reach the point of becoming the envisioned multipurpose driver of change.

4. Discussion and conclusion

This paper provides insight into the environmental sustainability of the current açaí industry on the floodplains of Pará within the Brazilian Amazon. The findings show a varied cultivation landscape differing in the extent to which their practices, and therefore the industry as a whole, are sustainable. While extractivist practices of açaí harvest show positive sustainability impacts, their production is limited and can not supply the rising global demand. The increasing number of monocultures according to national databases as a response to this demand on the other side of the management spectrum are presenting considerable risks to their surroundings. Agroforests, the intermediates of the NTFP management spectrum, present a second spectrum themselves. Within this, low-intensity variants could harbour great potential in balancing sustainability with production, while their high-intensity counterparts show monoculture tendencies and risks. These findings present part of a current trade-off in which socio-economic development and sustainable development are currently at tension. While more intensive management practices and expansion have the potential to increase production levels and boost rural income, they are accompanied by negative impacts on the ecosystems in which they reside. As the global demand for açaí is expected to continue its rise, so is a shift to more intensive management actions and therefore increasing numbers of monocultures appearing on the floodplain. Given this future perspective, the need to take action is especially urgent now if we want to protect the amazon forests and ensure an environmentally sustainable and resilient sector in the face of changes predicted by climate change. By learning lessons from history such as presented in parallel with the rubber sector, this paper reiterates this significance of timely action and the potential of diversification to ensure a sustainable future encompassing both socio-economic security as well as environmental sustainability.

The current açaí sector in Pará shows several strengths in its potential to be a driver for sustainable development within the region. Especially given the current timing, a window of opportunity exists as açaí is currently the only emerging exception in the trend towards unsustainable land use transitions to soy cultivation and cattle ranching in the region. Açaí cultivation could represent a possibility for agriculture of the future. However, that is only the case if the industry's development can be guided towards low-intensity agroforestry systems, which show potential in carbon sequestration, promote sustainable use of water sources, conserve soil conditions and harbour high levels of biodiversity. If combined with further developments in waste use and bioenergy production, cultivation could become clean and ecologically sound. Nevertheless, there are also a number of threats that could lead this growing sector down a more unsustainable path and follow some of the tracks of the rubber industry. If expansion into pristine forests and monoculture areas keep increasing, ecosystem functioning could be negatively impacted and natural forests could be displaced. This could lead to the varzéa forests on the floodplains becoming more vulnerable to climate change as well as depletion and erosion of soils, pollution of waters, and lower biodiversity levels.

Several drivers to sustainable development have been described in this paper. First, a policy focus on incorporating elements of conservation- and climate change-focused policies into rural development and economic plans could be a driver towards more sustainable cultivation methods, especially revising recommendations on stem densities of açaí in the Pará state, including agroforestry under the Law of Protection of Native vegetation, and putting restrictions on expansion of cultivation grounds into forested areas. Beyond policy, certification shows to hold potential in being such a market-driver that could guide the industry towards sustainable production, with increasing international investments in schemes arising in recent years. Nevertheless, to reach the point of becoming this driver of sustainable change, the findings show certifier practices should be adjusted to ensure traceability and frequent audits. Alongside this, certification standards need to be revised, or a supplementary set of requirements should be developed incorporating the context- and species-specific needs of the sector, especially focusing on enabling distinction between different management intensities, to limit unsustainable monocultures from becoming certified.

Considerable lacking data and gaps regarding different management practices and their sustainability impacts in research hindered comparison across the existing management spectrum for themes discussed in this paper. Furthermore, an important lack of data was presented in this paper regarding the availability of information on the distribution and number of different cultivation systems currently present in literature and national databases, which showed to not reflect the current variety in cultivation practices. Furthermore, with limited to no existing traceability, product origins are currently unclear. This limitation could be illustrative of a parallel obstacle policy makers and certifiers are currently encountering. To these organs, this could hinder formulation of targeted plans for sustainable development within the region and the setting of well-informed certification standards. To address these gaps, collaborative efforts in research and data collection are essential. Such research should include a focus on distribution of different systems and their mapping, long-term ecological studies and impact assessments, socio-economic impact assessments, and improved accessible mapping practices. Furthermore, more research into sustainable intensification methods, and off-season production options could assist in achieving greater volumes of production without the need for expansion into forests.

The completeness of findings within this paper may have been constrained by an existing language barrier, causing particular difficulty in finding english-speaking interview partners alongside a limitation in the use of Portuguese articles. This limitation also reiterates the importance of making knowledge on the sector more accessible, as such barriers could also hinder important drivers of change, such as certifiers from the major importing countries. Furthermore, evaluation only included a limited number of themes proposed as most prominent by SIMeF, and left out socio-economic dimensions. Future research ought to also include these to generate a more complete and holistic overview of the current sector. To fully understand and assist the sustainable growth of the Açaí sector, future research should attempt to combine social and economic factors, and cover the entire production chain.

In conclusion, this study describes an outline on the environmental sustainability of the current açaí sector in the state of Pará and presents potential drivers of change within this landscape. Findings provided a number of focal points for future research, policymakers and certifiers to effectively steer the sector towards sustainable production and thereby sustainably develop the sector. If action is taken now, the sector could present a sustainable pathway for the future, but as we currently stand at a crossroad, it is to be seen whether monocultures will outcompete sustainable cultivation, or if agroforestry could emerge as the main and ecologically sound form of açaí cultivation on the floodplains of Pará.

References

Albiero, D., Da Silva Maciel, A. J., Mion, R. L., Viliotti, C. A., & Gamero, C. A. (2012). Proposta conceitual de colhedoras autopropelidas de açaí (Euterpe oleracea Mart.) para a região amazônica. *Revista Ciencia Agronomica*, *43*(2), 382–389. https://doi.org/10.1590/s1806-66902012000200023

Allen, D. E., Mendham, D., Bhupinderpal‐Singh, Cowie, A., Wang, W., Dalal, R. C., & Raison, R. J. (2009). Nitrous oxide and methane emissions from soil are reduced following afforestation of pasture lands in three contrasting climatic zones. *Soil Research*, *47*(5), 443. https://doi.org/10.1071/sr08151

Anderson, A. B. (1988). Use and Management of Native Forests Dominated by Açai Palm (Euterpe oleracea Mart.) in the Amazon Estuary. *Advances in Economic Botany*, *6*, 144–154. https://www.jstor.org/stable/43927526

Barham, B. L., & Coomes, O. T. (1994). Reinterpreting the Amazon rubber boom: investment, the state, and Dutch disease. Latin American Research Review, 29(2), 73–109. https://doi.org/10.1017/s0023879100024134

Béliveau, A., Lucotte, M., Davidson, R., Paquet, S., Mertens, F., Passos, C. J. S., & Romaña, C. (2017). Reduction of soil erosion and mercury losses in agroforestry systems compared to forests and cultivated fields in the Brazilian Amazon. Journal of Environmental Management, 203, 522–532. https://doi.org/10.1016/j.jenvman.2017.07.037

Biederman, L. A., & Harpole, W. S. (2012). Biochar and its effects on plant productivity and nutrient cycling: a meta‐analysis. Gcb Bioenergy, 5(2), 202–214. https://doi.org/10.1111/gcbb.12037

Brasil. (2014). Instrução normativa n. 09, de 30 de dezembro de 2013. Dispõe sobre a criação da Declaração Ambiental e sobre do Relatório Ambiental Anual. Imprensa Oficial do Estado do Pará, Belém, PA, 2 Jan, Caderno 2, 5–8.

Brondízio, E. S., Safar, C. A., & Siqueira, A. (2002). The urban market of Açaí fruit (Euterpe oleracea Mart.) and rural land use change: Ethnographic insights into the role of price and land tenure constraining agricultural choices in the Amazon estuary. *Urban Ecosystems*, *6*(1/2), 67–97. https://doi.org/10.1023/a:1025966613562

Brüning, K. (2015). Natural rubber. In *Springer eBooks* (pp. 1377–1382). https://doi.org/10.1007/978-3-642-29648-2_302

Bourscheit, A. (2022). NGOs and governments band together to avoid monocultures of açaí and cocoa in the state of Pará. *InfoAmazonia*. https://infoamazonia.org/en/2022/01/14/ngos-governments-monocultures-acai-cocoa/

CABI Compendium. (2019). *Euterpe oleracea (cabbage palm)* [Dataset]. https://doi.org/10.1079/cabicompendium.22204

Campbell, A. J., Carvalheiro, L. G., Maués, M. M., Jaffé, R., Giannini, T. C., Freitas, M. a. B., Coelho, B. W. T., & Menezes, C. (2018). Anthropogenic disturbance of tropical forests threatens pollination services to açaí palm in the Amazon river delta. *Journal of Applied Ecology*, *55*(4), 1725–1736. https://doi.org/10.1111/1365-2664.13086

Coelho, G. C. (2017). ECOSYSTEM SERVICES IN BRAZILIAN'S SOUTHERN AGROFORESTRY SYSTEMS. *Tropical and Subtropical Agroecosystems*, *20*(3). https://doi.org/10.56369/tsaes.2421

Corpocampo: Scaling-up açaí production in Colombia. (2023, December 5). *ArcGIS StoryMaps*. https://storymaps.arcgis.com/stories/12ff3c4472674dbf8adf21ec6ff442b2

Da Luz Freitas, J., Santos, E. S. D., De Oliveira Cruz, F., & Santos, A. C. D. (2020). Extractive activity of Euterpe oleracea Mart. (Acai palm tree) in the Araguari River Valley, Eastern Amazon. *Journal of Agricultural Studies*. https://doi.org/10.5296/jas.v8i2.15679

Damasco, G., Anhalt, M., Perdiz, R. O., Wittmann, F., De Assis, R. L., Schöngart, J., Piedade, M. T. F., Bacon, C. D., Antonelli, A., & Fine, P. V. A. (2022). Certification of açaí agroforestry increases the conservation potential of the Amazonian tree flora. *Agroforestry Systems*, *96*(2), 407–416. https://doi.org/10.1007/s10457-021-00727-2

Da Silva Azêvedo, H. S. F., De Azevedo, J. M. A., Da Silva, L. M., Martins, K., & De Campos, T. (2019). USO DA BIOLOGIA MOLECULAR PARA ESTUDOS GENÉTICOS EM AÇAÍZEIROS NA AMAZÔNIA BRASILEIRA. In *Stricto Sensu Editora eBooks* (pp. 120–135). https://doi.org/10.35170/ss.ed.9786580261031.09

Da Silva Barbosa, E., De Lima, H. V., De Lima Elias, L. M. S., Araújo, J. C. O., & Santos, A. V. F. D. (2022). Management of Açai areas in the Sustainability-Oriented Supply Chain in the municipality of Abaetetuba-Pará. *Journal of Agricultural Science*, *14*(3), 164. https://doi.org/10.5539/jas.v14n3p164

De Aguiar, M. I., Maia, S. M. F., Da S Xavier, F. A., De Sá Mendonça, E., Filho, J. a. A., & De Oliveira, T. S. (2010). Sediment, nutrient and water losses by water erosion under agroforestry systems in the semi-arid region in northeastern Brazil. *Agroforestry Systems*, *79*(3), 277–289. https://doi.org/10.1007/s10457-010-9310-2

De Azevedo. (2010). *SISTEMA DE MANEJO DE ACAIZAIS NATIVOS PRATICADO POR RIBEIRINHOS*. https://www.edufma.ufma.br/wp-content/uploads/woocommerce_uploads/2013/06/Sistema-de-manejo-de-a%C3%A7aizais-nativos.pdf

De Bito Lima Soares, D. C., De Lima, H. V., Araújo, S. R., Ramos, R. J. C., & Da Silva Rocha, A. J. (2023). Occurrence and spatial distribution of native acai groves in high-production areas of the Amazon region. *Revista Ciencia Agronomica*, *54*. https://doi.org/10.5935/1806-6690.20230039

De Cássia Rodrigues Batista, C., De Oliveira, M. S., Araújo, M. E., Rodrigues, A. M., Botelho, J. R. S., Da S Souza Filho, A. P., Machado, N. T., & De Carvalho, R. N. (2016). Supercritical CO 2 extraction of açaí (Euterpe oleracea) berry oil: Global yield, fatty acids, allelopathic activities, and determination of phenolic and anthocyanins total compounds in the residual pulp. *Journal of Supercritical Fluids*, *107*, 364–369. https://doi.org/10.1016/j.supflu.2015.10.006

De Carvalho, J. E. U., & Nascimento, W. M. O. D. (2018). Technological innovations in the propagation of Açaí palm and Bacuri. *Revista Brasileira De Fruticultura*, *40*(1). https://doi.org/10.1590/0100-29452018679

De Farias Neto, J. T., De Oliveira, M. D. S. P., De Resende, M. D. V., & Rodrigues, J. C. (2018). Parâmetros genéticos e ganhos com a seleção de progênies de Euterpe oleracea na fase juvenil. *Cerne*, *18*(3), 515–521. https://doi.org/10.1590/s0104-77602012000300020

De Farias Neto, J. T., Yokomizo, G. K. I., & De Resende, M. D. V. (2020). Productive capacity and genetic variation behavior in progenies from irrigated açai according to plant age. *Agro@Mbiente On-line*, *14*. https://doi.org/10.18227/1982-8470ragro.v14i0.6409

De Jesus Batista, F., Jardim, M. a. G., Medeiros, T. D. S., & Lopes, I. L. M. (2011). Comparação florística e estrutural de duas florestas de várzea no estuário amazônico, Pará, Brasil. *Revista Arvore*, *35*(2), 289–298. https://doi.org/10.1590/s0100-67622011000200013

De Lima Yamaguchi, K. K., Pereira, L. F. R., Lamarão, C. V., Lima, É. S., & Da Veiga, V. F. (2015). Amazon acai: Chemistry and biological activities: A review. *Food Chemistry*, *179*, 137–151. https://doi.org/10.1016/j.foodchem.2015.01.055

De Oliveira, M. D. S. P., Santos, J. B. D., Amorim, É. P., & Ferreira, D. F. (2010). Variabilidade genética entre acessos de açaizeiro utilizando marcadores microssatélites. *Ciencia E Agrotecnologia*, *34*(5), 1253–1260. https://doi.org/10.1590/s1413-70542010000500025

De Oliveira, M. D. S. P., De Farias Neto, J. T., De a Mattietto, R., Mochiutti, S., & Carvalho, A. V. (2018). Açaí— Euterpe oleracea. In *Elsevier eBooks* (pp. 1–5). https://doi.org/10.1016/b978-0-12-803138-4.00002-2

Documentary: The children of the açaí industry | Brut. (2022, July 31). Brut. https://www.brut.media/us/entertainment/documentary-the-children-of-the-acai-industry-5abe6d21-cf23-4dfd-9cea-5ac51d16bb06

FairTrade International. (2017). Fairtrade Standard for Fresh Fruit. https://files.fairtrade.net/standards/Fresh_Fruit_SPO_EN.pdf

FairTrade International. (2019). Fairtrade Standard for Smallscale Producer Organizations. https://files.fairtrade.net/standards/SPO_EN.pdf

Ferreira, S. F., Buller, L. S., Maciel-Silva, F. W., Sganzerla, W. G., Berni, M. D., & Forster‐Carneiro, T. (2020). Waste management and bioenergy recovery from açaí processing in the Brazilian Amazonian region: a perspective for a circular economy. Biofuels, Bioproducts and Biorefining, 15(1), 37–46. https://doi.org/10.1002/bbb.2147

Freitas, M. a. B., Magalhães, J. L. L., Carmona, C. P., Arroyo‐Rodríguez, V., Vieira, I. C. G., & Tabarelli, M. (2021). Intensification of açaí palm management largely impoverishes tree assemblages in the Amazon estuarine forest. *Biological Conservation*, *261*, 109251. https://doi.org/10.1016/j.biocon.2021.109251

Freitas, M. a. B., Vieira, I. C. G., Albernaz, A. L., Magalhães, J. L. L., & Lees, A. C. (2015). Floristic impoverishment of Amazonian floodplain forests managed for açaí fruit production. *Forest Ecology and Management*, *351*, 20–27. https://doi.org/10.1016/j.foreco.2015.05.008

Gabbatiss, J. (2022, October 31). *Analysis: Bolsonaro election loss could cut Brazilian Amazon deforestation by 89%*. Carbon Brief. https://www.carbonbrief.org/analysis-bolsonaro-election-loss-could-cut-brazilian-amazon-deforestation-by-89/

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(38), 16732–16737. https://doi.org/10.1073/pnas.0910275107

Gollnow, F., & Lakes, T. (2014). Policy change, land use, and agriculture: The case of soy production and cattle ranching in Brazil, 2001–2012. *Applied Geography*, *55*, 203–211. https://doi.org/10.1016/j.apgeog.2014.09.003

Heinrich, M., Dhanji, T., & Casselman, I. (2011). Açai (Euterpe oleracea Mart.)—A phytochemical and pharmacological assessment of the species' health claims. *Phytochemistry Letters*, *4*(1), 10–21. https://doi.org/10.1016/j.phytol.2010.11.005

Homma, A. K. O., Nogueira, O. L., De Menezes, A. J. E. A., De Carvalho, J. E. U., Nicoli, C. M. L., & De Matos, G. B. (2006). Açaí: novos desafios e tendências. *Amazônia: Ci. & Desenv., Belém*. http://www.alice.cnptia.embrapa.br/bitstream/doc/578153/1/AcaiDesafiosTendencias.pdf

Homma, A. K. O. (2012). Extrativismo vegetal ou plantio: qual a opção para a Amazônia? *Estudos Avançados*, *26*(74), 167–186. https://doi.org/10.1590/s0103-40142012000100012

IBGE. (2022). *Produção agropecuária | IBGE*. https://www.ibge.gov.br/explica/producao-agropecuaria/acai-cultivo/br

Hueting, R. (1998). *SUSTAINABILITY IS AN OBJECTIVE CONCEPT*. https://www.semanticscholar.org/paper/SUSTAINABILITY-IS-AN-OBJECTIVE-CONCEPT-Hueting-Reijnders/58cf1ad8ae16260bf9fa6d1983b93478ae4170df

Lee, R., & Balick, M. J. (2008). Palms, people, and health. *Explore-the Journal of Science and Healing*, *4*(1), 59–62. https://doi.org/10.1016/j.explore.2007.10.009

Lima, G. (2023). *Exploring the exotic Açaí: growth, products, export, and overcoming challenges*. https://www.linkedin.com/pulse/exploring-exotic-a%C3%A7a%C3%AD-growth-products-export-overcoming-gustavo-lima/

Lira-Guedes, A. C., De Almeida Leal, G., Fischer, G. R., Aguiar, L. J. G., Júnior, N. J. M., Baia, A. L. P., & Guedes, M. C. (2021). Carbon emissions in hydromorphic soils from an estuarine floodplain forest in the Amazon River. *Revista Brasileira De Ciências Ambientais*, *56*(3), 413–423. https://doi.org/10.5327/z21769478941

Lopes, É. N., Soares‐Filho, B., De Souza, F. C., Rajão, R., Merry, F., & Ribeiro, S. C. (2019). Mapping the socio-ecology of Non Timber Forest Products (NTFP) extraction in the Brazilian Amazon:

The case of açaí (Euterpe precatoria Mart) in Acre. *Landscape and Urban Planning*, *188*, 110–117. https://doi.org/10.1016/j.landurbplan.2018.08.025

Miccolis, A., De Andrade, R. M. T., Pacheco, P., & CIFOR. (2014). *Land-use trends and environmental governance policies in Brazil: Paths forward for sustainability*. CIFOR.

Mikulková, A., Hájek, M., Štěpánková, M., & Ševčík, M. (2015). Forest certification as a tool to support sustainable development in forest management. *Journal of Forest Science*, *61*(8), 359–368. https://doi.org/10.17221/16/2015-jfs

Moegenburg, S. M., & Levey, D. J. (2002). Prospects for conserving biodiversity in Amazonian extractive reserves. *Ecology Letters*, *5*(3), 320–324. https://doi.org/10.1046/j.1461-0248.2002.00323.x

Morelli, J. (2011). Environmental Sustainability: a definition for environmental professionals. *Journal of Environmental Sustainability*, *1*(1), 1–10. https://doi.org/10.14448/jes.01.0002

Mouratiadou, I., Latka, C., Van Der Hilst, F., Müller, C., Berges, R., Bodirsky, B. L., Ewert, F., Faye, B., Heckelei, T., Hoffmann, M. P., Lehtonen, H., Lorite, I. J., Nendel, C., Palosuo, T., Rodríguez, A., Rötter, R. P., Ruiz‐Ramos, M., Stella, T., Webber, H., & Wicke, B. (2021). Quantifying sustainable intensification of agriculture: The contribution of metrics and modelling. *Ecological Indicators*, *129*, 107870. https://doi.org/10.1016/j.ecolind.2021.107870

Muñiz-Miret, N., Vamos, R., Hiraoka, M., Montagnini, F., & Mendelsohn, R. (1996). The economic value of managing the açaí palm (Euterpe oleracea Mart.) in the floodplains of the Amazon estuary, Pará, Brazil. *Forest Ecology and Management*, *87*(1–3), 163–173. https://doi.org/10.1016/s0378-1127(96)03825-x

National Energy Plan 2050 - Climate Change Laws of the World. (n.d.). https://climate-laws.org/document/national-energy-plan-2050_fe2d

Nascimento, R. J. S. D., Couri, S., Antoniassi, R., & Freitas, S. P. (2008). Composição em ácidos graxos do óleo da polpa de açaí extraído com enzimas e com hexano. *Revista Brasileira De Fruticultura*, *30*(2), 498–502. https://doi.org/10.1590/s0100-29452008000200040

Neumann, R. P., & Hirsch, E. (2000). *Commercialisation of non-timber forest products: Review and analysis of research*. CIFOR.

Ollinaho, O., & Kröger, M. (2021). Agroforestry transitions: The good, the bad and the ugly. *Journal of Rural Studies*, *82*, 210–221. https://doi.org/10.1016/j.jrurstud.2021.01.016

Painel da Floresta. (n.d.). *Painel Da Floresta*. Painel Da Floresta. Retrieved February 27, 2024, from https://www.paineldafloresta.org/

Peng, W., Sonne, C., Lam, S. S., Ok, Y. S., & Alstrup, A. K. O. (2020). The ongoing cut-down of the Amazon rainforest threatens the climate and requires global tree planting projects: A short review. *Environmental Research*, *181*, 108887. https://doi.org/10.1016/j.envres.2019.108887

Pepper, L. G., & De Freitas Navegantes Alves, L. (2017). Small-Scale Açaí in the global market: Adding value to ensure sustained income for forest farmers in the Amazon Estuary. In *Advances in agroforestry* (pp. 211–234). https://doi.org/10.1007/978-3-319-69371-2_9

Perkins, P. E., & Weinstein, B. (1985). The Amazon Rubber Boom 1850-1920. *Technology and Culture*, *26*(4), 865. https://doi.org/10.2307/3105644

Perrigo, A. (2020, August 11). The full impact of supermarket products. *Research Communities by Springer Nature*. https://communities.springernature.com/posts/the-full-impact-of-supermarket-products

Pezzey, J. C. (1992). Sustainability: an Interdisciplinary Guide. *Environmental Values*, *1*(4), 321–362. https://doi.org/10.3197/096327192776680034

Pico-Mendoza, J., Pinoargote, M., Carrasco, B., & Andrade, R. L. (2020). Ecosystem services in certified and non-certified coffee agroforestry systems in Costa Rica. *Agroecology and Sustainable Food Systems*, *44*(7), 902–918. https://doi.org/10.1080/21683565.2020.1713962

Pompeu, D. R., Da Silva, E. M., & Rogez, H. (2009). Optimisation of the solvent extraction of phenolic antioxidants from fruits of Euterpe oleracea using Response Surface Methodology. *Bioresource Technology*, *100*(23), 6076–6082. https://doi.org/10.1016/j.biortech.2009.03.083

Rahman, S. A., Jacobsen, J. B., Healey, J. R., Roshetko, J. M., & Sunderland, T. (2016). Finding alternatives to swidden agriculture: does agroforestry improve livelihood options and reduce pressure on existing forest? *Agroforestry Systems*, *91*(1), 185–199. https://doi.org/10.1007/s10457-016-9912-4

Ratnadass, A., Fernandes, P., Avelino, J., & Habib, R. (2011). Plant species diversity for sustainable management of crop pests and diseases in agroecosystems: a review. *Agronomy for Sustainable Development*, *32*(1), 273–303. https://doi.org/10.1007/s13593-011-0022-4

Resor, R. R. (1977). Rubber in Brazil: Dominance and Collapse, 1876-1945. *Business History Review*, *51*(3), 341–366. https://doi.org/10.2307/3113637

Rezende, C. L., Fraga, J. S., Sessa, J. C., De Souza, G. V. P., Assad, E. D., & Scarano, F. R. (2018). Land use policy as a driver for climate change adaptation: A case in the domain of the Brazilian Atlantic forest. *Land Use Policy*, *72*, 563–569. https://doi.org/10.1016/j.landusepol.2018.01.027

Ribeiro, S. C., Jardim, H. L., De Azevedo Ruchkys, Ú., Coelho, V. B. N., Bachi, L., & Soares‐Filho, B. (2020). Non-Timber Forest Products (NTFP) in the Brazilian Amazon and Cerrado biomes: multi scale governance for Implementing enhanced socio-biodiversity chains. *Sustentabilidade Em Debate*. https://doi.org/10.18472/sustdeb.v11n2.2020.28393

Roy, D. (2022, August 24). Deforestation of Brazil's Amazon has reached a record high. What's being done? *Council on Foreign Relations*. https://www.cfr.org/in-brief/deforestation-brazils-amazon-has-reached-record-high-whats-being-done

Sabbe, S., Verbeke, W., & Van Damme, P. (2009). Analysing the market environment for açaí (*Euterpe oleracea*Mart.) juices in Europe. *Fruits*, *64*(5), 273–284. https://doi.org/10.1051/fruits/2009022

Salazar, M. (2021, July 26). *'Stampede' of legislation threatens accelerated destruction of the Amazon*. Mongabay Environmental News. https://news.mongabay.com/2021/07/stampede-of-legislation-threatens-accelerated-destruction-of-the-amazon/

Salisbury, D. S., & Schmink, M. (2007). Cows versus rubber: Changing livelihoods among Amazonian extractivists. *Geoforum*, *38*(6), 1233–1249. https://doi.org/10.1016/j.geoforum.2007.03.005

Salo, M., Sirén, A., & Kalliola, R. (2013). Açaí. In *Diagnosing Wild Species Harvest*. https://doi.org/10.1016/b978-0-12-397204-0.00011-5

Santos, P. Z. F., Crouzeilles, R., & Sansevero, J. B. B. (2019). Can agroforestry systems enhance biodiversity and ecosystem service provision in agricultural landscapes? A meta-analysis for the Brazilian Atlantic Forest. *Forest Ecology and Management*, *433*, 140–145. https://doi.org/10.1016/j.foreco.2018.10.064

Santos, S. R. M. D., Miranda, I. S., & Tourinho, M. M. (2004). Análise florística e estrutural de sistemas agroflorestais das várzeas do rio Juba, Cametá, Pará. *Acta Amazonica*, *34*(2), 251–263. https://doi.org/10.1590/s0044-59672004000200013

Santos, V. O., Queiroz, L. S., Araújo, R. O., Ribeiro, F. C. P., Guimarães, M. N., Da Costa, C. E. F., Chaar, J. S., & De Souza, L. K. (2020). Pyrolysis of acai seed biomass: Kinetics and thermodynamic parameters using thermogravimetric analysis. *Bioresource Technology Reports*, *12*, 100553. https://doi.org/10.1016/j.biteb.2020.100553

Sato, M. K., De Lima, H. V., Costa, A. N., Rodrigues, S., Mooney, S. J., Clarke, M. L., Pedroso, A. J. S., & De F Maia, C. M. B. (2020). Biochar as a sustainable alternative to açaí waste disposal in Amazon, Brazil. *Process Safety and Environmental Protection*, *139*, 36–46. https://doi.org/10.1016/j.psep.2020.04.001

Schauss, A. G., Wu, X., Prior, R. L., Ou, B., Patel, D. K., Huang, D., & Kababick, J. P. (2006). Phytochemical and Nutrient Composition of the Freeze-Dried Amazonian Palm Berry, *Euterpe oleraceae* Mart. (Acai). *Journal of Agricultural and Food Chemistry*, *54*(22), 8598–8603. https://doi.org/10.1021/jf060976g

Scherwinski‐Pereira, J. E., Da Silva Guedes, R., Da Silva, R. A., Fermino, P. C. P., Luís, Z. G., & De Oliveira Freitas, E. (2012). Somatic embryogenesis and plant regeneration in açaí palm (Euterpe oleracea). *Plant Cell, Tissue and Organ Culture (PCTOC)*, *109*(3), 501–508. https://doi.org/10.1007/s11240-012-0115-z

Schroth, G., Moraes, V. H., & Da Mota, M. (2004). Increasing the profitability of traditional, planted rubber agroforests at the Tapajós river, Brazilian Amazon. *Agriculture, Ecosystems & Environment*, *102*(3), 319–339. https://doi.org/10.1016/j.agee.2003.09.001

Schroth, G., Fonseca, G., Harvey, C. A., Gascon, C., Vasconcelos, H. L., & Izac, A. M. N. (2005). Agroforestry and biodiversity conservation in tropical landscapes. *Choice Reviews Online*, *42*(06), 42–3398. https://doi.org/10.5860/choice.42-3398

Schulz, M., Magnani, M., Gonzaga, L. V., Costa, A. C. O., & Fett, R. (2016). Juçara fruit (Euterpe edulis Mart.): Sustainable exploitation of a source of bioactive compounds. *Food Research International*, *89*, 14–26. https://doi.org/10.1016/j.foodres.2016.07.027

Selecky, T., Bellingrath-Kimura, S. D., Kobata, Y., Yamada, M., Guerrini, I. A., Umemura, H. M., & Santos, D. a. D. (2017). Changes in Carbon Cycling during Development of Successional Agroforestry. *Agriculture*, *7*(3), 25. https://doi.org/10.3390/agriculture7030025

Shanley, P., Pierce, A., Laird, S. A., & Robinson, D. J. (2008). *Beyond timber: certification and management of non-timber forest products*. https://doi.org/10.17528/cifor/002543

Shanley, P., Pierce, A., Laird, S. A., Binnqüist, C. L., & Guariguata, M. R. (2016). From Lifelines to Livelihoods: Non-timber Forest Products into the 21st Century. In *Springer eBooks* (pp. 2713–2760). https://doi.org/10.1007/978-3-642-54601-3_209

Soares, Z. T., De Castro Silva, A. B., & Dias, I. P. R. C. (2020). MANEJO SUSTENTÁVEL e POTENCIAL ECONÔMICO DA EXTRAÇÃO DA MAURITIA FLEXUOSA / SUSTAINABLE MANAGEMENT AND ECONOMIC POTENTIAL OF MAURITANIA FLEXUOSA EXTRACTION. *Brazilian Journal of Development*, *6*(9), 67307–67329. https://doi.org/10.34117/bjdv6n9-241

Tamboracai. (2017). Traditional Açaí: Understanding the forests of the Amazon Estuary (Part 1). *Tambor® | a PASSION FOR Premium Açaí*. https://tamboracai.com/sustaining-and-shaping-the-forests-of-the-amazon-estuary/

Tregidgo, D., Campbell, A. J., Rivero, S., Freitas, M. a. B., & Almeida, O. (2020). Vulnerability of the Açaí palm to climate change. *Human Ecology*, *48*(4), 505–514. https://doi.org/10.1007/s10745-020-00172-2

Tropical Acai. (2022, January 18). Lessons from the Amazon: How Sustainability Plays a Big Role in Tropical Açaí's Success. PR Newswire. https://www.prnewswire.com/news-releases/lessons-from-the-amazon-how-sustainability-plays-a-big-role-in-tropical-acais-success-301460959.html

Venturieri, G. C. (2014). Plano de manejo para os polinizadores do açaizeiro *Euterpe oleracea* (Arecaceae). In M. Yamamoto, P. E. Oliveira, & M. C. Gaglianone (Eds.), *Uso sustentavel e restauracao da diversidade dos polinizadores autoctones na agricultura e nos ecossistemas relacionados: Planos de Manejo*. Rio de Janeiro: Funbio.

Walker, R., Browder, J. O., Arima, E., Simmons, C., Pereira, R., Caldas, M. M., Shirota, R., & De Zen, S. (2009). Ranching and the new global range: Amazônia in the 21st century. *Geoforum*, *40*(5), 732–745. https://doi.org/10.1016/j.geoforum.2008.10.009

Watts, J. (2023, January 26). Human activity and drought 'degrading more than a third of Amazon rainforest.' *The Guardian*. https://www.theguardian.com/environment/2023/jan/26/human-activity-and-drought-degrading-more-than-a-third-of-amazon-rainforest

Weinstein, S., & Moegenburg. (2003). Açaí Palm Management in the Amazon Estuary: Course for Conservation or Passage to Plantations? on JSTOR. *www.jstor.org*. https://www.jstor.org/stable/26396631

Willemen, L., Crossman, N. D., Newsom, D., Hughell, D., Hunink, J. E., & Milder, J. C. (2019). Aggregate effects on ecosystem services from certification of tea farming in the Upper Tana River basin, Kenya. *Ecosystem Services*, *38*, 100962. https://doi.org/10.1016/j.ecoser.2019.100962
Yokomizo, G. K. I., De Farias Neto, J. T., & De Oliveira, M. D. S. P. (2016). Ganho esperado na seleção de progênies de polinização aberta de Euterpe oleracea para produção de frutos. *Scientia Forestalis*, *44*(109). https://doi.org/10.18671/scifor.v44n109.23

Appendix

Appendix I: Interview Guide

The following overview presents a summary of the semi-structured interview questions as part of this research.

Recording: Can I record this interview to ensure accuracy and correct referencing in my paper? The recordings will be kept in a private google drive only accessible to me and used only for research purposes.

Information use: Can I use the information you share in this interview in my research paper?

Attribution: Is it okay for me to mention you in your research paper or would you like to remain anonymous?

Sharing of the final work: After I complete my paper, would you like to receive a copy of the work?

Background:

- Could you describe your past and or current role within the acai industry in the Brazilian Amazon?
- Are you familiar with the different management types and intensities of acai cultivation?
- Are you familiar with the terms ‘extractivism’, ‘agroforestry’, and ‘monoculture’?

Environmental sustainability

- Based on your knowledge and experience, generally, how do you describe the sustainability impact/effects of (insert theme) along the management gradient?

Personal perspectives

- Are there any opportunities or potential improvements you see for the current sector?
- Are there key challenges that need to be overcome within the developing sector?

Gaps: From your perspective, what data, research or available information is currently lacking in the sector?

Closing

- Do you have any final questions or comments you would like to share?
- Who else would you recommend I reach out to for my paper?