



Certification of açai agroforestry increases the conservation potential of the Amazonian tree flora

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Abstract The harvesting of açai berries (palm fruits from the genus *Euterpe*) in Amazonia has increased over the last 20 years due to a high local and global market demand and triggered by their widely acclaimed health benefits as a ‘superfood’. Although

such increase represents a financial boom for local communities, unregulated extraction in Amazonia risks negative environmental effects including biodiversity loss through açai intensification and deforestation. Alternatively, the introduction of certified sustainable agroforestry production programs of açai has been strategically applied to reduce the exploitation of Amazonian forests. Local açai producers are

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required to follow principles of defined sustainable management practices, environmental guidelines, and social behaviors, paying specific attention to fair trade and human rights. In this study we investigate whether sustainable agroforestry and certification effectively promotes biodiversity conservation in Amazonia. To address this question, we conducted a forestry inventory in two hectares of long-term certified açai harvesting areas to gain further knowledge on the plant diversity and forest structure in açai managed forests and to understand the contribution of certification towards sustainable forest management. On average, we found that certified managed forests harbor 50% more tree species than non-certified açai groves. Trees in certified areas also have significantly higher mean basal area, meaning larger and hence older individuals are more likely to be protected. Certified harvesting sites also harbor dense populations of threatened species as classified by the International Union for Conservation of Nature (e.g. *Virola surinamensis*, classified as ‘endangered’). Besides increasing the knowledge of plant diversity in açai managed areas, we present baseline information for monitoring the impact of harvesting activities in natural ecosystems in Amazonia.

Keywords *Euterpe* · Açai management · Flooded forests · Biodiversity conservation · Amazonia

Introduction

The expansion of the açai (*Euterpe* sp.) fruit economy in Amazonia has not only supplied a growing worldwide demand but has also helped to establish new frontiers of commercialization. The market boom for açai berries has motivated producers to expand açai agroforestry into pristine and unmanaged forests, especially in eastern Amazonia (Brondizio 2008). Although açai agroforestry does not involve outright deforestation, intensive management practices gradually replace native tree species by thinning and/or with dense açai palm plantings in the understory to enhance productivity (Homma et al. 2006; Freitas et al. 2015). Besides, management practices typically include the gradual removal of other native trees near açai palms, promoting canopy opening, and reducing overall competition for light and nutrients. This unregulated

management leads to an erosion of the regional flora and can cause considerable changes in the vegetation structure and ecosystem functioning of Amazonian forests (Freitas et al. 2015).

Given the rampant habitat loss and reduction in forest biodiversity due to recent açai expansion (Freitas et al. 2015; Campbell et al. 2018; Bezerra et al. 2020) and the vulnerability of açai palm forests to climate change (Tregidgo et al. 2020), an innovative strategy for sustainable agroforestry management is urgently needed to prevent biodiversity loss and deforestation. Currently, the açai market in Brazil lacks a clear and uniform policy that regulates the promotion of biodiversity conservation in harvesting areas. Yet, due to high demand for organic and sustainable products, açai food companies (especially from North America and Europe) have invested in certification programs that inform consumers about whether the product is in accordance with health, ecosystem conservation, and human rights (e.g. USDA Organic, Regenerative Organic, Biodynamic, Fair trade and Fair for Life).

Certified açai agroforestry may provide many environmental and social benefits. It can improve livelihoods for local residents, promote conservation of intact forests that harbor high biodiversity, and prevent unregulated deforestation that, in turn, exacerbates global climate change (Weinstein and Moegebenburg 2004; Lovejoy and Nobre 2018; Brando et al. 2020). Certifiers have a diverse array of objectives and standards, meaning that they do not necessarily address all facets of sustainability (e.g., Perrigo et al. 2020), but most define criteria relating to environmental and social outcomes (World Conservation Monitoring Centre 2011).

In tropical countries, such as Brazil, third party certification could play an important role considering the negative effects of a growing commodity production (Gibbs et al. 2010), and the need for governmental capacity and resources to regulate agriculture effectively (Barrett et al. 2001). “Fair for Life” is a Fair Trade certification standard developed and managed by EcoCert Group. Sambazon Inc., has been certified to the first standard developed by Ecocert since 2008 and was the first company to have Fair Trade certified açai. “Fair for Life” is composed by the “Fair Trade and Responsible supply-chain” certification and the “For Life Standard” for “Corporate Social Responsibility” certification. Both have environmental

requirements at the local and corporate levels as a corner stone of the certification scheme. For an açaí product to become Fair for Life certified, local producers and harvesters must follow standards regarding the respect of human rights and fair working conditions, promotion of biodiversity and sustainable agroforestry practices, and have a positive impact on local communities (EcoCert Group 2020). Each operation is audited annually by the Ecocert group to ensure the companies are following these rules.

With the increasing public, governmental, and corporate interest in sustainable consumption (Govindan 2018; Matharu et al. 2020), it is important to understand the contribution of sustainable agroforestry and certification in promoting biodiversity conservation. Here, we determine tree species composition and forest structure of fair for life certified açaí harvesting areas in eastern Amazonia and compare our results with (1) non-certified açaí plantations and (2) transects in intact Amazonian flooded forests. Our aim is to explore the potential contribution of açaí agroforestry and certification to halting deforestation and species loss in Amazonian forests. We predict that certified harvesting areas harbor a richer tree community and a less impacted forest than non-certified sites. Additionally, this study establishes research plots in areas never sampled before and used sampling methodologies compatible with protocols used by researchers worldwide. Thus, our results could potentially contribute to larger-scale biodiversity studies.

Methods

Study sites

The certified harvesting areas sampled in our study are located in Eastern Amazonia. Sampling sites were placed on private lands situated along tributary water channels of the Amazonas River. The primary habitat in this region is seasonally flooded forest (known in Amazonia as *várzea* forests) and the açaí palm (*Euterpe oleracea* Mart.) is a dominant and widespread palm species native to these habitats. Here, we conducted tree-plot inventories that encompassed the spectrum of açaí management varying from an almost complete replacement of trees with açaí to no tree removal or destructive interference. We sampled harvesting lands that have been certified in the last

12 years through the partnership between Sambazon Inc. (<https://www.sambazon.com/>) and ECOCERT Group (<https://www.ecocert.com>) as part of the “Fair for Life” fair trade certification. This certification is based on principle that threatened or endangered species and habitats are protected and natural ecosystems are not destroyed. More information about requirements and criteria that are expected to be met under the Fair for Life certification is available in the Table S1.

This study comprises three main distinct sets of inventory plots: (1) 20 plots of certified açaí managed forests established along in eastern Amazonia along the Mariazinho River in Breves County, Pará State, Brazil (S 00° 51.902' W 51° 04.961') and Gurupá County, Pará State, along the Mararú River (S 1° 11.167' W 51° 32.732') and in the Bailique Archipelago region, Amapá State (N 0°28'49.77" and W 50°24'39.74"); (2) 24 plots of non-certified açaí groves published by Freitas et al. (2015) named in their publication as “managed sites”; (3) total of 50 plots from intact and unmanaged flooded forests sites (named here as control plots). 38 control plots were made available by the PELD-MAUA research group (<https://peld-maua.inpa.gov.br>). This research network manages a large dataset of forestry inventories held across flooded forests in the Amazon Basin (Fig. 1, Table S3). In addition, 12 control plots were published by Freitas et al. (2015), named in their publication as “unmanaged control sites” (Fig. 1, Table S3).

Sampling

For certified harvesting areas, the 20 plots were 0.1 ha in size each (20 m × 50 m), representing a cumulative sampling area of 2 hectares. Using maps and GIS resources, the 0.1 ha-plots were randomly selected a priori and established within each of the twenty certified harvesting lands visited. All woody plant species with a diameter at the breast height (DBH) above 10 cm (considered here as ‘trees’) were measured, collected, and identified to species when possible. The fieldwork was comprised by two expeditions held in August 2019 and January 2020. Voucher specimens for each tree species have been deposited at the INPA (Instituto Nacional de Pesquisas da Amazônia) Herbarium in Manaus, Brazil. Taxonomic classification followed APG IV (<http://www>.

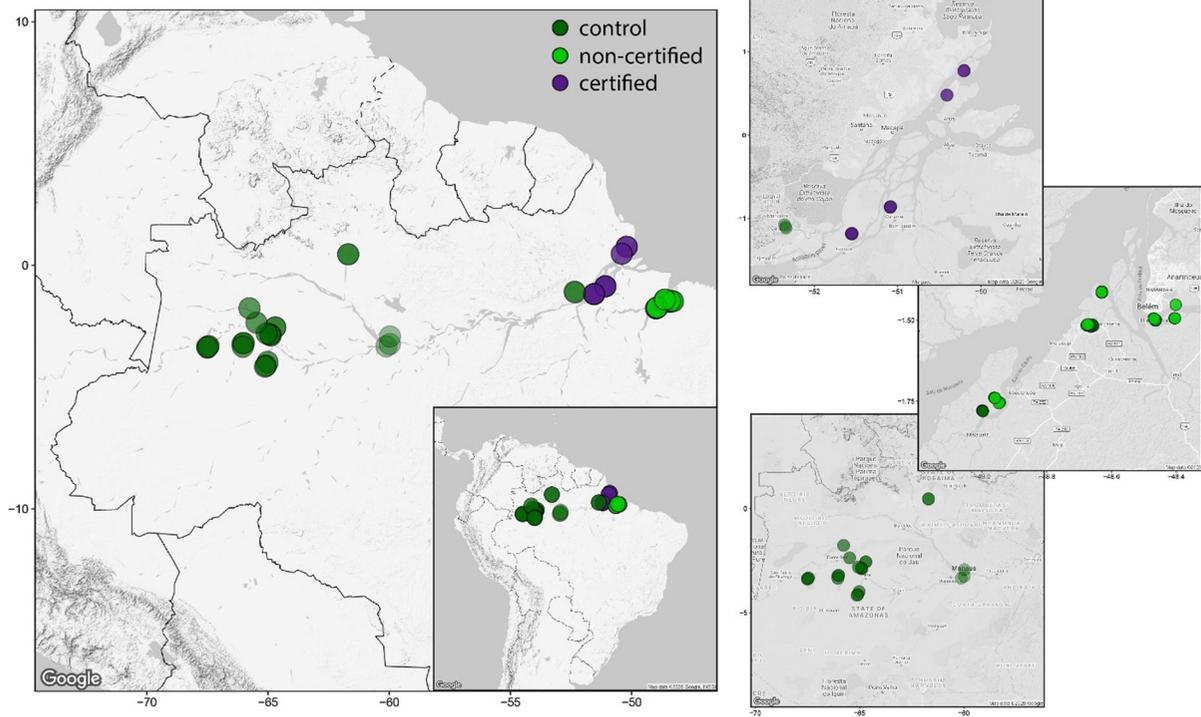


Fig. 1 Geographical location of 94 study sites located across flooded forests in the Brazilian Amazonia. Control plots represent intact flooded forests with no influence of açai management practices. 38 control plots were made available by the PELD-MAUA data network (<https://peld-maua.inpa.gov.br>) and 12 control plots are available in Freitas et al. (2015).

motobot.org) and species names were checked against the Plants of the World online (POWO, <http://www.plantsoftheworldonline.org/>). For details of sampling methods of non-certified harvesting areas and control plots (Table S3), please see Freitas et al. (2015) methods section and the PELD-MAUA research group data repository (<https://peld-maua.inpa.gov.br>).

Analysis

We calculated diversity (species richness, Fisher diversity index) and forest structure (basal area, açai clump density) parameters for the certified, non-certified, and control data sets. Diversity and basal area metrics are calculated accordingly to scientific literature on Amazonian floodplains (e.g., Assis et al. 2015, 2019). Fisher's α diversity index was determined according to the formula $S = \alpha \times \ln(1 + n/\alpha)$ where S is the number of species, n is the number of individuals, and α is Fisher's alpha. Tree basal area

Non-certified plots are available in Freitas et al. (2015) and comprise of forests managed for açai production by riverine smallholders that are free of certification standards. Certified plots are made available by this study and represent forests managed for açai production that has been under the Fair for Life certification since 2008

was calculated based on the formula $g = (\pi \times DBH^2)/4$ where g is basal area in m^2 . To compare the diversity and forest structure of certified, non-certified, and control plots we used the non-parametric Wilcoxon test as variables were not normally distributed. We then performed a linear model to test the association between species richness/basal area and the açai density among certified, non-certified, and control plots. All statistical analyses were performed in R 3.4.1 (R Core Team 2020) using the package "vegan" (Oksanen et al. 2020).

We acknowledge that the control, certified and non-certified plots are not evenly distributed across the geographic space and the majority of certified and non-certified plots are skewed to Eastern Amazonia. Therefore, results on tree diversity and forest structure could also reflect responses to geographic variation, including the climatic difference, disturbance history and the effects associated with the spatial distance across the region. Despite the potential spatial bias,

there is no known evidence for local tree diversity, long-term disturbance history or climate in flooded várzea forests to be remarkably different between certified plots vs. non-certified plot sites. In Eastern Amazonia, Amapá and Pará States are two of the most expressive areas in terms of açai production and marketing in Brazil and açai managed forests are frequently found across várzea forests in this region.

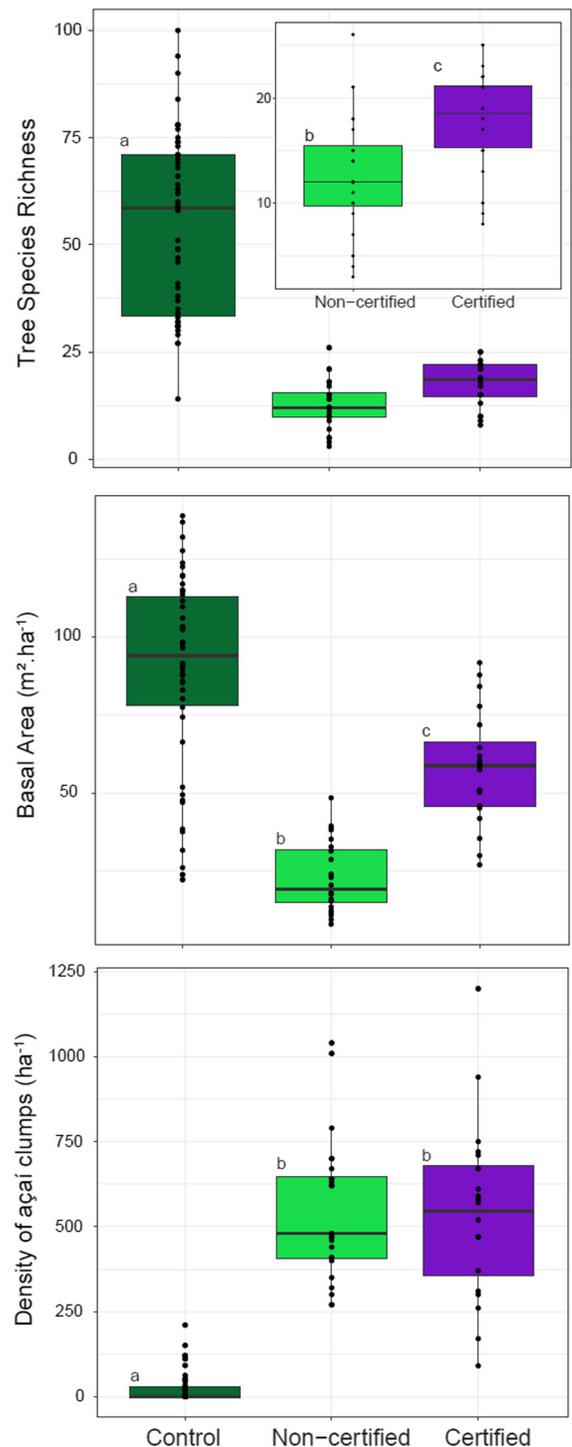
To disentangle the effects of certification, climatic differences, and geographic distance among plots, we performed a decomposition of the explained variation using distance-based redundancy analysis (db-RDA) available in the R package “vegan” (Oksanen et al. 2020). Temperature and precipitation data were extracted from the Worldclim database (www.worldclim.org/data) and the variation of temperature and precipitation variables were reduced based on principal component analysis. Linear distances among all plots were calculated using the R package “geosphere” (Karney 2013).

Results

Species composition and structure of certified açai harvesting forests

In total, we sampled 131 tree species at the certified sites represented by 36 botanical families and 109 genera (Table S2). The number of families and tree species accounted for 50% and 18% of the MAUA database (control group) that includes floristic data from forests across Amazonia. On average, certified açai managed forests harbored a greater number of tree species than non-certified açai (Fig. 2a). The number of tree species was significantly higher ($P = 0.00634$) in certified harvesting areas and 50% higher than non-certified groves, on average (Table 1). In contrast, both certified and non-certified forests are less diverse in terms of species richness in comparison to the control plots ($P = 1.0087e^{-9}$, $P = 1.654e^{-8}$ for both pairwise Wilcoxon tests).

In terms of forest structure, certified açai forests had trees with greater values of basal area per hectare ($P = 0.01567e^{-6}$), Fig. 2). On average, basal area values were ca. 150% higher in certified forests (Table 1). The largest individual trees were from the species *Ceiba pentandra* (L.) Gaertn., *Spondias monbin* L. and *Mora paraensis* (Ducke) Ducke with



diameters over 120 cm at the breast height (DBH). All certified studied plots obtained basal area values (26.9–91.7 m²·ha⁻¹) within the range of variation comparable to intact forests (Table 1, Fig. 2).

◀ **Fig. 2** Comparisons of tree species richness, basal area, and density of açai clumps among certified, non-certified and control plots. Boxplots above shows the distribution of the data based on the median, first and third quartile, and minimum and maximum values. Letters on the left upper corner of each box represent the result of the pairwise and non-parametric Wilcoxon test. Distinct letters indicate a significant statistical difference among groups (p -values are displayed in the main text of the manuscript)

Although species richness and basal area significantly differed between certified and non-certified plots, we found no significant difference between açai abundance when both groups are compared (Fig. 2c, $P = 0.8781$). Therefore, certified areas were richer in terms of floristic composition, had a larger forest stature (higher basal area), and possessed comparable açai density as non-certified forests.

Relationship between richness and açai clump density

We found a negative relationship between the density of açai clumps and the species richness in açai managed forests. The higher the açai clump density is, the lower the diversity of tree species is in both certified and non-certified harvesting areas (Fig. 3). However, certified data showed a trend with a lower slope than non-certified data (slope_{certified} = -0.01 , $R^2_{\text{certified}} = 0.215$; slope_{non-certified} = -22.75 , $R^2_{\text{non-certified}} = 0.677$, respectively). Even in sites with a high density of açai clumps, certified harvesting areas tend to have a more species rich composition and a larger tree basal area than non-certified açai groves (Table 1, Fig. 3).

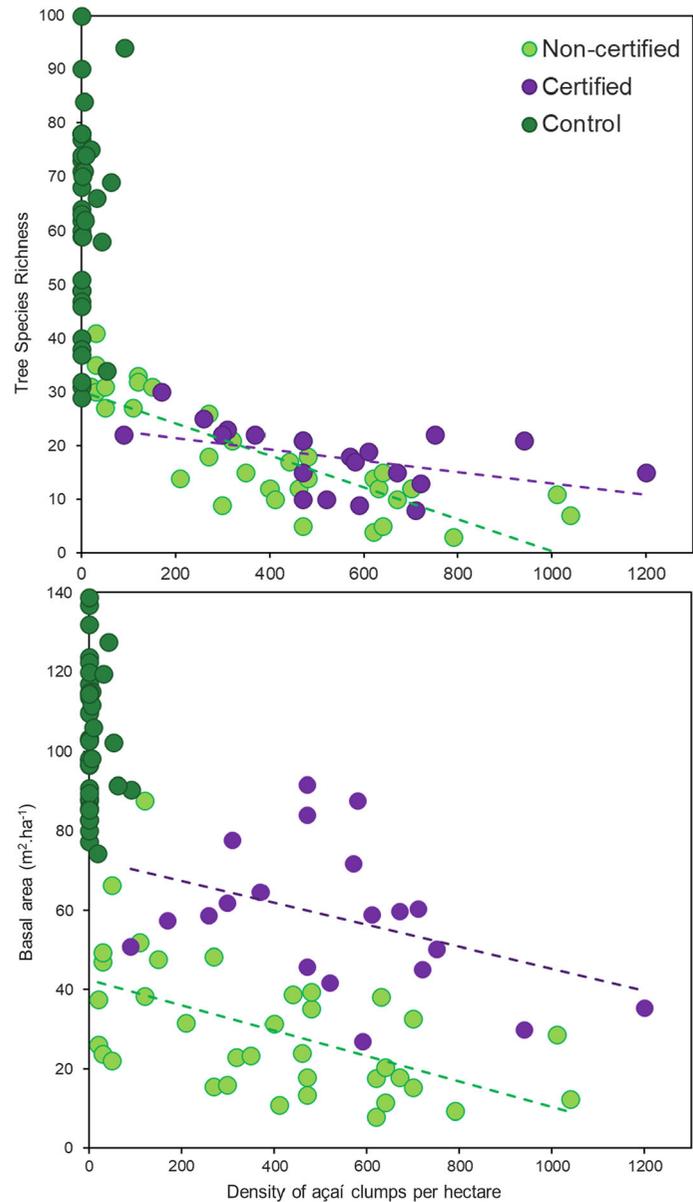
The relationship between the density of açai clumps and the species richness is still significant when the explained variation is partitioned using the db-RDA analysis. Despite the climatic distinction over a large spatial range among the studied plots (Figure S1A), we did not find supportive evidence that species richness could be associated with the climatic variation over the space. We did find a partial association between richness and the spatial distances among the plots (Figure S1B), possibly due to the overwhelming number of control plots from the PELD-MAUA research network that are located in western Amazonia. Even though the spatial correlation is present, the number of species among certified, non-certified, and

Table 1 Floristic and structural parameters of certified, non-certified açai harvesting areas and native várzea flooded forests

	No. families	Species richness	Fisher's α diversity	Basal area ($\text{m}^2 \cdot \text{ha}^{-1}$)	Açai clump density (ha^{-1})	No. plots
Control	24.4 \pm 7 (39–12)	54.4 \pm 20.8 (100–14)	20.3 \pm 8.7 (39.2–5.22)	89.1 \pm 30.5 (138.7–22.19)	25.4 \pm 45.2 (210–0)	50
Non-certified	8 \pm 2.6 (13–3)	12.6 \pm 5.5 (26–3)	4.4 \pm 2.7 (10.8–0.6)	22.8 \pm 11.8 (40.4–8)	549.1 \pm 136.7 (1040–270)	24
Certified	10.6 \pm 2.8 (14–7)	17.6 \pm 5.6 (30–8)	5.4 \pm 2.8 (10.3–1.96)	58 \pm 10.9 (91.7–26.9)	538.5 \pm 203.9 (1200–90)	20

Control data represent the PELD-MAUA dataset, a tree-plot network for seasonally flooded forests located across the Amazon Basin. Numbers displayed represent the average \pm standard deviation (max–min range)

Fig. 3 Linear correlation between tree species richness and basal area against density of açai clumps in certified and non-certified plots. Both graphs show a negative relationship and as the density of açai clumps increases in managed forests the number of species and the basal area of both certified and non-certified tend to decrease. However, the decrease in species richness at certified plots is less pronounced than non-certified plots (slope and R^2 values are displayed in the main text of the manuscript)



control plots was still significantly explained by the density of açai clumps in the studied managed forests (Figure S1B).

Flora of certified açai managed forests

The most dominant botanical families found in the certified plots were Fabaceae (27 spp., 303 individuals), followed by Myristicaceae (2 spp., 95 individuals), Malvaceae (9 spp., 78 individuals), Anacardiaceae (2 spp., 64 individuals), and

Euphorbiaceae (4 spp. 49 individuals). These families together account for more than 50% of the total number of tree species sampled in certified managed sites (Table S2). *Virola surinamensis*, the most representative tree species, and *Minquartia guianensis* are registered in the IUCN red list as endangered taxa. Some popular agroforestry species, including non-natives, were also found amid certified forests (e.g. *Mangifera indica*, *Theobroma cacao*, *Spondias mombin*, *Musa spp.*).

Discussion

Can certification of açai agroforestry support conservation of the Amazonian flora?

Despite the lack of a temporal monitoring assessment in our experimental setup, we identify that managed sites after 12 years of certification have a higher species richness than non-certified groves. Additionally, the forest structure of certified sites is considerably more intact compared to non-certified areas. Even though açai abundance is similar across the different sites and the potential for fruit productivity may be then equivalent, the basal area of native trees was much higher in certified than non-certified managed areas. We presume that certified producers preferentially take conservative and lower impact measures regardless of the prior state of conservation of managed sites. Therefore, even if the certified plots included in our study had a better conservation status (e.g., with higher species richness and biomass) before certification was implemented, certified and trained producers acted differently than the intense and uncontrolled management usually applied by non-certified producers (as in Freitas et al. 2015). In addition, regardless of a possible geographical bias in the sampling design, certification and best management practices on their own appear to have a noteworthy effect on protecting the tree diversity and the forest structure of açai harvesting forests. Our comparisons allow us to conclude that there is a high conservation potential of certified açai agroforestry to reduce the degradation of the Amazonian tree flora.

During the certification training, producers are informed about the role of biodiversity and respective ecosystem services. In addition, harvesters are prohibited from engaging in illegal logging and are encouraged to avoid excessive cutting of large trees at managed sites. Although less destructive than clear-cutting of tropical forests, unregulated açai management can still cause considerable losses to the species composition and forest structure of Amazonian forests. For instance, certified managed sites harbor many trees with large diameters (larger than 100–120 cm of DBH) and heights (30–40 m). According to the relationship between richness/biomass and açai density described by Freitas et al. (2015), we expected to find low values of açai density at the certified study sites, especially in those plots with

higher basal area. Surprisingly, açai density between certified and non-certified managed sites was not significantly different. Therefore, certified managed sites can hypothetically maintain fruit production at similar rates to non-certified forests, if the mean fruit production per açai palm happens to be the same disregarding the abiotic differences among plots.

Recent studies have assessed the ecological outcomes and provided evidence for the positive impacts of certification (Willems et al. 2019; Furumo et al. 2020, Pico-Mendoza et al. 2020). For instance, certified coffee agroforestry from Costa Rica were less prone to deforestation and provided more ecosystem services than non-certified forests (Pico-Mendoza et al. 2020). Similar findings were shown in Colombia where certified coffee plantations had an increased diversity of shade-trees compared to uncertified farms (Ibanez and Blackman 2016). However, certification also has its limitations (Waldman and Kerr 2014), with complex and expensive processes that often limit small productions (Loconto and Dankers 2014; Brandi et al. 2015). Although certification is not the only avenue to sustainability, it can provide a regulated system to accomplish and detail advancements through identifying indicators and auditing açai management practices.

In line with our results, we suggest that açai certification can promote ecologically sound management to supply national and international markets. In addition, with a combined effort to aggregate producer cooperatives, certification provides a platform to better support the livelihoods of açai producers as they face the growing and changing market.

The future of açai management certification

Considering the rising market, certification can be a vital mechanism for gaining appreciation and increasing value for açai superfood products (Hogarth 2004; de Oliveira and Schwartz 2018). In 2016, approximately 300,000 tons of açai-based products were sold around the world (Future Market Insights 2017). Also, the açai global market is projected to exceed 1 million tons in sales and hit nearly 2 billion USD in revenue by the end of 2026 (Future Market Insights 2017). With more than 55% market share, Latin America will dominate the global sales towards the end of the projected period.

In Brazil, new opportunities for açai management certification are emerging (Anderson and Jardim 2019) and 92% of producers who had heard of certification consider it an advantageous route for reaching a better valuation for their açai (Pepper and Alves 2017). Several third-party certification programs offered in Pará and Amapá States (e.g. ECOCERT Brasil, IBD Certifications, and IMA-FLORA) are mostly directed to large-scale producers or cooperative farmers but these companies have started to extend programs more suitable for small-scale açai producers (Pepper and Alves 2017; Johnson et al. 2018), offering them an edge in international markets.

Embracing a tactical approach for expanding certification in priority zones in Amazonia should involve collaboration across a number of sectors. Governments and civil society will have to act along with açai food companies and investors to identify how certification might offer the greatest benefits to biodiversity protection and sustainable livelihoods. Frontiers of expansion for commercial açai groves could be the focal point for the application of norms to safeguard intact forests.

Authors' contribution GD, MA and PVAF conceived the project. GD, PVAF and ROP performed fieldwork and data collection. GD performed data analysis and led the manuscript writing. FW, RLA, JS and MTFP provided additional data from control plots and revised the manuscript. AA, CDB and PVAF revised and supervised the manuscript writing.

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Data availability Data will be promptly available under request to the corresponding author.

Declarations

Conflict of interest The authors declare that they have no conflicts of interest.

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