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ORIGINAL RESEARCH

Uncovering the Potential for the Sustainable Commercialization of Non-Timber Forest Products: Palm Fruits in Pando, Bolivia

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Abstract

Palm fruits are important non-timber forest products for rural people's livelihoods in the Amazon region, as many are nutritious foods and have the potential to generate income. However, in Pando, Bolivia, their commercialization is in most cases still underdeveloped. This study aimed to assess the potential of four palm fruits for sustainable commercialization and to identify their related promoting and hindering conditions. The palm fruits studied were açaí (*Euterpe precatoria* Mart), majo (*Oenocarpus bataua* Mart), motacu (*Attalea phalerata* Mart. ex Spreng) and palma real (*Mauritia flexuosa* L.f.). We gathered data from 14 key informants using semi-structured online interviews, 10 community members using structured interviews, and literature. We analyzed the data with qualitative content analysis and a multi-criteria decision-making method. Açaí has the highest potential due to its high abundance, demand, and specialized institutional support, among others. Majo, with a medium potential, benefited from its similarities with açaí regarding harvesting and processing, but still has technical processing deficiencies. Palma real and motacu had low potential because of low demand and lack of knowledge regarding harvesting and processing. This study demonstrates the importance of considering multidisciplinary factors when assessing sustainable commercialization potentials.

Keywords Non-wood forest products · Rural development · South America · Sustainable harvesting · Sustainable value chains · Wild fruits

Introduction

Non-timber forest products (NTFP) are biological materials other than timber that are extracted from forests for human use (De Beer and McDermott 1989). Palms are among the most important providers of NTFP in the Amazon, due to their wide range of uses for local communities and their high market value (Balslev

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et al. 2015; Moraes et al. 2015; Shackleton et al. 2018; Smith 2014). Palm hearts, palm fruits and seeds are eaten crude and are processed into foods and drinks (Balslev 2011; Moraes et al. 2015). Lately, palm fruits have gained increasing importance since they became recognized sources of scarce nutrients, such as unsaturated acids and antioxidants (Darnet et al. 2011; dos Santos et al. 2015; Moraes 2014; Smith 2014). As a result, they gained high economical potential, as some were demanded by international markets (Moraes 2014; Smith 2014). Moreover, palm fruits harvesting does not mean a threat to the palm, whereas the previously widespread palm heart exploitation techniques required its chopping. Numerous studies pointed out the high diversity of palms in the Bolivian Amazon, which is believed to represent 19% of all Amazonian palm species, nevertheless, only a few are currently commercialized (Araujo-Murakami et al. 2016; Balslev et al. 2015; Herencia 2013; Moraes 2014, 2020).

The literature on the benefits of NTFP commercialization fits well with palm fruits, as these mainly contribute to: (a) the improvement of livelihoods, by the increase in income and employment opportunities (Belcher and Schreckenberg 2007; Stanley et al. 2012); and (b) conservation, as it is argued that rural people will maintain forests to profit from the economic benefits they generate (Belcher and Schreckenberg 2007; Neumann and Hirsch 2000). However, NTFP commercialization also has critics. Some researchers found that the increase in NTFP value and demand creates high pressure on forests, which can cause ecological damages, risk the depletion of resources, and can affect the livelihoods of local communities, who depend on them (Belcher and Schreckenberg 2007; Marshall et al. 2006). The risk of forest depletion might be especially high when products move from self-consumed to commercial ones, as local harvesters lack experience in establishing sustainable harvest levels at larger scales (Areki and Cunningham 2010; Stockdale 2005). This was the case of several NTFP in the Amazon, whose exploitation followed the *boom and bust* pattern (Homma 1992).

To prevent the depletion of NTFP resources and ensure their sustainable production, their responsible management and commercialization are key. However, sustainable commercialization can be challenged by multiple factors (Shackleton 2015) which include ecological, social, economic, cultural, institutional, political, and marketing-related aspects (Avocèvou-Ayisso et al. 2009; Gould et al. 1998; Hernández-Barrios et al. 2015; Marshall et al. 2006; Wynberg and van Niekerk 2015). Moreover, these aspects interact with each other, adding to its complexity, but also pointing out the need to address sustainable NTFP commercialization in a multidisciplinary manner (Wynberg and van Niekerk 2015).

In this context, this study aimed to assess the potential for sustainable commercialization of four palm fruit species. This, with the objective to explore them as alternatives for economic diversification, especially important in Pando, whose economy, highly dependent on Brazil nut is prone to external threats (Callo-Concha et al. 2022). The study method consisted of data collection through interviews and literature on the selected palm fruits. For the assessment of potentials, we applied an *ad-hoc* multi-criteria analytical framework that evaluated simultaneously the ecological, socio-economic, institutional support and policy, and market and value chain-related criteria found to have an influence on the sustainable

commercialization of NTFP, a holistic approach not commonly found in the literature. Consequently, we present detailed results, providing a comprehensive description of the current situation in the study area, considering all criteria. We also assess the potential for sustainable commercialization for each palm fruit. Finally, our discussions identify actionable points specific to each palm fruit.

Methods

Study Area

The study area extended along the western flank of the department of Pando, Bolivia, in the provinces of Manuripi and Nicolás Suárez. This area includes the protected area *Reserva Nacional de Vida Silvestre Amazónica (RNVSA) Manuripi.* The study area exhibits a tropical wet-dry climate area, is highly biodiverse and is covered by humid rainforests (Arnfield 2020; Ministerio de Medio Ambiente y Agua et al. 2013). The RNVSA Manuripi has a total area of 747,000 ha, 67% of which is classified as *Area for harvesting non-timber forest products* (Ministerio de Medio Ambiente y Agua et al. 2013) (Fig. 1).

Palm Fruits Selection

The selection of palm fruits for this study followed three general criteria: (i) species that grow in the study area, (ii) species that were commonly used in Pando or in neighboring Amazonian regions and considered promissory for commercialization after Araujo-Murakami et al. (2016) and/or Antezana Guerrero et al. (2001); and (iii) species that showed some market penetration in the study area or neighboring regions. After that, the species selected were açaí (*Euterpe precatoria* Mart), majo (*Oenocarpus bataua* Mart), motacú (*Attalea phalerata* Mart. ex Spreng), and palma real (*Mauritia flexuosa* L.f.) (Fig. 2).

Analytical Framework

The analytical framework was built on the literature about the factors influencing the sustainable commercialization of NTFP. It was composed of four criteria, each of them disaggregated into a comprehensive set of three to eight indicators (Fig. 3; a detailed description of each indicator is given in Appendix 1). Analytically, we operated inversely. We first identified the importance of each indicator, then aggregated the indicators within each criterion, and finally calculated an overall index of sustainable commercialization for each palm fruit.

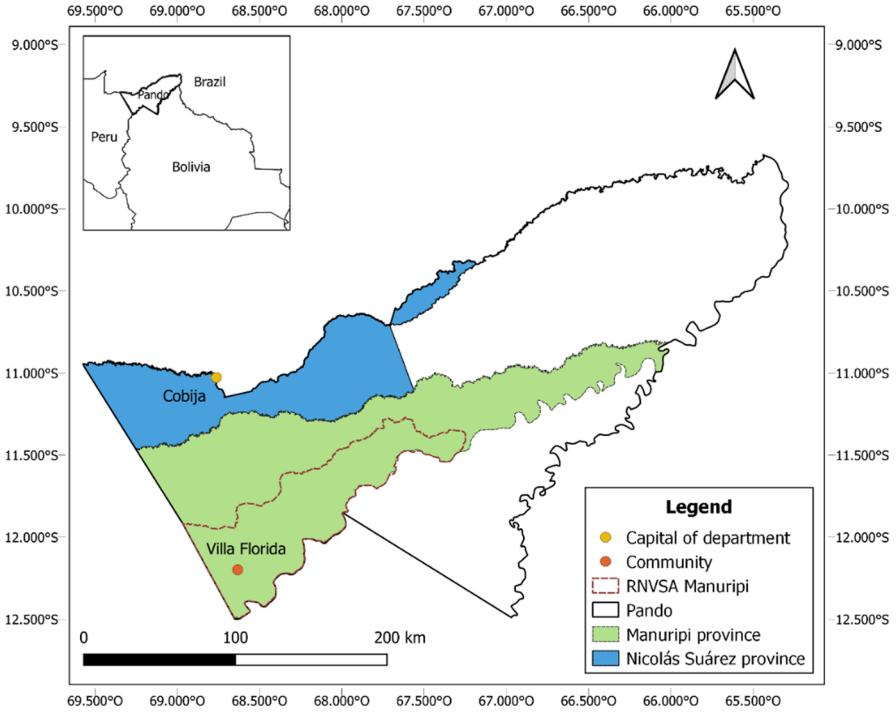

Fig. 1 Map of the study area in Pando

Sample

Amid the Covid-19 pandemic, the methodology of this research had to be modified by adapting field data collection methodologies to the use of secondary data and interviews. Key informants, local community members and literature on palm fruits were the key sources to gain information on the indicators set for the analytical framework. For identifying the key informants, we used snowball sampling. Research partners in the study area (representatives of NGOs and researchers), and successive interviewees were asked for knowledgeable people on palm fruit commercialization in Pando (Bernard 2011). Out of 23 key informants identified, 14 key informants agreed to be interviewed, which included:

- Five officers of NGOs related to research, conservation, sustainable development, and technical advice about NTFP;
- Four representatives of government institutions, i.e., ministries, departmental institutions, and the sanitary service of agriculture and food safety;
- Two retailers of NTFPs;
- Two private consultants and researchers;
- One member of a palm producer association.

Fig. 2 **a** Fruits of açaí (*Euterpe precatoria Mart*), from ACEAA. **b** Inmature fruits of majo (*Oenocarpus bataua Mart*), from Salomon (n.d.) Tropicos.org. CC BY-NC-SA. **c** Inmature fruits of motacu (*Attalea phalerata Mart. ex Spreng*), from Stang (2007) Tropicos.org. CC BY-NC-SA. **d** Fruits of palma real (*Mauritia flexuosa L.f*), from Huamán (n.d.) Tropics.org. CC BY-NC-SA

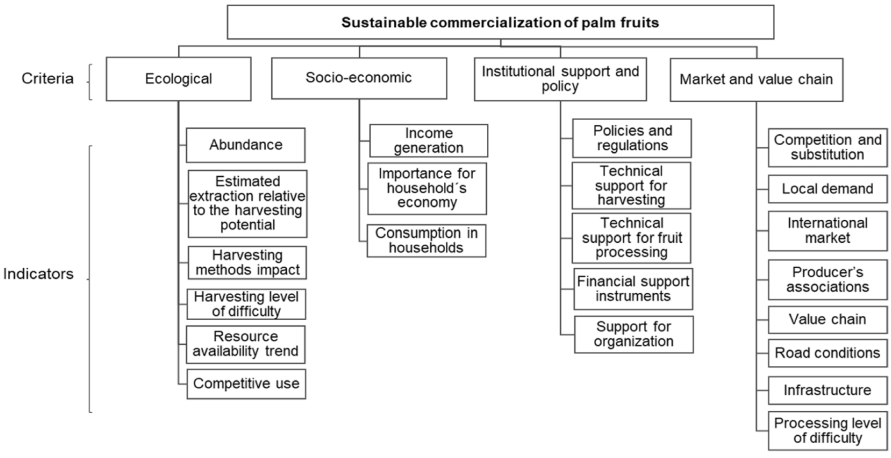

Fig. 3 Ad-hoc analytical framework for the sustainable commercialization of palm fruits

Concerning grass–root sources, community members from the community of Villa Florida, acknowledged by its pioneer role in palm fruits production and trade, were interviewed. We used snowball and convenience sampling (Bernard 2011) to identify community members with experience in harvesting or processing palm fruits for commercialization or self-consumption. Firstly, we contacted the leaders of the community, who then recommended other interviewees potentially willing to participate. As it was Brazil nuts harvesting season at the time of our fieldwork, many community members were not available for interviews, whereby we could interview 10 community members.

For the identification of scientific literature about the indicators selected, we did an online search in the scientific databases Scopus and the search engine Google scholar using keyword combinations in both English and Spanish using the following terms: non-timber forest products, palms, palm fruits, Bolivia, Pando, Amazon, Manuripi reserve, açaí, majo, palma real, motacú, *Euterpe precatoria Mart*, *Oenocarpus bataua Mart*, *Attalea phalerata, Mauritia flexuosa,* commercialization, harvesting, policies, normatives, market, ecology. The literature found was categorized by species (60 documents in total), and criteria defined in the analytical framework (56 in total). Additionally, we asked key informants for local documents and existing authoritative reports.

Data Collection

We applied semi-structured interviews with the key informants on the ecological criteria, institutional support and policy criteria, and market and value chain criteria defined in the analytical framework. We did not include the socio-economic criteria, which rather weighed the palm fruits' importance at a household level. The interview guide was structured after the criteria and indicators set in the analytical framework (Appendix 3).

The questions were open-ended. There were specific questions for each of the indicators, followed with complementary questions. As the background and knowledge of the key informants varied, not all questions were answered by all of them. The interviews were mostly conducted virtually, and only one key informant preferred to answer them in writing.

Interviews with community members were done by a field assistant. The interviews were structured with questions addressing all indicators but underlining some on the market and value chain criteria more closely related to the community members' day-by-day knowledge. Questions were open-ended, except for the ones regarding the socio-economic criteria which offered multiple choices.

Information from the bibliographic review assessed the indicator *abundance* from the ecological criteria, the indicator *policies and regulations* from the institutional support and policy criteria, and to complement others.

Data Analysis

The main analytical tools applied were qualitative content analysis (Mayring 2014) and Multiple Criteria Decision Making (MCDM) analysis (Mendoza and Prabhu 2000). For the qualitative content analysis, we transcribed the answers to the open-ended questions, selecting the information relevant to our analytical framework. The coding tree was based on our analytical framework: the first level contained *codes* directly related to the indicators of the framework, containing general information but not addressing specific palm fruits e.g., local_demand. The second level, *sub-codes,* fine-tuned codes for each palm fruit, e.g., local_demand:Asai. A third level specified trends or categorizations of codes, e.g. local_demand:decreasing, harvesting_difficulty:difficult. The analysis was made with the software Atlas.ti (Lewis 2004; Weitzman and Miles 1995).

To analyze the palm fruits' potential, we used MCDM analysis, which is an approach that accounts for multiple criteria to explore alternatives for decision-making (Mendoza and Martins 2006). MDCM analysis can use quantitative and qualitative data. Thus, quantitative assessments can be complemented with expert opinions or common knowledge, which is advantageous when quantitative data is not complete, and comprehensive assessments are aimed for (Mendoza and Martins 2006; Niekamp et al. 2015). To operationalize the analysis, we applied the Simple Multi-Attribute Rating Technique (SMART). SMART requires to formulate an overarching objective, and to set a structured hierarchy of criteria and indicators that are evaluated with numerical values according to the objective (Taylor and Love 2014; Mendoza and Prabhu 2000).

The MCDM calculations were made according to the following steps (modified from Fahlepi (2020) and Taylor and Love (2014)):

(a) The first step was to calculate the weight values for each indicator. We started by giving each of the four criteria the same weight value (0.25), so each criterion had an equal weight in the calculations, and the sum of the weight values of the four criteria is 1. Similarly, the weight value of each subordinate indicator was assigned the same weight values. For example, the weight value of each of the ecological indicators was the proportion of the weight of the ecological criteria and the number of ecological indicators ($Weightofecologicalindicators = \frac{0.25}{6} = 0.04$).
(b) As a second step, the rating values for each indicator were set using Likert scales from 1 to 3 (Appendix 5). For example, the rating values for the indicator harvesting level of difficulty were (1) difficult harvesting, (2) medium harvesting difficulty, and (3) easy harvesting.
(c) Each palm fruit was then rated according to pre-defined values, e.g. for the indicator harvesting level of difficulty (1 = most difficult, and 3 easiest): Açaí (2), Majo (2), Motacu (3) and Palma real (1).
(d) Then we calculated the utility values of each indicator, by multiplying, for each palm fruit, the weight of each indicator with its rating value. For example, for açaí, the utility value of the indicator harvesting level of difficulty was 0.08 (weight of the indicator = 0.04, rating value = 2).

(e) Lastly, we calculated the final rating values of each palm fruit by adding up the utility values of indicators and criteria. These values were classified into the categories: low potential (1–1.66), medium potential (1.67–2.32) and high potential (2.33–3) (Appendix 7).

Results

Ecological Criteria

Abundance. All the four palm species, açaí, majo, motacu and palma real were found in the RNVSA Manuripi (Herencia 2013). Among them, açaí and majo were the most abundant (Antezana Guerrero et al. 2001; Rodriguez and Montero 2002). Forest inventories with different scales, in the Bolivian Amazon and Pando (Araujo-Murakami et al. 2015; Mostacedo et al. 2006) and in the overall southwestern Amazon region (Selaya et al. 2017), found diverging density values. Still the abundance of açaí in the RNVSA Manuripi (ACEAA 2016) was considerably higher than in the other sites (Table 1). Palma real, which prospers in hard-to-access flooded areas, is often not considered in forest inventories (Mostacedo et al. 2006), therefore, its density might be higher than suggested by these studies (Mendieta-Aguilar et al. 2015; Kahn 1988), as suggested by key informants.

Relative estimated extraction. The species with the highest estimated extraction relative to its full harvesting potential was açaí. Key informants' estimations of Asai fruits harvested in Pando ranged from 1 to 50%. In the community of Villa Florida, where there is a processing plant for palm fruits, local community members estimated that açaí extraction from the current stocks ranged from 30 to 70% with an average of 61%, while according to secondary data, harvesting rates in this community are barely around 1% (ACEAA 2016; WWF 2020).

For the other palm species, two key informants gave approximated values, saying that majo (5–10%) was harvested more than motacu and palma real (around 1% each), whereas the remaining key informants mentioned that the extraction levels of all three species are generally low.

Harvesting methods impact. In the case of açaí and majo, key informants and community members reported that climbing palms to collect the fruits was the most common and widespread harvesting practice, which does not cause damage to the palms (Fig. 4a). Cutting the palms, which kills the plant and can therefore quickly have negative impacts on palm populations, was less often mentioned. Three key informants reported that cutting majo palms is still occurring justified on the grounds that they were more difficult to climb, and only one added that Brazil nut collectors might occasionally cut açaí palms for self-consumption. In the case of motacu and palma real, there were very few answers because they were infrequently harvested (Table 2). However, respondents asserted the use of non-destructive methods.

Harvesting level of difficulty. Climbing palms was described to be physically demanding, it requires some equipment, and is done only by trained people. Açaí is slightly easier to climb than majo as its trunk is thinner; motacu is the easiest to harvest because fruits can be picked with a small ladder as it has a small height;

Table 1 Palm species density

Palm fruit	Abundance (individuals/ha)			
	Authors			
	Araujo-Murakami et al. (2015)	Mostacedo et al. (2006)	Selaya et al. (2017)	ACEAA (2016)
	Scale			
	Bolivian Amazon (Sample size = 35 ha)	Pando (Sample size = 16 ha)	MAP region (Sample size = 41 ha)	Community Villa Florida (Sample size = approx. 11 ha)
Açaí (*Euterpe precatoria)*	15.9	28.3	16	66
Majo (*Oenocarpus bataua)*	12.7	14.1	4.1	–
Motacu (*Attalea phalerata)*	1.6	1.4	1.2	–
Palma real (*Mauritia flexuosa*	–	–	0.1	–

and palma real is the most difficult to harvest because of its high height, large trunk width and its growth in swampy areas. For palma real specifically, the need for harvesting training was mentioned.

Availability trends. Six key informants mentioned how harmful palm heart harvesting was for açaí palm populations until some decades ago and that the consequences on the total production of palm fruits are still visible today. Still, seven key informants, and all community members of Villa Florida, confirmed that the population of açaí is now constant or even increasing due to proper harvesting methods, natural regeneration, cultivation, and regulatory control of sustainable harvesting methods inside the RNVSA Manuripi. Two key informants reported a decrease of majo, motacu and palma real because of cutting harvesting techniques or deforestation, whereas four mentioned their increase due to low harvesting quantities and a higher consciousness regarding their conservation. The rest reported a stable trend or having no information about it.

Competitive use. Competitive uses of other parts of the palms were hardly reported for any of the palm fruits investigated. Only one community member in Villa Florida mentioned that the extraction of palm hearts is still ongoing.

Socio-Economic Criteria

Income generation. The interviewed community members from Villa Florida reported earnings averaging 128.8Bs (18.7$/16.5€) per day, from harvesting açaí and majo fruits. Palm fruits' harvesting is seasonal, açaí is harvested between March and September, majo between September and March, and community members

Fig. 4 **a** Harvesting of açaí fruits climbing the palm, source: Miguel Villavicencio. **b** Açaí pulp final product, source: Víctor García. **c** Infrastructure of the processing plant in Villa Florida, source: Víctor García

Table 2 Main harvesting methods for palm fruits ($n = 24$, missing = 2)

Respondents	Palm fruits harvesting methods	Frequency of responses			
		Açaí	Majo	Motacu	Palma real
Community members ($n = 10$)	Climbing the palm	10	10	–	–
	Not specified	–	–	10	10
Key informants ($n = 12$)	Climbing the palm	11	8	1	4
	Cutting the palm	–	3	–	–
	Using a stick to drop the fruits	–	–	1	1
	Using a ladder to reach the fruits	–	–	2	–
	Not specified	1	1	8	7

work about 2–3 days per week, depending on the capacity of the processing plants and their demand.

Importance for households' economy. Açaí and majo were labelled as important or very important for the incomes of most interviewed community members (90%), while motacu and palma real were not economically important for most of them (90%).

Consumption in households. Açaí and majo were said to be consumed regularly by most of the community members (80 and 90%, respectively), while motacu and palma real were mostly not consumed at all or to a very small extent (80 and 100%, respectively).

Institutional Support and Policy Criteria

Policies and regulations. As a result of the agrarian reform of the year 2008, large parts of the land in Pando passed from private properties (e.g., *barracas)* to ownership of peasant and rural communities, granting them the legal right to extract NTFP (INRA 2008).

Communities located inside the RNVSA Manuripi have a shared governance scheme, that involves state and community representatives. This scheme is coordinated by the *Servicio Nacional de Áreas Protegidas* (SERNAP) on behalf of the Ministry of Sustainable Development and Planification (Coronel and Solorzano 2017). Each community must elaborate a management plan according to the normatives for the sustainable use of the land and natural resources (*Plan de Gestión Integral de Bosques y Tierra* (PGIBT)), as well as an operative management plan (*Plan Operativo de Gestión Integral* (POGI)), that details the field activities. These two plans are conditional to allow the exploitation of resources (Autoridad de Fiscalización y control social de bosques y tierra, 2013; FAO 2017).

For instance, in the PGIBT of the community Villa Florida, specific guidelines for the harvesting of açaí and majo exist: harvesting has to be made in a designated forest area, only ripe fruits should be collected climbing the palms, and 20% of the palms should be reserved as 'seed trees' and left unharvested (Peñaranda 2015). Key informants reported that, as for now, most guidelines seem to be fulfilled, except for the 'seed trees' rule. Harvesters prioritize collecting palms after the fruit ripeness, straightness of the palm proximity to the community and number of fruits per palm, and disregard de-selecting 'seed trees'.

Formal requirements are also needed for the commercialization of NTFP, i.e., registration of enterprises or associations by the *Autoridad de Fiscalización y Control Social de Bosques y Tierra (*ABT), the municipality, and the *Servicio Nacional de Sanidad Agrícola y Agropecuaria* (SENASAG), to secure the safety of processing and commercialization of food products (de la Torre et al. 2011).

Technical support for harvesting. Technical support was mentioned by key informants to be provided by governmental and non-governmental institutions, and one private enterprise (Appendix 6), mostly targeting açaí. The NGOs support is related mostly to the training on harvesting techniques and practices (also useful for majo), evaluations of productive potentials of forest patches, and provision of specialized security climbing equipment. Moreover, the NGOs Asociación Boliviana para la Investigación y Conservación de Ecosistemas Andino Amazónicos (ACEEA) and Centro de Investigación y Promoción del Campesinado (CIPCA) launched initiatives to assess the abundance and productive potential, and to provide harvesting training for palma real, as the interest in this fruit is increasing. Governmental institutions support, in line with national programs that promote palm fruit harvesting and commercialization, by giving technical training to harvesters and having developed a protocol of good harvesting practices for açaí.

Technical support for processing. Key informants reported that technical support for processing palm fruits targeted açaí. It was also mentioned that the recent launching of the Bolivian norm for açaí pulp (IBNORCA 2021), may contribute to standardize the product processing, quality and safety, and easing its market uptake. The

governmental institutions mainly built processing plants, while non-governmental institutions provided training on processing techniques and sanitary conditions. Nevertheless, not all the initiatives were successful, as one key informant stated:

> "Most of the municipalities tried to help set up processing plants in different places, but they had problems with the cold chain, most of them stopped working or are working privately." (KI10).

A key informant reported that a consortium led by the World Wide Fund for Nature (WWF) with SERNAP and a private company, has successfully set up a processing plant in Villa Florida used for açaí but also used to a lesser extent for majo. Related to this, key informants underlined the importance of collaboration between governmental and non-governmental institutions.

As for the other palm fruits, some operators are exploring the possibility of using existing açaí processing infrastructure for palma real. No specific initiatives were mentioned for motacu.

Financial instruments. According to key informants, producers and organizations involved in palm fruit harvesting and processing face difficulties to get bank loans, as they often cannot fulfill the guarantees requested. Moreover, when commercializing palm fruits, they also face challenges with fulfilling formalities required for taxation, which needs financial knowledge that producers often lack. Instead of bank loans and administrative support, the support mainly came in the way of goods from non-governmental institutions and international cooperation agencies and in partly covering the costs for equipment and infrastructure for producing and processing açai by governmental organizations. Previously, a decree which stated that the government would provide funds for NTFP-related businesses through development banks existed, but it was never put in practice. Still, the Bolivian government has been increasing the promotion of palm fruit´s commercialization through new national programs in the last years. An example is the recently released *Plataforma Interinstitucional de Articulación de Complejos Productivos de Frutos Amazónicos* (PICFA) (PICFA 2020) which aims to develop the public and private sectors, and plans to offer grants to producers.

Organizational support. Most key informants asserted the endorsement of palm fruit producer associations by governmental and non-governmental institutions, including support in the formation, organization, and administration of palm fruit harvesting and trade, and the processing and commercialization of palm fruits.

Market and Value Chain Criteria

Local demand trend. Key informants agreed that the local demand for açaí has increased in the last years, as local people are better informed of its high nutritional quality. Shops selling açaí boomed in Cobija, the capital of Pando, where several açaí by-products are sold. Also, açaí's national demand increased significantly in Bolivian cities like Cochabamba, La Paz, and Santa Cruz. In the case of the other three palm fruits, no specific demand trend was identified by key informants. Majo was said to be consumed in rural villages and sometimes sold in small quantities in

local markets. However, this is not the case for motacu and palma real, for which there is no demand. Nonetheless, it was mentioned that palma real could reach a local market in the future:

> "I would say that palma real is a very promising product, it is not going to take too much time until it is untapped due to its nutritional qualities, … so I believe that it will rise up as long as we start to give it a value." (KI12).

International markets. Key informants reported that the only palm fruit product exported from Bolivia to international markets is freeze-dried açaí. The company is situated in the district of Santa Cruz but there is none that exports from Pando. Key informants agreed that the international demand for açaí is increasing, which is so far covered by Brazil. Key informants mentioned that some açaí was sent from Pando to Santa Cruz to be processed and exported to Brazil from there.

According to key informants, the other three palm fruits lack of international markets. For palma real, however, it is acknowledged that there is a high potential for international commercialization, as it is already known and demanded in neighboring countries, such as Peru. Nevertheless, an international market is still perceived as far to reach, as suggested by one key informant:

> "With açaí, in theory, it shouldn't be so difficult as it is not something new, it is already positioned by Brazil years ago. Still, in 5 years, we haven't gone too far, imagine about the other products, to have a real potential a lot of time must pass, and at this pace, it is not going to happen in the short term." (KI04).

Producers' associations. Key informants reported that there are around six associations of açaí producers in Pando, some of which work also with majo on a small scale, but none with palma real or motacu. Some associations claim to be producers of Amazonian fruits in general, opening the possibility to include other palm species in the future. These associations are part of the *Federation of Açaí and Amazonian fruits of Pando* (FEDAFAP), whose objective is to facilitate a joint work among members and to have a strong representation before authorities and other organizations.

Value chain. Açaí was the only palm fruit with an existing value chain where harvesters, processors and traders are distinguishable. There is a good connection between harvesters and processors, as both roles are regularly played by the same association or by closely related individuals. However, the connection between processors and traders is not that clear, mainly because commercialization is dynamic and unstable, and lack of formal contracts. Still, there are a few private traders from Cobija who have established close and reliable relationships with some communities. It is foreseen that the açaí value chain could also be used eventually to trade majo.

Infrastructure. The existing processing, transporting and storing infrastructure was built targeting açaí, but is also used for majo when needed. There is no infrastructure for motacu and palma real, as they are neither processed nor traded commercially.

Infrastructure conditions vary among communities and organizations. The few plants that have good sanitary and technological conditions were set up with the support of governmental and non-governmental institutions, e.g. the processing plant in Villa Florida (Fig. 4b), while the remaining plants have insufficient conditions. The major problems are the lack of a cold chain, facilitating the refrigeration of the products along its transportation, and the absence of a freeze dryer machine, which could facilitate the trade of açaí regionally, nationally and even internationally. As mentioned by a key informant that was a retailer:

> "There are complications in the secondary transportation, after the pulp is processed it has to be transported in a refrigerator truck, […] some of them store it in freezers, some others have a cold chamber, but the majority do it in Styrofoam Boxes where they keep certain conditions, but they have to take them fast to the market, or by plane to La Paz and Santa Cruz, with high costs which don't make it competitive." (KI02).

Road conditions. Most secondary roads are not paved, and the main road towards Cobija, that crosses the study site, is only partly paved, which makes the transport of products difficult, especially during the rainy season. Furthermore, these poor road conditions and the associated long journeys impair the quality of the products. Furthermore, açaí and majo have a very short shelf life when not stored in a cold chamber.

Processing level of difficulty. The main steps for processing açaí pulp are the sifting, the boiling for disinfection, the depulping of the fruits, and the packaging (Fig. 4c). For majo, the machinery and the main processing steps are the same as for açaí. Nevertheless, a few differences were pointed out: majo's fruits need more boiling time and the temperature needs to be controlled more precisely; because of its higher content of oils, it is more difficult to clean the machinery; the fruits are more perishable and need to be processed within 20 h after being harvested (in comparison to 48 h for açaí); and once processed, majo pulp does not last long, and goes bad easily when unfrozen.

Motacu and palma real are processed using traditional methods and only on a small scale. Motacu´s pulp is harder to extract by the characteristics of the fruits, which are bigger than açaí and majo but with less flesh. For palma real, there is not yet a technology to extract the pulp.

Palm Fruits Potential

MCDM results indicate the potentials for sustainable commercialization of the four selected palm fruits being 3 the highest possible value and 1 the lowest for each indicator (Appendix 7; Fig. 5). According to the categories defined, açaí was the only palm fruit with a high potential (final rating value = 2.59), followed by majo with a medium potential (final rating value = 2.23), and palma real (final rating value = 1.48) and motacu (final rating value = 1.43) with low potentials. Açaí showed the highest rating values for the *market and value chain* criteria (0.61), as well as for the *institutional support and policy criteria* (0.65). Açaí and majo, presented the

same high *socioeconomic* rating values (0.67), while motacu and palma real had the same low ones (0.25). For the *ecological criteria*, there were only slight differences between the indicators for all four palm fruits (between 0.54 and 0.67).

Discussion

In this study, we aimed to assess the potential for sustainable commercialization of the palm fruits of açaí, majo, motacu and palma real. We found that the criteria and indicators differ for each palm fruit, and so the potentials for their sustainable commercialization. The discussion addresses the potentials of each palm fruit, highlighting the main reasons for their high/low potential, followed by the factors that are common to all.

Commercialization Potentials of the Four Palm Fruits

We found that açaí has the highest commercialization potential in Pando, as demonstrated by the favorable ratings in all four criteria. The much more developed market and value chain conditions for açaí compared to the other palm fruits was due to the interest and investments from institutions driven by the unsatisfied market demand on local, national and international levels. In addition to this, the related knowledge

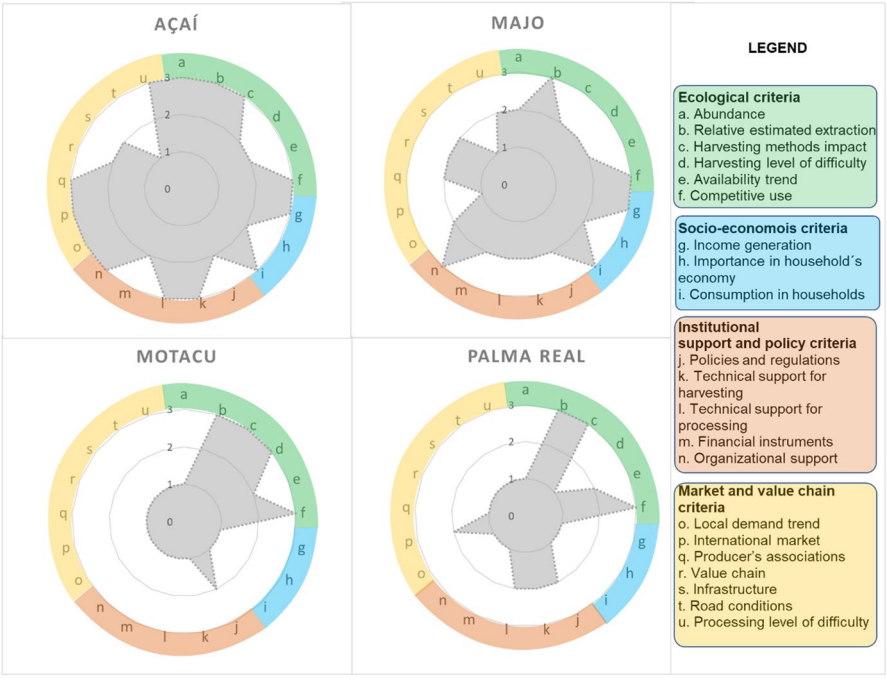

Fig. 5 Rating values per indicator for the four palms

developed in Brazil (ACEAA 2020; Lorini 2016), which was transferred to Pando through the different institutions, was essential for setting up the baseline of the activity in the region. Regarding the ecological criteria, the high abundance and low harvesting rates of açaí, ensured a high ecological sustainable harvest. Still, higher estimations of extraction rates by community members compared to the ones calculated in Villa Florida (ACEAA 2016; WWF 2020), show that extraction rates might be higher in more accessible forest patches, and therefore better known by community members, than in remote forests. However, our results suggest that extraction rates are still far from overexploitation even in accessible forests. Therefore, the unsatisfied market demand for açaí could be met, at least to some extent, by increasing harvesting rates.

As for the socio-economic aspect, the reported daily income of local farmers harvesting açaí and majo in Villa Florida surpassed the established rural Bolivian and international extreme daily poverty lines (1.8$ and 1.9$ respectively (INE 2020; The World Bank 2011)), which, according to Stanley et al. (2012), can be used as a methodology to define economic sustainability thresholds. This evidence shows the potential of palm fruits to contribute to local incomes. However, a limitation to this is the discontinuity of palm fruit harvesting, due to its seasonality and contract instability (Lorini 2016). Therefore, the economic potential of these two palm fruits relies on being complementary to other sources of income, a common characteristic of NTFPs (Ruiz-Pérez et al. 2004; Schreckenberg et al. 2006c; Belcher and Schreckenberg 2007). For example, if commercialization of açaí and majo becomes a more stable activity when harvested in succession to Brazil nut, they may become a strategy to stabilize household income along the year and increase resilience to the Brazil nut production and price fluctuations.

Majo´s medium commercialization potential largely originated from its harvesting and processing similarities with açaí, allowing to make use of the existing infrastructure targeted for açaí and easing majo's inclusion in national and NGO programs. Nevertheless, majo's high perishability is a limitation to reach markets efficiently. In this context, majo may not have the same future potential as açaí to reach local markets as processed pulp but could be promoted for local fresh consumption instead. Moreover, research to develop the technologies to extend majo's perishability could enhance its potential for sustainable commercialization.

The low potentials for sustainable commercialization of palma real and motacu in Pando, are mainly because of the poor demand, insufficient to developing markets and value chains. Nevertheless, palma real has caught the interest of rural associations and local institutions, who recognize its untapped economic potential as they are aware of the long consumption tradition and the high economic importance it has in countries such as Peru (Moraes et al. 2020; Rojas-Ruiz et al. 2006; Trujillo et al. 2011). Still, in Pando the lack of knowledge about its abundance, harvesting and processing methods, represents a big challenge for starting its commercialization. Initiatives to generate this knowledge are still in an experimental stage, but, as it already exists in neighboring countries, a knowledge transfer to Pando through institutional programs, such as in the case of açai, could ease and accelerate the process.

A special characteristic of palma real is its location in flooded areas, which makes its inventory, harvesting and transportation difficult. Benefits could be drawn from

this fact if it was used as a marketing strategy to promote their sustainable extraction and consumption, as they are an important species for the conservation of water bodies (Moraes et al. 2020).

Even though harvesting motacu is much easier than harvesting the other palms, the lack of interest in increasing motacu's consumption or commercialization in Pando, can be explained by the fact that motacu fruits growing in Pando have less fleshy pulp compared to other palm fruits and compared to other motacu varieties, or species also commonly called "motacu" from other regions (Peralta 2009). Therefore, it could be relevant to do research to identify if other motacu subproducts, like seeds oil, which was suggested to be a promising product for *Attalea princeps* (formerly mistakenly identified as *A. phalerata* (Moraes et al. 1996; Moraes and Pintaud 2016)), could bear more potential for commercialization.

General Factors Influencing Palm Fruit Commercialization Potentials

Sustainable ecological conditions provide the basis for developing sustainable commercialization of palm fruits (Hall and Bawa 1993). Hence, monitoring the abundance of palms and harvested quantities of palm fruits is essential for ensuring their sustainable use (Hall and Bawa 1993; Chamberlain et al. 2019; Stanley et al. 2012). Within the study area, we were only able to obtain information on harvesting levels for açaí in Villa Florida, where the extraction appears to be sustainable. As Villa Florida is one of the few communities harvesting açaí for commercialization, it is probable that similar harvesting potential lies untapped also in other communities of Pando. The same is also expected for the other palm fruits, which are less commercialized or only at times self-consumed, as shown for majo (Vos et al. 2016). One important factor that favors ecological sustainability is the use of recommended harvesting methods, which do not cause negative impacts on the palms, i.e., climbing the palms, (Rocha and Viana 2004; Peralta 2007). Nevertheless, it remains unclear what effects higher harvesting rates of palm fruits would have on the palm abundance, since so far, studies about the ecologically sustainable harvesting rates of palm fruits were based on harmful harvesting techniques only, like cutting down the palm (Peña-Claros and Zuidema 2000; Avalos et al. 2013; Rocha and Viana 2004).

Sustainable commercialization also requires an enabling political framework that ensures the conditions to develop economic activities (Mallik 2000). Land tenure and resources extraction regulations in Pando comply with the *agrarian justice principles,* meaning that it guarantees access to land to those in need of the resources for their livelihoods, and counts with regulations for resource's extraction (Franco and Borras 2019). This creates an advantageous scenario to the benefit of rural population in contrast to *extractivism*, where powerful players are the beneficiaries by using socio-ecologically destructive depletion practices (Chagnon et al. 2022).

Even though there is a well-established tradition of commercializing some NTFP, especially Brazil nut and rubber, in Pando, palm fruits are still not well represented in the regulatory and financial sectors, as it is a relatively new economic activity (Tonore et al. 2019). In the Bolivian context, forestry regulations have been historically directed to timber production and biodiversity conservation (Cronkleton and

Pacheco 2010; Schreckenberg et al. 2006b), and in the past, palms were suggested to be harvested for palm heart commercialization. This situation is different now, since new norms, protocols and programs were released by the government relating to harvesting and processing of açaí (PICFA 2020). NGOs and governmental institutions´ will have an important role in developing alternatives to overcome the financial and political barriers. Relatedly, the difficulties that producer associations face in formalizing their entrepreneurships are particularly hard, which could be a reason why some small producers prefer to stay informal. Bureaucratic barriers and hard-to-understand legal regulations were already identified in Bolivia more than a decade ago (Shackleton et al. 2007; Schreckenberg et al. 2006b; Belcher and Schreckenberg 2007) and remain a limiting factor. Moreover, the lack of financial capacities heavily affects palm fruit commercialization, as rural people´s economies do not allow to face the costs of formalization and setting up the necessary infrastructure.

As seen in the case of açaí in the community Villa Florida, consortia have allowed this community to become one of the leaders in açaí commercialization in Pando. This shows that harmonized and coordinated initiatives can be important to overcome commercialization barriers (Schreckenberg et al. 2006b) and indicates that consortia and platforms can serve as a baseline for the future development of majo and palma real commercialization.

Furthermore, the low number of processing plants and poor conditions of some of them, is also a barrier to increase the processing volumes. A financial system that enhances rural associations' purchasing power, together with the support of NGOs, private companies and governmental institutions, would be key to increase the number of well-equipped processing plants. Nevertheless, there are still other limitations at regional level, such as poor road conditions and lack of basic infrastructure, e.g. water and electricity. These shortcomings require bigger governmental investments to promote local economic activities, like the ones based on NTFP, and the general growth and development of the region.

Methodologically, this study demonstrates the importance of holding a broad perspective on assessing the several dimensions that influence sustainable commercialization, and the interrelations among them. The applied SMART methodology has proven to be useful by its flexibility to uptake quantitative and qualitative data, and its usefulness to identify further research spots and areas of intervention, which makes it useful as a monitoring tool to track changes over time, as well as to assist stakeholders in decision-making processes. Nevertheless, the multidisciplinary approach also presented some limitations, as in order to include a wide number of indicators, the assessment of some of them was done using proxy methods, leaving room for methodological improvements.

Conclusions

Palm fruit commercialization is still in an early phase in Pando, in comparison to Brazil nut, which is the economic backbone in the area. Nevertheless, advances in açaí collection and trade may continue favorably in the following years as demands grow, and rural organizations and institutions keep supporting it. If evolved as expected, this may drag the development of commercialization of other palm species, such as majo. But, this expected development should be focused on the local level first before thinking on national and international markets, as there is still a way to go to establish more functional and profitable açaí value chains at a regional level.

Still, açaí and majo have already shown to be able to generate supplementary income to rural populations. Even though the activity is far from being the main economic activity, it offers an opportunity for diversification in a region highly dependent on Brazil nut, having as an advantage the seasonal convenience as it coincides with the off-season of Brazil nuts. Additionally, if the economic importance of this activity increases through targeted incentives to increase production, this activity has a big potential to promote forest conservation, as it was shown to be an ecologically sustainable activity.

Appendix 1. Analytical framework

See Table 3.

Table 3 Analytical framework description

Criteria and indicators	Description
Ecological criteria	
Abundance	Metric that gives information about the presence of a particular species in a certain forest area (Chamberlain et al. 2019). Defined using the parameter species density, which is the number of individuals of a species per unit area
Relative estimated extraction	Assesses the people's perception of the extracted percentages of a palm fruit in relation to the total production of the forest. It serves to estimate the remaining harvesting potential by comparing harvesting quantities to productivity (Chamberlain et al. 2019; Stanley et al. 2012)
Harvesting methods impact	Defines if the harvesting methods and criteria used are knowledge-based and if they could cause negative impacts on the individuals or population (Pandey et al. 2016; Wynberg and van Niekerk 2015)
Harvesting level of difficulty	Defines how difficult the harvesting methods are according to the characteristics of the palm
Availability trend	Describes the availability trend of the resources (increasing, stable, or decreasing) in the last decades. Relevant to understand the dynamics of the production due to internal, external, or environmental drivers (Dahlberg 2015; Pérez et al. 1996)
Competitive use	Assesses if the palm fruits have other important local uses that could hinder the abundance of the species or be in conflict with the extraction of fruits. E.g., the consumption of palm hearts or use of the stem as wood (Weigend et al. 2015)
Socio-economic criteria	
Income generation	Assesses if the income from a day of work with a palm fruit gives a return to the household that is enough to purchase a survival basket, comparing it with the regional poverty line (Stanley et al. 2012)
Importance for household´s economy	Assesses how important rural householders perceive the income they get from the commercialization of the palm fruits (Neumann and Hirsch 2000)
Consumption in households	Assesses how often rural householders consume palm fruits, to estimate how important they are for their daily diet
Institutional support and policy criteria	
Policies and regulations	Describes how the current policies and regulations related to access to land, access to the resources, manufacturing, and sanitation support or hinder palm fruits commercialization (Laird et al. 2010; McLain and Lawry 2015; Schreckenberg et al. 2006a, b, c)
Technical support for harvesting	Refers to the technical support provided by governmental or non-governmental institutions to rural householders and producers associations, regarding adequate harvesting methods and species management (Marshall et al. 2003)
Technical support for processing	Refers to the technical support provided by governmental or non-governmental institutions to rural householders and producers associations, related to the adequate processing methods and equipment needed to maintain the quality of the product necessary for commercialization (Marshall et al. 2003)
Financial instruments	Assesses the financial support given to producers, that allows them to have financial or material capital to facilitate their economic development, through financial instruments such as reduction of taxes, subsidies, credits, loans, etc. (Marshall et al. 2003)

Table 3 (continued)

Criteria and indicators	Description
Organizational support	Assesses the support from governmental or non-governmental institutions to the formation of rural organizations dedicated to palm fruits production, like producers' associations or federations
Market and value chain criteria	
Local demand	Defines if the palm fruits have a current local market and its demand trend (increase, stability, or decrease)
International market	Defines if the palm fruits have a current established or potential international market, which access is restricted for many NTFPs in rural areas (Belcher and Schreckenberg 2007; Schreckenberg et al. 2006a, b, c)
Producer's associations	Determines the existence of producers' associations for specific palm fruits. These are important to allow to share costs of investments among the members and improve products quality as well as their bargaining power (Belcher and Schreckenberg 2007; Marshall et al. 2006)
Value chain	Determines if the product has a defined value chain and how is the connection between the links of the production chain perceived. Important to facilitate the arrival of the product to the market efficiently, to increase the resilience of the value chain to external market factors like competition or substitution; and to ensure a fair distribution of the profits (Marshall et al. 2006; Schreckenberg et al. 2006a, b, c)
Road conditions	Describes the conditions of the roads used to transport the products. Deficient conditions can affect transportation costs and the accessibility to the markets reducing competitiveness (Belcher and Schreckenberg 2007; Plotkin and Famolare 1992)
Infrastructure	Relates to the existence and actual state of the infrastructure needed for processing to achieve quality standards for commercialization (Marshall, et al. 2006). The infrastructural conditions include processing equipment and post-harvesting storage, necessary to avoid losses of perishable products. Proper storage is important for the efficacy of the sale, as it extends the economic life of the harvest and allows the harvesting of big volumes (Belcher and Schreckenberg 2007)
Processing level of difficulty	Defines how difficult the processing methods are according to the characteristics of the fruits

Appendix 2. Interviewee's information

See Tables 4 and 5.

Table 4 Key informants' information

Interviewee	Sex	Type of organization/occupation	Organization
KI01	Male	NGO	Centro de Investigación y Promoción del Campesinado (CIPCA)
KI02	Male	NGO	Centro de Investigación y Promoción del Campesinado (CIPCA)
KI03	Male	NGO	Asociación Boliviana para la Investigación y Conservación de Ecosistemas Andino-Amazónicos (ACEAA)
KI04	Male	NGO	World Wildlife Fund (WWF)
KI05	Male	NGO	Herencia
KI06	Male	Governmental institution	Ministerio de Desarrollo Rural y Tierra
KI07	Male	Governmental institution	Servicio Nacional de Sanidad Agrícola (SENASAG)
KI08	Male	Governmental institution	Servicio Nacional de Sanidad Agrícola (SENASAG)
KI09	Female	Governmental institution	Former worker of Servicio Departamental Productivo (SEDEPRO)
KI10	Male	Retailer	Retailer of açaí products
KI11	Male	Retailer	Retailer of açaí products
KI12	Male	Federation of producers associations	Federación de Cosechadores de Asaí y Frutos Amazónicos de Pando (FEDAFAP)
KI13	Male	Consultant	Private consultant and researcher
KI14	Female	Consultant	Private consultant and researcher

Table 5 Community members´ information

Interviewee	Community	Age	Sex	Occupation
VILLA01	Villa Florida	52	Male	NTFPs extraction
VILLA02	Villa Florida	36	Female	NTFPs extraction
VILLA03	Villa Florida	31	Male	Agriculture and NTFPs extraction
VILLA04	Villa Florida	26	Male	NTFPs extraction
VILLA05	Villa Florida	33	Male	NTFPs extraction
VILLA06	Villa Florida	58	Male	NTFPs extraction, general secretary of the community
VILLA07	Villa Florida	21	Female	Housewife
VILLA08	Villa Florida	48	Female	NTFPs extraction
VILLA09	Villa Florida	42	Male	Agriculture and NTFPs extraction
VILLA10	Villa Florida	44	Male	NTFPs extraction

Appendix 3. Interview guideline for Key informants

1. ¿A qué se dedica?
2. ¿Su trabajo estuvo o está relacionado a PFNM como los frutos del asaí, motacú, majo o palma real?

Aspectos ecológicos

3. ¿Qué método se usa para aprovechar los productos?
4. ¿Hay algún criterio para seleccionar a las palmeras que se van a aprovechar?
5. ¿Considera que esa forma de aprovechamiento de estas palmeras es sostenible y permite mantener la abundancia de la especie en el bosque?
6. ¿De la cantidad de producto disponible en el bosque para ser aprovechado, cuanto cree que es realmente aprovechado aproximadamente en porcentaje?
7. ¿Considera que la tendencia de la cantidad de producto en el bosque en los últimos 20 años ha disminuido, se ha mantenido o ha aumentado?
8. Si ha disminuido o aumentado:

¿A qué cree que se debe el cambio?

9. ¿Hay algún otro uso que se le dé a la especie que afecte o que esté en conflicto con la producción de frutos? (ej. palmito o madera)

Soporte y aspectos legales

10. ¿Alguna institución ofrece o ha ofrecido algún tipo de soporte técnico en relación a los métodos de aprovechamiento o manejo de las especies en el bosque para alguno de los productos?
11. ¿En qué consiste este soporte?

12. ¿Y respecto al procesamiento y cómo mantener la calidad del producto una vez cosechado?
13. ¿Cómo considera que ha sido el apoyo financiero para las actividades relacionadas a los productos, ha habido por ejemplo algún tipo de incentivo como reducción de impuestos, subsidios, acceso a créditos o préstamos?

Mercado y cadenas de valor

14. ¿Cómo ha sido la tendencia del mercado local de los productos en Pando en los últimos años? ¿Ha aumentado, disminuido o se ha mantenido estable?
15. ¿Alguno de estos productos se exporta?
16. Si se exporta, ¿La demanda ha aumentado, disminuido o se ha mantenido estable? ¿Cuál ha sido el motivo?
17. ¿Cree que los frutos de motacú, majo o palma real podrían tener potencial para la exportación? ¿Por qué?
18. ¿Qué otros productos existen en el mercado que puedan competir o sustituir a los productos?
19. ¿Existen organizaciones o asociaciones de colectores o procesadores para los frutos de motacú, majo o palma real?
20. ¿Considera que existe una buena conexión en las cadenas productivas (entre colectores, procesadores y comercializadores) que permitan al producto llegar fácilmente al mercado?
21. ¿Cómo considera que ha sido el apoyo del gobierno y otras instituciones en la formación de estas asociaciones?
22. ¿Los productos necesitan de algún tipo de proceso antes de ser comercializados? ¿En qué consiste ese proceso?
23. ¿Cómo considera que es el estado de la infraestructura, como instalaciones o maquinaria necesaria para dicho procesamiento?
24. ¿Cómo considera el estado de los medios para transportar el producto del bosque al lugar de venta? (Ej. Carreteras, caminos, vehículos)
25. ¿Qué tan intensa es la mano de obra requerida para el aprovechamiento y procesamiento de los productos? ¿Cuál de los productos requiere una mano de obra más intensa?

Datos del entrevistado:
Nombre:
Sexo: F/M
Lugar de trabajo:

Appendix 4. Community members survey questionnaire

1. ¿A qué se dedica?
2. ¿Ha trabajado o tiene experiencia con alguno de estos frutos?

Aspectos ecológicos

3. ¿Qué método se usa para aprovechar los productos?
4. ¿En qué época del año se aprovechan?
5. ¿Hay algún criterio para seleccionar a las palmeras que se van a aprovechar?
6. ¿Qué cantidad se aprovecha aproximadamente por día?
7. ¿De la cantidad de fruto que hay disponible en el bosque para ser recolectado, cuanto cree que realmente se recolecta aproximadamente?
8. ¿Considera que la cantidad de frutos en el bosque en los últimos 20 años ha disminuido, se ha mantenido o ha aumentado?
9. Si ha disminuido o aumentado:

¿A qué cree que se debe el cambio?

10. ¿Hay algún otro uso que se le dé a la especie que afecte la producción de frutos? (ej. palmito o madera)

Aspectos socioeconómicos

11. ¿Qué tan importante es el consumo de estos frutos en su alimentación?

Asaí:

Se consume constantemente ☐ Se consume a veces ☐

Se consume muy poco ☐ No se consume ☐

Majo:

Se consume constantemente ☐ Se consume a veces ☐

Se consume muy poco ☐ No se consume ☐

Motacú:

Se consume constantemente ☐ Se consume a veces ☐

Se consume muy poco ☐ No se consume ☐

Palma real:

Se consume constantemente ☐ Se consume a veces ☐

Se consume muy poco ☐ No se consume ☐

12. ¿Qué tan importante es el ingreso que recibe trabajando con estos frutos para su ingreso familiar?

Asaí:

Muy importante☐ Importante☐ Poco importante☐

No es importante☐

Majo:

Muy importante☐ Importante☐ Poco importante☐

No es importante☐

Motacú:

Muy importante☐ Importante☐ Poco importante☐

No es importante☐

Palma real:

Muy importante☐ Importante☐ Poco importante☐

No es importante☐

Appendix 5. Scoring table

See Table 6.

Table 6 Scoring table per indicator

Criteria and indicators	Indicators scoring scale		
	1	2	3
Ecological			
Abundance	0–5 palms/ha in average	>5–15 palms/ha in average	>15 palms/ha in average
Relative estimated extraction	High estimates in the majority of responses and in data if available	Medium estimates in the majority of responses and in data if available	Low estimates in the majority of responses and in data if available
Harvesting methods impact	Several reports of harvesting methods with negative impacts on the plant	Some reports of harvesting methods with negative impacts on the plant	Only harvesting methods without negative impacts on the plant reported
Harvesting level of difficulty	Difficult harvesting	Medium harvesting	Easy harvesting
Availability trend	Decreased	Stable or not defined	Increased
Competitive use	Competitive uses reported	–	No competitive uses reported
Socio-economic			
Income generation	No income generated	Average generated income lower than the poverty line	Average generated income higher than the poverty line
Importance for household´s economy	Not or little important for most of the respondents	Important for most of the respondents	Very important for most of the respondents
Consumption in households	Not or very little consumed for most of the respondents	Sometimes consumed for most of the respondents	Constantly consumed for most of the respondents
Institutional support and policy			
Policies and regulations	Policies and regulations create conditions that hinder NTFPs commercialization	Policies and regulations create conditions that promote NTFPs commercialization but with limitations	Policies and regulations create conditions that promote NTFPs commercialization
Technical support for harvesting	No technical support for harvesting	Some technical support for harvesting reported	Specialized harvesting technical support
Technical support for processing	No technical support for processing	Some technical support for processing reported	Specialized processing technical support
Financial instruments	No financial support instruments identified	Financial support only with material capital	Financial support with material capital and other financial instruments

Table 6 (continued)

Criteria and indicators	Indicators scoring scale		
	1	2	3
Organizational support	No support for the organization of associations provided	–	Support for the organization of associations provided
Market and value chain			
Local demand	High local demand	Medium demand	Low demand
International market	No consolidated international market	Potential international market -	Existence of an international market
Producer's associations	No producers' associations	The product can be included in producers' associations for Açaí	Existence of specialized producers' associations
Value chain	No value chain identified	Value chain with deficient connection	Value chain well connected
Road conditions	Bad road conditions	–	Good road conditions
Infrastructure	No infrastructure	Infrastructure with deficiencies	Infrastructure in good conditions
Processing level of difficulty	Very difficult or unknown processing methods	Known processing methods with difficulties	Processing methods without difficulties

Appendix 6. Institutions that provide technical support

See Tables 7 and 8.

Table 7 Institutions and programs providing management technical support

Group of respondents	Institution/program mentioned	
	Açaí and Majo	Palma real
Key informants ($n=9$)	-_**NGOs:** CIPCA, WWF, ACEAA, IPHAE and Herencia -_**Governmental institutions**: departmental, local, and municipal government, Ministry of Productive Development, Ministry of Rural and Land Development, and the Platform PICFA - **Governmental programs:** *Programa de inclusión Económica para Familias y Comunidades Rural* (ACCESO), Empoderar	**NGOs:** CIPCA, ACEAA
Community members ($n=10$)	-_**NGOs**: WWF, ACEAA, FAUTAPO, -_**Governmental programs:** ACCESO and Empoderar -_**Private enterprise**: Acailandia	**NGO:** ACEAA

Table 8 Institutions and programs providing processing technical support

Group of respondents	Institution/program mentioned	
	Açaí and Majo	Palma real
Key informants ($n=9$)	- *NGOs:* CIPCA, WWF, FAO, ACEAA - *Governmental institutions*: PICFA, IBNORCA	*NGO:* WWF
Community members ($n=10$)	- *NGOs*: WWF, ACEAA, FAUTAPO, INIAF - *Governmental institutions or programs:* SENASAG, - *Governmental programs:* ACCESO and Empoderar - *Private enterprise*: Acailandia, Ventana amazónica	*NGO:* ACEAA

Appendix 7. SMART analysis

See Table 9.

Table 9 SMART analysis

Criteria	Indicators	Weight	Açaí		Majo		Motacu		Palma real	
			Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value
Ecological	Abundance	0.04	3	0.13	2	0.08	1	0.04	1	0.04
	Estimated extraction from harvesting potential	0.04	3	0.13	3	0.13	3	0.13	3	0.13
	Harvesting methods impact	0.04	3	0.13	2	0.08	3	0.13	3	0.13
	Harvesting level of difficulty	0.04	2	0.08	2	0.08	3	0.13	1	0.04
	Resource availability trend	0.04	2	0.08	2	0.08	2	0.08	2	0.08
	Competitive use	0.04	3	0.13	3	0.13	3	0.13	3	0.13
	Sum	**0.25**	**16**	**0.67**	**14**	**0.58**	**15**	**0.63**	**13**	**0.54**
Socio-economic	Income generation	0.08	3	0.25	3	0.25	1	0.08	1	0.08
	Importance in household´s economy	0.08	2	0.17	2	0.17	1	0.08	1	0.08
	Consumption in households	0.08	3	0.25	3	0.25	1	0.08	1	0.08
	Sum	**0.25**	**8**	**0.67**	**8**	**0.67**	**3**	**0.25**	**3**	**0.25**

Table 9 (continued)

Criteria	Indicators	Weight	Açaí		Majo		Motacu		Palma real	
			Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value
Institutional support and policy	Policies and regulations	0.05	2	0.10	2	0.10	2	0.10	2	0.10
	Technical support for harvesting	0.05	3	0.15	2	0.10	1	0.05	2	0.10
	Technical support for processing	0.05	3	0.15	2	0.10	1	0.05	2	0.10
	Financial support	0.05	2	0.10	2	0.10	1	0.05	1	0.05
	Support for organization	0.05	3	0.15	3	0.15	1	0.05	1	0.05
	Sum	**0.25**	**13**	**0.65**	**11**	**0.55**	**6**	**0.30**	**8**	**0.40**

Table 9 (continued)

Criteria	Indicators	Weight	Açaí		Majo		Motacu		Palma real	
			Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value	Indicator value	Utility value
Market and value chain	Local demand trend	0.04	3	0.11	2	0.07	1	0.04	1	0.04
	International market	0.04	3	0.11	1	0.04	1	0.04	2	0.07
	Existence of producer's associations	0.04	3	0.11	2	0.07	1	0.04	1	0.04
	Value chain connection	0.04	2	0.07	2	0.07	1	0.04	1	0.04
	Infrastructure	0.04	2	0.07	2	0.07	1	0.04	1	0.04
	Roads conditions	0.04	1	0.04	1	0.04	1	0.04	1	0.04
	Processing level of difficulty	0.04	3	0.11	2	0.07	1	0.04	1	0.04
	Sum	**0.25**	**17**	**0.61**	**12**	**0.43**	**7**	**0.25**	**8**	**0.29**
Final value				2.59		2.23		1.43		1.48

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Declarations

Conflict of interest The authors declare no conflict of interest.

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