Landscape and Urban Planning xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Research Paper

Mapping the socio-ecology of Non Timber Forest Products (NTFP) extraction in the Brazilian Amazon: The case of açaí (*Euterpe precatoria* Mart) in Acre

E. Lopes[a], B. Soares-Filho[a], F. Souza[b], R. Rajão[c], F. Merry[d], S. Carvalho Ribeiro[a],*

[a] *Universidade Federal de Minas Gerais (UFMG), Centro de Sensoriamento Remoto, Programa Pós Graduação em Análise e Modelagem Sistemas Ambientais, Av. Antônio Carlos, CEP 31270-900, 6627 Belo Horizonte, MG, Brazil*
[b] *World Wildlife Fund WWF, Acre. Rua Hugo Carneiro, 811, Rio Branco, AC, Brazil*
[c] *Universidade Federal de Minas Gerais UFMG, Dep. Engenharia de Produção, Laboratório de Gestão de Serviços Ambientais, Av. Antônio Carlos, CEP 31270-900, 6627 Belo Horizonte, MG, Brazil*
[d] *Conservation Strategy Fund, Washington DC, United States*

ARTICLE INFO

Keywords:
Sustainable use reserves
Extractivist landscapes
Sustainable livelihoods

ABSTRACT

Non-Timber Forest Products (NTFPs) contribute to the livelihoods of more than 6 million households in the Brazilian Amazon. Of the three most important NTFPs in the Brazilian Amazon – rubber, Brazil nut, and açaí – the latter is the least known, but the one with the most potential and fastest growing markets. Here we map the socioecology of açaí extractive systems in the Western Amazon state of Acre, Brazil. We interviewed 49 extractivists in settlements and in the emblematic Extractivist Reserve Chico Mendes (RCM) to model ecology (tree density, productivity) and production chain of açaí (prices, costs and net revenues) for an area of 164,000 km^2. We estimate a potential annual production of 850 thousand tons for the entire Acre State, which could generate net revenues of US$ 71 million/yr. This is well above the average production of 136 thousand tonnes (over the last 25 years). Net revenues average US$ 57 $ha^{-1}.yr^{-1}$, with açaí contributing, on average, to 17% of the annual household income. In two case studies, we found a diversity of livelihoods comprising agriculture, NTFP collection, and livestock rearing that were grouped in two broad types of extractivist livelihoods: "old" and "new" settlers. Our results suggest that old settlers tend to focus on cattle ranching as their main economic activity, even inside extractive reserves (RESEX). The shift from extractivist activities to cattle ranching undermines the conservation role of this type of protected area. We conclude that without significant financial support in the forms of subsidies and other development programs NTFPs will continue to struggle against the economics of cattle ranching.

1. Introduction

Non Timber Forest Products (NTFPs) have been an essential component of traditional livelihoods in the Brazilian Amazon and still contribute to the economic, social and cultural livelihoods of 6 million households in the Brazilian Amazon (Gomes, Vadjunec, & Perz, 2012; Hecht, 2013). However, there is increasing evidence that traditional extractivist activities in the region, based solely on rubber and Brazil nut, are unlikely to generate adequate levels of income to support households (Hall, 2004; Jaramillo-Giraldo, Soares Filho, Carvalho Ribeiro, & Gonçalves, 2017). And despite their provision of ecosystem services and associated sociocultural values, NTFPs tend to be undervalued in regional markets, are regarded as economically marginal, and face stiff competition with other production options (Albers & Robinson, 2013; Gomes et al., 2012; Schroth, Moraes, & Mota, 2004; Shone & Caviglia-Harris, 2006; Athias & Pinto, 2008; Bayma, Wadt, Sá, Balzon, & Sousa, 2008; Homma, 2012; May, Soares-Filho, & Strand, 2013; Nogueira, de Santana, & Garcia, 2013; Turini, 2014).

As a result, initiatives that seek to enhance net revenue in extractivist landscapes continue to face difficult challenges (Carvalho Ribeiro et al., 2018). In this regard, a set of NTFPs were recently awarded formal recognition as part of the national socio-biodiversity heritage of Brazil (MMA, 2009) and various governments and public research institutes are pushing the domestication of NTFPs (Homma, 2012; Nogueira, Figueirêdo, & Müller, 2005). Efforts devoted to enhancing incomes from NTFPs, however, are pitted against the enduring appeal of cattle ranching (Bowman, Nepstad, & Rodrigues, 2012; Hoelle, 2015). Cattle ranching generates higher revenues and is attractively marketed through cowboy imagery, including country music and notions of social status and power (Hoelle, 2015; Duchelle &

---

* Corresponding author.
E-mail address: soniacarvalhoribeiro@igc.cart.ufmg.br (S. Carvalho Ribeiro).

https://doi.org/10.1016/j.landurbplan.2018.08.025
Received 4 January 2018; Received in revised form 30 July 2018; Accepted 12 August 2018

Please cite this article as: Lopes, E., Landscape and Urban Planning, https://doi.org/10.1016/j.landurbplan.2018.08.025

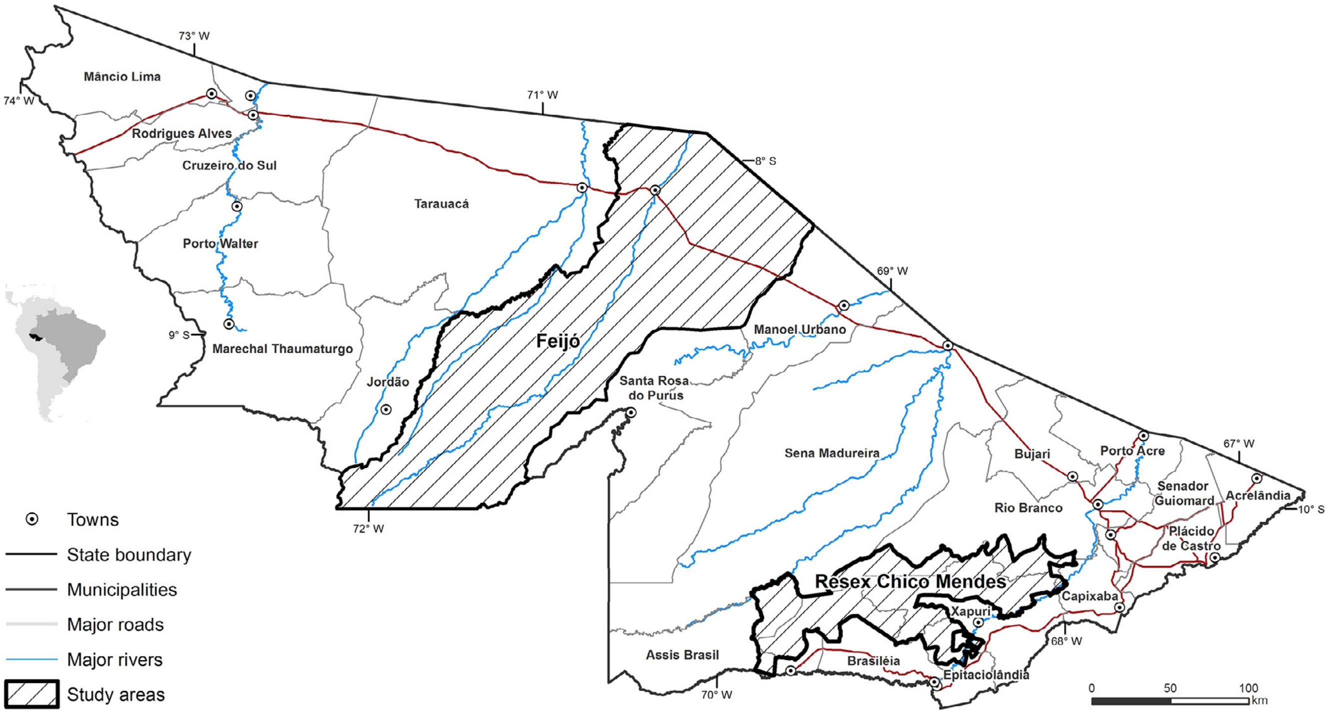

Fig. 1. Case study area.

Wunder, 2014). Indeed, despite initiatives in Brazil aimed at payments for ecosystem services (PES), such as the *bolsa floresta* or the promotion of socio-biodiversity chains (MMA, 2009), revenues from extractivist activities of NTFPs are often eclipsed either by products originating in intensive cultivation elsewhere (e.g. rubber plantations in Southeast Asia) or by other higher income activities like cattle grazing.

One emerging exception is possibly açaí, noted for its nutritional food qualities, which has become the most collected NTFP in Brazil, delivering the highest revenues from NTFP in the Brazilian Amazon (IBGE, 2017). Açaí has the potential to complement the revenues from other NTFPs with lower market values, such as rubber, thereby enhancing extractivist livelihoods (Homma et al., 2006). Açaí ranks as a hyper-dominant palm tree and is highly productive when compared to other NTFPs (ter Steege et al., 2013). Furthermore, unlike many tropical forest trees, açaí palm trees grow in higher density groves along accessible rivers, thus reducing collection and transportation costs.

Traditionally, the Amazonians who engage in extractive activities do so largely within sustainable use reserves (RESEX), indigenous lands, settlements projects, or in other state-owned land (i.e. undesignated land). In these areas extractivist activities of NTFP are reconciled with a broad set of agricultural activities. Indeed, forest livelihoods in the Amazon share diversified economic strategies, including off-farm labour, labour lending and natural resource harvest where available. In addition, an increasing number of private landowners are also adopting extractivist and related agroforestry systems (SAFs). These include clones of rubber more resistant to disease, and more productive açaí palm trees (Oliveira, Carvalho, Nascimento, & Müller, 2002).

The valuation of NTFPs within these different extractive systems has attracted the attention of many researchers. Even though a wide variation in estimates can be found, studies consistently show values between US\$ 3 ha^{-1} year^{-1} and US\$ 16 $\text{ha}^{-1}.\text{yr}^{-1}$ for NTFPs in sites in Peru (Godoy, Lubowski, & Markandya, 1993; Nunes et al., 2012). The PROFOR project (Siikamäki, Santiago-Ávila, & Vail, 2015), using a global meta-analysis of case studies, estimates average revenues for NTFP in Brazil as of US\$ 6.5 $\text{ha}^{-1}.\text{yr}^{-1}$ (Siikamäki et al., 2015). However, there is a great diversity of collection/extraction of NTFPs in the Amazon (AFI, 2009; Sousa &Euler, 2009). These differences occur across geopolitical boundaries (states and municipalities), types of infrastructure (paved/unpaved roads, existence/absence of storage collection points), market circuits (cooperative or intermediary), processing plants, and type of collectors, such as *extrativista*, in sustainable use reserves, or *assentados* in settlements (Cavalcante, Franchi, Lopes, & Mota, 2011; Nunes & Angelis, 2008). In this respect, Carvalho Ribeiro et al. (2018) provide the only attempt to date to geographically differentiate net revenues of a set of NTFPs across the entire Brazilian Amazon.

But despite decades of public investment and a rich body of local case studies, little is yet known about açaí harvest at the landscape level in the Brazilian Amazon, including yields distribution, peculiarities of collection processes, variation of costs of collection, and prices paid to producers, hence the resulting distribution of net revenues. To our knowledge, there is no study addressing the spatial distribution of annual revenues for native açaí. In order to fill in this gap, this paper addresses the following questions:

1. What are the socioecological characteristics of the extractivist landscapes in Acre, Brazil?
2. How could açaí (*Euterpe precatoria* Mart.) contribute to socio-ecological strategies of family forests in Acre, Brazil?
3. Does Acre have a significant future in açaí production?
4. What policy adjustments should the government make to encourage açaí production?

2. Case study

Acre is located in the western part of the Brazilian Amazon, occupying an area of 164 thousand km^2 (Acre, 2006) of which 146 thousand in covered in tropical rainforests (INPE, 2015). Acre's population is 733,000 people, of whom 27% live in rural areas (IBGE, 2010). Of families living in forest areas, 48% live in formal settlement projects established by INCRA (Instituto Nacional de Colonização e Reforma Agrária), 16% live in RESEXs and 6% in indigenous lands. Ten percent of Acre households practice riverine livelihoods (*ribeirinhos*), while 20% own private lands or live mainly off of farming jobs (Acre, 2014).

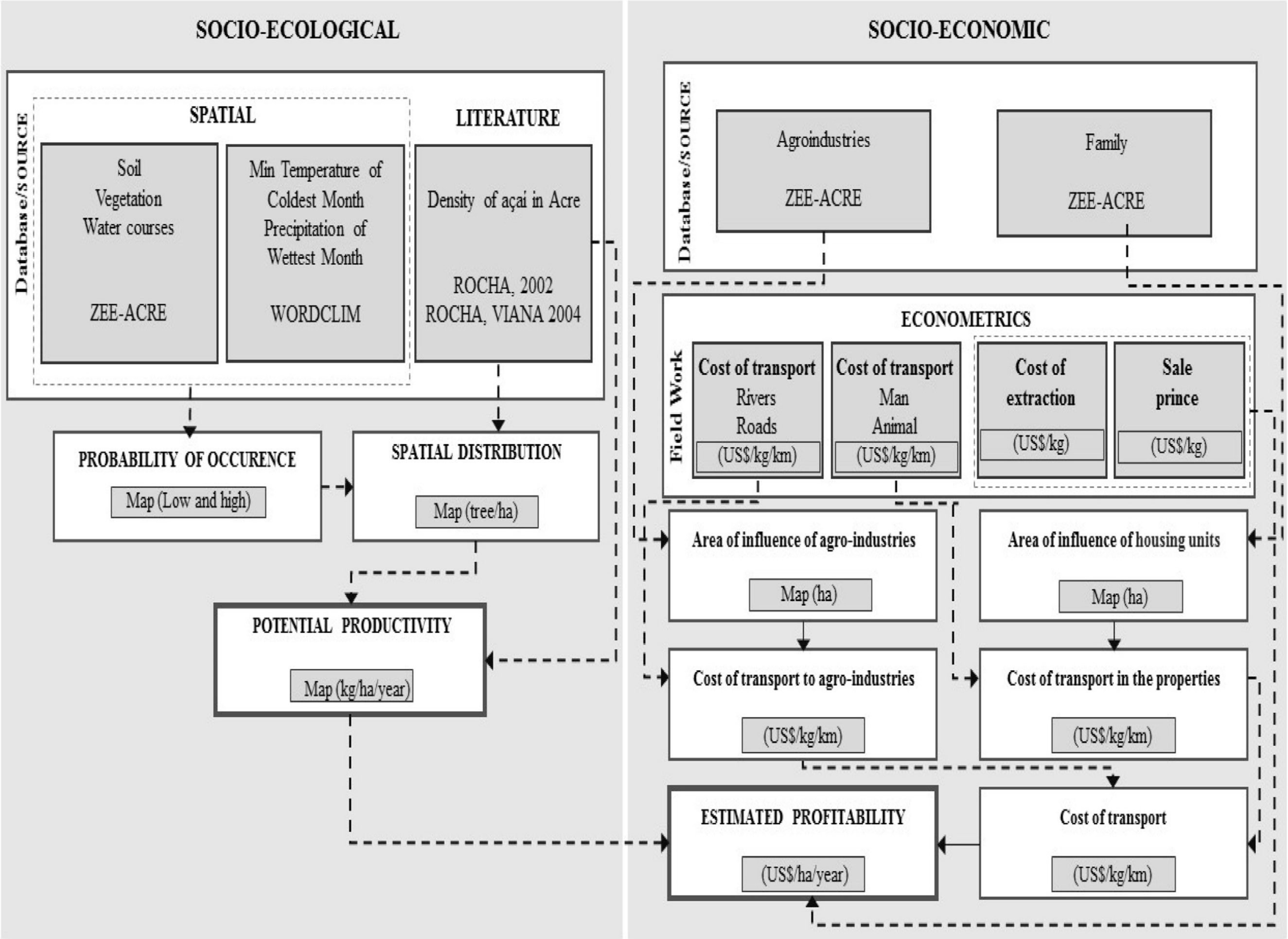

Fig. 2. Conceptual model.

In the State of Acre (Fig. 1), extractivist activities have been traditionally based on Brazil nut harvest (with an average annual collection between 1994 and 2015 of 9000 tons, and total annual revenues averaging about US$ 8 million), and rubber (with average annual production of 2000 tons and total annual revenues of US$ 5 million) (IBGE, 2017). Brazil nut and rubber in Acre have well-established production chains involving cooperatives that receive support from various government agencies and non-governmental associations.

Although there is no tradition of açaí harvest in the state of Acre, the interest in açaí has recently increased due to the growing national and international demands for the fruit. In fact, since 2013, açaí production in Acre has overtaken rubber. Açaí has to be pre-processed individually by each extractivist. Each household pre-processes the fruit into pulp and delivers it to the nearest cooperative or agro-industry. The two most common species of açaí palm trees in the Brazilian Amazon are *Euterpe oleraceae* Mart, found mostly in the eastern Amazon, and *Euterpe precatoria* Mart, found in the central and western part of the region. They are easily differentiated because *E. oleracea* has a multi stem clump, while *E. precatoria* has only one stem (Kahn, 1991; Moscoso, Albernaz, & Salomão, 2013; Vedel-Sørensen, Tovaranonte, Bøcher, Balslev, & Barfod, 2013; Weinstein & Moegenburg, 2004). The largest producer of açaí in the Brazilian Amazon is the state of Pará (78%), followed by Amazonas (13%) and Maranhão (6%). The states of Acre and Rondônia contribute only with 1% each to total açaí production in Brazil (IBGE, 2017).

In recognition of the growing market opportunity the government of Acre launched PROAÇAÍ programme (Acre, 2014) to encourage açaí production, through harvest in native forests and domestication in plantations. With an investment of US$ 14 million, of which 9% is aimed at mapping the potential of açaí, 72% to implementing agroforestry systems, 3% to training of producers, and 16% to strengthening agro-industries, the goal of the PROAÇAÍ programme is to give a boost on extractivist livelihoods. Within this programme, the Acre government has established three priority areas for açaí production: Feijó and Tarauacá, Sena Madureira, and the Chico Medes Extractive Reserve (RCM) (Fig. 1).

We selected two of the PROAÇAÍ priority areas for our case study: Feijó and RESEX Chico Mendes (RCM). The first, Feijó, because this municipality produces 22% of all açaí in Acre; and the second, the RESEX Chico Mendes, because it was the first RESEX to be created in Brazil and is considered a symbol of extractivist livelihoods, and there have been frequent policy and investment initiatives carried out there to promote the socioeconomic development of forests (Acre, 2014).

3. Methods

3.1. Data collection and descriptive statistics

To collect the necessary data to build the models, we contacted five governmental and non-governmental institutions (See the full list of organizations in the Supplementary Material Table S1) and organized one expert workshop in Acre. In this workshop, we collected data on the spatial distribution of açaí, as well as records of productivity (per stem and tree). We also discussed the factors affecting economic returns, such as prices and costs of collection. In addition, we conducted semi-structured interviews with 49 families living in the Chico Mendes

RESEX (n = 26) and in the Feijó settlement (n = 23 in Parque das Ciganas, located at km 62 on BR-364, *Ramal* Maravilha, and the community of the Seringal) (Fig. 1). The interviews gathered information on the description and types of extractivist livelihoods, including details such as family composition, household activities and the characteristics of extractive system (Table S2). Data collected through focus groups with experts and semi-structured interviews with extractivists were used to parametrize the spatially explicit model. We then grouped 27 variables from the questionnaire into a Principal Component Analysis (PCA) and Cluster Analysis (CA) for characterizing different types of extractivist livelihoods in Acre. Input variables were transformed (Varimax rotation) into three components explaining 75% of the variance. We used the three components as input for a clustering analysis (k-means).

3.2. Spatial modelling

Using the data we collected and based on secondary data (Table S3), we developed spatially explicit models for açaí production. The first model (Fig. 2) estimates the ecology of the native açaí harvesting system through three major steps: (1) Favourability of palm tree occurrence (0–1), (2) Tree density (number of trees per ha), and (3) Yields (kilograms of açaí collected per ha). Our sample for this component was of 4850 trees but it was highly clustered, which means it has only a small geographic representation (Figs. S1, S3 and S4), and, unfortunately, there is a lack of açaí data points in biodiversity databases (e.g. specieslink had only 28 açaí trees, some of which were not georeferenced). Thus, we developed our ecological model by using a multicriteria analysis based on expert knowledge.

The second model component is an economic analysis that calculates net annual revenue per hectare (Fig. 2). The model spatial resolution is of 4 ha (200 × 200 m). Both components were developed using Dinamica EGO platform (Soares-Filho, Rodrigues, & Follador, 2013). Our model focuses on native açaí palm trees only, so açaí plantations are excluded. Our spatial dataset (Table S2) comprises vegetation, soils, watercourses, minimum temperature of coldest month, and minimum rainfall of wettest month as input for a multi-criteria analysis aimed at identifying favourable environments for the occurrence of açaí in Acre. Multi-Criteria Decision Analysis (MCDA) is based on Multi-Attribute Value Theory (Acosta et al., 2016) so that:

$$V(X_1,\cdots,X_n) = \sum_{i=1}^{n} W_i V_I(X_i) \tag{1}$$

where *Wi* are weights and *Vi* are scores for variable attributes.

To each variable category is assigned a score from 0 to 10 according to its association with açaí occurrence (Table S4). Açaí palm trees occur in riparian forests, whereas *Campinaranas* and sub-montane forests are not favourable. Açaí palm trees occur on eutrophic and dystrophic soils and are the most frequent on alluvial hydromorphic soils (Kahn, 1991). In general, native açaí palm trees are more common where annual rainfall ranges from 2000 to 2700 mm with average temperatures around 28 °C. In addition, açaí palm trees grow well in regions with mean monthly temperatures above 18 °C and abundant solar radiation (Machado, 2013).

In addition to variables listed in Table S4, we derived the Topographic Wetness Index (TWI) from topographic data obtained by the Shuttle Radar Topography Mission (SRTM). The TWI index indicates the water content in the soil divided into hydromorphic and no hydromorphic soils (Evaristo, Silveira, Mantovani, Sirtoli, & Oka-Friori, 2008). TWI is defined as a function of slope and the water flux measured by the area of contribution, as follows:

$$\mathrm{TWI} = \ln(\mathrm{As}/\tan(\beta)) \tag{2}$$

The Topographic Wetness Index (TWI) is calculated by using the natural logarithm of the ratio between *As*, which is the area of contribution multiplied by the size of the cell grid in square meters and β represents the slope in radians. TWI was classified into four categories, with the wettest areas scoring highest. The TWI map was then classified into three categories: high favourability ≥ 0.8, intermediate favourability ≥ 0.5 and < 0.8, and low favourability < 0.5.

We discussed the weights for each variable and their scores (Table S5) with five experts on açaí in Acre at workshop conducted by World Wildlife Fund (WWF). Finally, we removed the deforested areas from the analysis using PRODES (INPE, 2015).

From the MCA, we developed a tree density map (trees.ha^{-1}) by rescaling the favourability values to observed tree abundance. There are different estimates for tree density of *E. precatoria* Mart. A global estimate for the entire Amazon points out to a maximum abundance of 168 palm.ha^{-1} (ter Steege et al., 2013). However, in Acre alone there are records of tree densities up to 280 palms.ha^{-1} (Acre, 2006). In the forests of *"várzea"* (floodplains), densities range from 23 to 118 palms.ha^{-1}, while in *terra firme (non-flooded land)*, tree density ranges from 10 to 45 palms.ha^{-1}. The largest and smallest tree densities (from 0.2 to 280 palms.ha^{-1}) are observed in the Baixo Acre region. In Alto Acre, densities range from 0.8 to 75 palms.ha^{-1}, while in Tarauacá and Envira, there are records from 46 to 56 palms.ha^{-1} (Acre, 2006; Rocha, 2002, 2004; Rocha & Viana, 2004).

According to literature and to our interviews, açaí palm tree (*E. precatoria* Mart.) produces, on average, 4.5 kg per bunch (Bayma et al., 2008). This average value is of 7.5 kg.palm^{-1} in *várzea* forests and 6.2 kg.palm^{-1} in the areas of *terra firme* (Rocha & Viana, 2004). We also gathered costs of açaí extraction. The labour cost, which is part of the cost of extraction, consists of two different types: specialized extractivist labour for collecting açaí (e.g. to climb the tree, U$$ 0.10 kg^{-1} to US$ 0.20 kg^{-1}) and non-specialized labour (e.g. for all other agricultural activities, US$ 0.041 kg^{-1} to US$ 0.11 kg^{-1}).

The collection of the açaí fruits begins in the morning. On average, skilled extractivists climb 10–20 açaí palm trees per day. According to our interviewees, an açaí palm tree can produce, on average, 19 ± 16 kg.yr^{-1}.palm^{-1} (in 1–4 bunches). However, roughly 50% of the palm trees are unsuitable for collection because either they do not have a straight stem for climbing, or they are not in a productive stage. In the ones where climbing is possible along with appropriate maturation of the fruits, the fruits are removed from the bunches and stored in a bag with a capacity of 50 kg. They are subsequently carried to the household facility where they are pre-processed.

Açaí is traded in containers called *"lata"* (buckets) *of* 14 kg each. During the period of our interviews (2016) one *lata* was traded between US$ 5.47 and US$ 8.88 (Table S6). Out of the harvest period the price is higher, ranging from US$ 8.59 to 11.46 (Table S7). Our results show that, on average, one kilo of the fruits is traded for US$ 0.55 by the Companhia Nacional do Abastecimento (Conab, 2016).

We estimate the cost of açai extraction by applying local labour opportunity costs based on the daily value of specialized work to collect the fruits (mean = US$ 0.6 per kg, from US$ 0.3 to 2, as of 2016) multiplied by 72 days (harvest of 3 months with six work weekdays). To this values we added the annual depreciation cost of equipment (US$ 20), divided by the kilograms produced. Since site productivity is of paramount importance for cost-effectiveness of collecting açaí, we consider that in areas where productivity (kg.ha^{-1}) is above the mean, the costs of collecting 1 kg of açaí is considerably lower compared to the costs of collecting 1 kg of açaí in areas of low productivity.

Modelling of transport costs consists of two steps (Fig. S2). First we calculate the area of influence of each community by estimating transport costs from collecting sites in the forest to the nearest extractivist household place. In a second step, we use the agro-industry locations to calculate the transport cost from household places to the nearest agro-industry or cooperative. Hence, the model calculates an accumulated cost surface from point of collection in the forest to the household locales and then to the agro-industry (final destination), according to the type of road/waterway and mode of transport (boat or car). In the model, we consider that açaí is only processed in the agroindustry. We also assume that transportation always takes the least cost pathway between source and destination using a mix of transport modes (boat, car, man plus ox) and associated costs. The potential net revenue of açaí extraction (US$.ha^{-1} yr^{-1}) for a location (x,y) in the native forest is calculated as follows:

$$NET\ Revenue_{x,y} = P_p * (P_s - (C_{ex} + C_{trans})) \tag{3}$$

where P_p is the potential yield, P_s sales price, C_{ex} extraction cost, and C_{trans} the transport cost.

4. Results

4.1. Socioecology of açaí extractivist livelihoods

The majority of families in the region comprise five people. Those families have lived in the area for over 20 years in the case of RCM and 11 years in the case of the Feijó settlements. The extractivist livelihoods in Acre rely heavily on family labour. The men and children collect açaí fruits, and women primarily process the fruit. Average revenue for these households is US$ 57 ha^{-1} yr^{-1}, of which açaí collection contributes with 17%. Activities undertaken by extractivists in the State of Acre are divided into four major types: agriculture, livestock, animal husbandry, and collection of NFTPs (Table 1).

Families in the RCM and settlements together produce about 207 ton yr^{-1} of products derived from agriculture, livestock, animal husbandry (mainly poultry), and NFTPs generating a total annual gross revenue of US$ 86,000. As a whole, settlers in Feijó produce a larger number of products (12) than those of the extractivists in RCM (6) (Tables 1 and S8). Even though families collect many NTFPs for their own consumption in the RCM, only three products are commercialized: Brazil nut, rubber and açaí. These three products account for around 30% of annual production and 17% of incomes in both Feijó settlements and in the RCM (Table 1). In the RCM, the main NTFP is Brazil nut, which accounts for 96% of the harvest production in tonnes per year (ton yr^{-1}) and 90% of the income, a total of US$ 16,000 yr^{-1}, which is approximately US$ 602 yr^{-1} family^{-1}. Rubber, the emblematic product of the RCM, corresponds to only 2% (0.6 ton yr^{-1}) of production and 8%, US$ 1500 yr^{-1} of the total income. Açaí harvest is carried out by specialized labour, mainly contracted by the cooperative but occasionally by the extractivist. The harvest represents only 2% (0.5 ton yr^{-1} and 19 ± 82 kg yr^{-1} family^{-1}) of production, generating an income of US$ 270 yr^{-1} (US$ 10 ± 45 yr^{-1} family^{-1}).

In the Feijó settlements, the only NTFP collected is açaí, which contributes with 32% of the annual household production (33 ton.yr^{-1} and 1 ± 2 ton yr^{-1} family^{-1}) and to 17% of annual income (US$ 14 tousand.yr^{-1}, 0.6 thousand yr^{-1} family^{-1}). Settlers collect 22 ton yr^{-1} (average 0.9 ± 2 ton yr^{-1} family^{-1}) of fruit and, 11 tonyr^{-1} (average 0.5 ± 1 ton yr^{-1}) of açaí pulp (Tables 2, S8 and S9). In both RCM and Feijó settlements, livestock rearing is the activity that represents the largest share of household income. Despite settles being often referred to as "livestock kings", our results show that the larger annual production of cattle occurs in the RCM.

Based on the PCA and cluster analysis, we classified our interviewees into two household groups: "old" and "new" settlers (Table S10). The main differences between the groups are the volume produced of agroforestry products, annual gross income, sojourn time in the property, size of the property, and areas of capoeira (secondary regrowth). The value paid per kilo of açaí also differs between the two groups. The group of "new" settlers comprises 40 extractivists and includes all interviewees from the Feijó settlements along with some extractivists from the RCM. The average holding of this group is smaller than that of "old" settlers, on average 97 ± 165 ha; the average area of *capoeira* and pasture is 3 ha. The group of "old" settlers is composed by 9 households, all of them living in the RCM. Those households have bigger estates, with holdings averaging 260 ± 263 ha. This group's household income comes mainly from livestock. Our results also show that the 9 households of "old settlers", all well established in the RESEX, have been increasing their negotiating power and thus are receiving higher prices for NTFPs. However, these consolidated extractivists seem to be investing their revenues from NTFP in cattle grazing. Cattle rearing is viewed by extractivists as a safe way to invest their money and build status that in turn results into leverage (Hoelle, 2015, Duchelle & Wunder, 2014).

Table 1
Representativeness of activities in RESEX and Settlements.

	RCM		Settlements	
	Production	Income	Production	Income
Agriculture	40%	13%	45%	21%
Livestock	25%	61%	21%	56%
Animal husbandry	5%	9%	2%	6%
NTFP	30%	17%	32%	17%

5. Spatial modelling of productivity

Much of the territory of Acre is highly favourable for açaí palm trees, mainly in the west (Fig. 3). The areas indicated as priorities by the government of Acre show indeed high favourability of occurrence. According to our estimates, palm tree density averages 37 ± 14 tree.ha^{-1} and are within the range of 11–118 tree.ha^{-1}. Our estimates point out that Acre holds the potential to produce 849 thousand tons.yr^{-1} of açaí, with yields averaging 252 ± 108 kg.ha^{-1}.yr^{-1} (mode = 173 kg.ha^{-1}.yr^{-1}) and varying between 68 and 885 kg.ha^{-1}.yr^{-1} (Fig. 3). Sustainable use reserves may produce 196 thousand tons.yr^{-1}, the highest potential production of açaí in Acre, with an average yield of 210 ± 97 kg.ha^{-1}.yr^{-1} (Table 3).

The price paid to extractivists varies greatly depending on the year and season. The average price of açaí was marketed at approximately US$ 0.20 kg^{-1} in 2016. For the same year, the transport costs of açaí in Acre ranged between US$ 0.001 kg^{-1}.km^{-1} (for boat) to US$ 0.004 kg^{-1}.km^{-1} (for man + ox within the forest). The cost of extraction açaí was between US$ 0.29 kg^{-1} to US$ 2.0 kg^{-1}, average of US$ 0.57 kg^{-1}. In total, the annual gross revenue from harvesting açaí in Acre may reach US$ 71 million.yr^{-1}, with mean net revenue of US$ 21 ± 11.ha^{-1}.yr^{-1} (maximum = US$ 83 ha^{-1}.yr^{-1}) (Fig. 3 and Table 4).

6. Discussion and conclusion

The role of NTFPs in enhancing local livelihoods in the Amazon and reducing deforestation has been the topic of a protracted debate. The consensus is that NTFPs can be a productive element of rural livelihoods, although not enough to trump revenues from traditional agriculture or ranching (Godoy et al., 1993, 2000; Hecht, 2013; Homma, 2008; Humphries et al., 2012; Myers, Clarkson, Reeves, & Clarkson, 2013; Peters, Gentry, & Mendelsohn, 1989). Acre is one of the States leading the push towards sustainability and is at the forefront of NTFPs production. In Acre, however, there is clear priority in both policy and research agendas for incentivizing the collection of NTFPs inside sustainable use reserves, despite the potential of settlement projects.

In this respect, our results show that while there are variations in extractive systems depending on the type of land management (e.g. RESEX *vs* settlements), the contribution of NTFPs to annual income of family forests is virtually the same (17%). Furthermore, our results show that açaí revenues are substantially higher than other estimates for NTFPs such as Brazil nut (Nunes et al., 2012) and rubber (Jaramillo-Giraldo et al., 2017). Our results broadly agree with other literature, including the estimates of net revenues of US$ 97 ha^{-1}.year^{-1} for a set

Table 2
Major characteristics of two groups.

	Old Settlers			New Settlers		
	Production (Tons/year)	Annual revenue (Thousand US$)	Annual revenue (%)	Production (Tons/year)	Annual revenue (Thousand US$)	Annual revenue (%)
Agriculture	5	1.5	20%	1	0.5	18%
Livestock	2	4.4	57%	0.7	1.6	60%
Animal husbandry	0.4	0.8	11%	0.08	0.2	6%
Non-timber	4	0.9	12%	0.8	0.4	16%

of three products (rubber, açaí and fish) for the case study of Guamá river in Brazil (Godoy et al., 1993). Nevertheless, the estimates from our study are well above those of US$ 6.5 for NTFPs in Brazil from PROFOR (Siikamäki et al., 2015).

According to our estimates, in total, açaí production in Acre may deliver US$ 71 million per year. This estimate is well above the current production of US$ 6 000 for the whole region. Our results thus suggest that even for locales with high extractivist rates, the quantity of açaí annually collected falls well below the biome's sustainable potential harvest. Our findings are also supported by other studies that report sustainable collection patterns in the extractivist landscapes in Brazilian Amazon (Scoles & Gribel, 2012, 2011, Jaramillo-Giraldo et al., 2017). It is worth mentioning that a sustainable development strategy should also include açaí plantations. In fact, agroforestry systems including Brazil nut and açaí may provide a sound strategy for the future. Nonetheless, we must not forget the role of native forests in providing the extractivist sociocultural identity as well as many ecosystem services and goods (Carvalho Ribeiro et al., 2018).

It is clear that extractivist livelihoods, in addition to the collection of NTFPs (for subsistence and trade), encompass activities such as agriculture, livestock rearing and animal husbandry. Indeed, our results suggest that the long-term established extractivists tend to transition into cattle ranching as their main economic activity, even inside sustainable use reserves. The shift from extractivist activities to ranching undermines the conservation role of this type of protected area, despite NFTPs being subsidized and nurtured by the Brazilian government, as the case of the socio-biodiversity program (MMA, 2009).

Table 3
Potential annual production in types of land designation.

Land designation	Thousand tons	Average (kg/ha/year)	Standard deviation (kg/ha/year)
Sustainable use reserves	196	210	97
Private	156	273	108
Indigenous lands	125	210	98
Discriminated area	115	273	118
Undesignated land	106	241	117
Integral protection	97	210	110
Settlements	55	273	120

In closing, we provide evidence that Acré native forests hold the potential to make sustainable açaí production and that there is a willingness of the local communities to harvest it despite Acre not being traditionally an açaí producer. This implies that there is a significant future for Açaí production in the region. We also note that the settlement communities depend on NTFPs to a similar extent as the communities within the RESEXs. In this respect, we recommend that financial support and incentive programs should focus on all rural

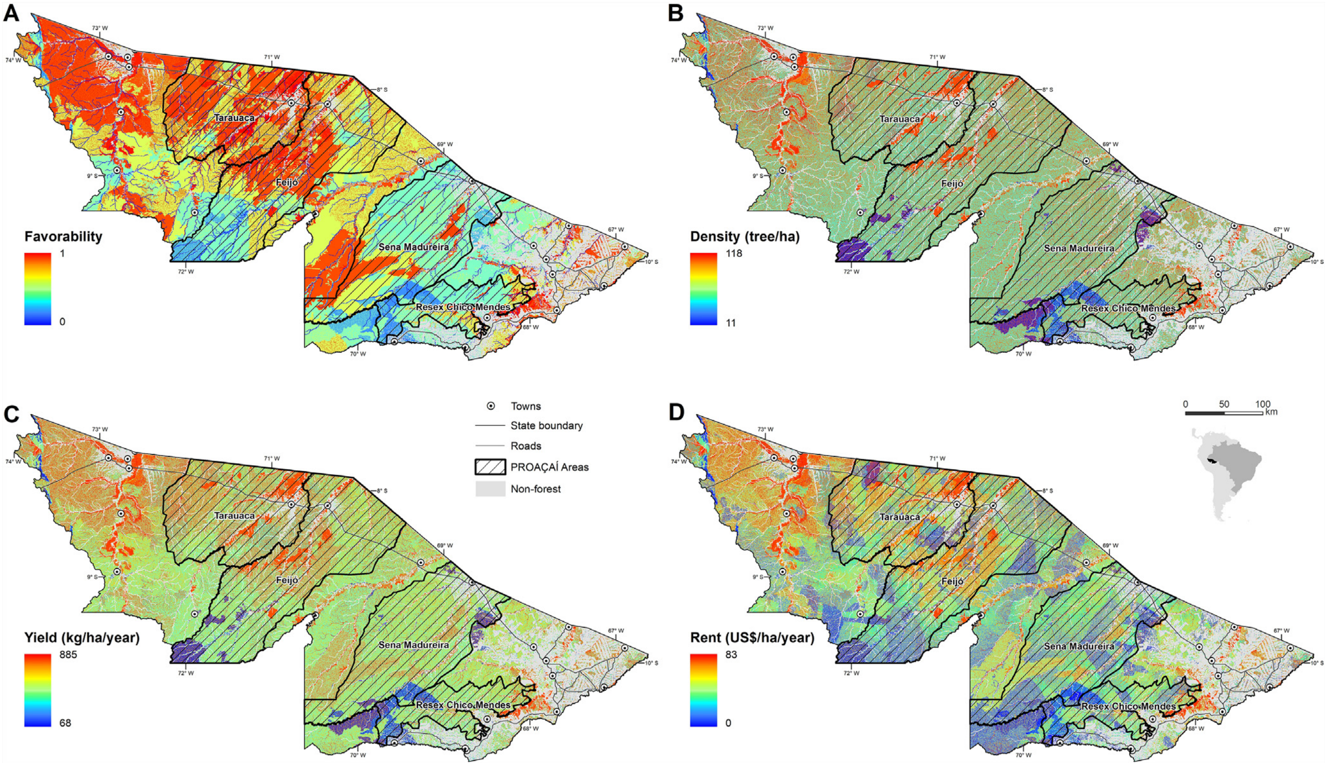

Fig. 3. Favourability of occurrence (A), tree density (B), yield (C) and rents (D).

Table 4
Revenues of açaí in types of land designation. Conversion factor was 3,36 (Reference year is 2015).

Land designation	Million (US $/year)	Average (US $/ha/year)	Standard deviation (US$/ha/year)
Sustainable use reserves	16	20	10
Private	13	22	11
Indigenous lands	10	19	10
Discriminated area	10	22	12
Undesignated land	9	33	18
Integral protection	8	22	11
Settlements	5	23	12

communities, as much as budgets will allow, and not solely on extractivists within the protected areas. Finally, without significant financial support in the forms of subsidies and other development programs NTFPs will continue to struggle against the economics of cattle ranching.

Acknowledgements

We are thankful to CAPES (Coordenação e Aperfeiçoamento de Nível Superior) and CNPQ (Conselho Nacional de Desenvolvimento Científico e Tecnológico) in Brazil for providing Master, Post-doctoral (300013/2015-9 Young Talent Scholarship – Science Without borders), and research scholarships. Funding to support this research was also provided by World Wildlife Fund, the Gordon and Betty Moore Foundation (2076) and World Bank (7172920). BSF also receives support from the Humboldt Foundation. We are also thankful to five anonymous reviewers for revising a previous version of this manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2018.08.025.

References

Acosta, L. A., Wintle, B. A., Benedek, Z., Chhetri, P., Heymans, S. J., Onur, A. C., ... Shoyama, K. (2016). *Chapter 2: Using scenarios and models to inform decision making in policy design and implementation*.

Acre (2006). Zoneamento Ecológico-Econômico do Acre Fase II – Documento Síntese – Escala 1:250.000 11. Rio Branco.

Acre (2014). *Projeto de Fortalecimento da Cadeia de Valor do Açaí no Estado do Acre.* Retrieved fromhttp://www.mi.gov.br/c/document_library/get_file?uuid=92be8886-196b-48b4-ba1f-439cd2698ebe&groupId=10157.

AFI (2009). *Shelled Brazil nuts AFI specifications for shelled Brazil nuts.* Retrieved fromhttps://www.afius.org/resources/Documents/AFI Specifications/brazil-nuts.pdf.

Albers, H. J., & Robinson, E. J. Z. (2013). A review of the spatial economics of non-timber forest product extraction: Implications for policy. *Ecological Economics, 92*, 87–95. https://doi.org/10.1016/j.ecolecon.2012.01.021.

Athias, R., & Pinto, R. P. (2008). *Estudos Indígenas: Comparações Interpretações e Políticas.* São Paulo: SÉRIE JUSTIÇA E DESENVOLVIMENTO/IFP-FCC.

Bayma, M. M. A., Wadt, L. H. de O., Sá, C. P. de, Balzon, T. A., & Sousa, M. de M. M. (2008). Custo e Rentabilidade da Atividade de Extração de Açaí em Áreas de Baixio na Reserva Extrativista Chico Mendes, Seringais Porvir, Filipinas, Etelvi, no Acre. Comunicado Tecnico 170 ISSN 0100-8668 Rio Branco, 4–7. Retrieved from https://www.infoteca.cnptia.embrapa.br/bitstream/doc/494669/1/comunicado170.pdf.

Bowman, M. S., Nepstad, D. C., & Rodrigues, H. O. (2012). Persistence of cattle ranching in the Brazilian Amazon: A spatial analysis of the rationale for beef production. *Land Use Policy, 29*(3), 558–568. https://doi.org/10.1016/j.landusepol.2011.09.009.

Carvalho Ribeiro, S. M., Soares Filho, B., Leles Costa, W., Bachi, L., Ribeiro de Oliveira, A., Bilotta, P., ... Cioce Sampaio, C. (2018). Can multifunctional livelihoods including recreational ecosystem services (RES) and non timber forest products (NTFP) maintain biodiverse forests in the Brazilian Amazon? *Ecosystem Services, 31*, 517–526.

Cavalcante, K. V., Franchi, T., Lopes, R. H., & Mota, J. A. (2011). O extrativismo no século XXI: A castanha no Amazonas. In IX Encontro da Sociedade Brasileira de Economia Ecológica – Políticas Públicas e a Perspectiva da Economia Ecológica (p. 21). Brasília. Retrieved from http://www.ecoeco.org.br/conteudo/publicacoes/encontros/ix_en/GT4–100-20110619183937.pdf.

Conab. (2016). Preços médios mensais do açaí. Disponível.

Duchelle, A. M. Y. E., & Wunder, S. (2014). Smallholder specialization strategies along the forest transition curve in Southwestern Amazonia 64. http://doi.org/10.1016/j.worlddev.2014.03.001.

Evaristo, S. A., Silveira, C. T. da, Mantovani, L. E., Sirtoli, A. R. dos A., & Oka-Friori, C. (2008). Landscape Atributes Derived From Digital Elevation Model and Relationships With Soils. Retrieved from *Scientia Agraria, 9*, 317–329. http://revistas.ufpr.br/agraria/article/view/11517/8108.

Godoy, R., Lubowski, R., & Markandya, A. (1993). A method for the economic valuation of non-timber tropical forest products. Retrieved from *Economic Botany, 47*(May 1988), 220–233. https://link.springer.com/content/pdf/10.1007%2FBF02862288.pdf.

Godoy, R., Wilkie, D., Overman, H., Cubas, A., Cubas, G., Demmer, J., ... Brokaw, N. (2000). Valuation of consumption and sale of forest goods from a Central American rain forest. Retrieved from *Nature, 406*(July), 1995–1996. https://www.nature.com/nature/journal/v406/n6791/pdf/406062a0.pdf.

Gomes, C. V. A., Vadjunec, J. M., & Perz, S. G. (2012). Rubber tapper identities: Political-economic dynamics, livelihood shifts, and environmental implications in a changing Amazon. *Geoforum, 43*(2), 260–271. https://doi.org/10.1016/j.geoforum.2011.09.005.

Hall, A. (2004). *Political economy extractive reserves : Building natural assets in the Brazilian Amazon (No. 74).* Retrieved fromhttp://scholarworks.umass.edu/cgi/viewcontent.cgi?article=1060&context=peri_workingpapers.

Hecht, S. (2013). *In the realm of rubber, the scrumble for the Amazon and the lost paradise of Euclides da Cunha.* Chicago: The University of Chicago Press.

Hoelle, J. (2015). *Rainforest Cowboys: The rise of ranching and cattle culture in Western Amazonia.* University of Texas Press212.

Homma, A. K. O. (2012). Extrativismo vegetal ou plantio: Qual a opção para a Amazônia? *Estudos Avançados, 26*(74), 167–186. https://doi.org/10.1590/S0103-40142012000100012.

Homma, A. K. O. (2008). *Extrativismo, Biodiversidade e Biopirataria na Amazônia.* EMBRAPA Texto para Discussão 27, ISSN 1677-5473.

Homma, A. K. O., Nogueira, O. L., de Menezes, A. J. E. A., de Carvalho, J. E. U., & Nicoli, C. M. L. G. B. de M. (2006). Açaí: Novos Desafios E Tendências. Retrieved from *Amazônia: Ciência E Desenvolvimento, 1*(2), 7–23. http://www.alice.cnptia.embrapa.br/bitstream/doc/578153/1/AcaiDesafiosTendencias.pdf.

Humphries, S., Holmes, T. P., Kainer, K., Gabriel, C., Koury, G., Cruz, E., & Miranda, R. De. (2012). Are community-based forest enterprises in the tropics financially viable? Case studies from the Brazilian Amazon. *Ecological Economics, 77*, 62–73. https://doi.org/10.1016/j.ecolecon.2011.10.018.

IBGE (2010). *Censo Demográfico – Tabela 3153 – Domicílios particulares permanentes, por situação do domicílio e a existência de compartilhamento da responsabilidade pelo domicílio com a pessoa responsável – Resultados Preliminares do Universo.* Retrieved fromhttp://www2.sidra.ibge.gov.br/bda/tabela/listabl.asp?z=cd&o=6&i=P&c=3153.

IBGE (2017). *Tabela 289 – Quantidade produzida e valor da produção na extração vegetal, por tipo de produto extrativo.* Retrieved fromhttp://www.sidra.ibge.gov.br/bda/tabela/protabl.asp?c=289&z=p&o=30&i=P.

INPE (2015). *Desmatamento do PRODES.* Retrieved fromhttp://www.obt.inpe.br/prodes/Prodes_Taxa2015_consolidada.pdf.

Jaramillo-Giraldo, C., Soares Filho, B., Carvalho Ribeiro, S. M., & Gonçalves, R. C. (2017). Is it possible to make rubber extraction ecologically and economically viable in the Amazon? The Southern Acre and Chico Mendes reserve case study. *Ecological Economics, 134*, 186–197. https://doi.org/10.1016/j.ecolecon.2016.12.035.

Kahn, F. (1991). Palms as key swamp forest resources in Amazonia. *Forest Ecology and Management, 38*(3–4), 133–142. https://doi.org/10.1016/0378-1127(91)90139-M.

Machado, R. L. B. (2013). *Caracterização do sistema agroextrativista familiar do açaízeiro nativo (Euterpe oleraceae Marte.), na comunidade quilimbola São Maurício, Alcântara, Maranhão*.

May, P. H., Soares-Filho, B. S., & Strand, J. (2013). *How much is the Amazon worth? The state of knowledge concerning the value of preserving Amazon rainforests*.

Myers, S. C., Clarkson, B. R., Reeves, P. N., & Clarkson, B. D. (2013). Wetland management in New Zealand: Are current approaches and policies sustaining wetland ecosystems in agricultural landscapes? *Ecological Engineering, 56*, 107–120.

MMA. (2009). Plano nacional de promoção das cadeias de produtos da sociobiodiversidade. Brasília. Retrieved from http://www.mda.gov.br/sitemda/sites/sitemda/files/user_arquivos_64/PLANO_NACIONAL_DA_SOCIOBIODIVERSIDADE-_julho-2009.pdf.

Moscoso, V., Albernaz, A. L., & Salomão, R. de. P. (2013). Niche modelling for twelve plant species (six timber species and six palm trees) in the Amazon region, using collection and field survey data. *Forest Ecology and Management, 310*, 652–662. https://doi.org/10.1016/j.foreco.2013.08.064.

Nogueira, A. K. M., de Santana, A. C., & Garcia, W. S. (2013). A dinâmica do mercado de açaí fruto no Estado do Pará: de 1994 a 2009. *Revista Ceres, 60*(3), 324–331. https://doi.org/10.1590/S0034-737X2013000300004.

Nogueira, O. L., Figueirêdo, F. J. C., & Müller, A. A. (2005). Sistemas de Produção 4 Açaí (Embrapa Am). Belém, PA. Retrieved from https://www.infoteca.cnptia.embrapa.br/infoteca/bitstream/doc/408196/1/SISTEMAPROD4ONLINE.pdf.

Nunes, F., Soares-Filho, B., Giudice, R., Rodrigues, H., Bowman, M., Silvestrini, R., & Mendoza, E. (2012). Economic benefits of forest conservation : Assessing the potential rents from Brazil nut concessions in Madre de Dios, Peru, to channel REDD+. *Environmental Conservation, 39*(2), 132–143. https://doi.org/10.1017/S0376892911000671.

Nunes, S. P., & Angelis, T. de. (2008). Estudo Exploratório da Cadeia Produtiva da Castanha-do- Brasil. Curitiba. Retrieved from http://www.deser.org.br/pub_read.asp?id=121.

Oliveira, M. do S. P. de, Carvalho, J. E. U. de, Nascimento, W. M. O. do, & Müller, C. H.

(2002). *Cultivo do Açaízeiro para Produção de Frutos. (Embrapa, Ed.)*Retrieved from (26th ed). Belém, PA: Ministério da Agricultura, Pecuária e Abastecimento. https://www.agencia.cnptia.embrapa.br/Repositorio/Producaodefrutos+Circ_tec_26_000gbz56rpu02wx5ok01dx9lcobm2bes.pdf.

Peters, C. M., Gentry, A. H., & Mendelsohn, R. O. (1989). Valuation of an Amazonian rainforest. Retrieved from *Nature, 339*, 655–656. https://www.nature.com/nature/journal/v339/n6227/pdf/339655a0.pdf.

Rocha, E. (2002). *Aspectos ecológicos e sócio-econômicos do manejo de Euterpe precatoria Mart. (Açaí) em áreas extrativistas no Acre.* Brasil: Universidade de São Paulo.

Rocha, E. (2004). Potencial ecológico para o manejo de frutos de açaízeiro (Euterpe precatoria Mart.) em áreas extrativistas no Acre, Brasil. *Acta Amazonica, 34*(2), 237–250. https://doi.org/10.1590/S0044-59672004000200012.

Rocha, E., & Viana, V. M. (2004). Manejo de Euterpe precatoria Mart. (Açaí) no Seringal Caquetá, Acre, Brasil Management of Euterpe precatoria Mart. (Açaí) in Seringal Caquetá, Acre, Brazil. Scientia, pp. 59–69.

Schroth, G., Moraes, V. H. F., & Mota, M. S. S. (2004). Increasing the profitability of traditional, planted rubber agroforests at the Tapajós river, Brazilian Amazon, 102, 319–339. http://doi.org/10.1016/j.agee.2003.09.001.

Scoles, R., & Gribel, R. (2011). Population structure of Brazil nut (Bertholletia excelsa, Lecythidaceae) stands in two areas with different occupation histories in the Brazilian Amazon. *Human Ecology,* 455–464.

Scoles, R., & Gribel, R. (2012). Forest ecology and management the regeneration of Brazil nut trees in relation to nut harvest intensity in the Trombetas River valley of Northern Amazonia, Brazil. *Forest Ecology and Management, 265*, 71–81. https://doi.org/10.1016/j.foreco.2011.10.027.

Shone, B. M., & Caviglia-Harris, J. L. (2006). Quantifying and comparing the value of non-timber forest products in the Amazon. *Ecological Economics, 58*(2), 249–267. https://doi.org/10.1016/j.ecolecon.2005.07.009.

Siikamäki, J., Santiago-Ávila, F. J., & Vail, P. (2015). *Global assessment of non wood forest ecosystem services spatially explicit meta-analysis and benefit transfer to improve the World Bank's forest wealth database.* Retrieved from.

Soares-Filho, B., Rodrigues, H., & Follador, M. (2013). A hybrid analytical-heuristic method for calibrating land-use change models. *Environmental Modelling and Software, 43*, 80–87. https://doi.org/10.1016/j.envsoft.2013.01.010.

Sousa, W. P. & Euler, A. M. C. (2009). Diagnostic of the Brazil nut's (Bertholletia excelsa Bonpl.) productive sector and trade in South Amapá Territory. Embrapa.

ter Steege, H., Pitman, N. C. A., Sabatier, D., Baraloto, C., Salomão, R. P., Guevara, J. E., ... Silman, M. R. (2013). Hyperdominance in the Amazonian tree flora. *Science, 342*(6156), 1243092. https://doi.org/10.1126/science.1243092.

Turini, E. T. (2014). Proposta de preços mínimos safra 2013/2014. Produtos da socio-biodiversidade. In Proposta de preços mínimos (Vol. III, pp. 5–19).

Vedel-Sørensen, M., Tovaranonte, J., Bøcher, P. K., Balslev, H., & Barfod, A. S. (2013). Spatial distribution and environmental preferences of 10 economically important forest palms in western South America. *Forest Ecology and Management, 307*, 284–292. https://doi.org/10.1016/j.foreco.2013.07.005.

Weinstein, S., & Moegenburg, S. (2004). Açaí palm management in the Amazon Estuary: Course for conservation or passage to plantations? *Conservation & Society, 2*(2), 315–346.