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Knowledge, use, and management of mangaba (*Hancornia speciosa* Gomes) by extrativist communities on the coast of Rio Grande do Norte, Northeast Brazil

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ABSTRACT

Mangaba (*Hancornia speciosa*) is a native fruit tree of Brazil and of great importance as an alternative source of income and subsistence for many rural communities of the Northeast region. This study aimed to identify and characterize the uses, local knowledge and management practices of *H. speciosa* in extrativist communities of the state of Rio Grande do Norte, Northeast Brazil. Semi-structured interviews were conducted with 59 informants. The importance of mangaba was analyzed based on the mentioned types of uses and by calculating the use diversity index and consensus value among the interviewees. Knowledge of *H. speciosa* is equally distributed among communities. The categories of food (0.39) and commercialization (0.37) were the most relevant use categories. No significant differences were found in the diversity of uses between genders ($p>0.05$, $U=414$), with the only differences being found between age groups, for informants over 40 years of age (IDV: $p<0.05$, $H=25.37$; IVE: $p<0.05$, $H=24.07$). Results show that the informants are dependent on the resources offered by this species, and that its importance is mainly related to the use of fruits for food and commercialization. The main form of management of mangaba was collecting the fruit, followed by promotion, tolerance, and protection.

Keywords: Apocynaceae, ethnobotany, plant conservation, local knowledge, management, mangaba

Introduction

Although the collection and use of plants with potential social, economic and cultural value are common practices in different cultures around the world (Blancas *et al*. 2013; Feitosa *et al*. 2014; Geller *et al*. 2015), these actions may bring challenges for preserving these exploited plant resources. This becomes evident when there is a significant reduction in the population size of the exploited species, which can lead to a risk of local extinction (Marshall & Hawthorne 2012). In addition, fragmentation of habitats due to increased environmental degradation and anthropogenic action have contributed to intensify this process.

The local communities which use the plant resource are the first to realize its reduced availability, and are therefore holders of expressively important knowledge about the use and management of species, as well as for elaborating strategies which can subsidize the sustainable use of these resources (Soldati & Albuquerque 2012).

The dialectical relationship between ethnobiological knowledge and local management practices of natural

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resources shapes ecosystems and affects plant populations (Ghimire *et al.* 2004). Some species in a managed ecosystem may become extinct as a result of this action, even though the full effect of this interference may result in a real increase in the ecological and biological diversity of a specific place or region (Diegues 2019).

The use of distinct ecological environments has favored many human populations in the discovery of potentially useful plant resources over time, with some little explored and even unknown. Human actions have been historically assimilated in several perspectives, including those which modify species and landscapes (Reis *et al.* 2010). Therefore, even forest landscapes considered native have resulted from the interaction between natural processes and human activities, as evidenced by studies on the influence of the activities of indigenous populations on the current formation of the Amazon Forest (Clement 1999; Magalhães 2011; Levis *et al.* 2012; Levis *et al.* 2017).

The management of plant species may cause phenotypic changes in the characteristics of a plant which is targeted by human selection over time, and therefore lead to a domestication process (Sousa Júnior *et al.* 2016). The management of plant populations in their different domestication levels is accompanied by a domestication process of the landscape (Clement 1999). This process may occur intentionally (or not) through the selection of desired plants (Zohary 2004), which implies changes in landscape ecology and plant population demography (Harris 1989). Such changes aim to turn landscapes into more productive and safer areas for humans populations (Clement 1999). Both processes have different degrees of intensity and are interrelated (Alves *et al.* 2016). Thus, the concept of landscape has been used to understand how people interpret local conceptions, use patterns and management of landscapes, and also how local knowledge can contribute to ecological sustainability (Filippon 2014).

Among species which stand out for their socioeconomic and cultural importance, the mangaba (*Hancornia speciosa*, Apocynaceae) is a fruit tree native to Brazil with wide geographical distribution, including the Coastal Tableland of the Northeast, the Cerrado of the Central-West, in the North and Southeast regions of Brazil (Vieira *et al.* 2017). It is a species with high potential in various sectors and production chains such as in agroindustry, latex production, and extraction of pharmaceutical and nutraceutical substances (Almeida *et al.* 2016). It is highly appreciated for the organoleptic characteristics of its fruits, presenting high nutritional value, and is rich in vitamins A, B1, B2, and C, in addition to iron, phosphorus, calcium, and proteins (Tomazi *et al.* 2018). Mangaba is also considered a functional food with antioxidant, anti-diabetic, and anti-obesity properties (Bailão *et al.* 2015). It has important economic value for the Northeast region due to the various possibilities of use of its fruits which can be consumed both *in natura* and in processed form (juices, jellies, ice cream, etc.).

All of these qualities attributed to *H. speciosa* fruit are reflected in its economic value and as a livelihood resource for countless families in the Northeast region. Despite the socio-economic potential of the species, environmental degradation has intensified the reduction of its remaining areas due to intense real estate expansion, the unsustainable use of these resources, and the practice of sugarcane and coconut monocultures, which contribute to the genetic erosion of the species, threatening it with extinction (Sá *et al.* 2011).

In view of this highly complex scenario of the interactions between cultural, socioeconomic, and biological factors, it is important to understand the motivations and contexts which lead to certain practices in managing plant genetic resources. Thus, the ethnobotanical characterization of knowledge and traditional management techniques can provide important information on the practices which interact with the population ecology of the species and on the relationship among knowledge, management practices, and institutional relations (Baldauf & Santos 2013).

Studies on the use and management of tree species, emphasizing the domestication processes of plants and landscapes by local populations have been reported in several species in the Amazon (Clement *et al.* 2010). Among them, castanheira-do-brasil (*Bertholletia excelsa*), pupunha (*Bactris gasipaes*), cacau (*Theobroma cacao*), guaraná (*Paullinia cupana* var. *sorbilis*) (Clement *et al.* 2009; 2010) e piquiá (*Caryocar villosum*) (Alves *et al.* 2016). In the region of Northeast Brazil, the main studies are with umbu (*Spondias tuberosa*) (Lins Neto *et al.* 2010; 2012), pequi (*Caryocar coriaceum*) (Sousa Júnior *et al.* 2013; 2016) and cacti (Lucena *et al.* 2015).

Ethnobotanical studies which characterize the knowledge, use, and management of *H. speciosa* are still incipient. Most ethnobotanical research has attributed considerable economic and medicinal value of this species for local communities in the northeast region of Brazil (Rodrigues & Carvalho 2001; Monteles & Pinheiro 2007; Silva *et al.* 2011a; Duarte *et al.* 2013). However, there are no records of studies addressing local knowledge and management of this species with a focus on the domestication processes. Other tree species have been studied regarding their use and management by local human populations, integrating conservation and exploitation aspects of tree species in Brazil (Lins Neto *et al.* 2010; Sousa Júnior *et al.* 2013; Adan *et al.* 2016). Therefore, the knowledge about the uses and the local needs met with mangaba tree products, the social groups which depend on these resources or how they are extracted may have important implications, not only from scientific and economic viewpoints, but also conservationist (Rufino *et al.* 2008). In addition, it is necessary to investigate the local perception of the importance of the mangaba tree because, in addition to being part of the value system of a culture, such knowledge is important for the success of practices aimed at environmental conservation (Byg & Baslev 2001).

The interaction with plant resources occurs in different ways among individuals; in this aspect, it is important to understand the influence of gender and age on local knowledge of this species. Several ethnobotanical studies highlight gender and age among the factors which interfere in the knowledge and use of plant species by local populations (Merétika *et al.* 2010; Silva *et al.* 2011b; Cruz *et al.* 2013; Feitosa *et al.* 2014; Oliveira *et al.* 2017). In some social contexts, gender exerts an important influence on local knowledge, affecting the behavior and occupation of individuals (Silva *et al.* 2011b). Plant use preferences, either by men or women of different ages, are generally associated with the division of labor in the communities (Voeks 2007; Camou-Guerrero *et al.* 2008). Studies on the distribution of the knowledge related to the use of medicinal plants point out that knowledge tends to be greater among women than men (Silva *et al.* 2011b; Almeida *et al.* 2012). Studies have also shown that older individuals have more knowledge about medicinal and food plants (Yineger *et al.* 2008; Silva *et al.* 2011b; Silva *et al.* 2019). According to Voeks (2007), people acquire more knowledge with age, and therefore there is a tendency for greater accumulation of knowledge among older people.

In view of the above, this study aimed to identify and characterize the uses, local knowledge, and management practices of *H. speciosa* in extrativist communities on the coast of Rio Grande do Norte, in northeast Brazil. The study was performed so as to answer the following questions: what are the uses of *H. speciosa*? Does local knowledge about the uses of *H. speciosa* differ with regard to age and gender? Do the extractors recognize local varieties of *H. speciosa*? What is the management regime of *H. speciosa* and the factors which influence such practices?

Materials and methods

Characterization of the study area

This study was conducted in the rural communities of Timbó, Boa Água, and Bonfim, in the Nísia Floresta municipality, coastal region of the state of Rio Grande do Norte (NE Brazil) (Fig.1). This study area is located within the Macaíba micro-region, belonging to the Metropolitan Region of Natal and occupies an area of 307,842 km^2 (IDEMA 2013). The vegetation of the location as well as its surroundings is formed by the largest Atlantic Forest remnant in Rio Grande do Norte, composed of restinga vegetation, mangroves, floodplains, coastal tablelands, and subperipheral forest. Part of this Atlantic Forest area is known as the National Forest - FLONA de Nísia Floresta, with an area of 175 hectares (IDEMA 2013). The three communities were chosen taking into account their having both common and private areas of mangaba tree occurrence, a greater number of actors involved, and accessibility to the sites.

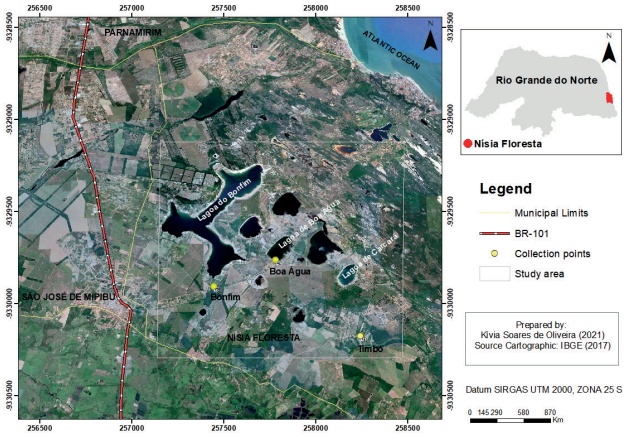

Figure 1. Location map of the rural communities of Timbó, Bonfim and Boa Água, Nísia Floresta municipality, in the state of Rio Grande do Norte, Northeast Brazil.

The municipality's economy is mainly based on subsistence agriculture with sugarcane and cassava planting as temporary crops, coconut and papaya cultivation as permanent crops (IBGE 2017), and livestock. The community of Timbó is a still developing district, composed of approximately 229 families. The main livelihood source is agriculture, however complementary income is obtained from mangaba extractivism, coconut leaf crafts (*Cocos nucifera* L.), "lead-vine" (*Cuscuta racemosa*), artisanal fishing, and tourism activities due to the beauty of the Carcará Lagoon. Some families have abandoned agriculture, especially mangaba extractivism, in order to obtain more income from the tourism activity that is growing in the region (Oliveira & Aloufa 2019).

The Boa Água community is currently composed of 105 resident families. Mangaba extractivism and livestock are important income sources for the population, along with tourism which is in a strong expansion process due to the beauty of the Boa Água Lagoon, followed by agriculture and commerce; others work on private properties. There is practically no job generation for the residents, and therefore many young people have to seek employment outside the community (Oliveira & Aloufa 2019).

The Bonfim community is currently composed of 50 resident families. This community is quite similar to Timbó and Boa Água in relation to the main practices developed in agriculture. Most families live on mangaba extraction, while others work on private properties as the region has many farmers. In addition, there are similarities between the communities in relation to landscape management areas with the presence of tablelands, and sugarcane and coconut monocultures. These communities directly depend on the extraction of plant resources available in this location, among which mangaba represents one of the main resources.

Legal and ethical aspects

This research was approved by the Ethics Committee (CEP) of the Health Sciences Center of the Universidade Federal do Rio Grande do Norte, under registration no. 80013917.9.0000.5537. The Informed Consent Form (TCLE) was used when the participants, after being informed about the design and nature of the research, were invited to participate in the study.

Ethnobotanical data

Before starting data collection, technical visits were made with community members to clarify the intentions of the work to be conducted. Subsequently, semi-structured interviews were conducted with mangaba collectors from the communities of Timbó, Bonfim, and Boa Água to obtain information on the use, knowledge, collection of fruits, and managed populations of *H. speciosa*. In addition, socioeconomic data were collected (age, gender, occupation, etc.). The selection criteria for the participants included local informants who declared themselves as mangaba collectors because they had local knowledge and practices obtained from the use, fruit extraction or management of *H. speciosa*. Participant observation was performed consisting of experience and participation by the researcher in the various activities performed by local informants, with interviews based on semi-structured scripts (Albuquerque *et al*. 2010). The interviews were conducted between August 2017 and October 2018.

The choice of informants for the research was made through the "snow-ball" technique (Albuquerque *et al*. 2010), resulting in a total of 59 participants: 28 in Timbó, 10 in Boa Água, and 21 in Bonfim. The minimum age observed among the interviewees was 20 years and the maximum, 82. To justify the sample size, the technique of theoretical data saturation was used to establish or close the final size of the sample under study, discontinuing the acquisition of new components when the responses, in the opinion of the researcher, began to repeat themselves or have some redundancy (Fontanella *et al*. 2008).

Of the total 59 participants, 52.54 % were women and 47.46 % men, aged 19-82 years. Most people interviewed were between 41 and 60 years old, and 57.63 % were married. Of the total interviews, 47.46 % were conducted in the community of Timbó, 35.59 % in Bonfim, and 16.95 % in Boa Água. The participants had a low education level: 59.32 % of them had not finished primary education, and 22.03 % were illiterate. The number of people per family varied between 1 and 9, the majority (42.37 %) being composed of 3 to 4 people. The majority of the residents surveyed were farmers earning less than the minimum monthly salary (R$ 998.00 per month).

A comparative analysis of the informants' knowledge based on their occupation, age, and gender was performed based on six quantitative measures: the informant's diversity value (IDV), consensus value for types of use (VCTU), the informant's equitability value (IEV), the use diversity value (UDV), the use equitability value (UEV), and the consensus value for forms of use (VCFU). The IDV index represents the number of use-citations by a given informant (Ux) divided by the total number of uses. It measures how many interviewees use a given species and how this knowledge is distributed among the interviewees. IEV is the informant's diversity value (IDV) divided by the highest value diversity index found (IDVmax). This index measures the degree of homogeneity of the interviewee's knowledge. The UDV index is the number of indications registered for each category (food, medicinal, combustible, etc.) (U_{cx}) divided by the total number of indications for all of the categories (U_{ct}). This index reflects the importance of the use categories and how they contribute to the local use value. The VCTU index represents the number of times a use has been reported (TU) divided by the total of uses (U_t). This index measures the degree of agreement between informants regarding the uses of the species. The UEV index is the use diversity value (UDV) divided by the maximum value use diversity index (UDV_{max}). It measures the degree of homogeneity of knowledge in regards to the use-categories. The VCFU index represents the number of citations for a given form of use (*in natura*, juice, pulp, etc.) (M_x) divided by the total number of citations for all of the forms of use (M_t). It measures the degree of agreement between the informants regarding the forms of use of a given plant. These indexes are based on studies of Byg & Baslev (2001), Monteiro *et al*. (2006), and Lins Neto *et al*. (2010).

The objective of this analysis was to identify how knowledge about the uses of *H. speciosa* was distributed in the communities of Timbó, Bonfim, and Boa Água. Significant differences in terms of gender and age were tested using a Mann–Whitney U tests and Kruskal-Wallis test at 5% probability, respectively. All the analyses were processed using the IBM 20.0 software. All the informants were grouped according to age and gender classes into adults ≥ 40 years of age and < 40 years of age (Byg & Baslev 2001; Monteiro *et al*. 2006; Lins Neto *et al*. 2010); women 40 years or older (n = 24); women younger than 40 years (n = 8); men 40 years or older (n = 18); and men younger than 40 years (n = 9).

This study considered landscape units recognized by extractors for the use and management of mangaba. For the purposes of this study, landscape units are heterogeneous environments recognized by a local name and resulting from human activities with perceptive characteristics, and are functionally distinct from each other due to their uses, such as cultivation, grasslands, and settlement of houses (Hunn & Meilleur 2010).

Results

Knowledge, use, and management of ***H. speciosa***

According to the data obtained, the main use of mangaba is for food; in addition, 52.54 % of the interviewees cited the use of mangaba for medicinal purposes, 5.08 % for timber and 3.39 % for laticiferous and fertilizing purposes (Tab. 1). The informants attributed several uses to mangaba, with the fruit standing out the most (100 % of the citations), with uses in human food through *in natura* consumption or in processed form (pulp, ice cream, mousse, dindin, popsicle, jelly, candy, liquor, among others); latex (15.25 %) with use in the production of rubber and medicines; the shell and leaf (6.78 %) for medicinal use; and leaves (5.08 %) for organic fertilizer (Tab. 1).

From the interviews with the 59 local informants, a total of 20 forms of use (VCFU) were recorded for *H. speciosa*, including the food uses of the fruits, mainly juice (0.34) and pulp (0.11); and medicinal use, especially the use of latex of mangabeira (0.17) (Tab. 1). The same was observed for types of use (VCTU), where the food was more prominent (0.58) in relation to the others (Tab. 1).

Table 1. Consensus value for forms of use (VCFU) and types of use (VCTU) for *H. speciosa* in the rural communities of Timbó, Bonfim and Boa Água, Nísia Floresta, Rio Grande do Norte, Brazil.

Forms of use	VCFU	Forms of use	VCFU
In natura consumption (fruits)	0.03	Pudding	0.01
Sweet (fruits)	0.02	Jelly (fruit mature)	0.01
Juice	0.34	Liquor	0.01
Vitamin	0.02	Decoction (bark and inner bark)	0.04
Pulp	0.11	Infusion (leaves)	0.02
Mousse	0.02	Latex (rubber)	0.01
Ice cream	0.08	Latex (remedy)	0.17
"Dindin" (sacolé/ iced/ ice lolly)	0.05	Coal	0.01
Popsicle	0.06	Firewood	0.01
Cake	0.01	Organic fertilizer (leaves)	0.02
Types of use			**VCTU**
Food resource			0.58
Medicinal			0.30
		Diabetes	0.06
		Hypertension	0.02
		Cicatrization	0.04
		Gastritis	0.11
		Ulcer	0.01
		Anemia	0.01
		Hernia	0.07
		High rates	0.01
		Chikungunya	0.01
Wood			0.04
Rubber			0.02
Organic fertilization			0.03

The maximum value for the different uses which contribute to the total use of the studied species was obtained for the food category (ECU 1.0), followed by the marketing and medicinal categories (ECU 0.95 and 0.53, respectively). The results indicate that the knowledge about mangaba as a food and commercial and medicinal source is well distributed locally. The agreement among informants is much lower for the other categories, with values below 0.06 (Tab. 2). This suggests that food use and marketing of *H. speciosa* are the strongly developed practices in the region, and the knowledge is homogeneous and well distributed among informants in the communities.

Table 2. Use diversity value (UDV) and use equitability value (UEV) for the use categories indicated for *H. speciosa* in the rural communities of Timbó, Bonfim and Boa Água, Nísia Floresta, Rio Grande do Norte, Brazil.

Use categories	Used part	UDVs	UEV
Food	Fruits	0.39	1
Medicinal	Leaf, bark and latex	0.20	0.53
Commercialization	Fruits	0.37	0.95
Laticiferous	Latex	0.01	0.03
Combustible	Trunk and roots	0.02	0.05
Organic fertilization	Leaves	0.01	0.03

The species is widely known to Timbó, Bonfim, and Boa Água residents, since 59 respondents (31 women and 28 men) confirmed having knowledge of several uses for the species (Tab. 1). When the informant's diversity value (IDV) and the informant's equitability value (IEV) were compared by gender, no significant differences were observed between women and men ($p>0.05$, $U=414$), indicating that knowledge about the diversity of uses of the species is equally distributed between the genders. Considering the types of uses in relation to age, there was a significant difference regarding the informant's diversity value (IDV) for women and men over 40 years of age ($p<0.05$, $H=25.37$). Regarding the informant's equitability value (IEV), a significant difference was observed for women, regardless of age, and men (≥40 years of age) ($p<0.05$, $H=24.07$), showing a better distribution of knowledge compared to men with age < 40 years (Tab. 3).

There is a division of labor between men and women in the studied communities. Men are responsible for fishing, coconut collecting, construction activity (bricklayer's) and agriculture; and women are responsible for mangaba extractivism, crafts, domestic activities and help in agriculture. Although mangaba collection is a practice which is mainly performed by women, men have increased their participation in the activity.

Management of ***Hancornia speciosa***

Regarding the management practices observed in the communities, it is important to note that they were described based on the incipient management practices

defined in studies conducted for the Mesoamerican region of Mexico. Thus, the management practices observed in the communities of Boa Água, Timbó and Bonfim can be categorized based on Casas *et al*. (1997), González–Insuasti & Caballero (2007), and Blancas *et al*. (2010): (1) Collection of mangaba fruit is the main activity within the context of species management (100 % citations), followed by (2) promotion practices (50.85 %) (Fig. 2). The latter includes pruning, cleaning around the mangabeira trees, removal of dry branches, organic fertilization with the foliage of the plant itself or bovine manure, and the quick burning in mangabeiras. Also observed were (3) the tolerance management (44.07 %) in areas of farms and backyards (Fig. 2 E-F), keeping the trees naturally dispersed in the site in combination with the cassava crop or other species; and (4) the protection (40.68 %), eliminating parasitic plants popularly known as "cipó-chumbo" (*Cuscuta racemosa*) (Convolvulaceae), a plant devoid of roots and leaves, and the hemiparasite plant species popularly known as "erva-de-passarinho" (*Psittacanthus dichroos*) (Loranthaceae) (Fig. 2A-B), a name given because the fruit is dispersed by birds. The informants also reported that it is necessary to remove the ants, as they damage the mangabeiras. In the case of epiphytic plants, such as "xinxo" (*Hohenbergia ramageana*) (Bromeliaceae) (Fig. 2C), which is a kind of bromeliad, they are usually left in the mangabeiras because, according to the collectors, they do not harm the tree. Another epiphytic species cited by informants is the "imbé" (*Philodendron acutatum*) (Araceae) (Fig. 2D). Finally, (5) the seed sowing or seedling cultivation (28.81 %) was the least mentioned management practice, since according to local informants it is a naturally born plant. In general, seedlings naturally dispersed are transplanted to another location.

Table 3. Measurements of knowledge regarding mangaba (*H. speciosa*) in the rural communities of Timbó, Bonfim and Boa Água, Nísia Floresta, Rio Grande do Norte, Brazil.

Total number of informants	59
Number of use citations	259
Use categories	6
Informant's diversity value (IDV)	**Average and standard deviation (X ± SD)**
IDV Total	0.017 ± 0.008
IDV total for women	0.032 ± 0.013[a]
IDV for women (<40 years of age)	0.125 ± 0.040[b]
IDV for women (≥40 years of age)	0.043 ± 0.197[a]
IDV total for men	0.037 ± 0.017[a]
IDV for men (< 40 years of age)	0.107 ± 0.063[b]
IDV for men (≥ 40 years of age)	0.053 ± 0.024[ab]
Informant's equitability value (IEV)	**Average and standard deviation (X ± SD)**
IEV Total	0.439 ± 0.201
IEV total for women	0.484 ± 0.195[a]
IEV for women (< 40 years of age)	0.646 ± 0.208[a]
IEV for women (≥ 40 years of age)	0.509 ± 0.233[a]
IEV total for men	0.473 ± 0.225[a]
IEV for men (< 40 years of age)	0.111 ± 0.109[b]
IEV for men (≥ 40 years of age)	0.493 ± 0.226[a]

Note: Averages followed by the same letter in the column indicate nonsignificant values at 5 % probability.

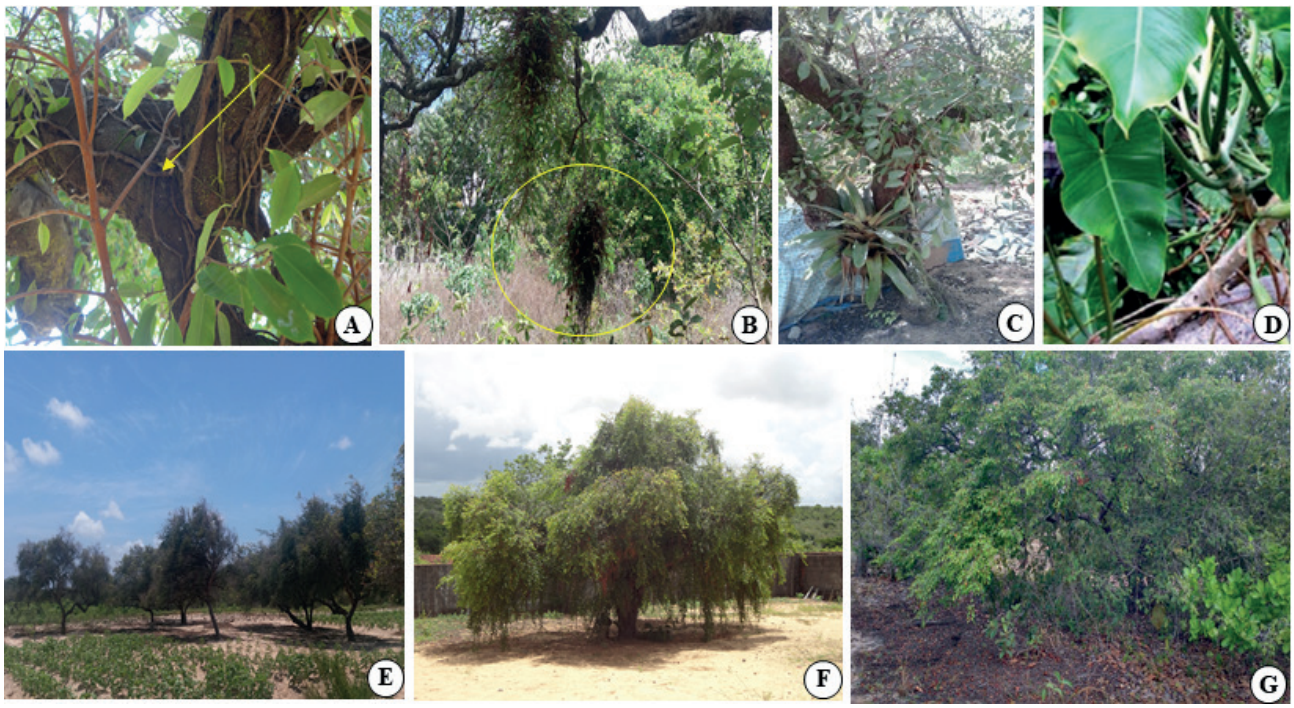

Figure 2. Protection and tolerance management of *H. speciosa*. **A-B**. "Erva-de-passarinho" (*P. dichroos*); **C.** "Xinxo" (*H. ramageana*); **D.** "Imbé" (*P. acutatum*); **E-F.** *H. speciosa* tolerated on private property; and **G.** Wild mangabeira individual. Photographs taken by Kívia Soares de Oliveira in 2019.

Other management types identified were breaking branches during collection and the quick-fire burning technique in the mangabeiras, both promotional management practices, as stated in interviews with informants:

> "[...] It is so much that when you prune the branch it is already bursting, it comes with the flower, and the flower is already sprouting the fruits, it is much faster, it accelerates the process. (Mangaba collector, 61 years of age). "
>
> "If you break a branch it will give more fruit, but it will take a while. And passing the fire quickly gives more fruit than breaking branches. The two of them give more fruits, only the fire gives more fruits. (Mangaba collector, 54 years of age)."

According to the informants, these strategies are used to increase fruit production in the next harvest, producing new branches ("regrowth"), with rapid growth and more beautiful ("leafy") growth. However, the informants also point out that if they are done frequently they can damage the mangabeira trees. These practices are questioned for not respecting the natural regeneration capacity of the plant.

Collection sites of mangaba and morphological diversity

A total of 26 landscape units used to collect mangaba were cited by the informants, most of them in regions of free tablelands, among which the most cited were those of Boa Água (30 citations), Alcaçuz (22 citations), Timbó (19 citations), and Tabatinga (15 citations). These landscape units appear as distinct environments from the collectors' perspective, especially regarding the density of mangaba individuals. The collection is also carried out on farms, since there are many farmers in the three communities. According to those interviewed, most people in their homes participate in the collection of mangaba fruits, especially at harvest time. The fruits are usually collected in all the landscape units outlined in this study, but access to the sites today is limited due to privatization of areas which were previously freely accessible.

According to the interviewees, the fruits are preferably collected in mangabeiras located in the tablelands (45.76 % citations), followed by the yard (22.03 % citations), farms (18.64 % citations), and areas close to home (13.56 % citations). There was greater consensus among informants regarding collection in the landscape unit known as the Boa Agua region. Many collectors live in this region and collect mangaba as a complementary source of income and/or survival. It is usually in this region that the collectors gather to sell the mangaba to the middlemen/distributors.

The collection is mainly performed in sites where access to the resource is allowed, showing that the collection is not performed for particularly individuals, but rather where mangaba is found and independent of its characteristics. The preferred collection sites cited by the informants were the tablelands of Alcaçuz and Mamãozinho for the largest quantity of fruit; Tabatinga for the proximity and access ("good walking forest"); Aningas for being more conserved and therefore having more mangabeiras and fruit available to collect; and in backyards and farms for the proximity and for having bigger and better quality mangabas.

The mangaba fruits are classified by collectors as: "*mangaba de tabuleiros*," which are small fruits with a thicker shell; "*mais sofrido*" with a more reddish coloration; while those from farms are large fruit with whitish flesh, a thinner

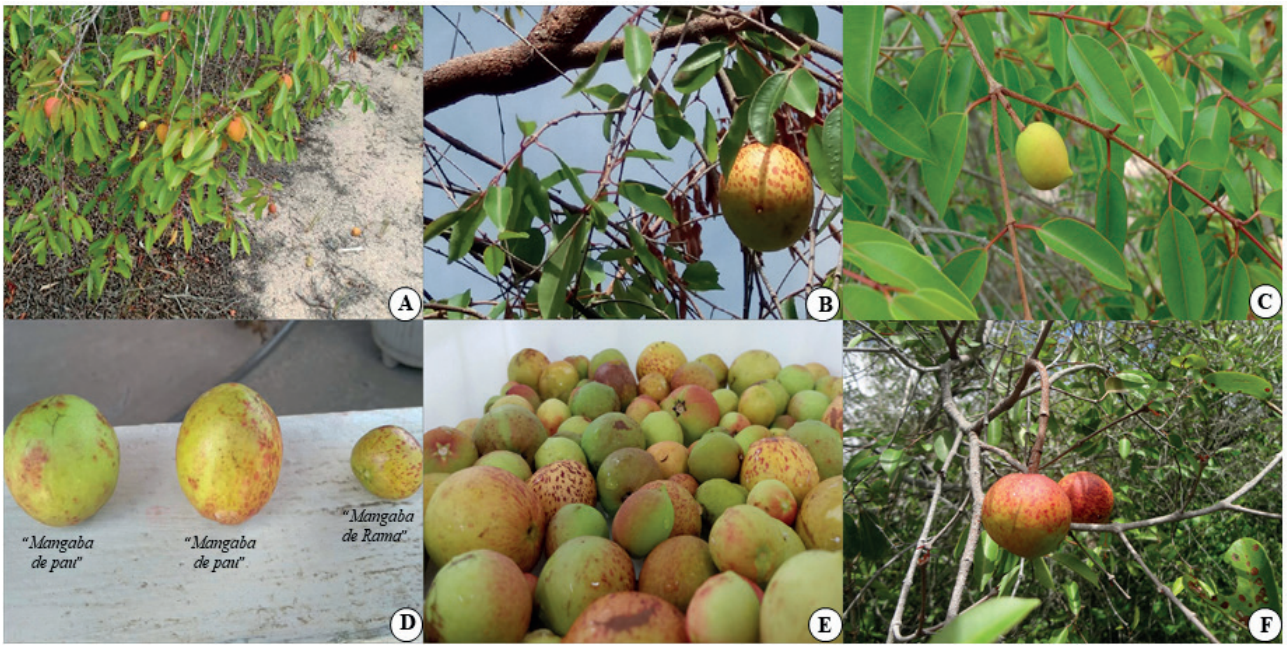

Figure 3. Mangaba fruits occurring in the rural communities of Nísia Floresta, Rio Grande do Norte, Brazil. **A.** "*Mangaba de rama*"; **B.** "*Mangaba de pau*"; and **C-F**. Morphological variation of mangaba fruits. Photographs taken by Kívia Soares de Oliveira in 2019.

shell, and "cleaner" (with fewer red stains). According to the collectors, both open and closed areas (tablelands) are found: popularly known as "*mangaba de pau*" (name given due to being born linked to the thickest branches of the tree), are bigger and redder, "painted" (yellow with the red stains in the peel); "*mangaba de rama*" (for being found in the tree branches) are smaller, but in larger quantity; the "*mangaba de sombra*" are those which have white pulp because they grow under the leaves, changing to yellowish when it is slightly ripe, and are light green tending to yellow with "clean" peels (without the red stains on the peels), and they are sweeter and tastier; and the "*mangaba de sol*" are painted (red stains, "gusts"), with thick peels. The local names "*rama*" and "*pau*" mangaba and "*sombra*" and "*sol*" mangaba are used to express the phenotypic variations associated with the size and color of the fruit, respectively (Fig. 3).

Discussion

Knowledge, use, and management of ***H. speciosa***

Our results show that the local knowledge on mangaba fruit is equally distributed among the members of the Timbó, Boa Água, and Bonfim communities in terms of gender; however, women and men over 40 years of age are traditional holders of the greater knowledge of diversity of uses, which is better distributed among women, regardless of age group. This can be explained by the fact that men also act, even if to a lesser intensity, in the management and marketing of this species (Sousa *et al*. 2019). Despite the greater participation of men in the activity, knowledge among women is better distributed, probably due to their participation in all mangaba extractivism activity stages (from collection to marketing). It is believed that this fact is also related to the differentiation of daily tasks between genders. According to Santos & Souza (2016), the division of labor between the genders is present in most groups which practice extractivism, with men being responsible for sea fishing and coconut collecting, while mangaba extractivism, fishing in the proximity of the mangrove and crafts are characterized as female activities. Oliveira *et al*. (2017b) found that knowledge about *Byrsonima crassifolia* and *B. coccolobifolia* is equally distributed among gender and age groups in the Darora community. Similarly, knowledge about the uses of *Stryphnodendron rotundifolium* showed no differences between genders or among age groups in a Brazilian savanna community (Feitosa *et al.* 2014). In contrast, the knowledge about the uses of *S. tuberosa* was equally distributed between men and women, despite gender differentiation in daily activities (Lins Neto *et al.* 2010). Sousa Júnior *et al.* (2013) found that knowledge on the use categories for the pequi fruit tree significantly differed between men and women.

Unlike gender, the age factor did affect the knowledge about the use of "mangaba" in the communities studied herein, with a tendency for wider knowledge among men (42-82 years) and older women (44-70 years) when compared with younger inhabitants. This fact can be explained by the collection time in the activity performed by the different genders. This further suggests that older people are likely to have more time to accumulate life long experiences (Silva *et al.* 2019). The lower knowledge level about the species among younger collectors can be explained by the lack of experience and contact with the region's plant resources, since their presence in the activity is usually higher during harvest periods when the resource is abundant. However, even with this lower participation in the activity, the young people had broad knowledge of the uses of "mangaba," which may reflect how important this resource is. The results are similar to those obtained by Monteiro *et al.* (2006) when they stated that knowledge about the use of plants is generally better distributed among the older than among the younger ones. For example, Hanazaki *et al.* (2000) conducted a study in two Caiçara communities in the Atlantic Forest and observed that the elders were more familiar with the art and medicinal use of plants.

Although mangaba fruit (*H. speciosa*) has various uses among the local population, the main mangaba usage category is food. The knowledge regarding these uses is evenly distributed between men and women of different age groups. The apparent uniformity of local knowledge is associated with high value regarding its use for food, demonstrating the importance of mangaba as a subsistence resource for human populations. Oliveira *et al*. (2018) report that the number of citations for species in the food and medicinal categories generally stands out, as they influence the survival of populations which are directly involved in the exploitation of natural resources, such as mangaba extractivist communities.

The uses associated with the species are mainly related with human food through consuming the fruit *in natura* and in processed form (juices, jellies, pulp, sweets, ice cream, liquors...), with both options being well accepted in the market (Pereira *et al*. 2012; Oliveira *et al*. 2017a). Other less evident uses can be employed such as for fuel, since the wood can be used as firewood for domestic use, as well as the use of latex for producing rubber, and leaves for organic fertilization. In studies on the diversity and uses of plants from the Cerrado, Lima *et al*. (2012) found that the most cited fruit trees were mangaba (*H. speciosa*), pequi (*Caryocar brasiliense*), and bacupari (*Tontelea micrantha*). There were two to eight uses attributed to these fruit trees, but the most common was for human food.

The bark, leaves and latex of *H. speciosa* are widely used medicinally by the residents of Timbó, Bonfim and Boa Água to treat gastrointestinal disorders (ulcer and gastritis), inflammation, hypertension, diabetes, anemia, and Chikungunya. The noted medicinal use of mangaba corroborates other studies which emphasize the bioactive properties of the species, demonstrating its potential for

antihypertensive, anti-diabetic, anti-obesity, antimicrobial, antioxidant, anti-inflammatory, cytotoxic, gastroprotective, vasodilator, and healing activities (Ferreira *et al*. 2007a; b; Moraes *et al*. 2008; Endringer *et al*. 2009; Marinho *et al*. 2011; Silva *et al*. 2011a; Geller *et al*. 2015; Pereira *et al*. 2015; Santos *et al*. 2016). For example, the bark produces several types of flavonoids, anthocyanins, catechins and tannins (Moraes *et al*. 2008). The leaves are used for drug extraction in blood pressure control (Silva *et al*. 2011a). In addition, mangabeira latex is used in popular medicine to promote liver functions and treat dermatological diseases, diabetes and hypertension (Ritter *et al*. 2002). In addition, *H. speciosa* latex is used to treat a variety of other diseases such as fungal diseases, sexually transmitted diseases, and tuberculosis (Sampaio & Nogueira 2005). This diversification of indications of medicinal uses highlights the importance of the medicinal category for local communities.

It was found that in the three communities studied the use of mangaba fruits for subsistence (mainly for human food in processed form or *in natura* consumption) and as an alternative source of income are the main practices of the three communities. The high values of diversity of the informants (IDV) registered for the mangaba in the studied communities indicate that both men and women showed to know more than half of the total uses cited for this species. Rufino *et al.* (2008), in studies conducted in the community of Buíque-PE, found low IDV values for babaçu (*Orbignya phalerata*), because only one informant showed to know more than half of the total uses cited for this palm tree (IDV 0.52), and more than half of the indices (65 %) ranged from 0.20-0.28. Additionally, according to these authors, the values of IDV obtained for ouricuri (*Syagrus coronata*) were lower than those registered for babaçu and only three informants reached values between 0.45-0.48, 13 % obtained indexes between 0.33 and 0.39, and half were in the range of 0.21-0.30.

All informants reported that mangaba has high potential for marketing. Considering that the main use attributed to mangaba is food, this species is one of the main sources of subsistence and income for numerous rural communities in the Northeast, and has been observed in studies with other species of socioeconomic importance, such as umbu (Lins Neto *et al*. 2010), pequi (Sousa Júnior *et al*. 2013), and muricis (Oliveira *et al.* 2017b). In studies on the use of flora by families settled in the Agroextractivist Settlement Project (PAE), Oliveira *et al*. (2018) found the predominance of native Brazilian species in the community (65.9 %), with mangabeira among the three species with the highest value of use for the community. Specifically, the authors asserted that mangabeira is among the species with great importance for subsistence and family income composition in the settlement. According to Byg & Baslev (2001), ethnobotanical studies carried out in different countries have shown that the local importance of a plant is a function of the quantity of uses existing in the community.

The commercialization of mangaba fruit is an important source of income for the three communities, emphasizing the socio-economic importance of the species for the region's traditional communities, especially during the harvest periods. This reinforces the importance of mangaba extractivism for the social reproduction and maintaining the ways of life of countless families, mainly those present in areas of community property, such as indigenous areas (Canguaretama, Rio Grande do Norte; Baía da Traição, Paraíba), extractive reserve (Resex Maracanã, Pará), quilombo (Sítio Histórico dos Kalunga, Goiás) and settlements (Pirambu, Sergipe) (Schmitz *et al*. 2009).

However, the only way to exploit mangaba is by selling it, and no other ways of processing the fruit are used, since there is no cooperative or association to strengthen the collectors' work in exploiting and commercializing the raw material. Most of the interviewees reported that the income from harvesting a mangaba crop enables them to meet their family's basic needs, such as for clothing and food. Some families take advantage of the harvest to purchase household appliances which facilitate domestic activities, in addition to investing in their children's studies. Thus, the social benefits generated by extractivism have a great influence on the quality of life of families. In studies conducted with extractivist communities in Sergipe, Santos & Souza (2016) found that this activity corresponds to 60 % of annual family income.

Mangaba fruits have a pleasant aroma and a large amount of nutrients, but are very perishable in their advanced maturation stage, which hinders *in natura* consumption. Therefore, fruit processing becomes promising for preparing ice cream, juices, liqueurs, and vinegars, increasing its shelf life (Oliveira Júnior *et al.* 2016). The fruit can be used in jelly manufacturing due to its high acidity; it has good use in producing ice cream, because in addition to adding value with its functional characteristics, it also has the capacity to instill flavor and inhibit crystal formation (Vieira *et al*. 2017). This reinforces the need to create a cooperative which adds value to the extractive product in the three communities, thus ensuring better use and improvement in the quality of life of families living from this resource.

Traditional populations are characterized by being able to recognize landscapes around them, and name them according to ecological characteristics and use (Silva *et al.* 2016). The local names "*mangaba de rama*" and "*mangaba de pau*", "*mangaba de sol*" and "*mangaba de sombra*" are used to express the phenotypic variations associated with the size and color of the fruits, respectively. Although the ethnovarieties of *H. speciosa* have been reported by extractors, they have not associated this resource with a specific botanical variety. Thus, characterizing ethnovarieties, as well as their uses, is based on the characteristics of the fruits, especially color, size, and taste. In studies developed by Adan *et al.* (2016),

the criteria used by extractors for identifying/characterizing ethnovarieties and botanical varieties of *Araucaria angustifolia*, as well as their use (current or potential), is based on the characteristics of the seeds, especially the maturation time. In contrast, Smith & Fausto (2016) studied pequi (*C. brasiliense*) and verified that the Kuikuro native people attribute first names to characteristics (fruit size, taste, pulp color, thorns in the endocarp...) instead of to specific varieties in order to characterize the phenotypic variation among individuals, unlike in the case of cassava among the Kuikuro themselves or among other indigenous groups in the Amazon.

Management of ***Hancornia speciosa***

Based on the management regimes described by local informants, mangabeira can be classified according to the management scale proposed by González-Insuasti & Caballero (2007) as a species under incipient non-selective management. Collection and promotion are the most frequent management practices observed in the initial stage of this process, without the intentional selection of desirable individuals. The preferred characteristics mainly occur in managed areas, similar to those found in *S. tuberosa* and *C. coriaceum*, where attention is directed to their fruits (Lins Neto *et al.* 2010; Sousa Júnior *et al.* 2013; 2016). In all of these cases, including the mangaba tree, cultural aspects guide the selection and management of desirable species. These features include the local usage preferences, the specific classifications which describe the quality of the desired trait, and the management of the species *in situ* (Lins Neto *et al*. 2010).

Among the factors which exert strong pressure on the intensity of plant resource management, reported by González-Insuasti *et al.* (2008), the land tenure system and the species biology might influence the management practices in mangaba harvesting. Linhares (2010) observed that young janaguba trees (*Himatanthus drasticus*, Apocynaceae) in small plantations in the state of Maranhão are preserved to protect the species and to guarantee future harvest. These tolerant practices are considered evidence of incipient management or domestication (Clement 1999; González-Insuasti & Caballero 2007). Similar practices were found in this study, mainly on private properties where mangaba trees are kept in combination or not with other species, to maintain the species and the availability of its resources. In addition, promotional practices were identified to favor the quantity and quality of fruit for marketing. However, such practices were not found in tableland areas generally more accessed by collectors, most likely because they are areas where access is free, and since the collector does not own the land, they only perform collection. Therefore, neither significant changes in the landscape nor investment in techniques to increase productivity are expected in these areas.

Several authors verified incipient management forms of plants and identified the following management types: tolerance, protection and promotion (Salinas *et al*. 1993; Casas *et al.* 1997a; Caballero 1990). Arboreal individuals with desirable characters and managed by human beings can be tolerated in specific areas, promoted by dispersion of their vegetative or sexual propagules, and protected from competitors or herbivores (Salinas *et al.* 1993; Avendaño *et al.* 2006; Casas *et al.* 2007). However, these practices are not only aimed at increasing the amount of desirable plant resources, but they also involve artificial selection favoring quality of the resources managed in a system (Lins Neto *et al*. 2014).

In studies on the spatial distribution of mandacaru individuals (*C. jamacaru* subsp. *Jamacaru*), Lucena *et al.* (2015) verified that the species is in a possible incipient domestication process because it is affected by some type of involuntary management which may be tolerance or protection; such factors have been recorded in the literature in other communities (Casas 2001; Blancas *et al*. 2010). For example, the Brazil nut (*Bertholletia excelsa* Bonpl.) is Amazonia's most important extractive product, contributing to the livelihood and food security of numerous of families in the interior of the region (Wadt & Kainer 2009), where it was observed that several populations along the Purus River in southern Amazônia have quite large seeds, suggesting an incipient domestication (Clement 1999).

According to Sousa Júnior *et al.* (2016), the pequi "*zelado*" (populations considered under incipient management) corresponds to an arboreal individual maintained and protected in a similar way to the protection granted to other plant species. This suggests that the promotion and protection of individuals are management tools which play an essential role in the domestication process (Sousa Júnior *et al*. 2016). Eliminating unwanted individuals observed in other plant species (Casas *et al.* 1997b) was not reported in the case of mangaba, according to the collectors. Moreover, elimination did not occur in studies with other tree species of potential value to northeastern Brazil, such as umbu (*S. tuberosa*) (Lins Neto *et al*. 2010) and pequi (*C. coriaceum*) (Sousa Júnior *et al.* 2016). Mangabeira is not eliminated because it represents an important source of income and food. In addition, people collect mangaba fruits regardless of their intrinsic characteristics (*e.g.*, size, flavor, peel color, pulp color...), because in most cases the difficulty of access to mangabeira trees and the limited resources make them collect mangabeira fruits which are available for collection or where access is still allowed.

In the case of the wild edible plants, it was verified that different management regimes, including selective harvesting, pruning, and favourable environmental modifications were applied to different groups of wild edible plants to ensure their sustainable use (LaRochelle & Berkes 2003). In this respect, human cultural values and traditional ecological knowledge of plant resources are therefore decisive for making management decisions in

order to ensure or increase the availability and/or quality of desired plant resources (Blancas *et al*. 2013). However, despite extensive ethnoecological knowledge and awareness of sustainable harvesting practices, market forces might cause communities to perform abusive harvesting of wild plant resources to meet both market demand and their immediate economic needs (Ghimire *et al*. 2004).

In studies at the agroextractivist settlement Pirambu-SE, Lima *et al*. (2019) found several forms of mangabeira management, among them: removing the "branch," locally known as "erva-de-passarinho", which grows on the trees; cleaning and grazing around the mangabeiras, avoiding letting the bush dominate, since it hinders the development of the plant and collection; applying fertilizer or using only the leaves from the ground as organic fertilizer; and leaves that fall from the mangabeira are collected and burned under the plant so that the leaves which are still in the tree also burn. Additionally, according to these authors, the branches are renewed with flowers and then the fruit appears; they perform the pruning so that the plant renews with branches and flowers. In this aspect, it can be inferred that current management practices in mangabeira individuals are shaped by factors which include economic and cultural values of the species and oriented to increase production and quality of the fruits.

According to Smith (2011), landscape domestication is the result of small changes in the environment and in the plant community resulting from various management practices which are taught by generations within traditional communities. In this context, changes in landscapes carried out over time by humans as a result of their needs can directly or indirectly affect the dynamics and population structure of a species through practices which may involve the promotion/protection, thickening, pruning, mowing/removing plants or even animal breeding (Filippon 2014). In the case of *H. speciosa*, changes in landscape units such as areas of farms/private properties and backyards where the species is under tolerance management, keeping the arboreal individuals naturally dispersed in the site, in combination with the management of other fruits and crops (i.e. cassava, potatoes, sugarcane) promotes a higher level of human intervention and land occupation, but adds a diversity of resources to the landscape by including other useful species in the space. Ferreira *et al*. (2019) studied intensive management forests around pre-Columbian and modern settlements in the Madeira-Tapajós interfluve and observed that *Euterpe precatoria* and/or *Attalea speciosa* individuals, which are important for food and medicine, showed a tendency to be more abundant in places closer to settlements. According to the authors, the presence of these species suggests possible enrichment. Therefore, enrichment of forests with species of interest may result in landscape domestication (Clement 1999; Smith 2011; Levis *et al*. 2018), and is expected in human populations which depend on plant resources for their livelihood (Stahl 2015).

Promotion management (pruning, organic fertilization, quick burning mangabeiras and breaking branches) used to increase the availability of fruits can also be interfering in the landscape structuring. Breaking branches during collection and quick burning of mangabeira trees, for example, may contribute to landscape degradation and interfere with processes such as flowering, fruiting and reproduction if they are performed frequently, which may be linked to the dynamics of survival of other interacting species (*e.g*., birds, mammals, insects and reptiles) which eat the fruit, disperse the seeds and participate in the pollination of the mangabeira flowers (Valiente-Banuet & Godínez-Alvarez 2002; Leal *et al*. 2007).

It is important to emphasize that the privatization of areas and the deforestation for monocultures (sugarcane and coconut) and construction of houses and tourist enterprises in the studied regions have also significantly contributed to the process of landscape modification, and consequently altered the populations of mangabeira individuals and the availability of resources available for collection. As a result, many collectors have to travel long distances in search of other spaces for mangaba collection, which may also compromise the continuity of this cultural practice which has subsidized the maintenance and survival of numerous extractivist families over the years, and play an important role in the conservation of mangabeira through its uses and local management.

The current study showed that mangabeira must be managed in a sustainable way because it is a species with economic potential and ecological interdependence with local biodiversity. It can be inferred herein that the conservation of the species is not endangered by its use, but possibly by the increase in deforestation of remaining areas of mangabeira, which increases the vulnerability of the species and socio-environmental conflicts for access to resources. This condition can interfere with the provision of ecosystem services which not only result in specific ecological problems for this species, but also for those which interact with it. Therefore, the performance of management practices together with the traditional knowledge of the communities can provide precise information on how local practices interact with mangabeira populations. The vast knowledge possessed by local people, particularly local specialists, on the uses, biological and ecological aspects, and extraction process of mangaba has great implications for developing appropriate strategies for biological and ecological research for the management and conservation of these resources (Ghimire *et al*. 2004). Finally, we emphasize that the different management practices identified in this study may have distinct ecological impacts on *H. speciosa* populations. Thus, the characterization of ethnobotanical knowledge related to management practices represents a fundamental step for devising sustainable management strategies for any plant species (Baldauf & Santos 2013).

Conclusion

Our study provides insight into the knowledge, use and management of *H. speciosa* in three rural communities in Rio Grande do Norte in Northeast Brazil. The communities have wide usage knowledge of the species, among which food and medicinal uses stand out. Knowledge on the uses of *H. speciosa* is evenly distributed between the genders, but is influenced by age groups, with older individuals and/or individuals with a longer history in the activity being traditional holders of greater knowledge of uses. Local informants are dependent, exclusively or partially, on the resources offered by this species, and its value is mainly based on food and commercialization uses of the fruit, widely known and still in current use among informants.

The fact that collectors identify ethnovarieties and develop management practices of *H. speciosa* individuals, especially in promotion, tolerance, and protection of the species with the objective of increasing the production of fruits with specific qualities (*e.g.*, size, color, and flavor) is a significant finding which can influence the future of the species. This is an important fact given the recurrent and extensive history of deforestation and reduction of the species in several Northeast regions. In this respect, local informants recognize that keeping resources naturally dispersed is more economically viable than cultivating them because of the ecological characteristics (*e.g.*, seed recalcitrance, longevity) of the species. The relationship between phenotypic variation and local management identified in this study suggests a possible incipient domestication process of the species. Some currently used management practices by extractors may negatively influence the regeneration and maintenance of the species. For example, breaking branches during collection and quick burning in mangabeiras may affect flowering and fruit production in the next few harvests. One implication of the current scenario, which now makes access to resources difficult due to the privatization of the areas, is that people with a long history of sustainable use must move away from traditional management techniques and find less desirable alternatives to ensure their livelihood. Finally, one of the great challenges here is to implement conservation policies for this species which enables access to land, use of resources, and also takes into account the complex and evolving relationship with the people who manage and depend upon it.

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