



Management of *Lepidocaryum tenue* and *Socratea exorrhiza*, two Amazonian palms used for thatching

Manejo de *Lepidocaryum tenue* y *Socratea exorrhiza*, dos palmas usadas para techado en la Amazonia

Jaime A. Navarro López, Rodrigo Bernal, Gloria Galeano

Databases and Inventories

Abstract

Background: The palms *Lepidocaryum tenue* and *Socratea exorrhiza* provide the raw material for one of the most prized thatches of the Colombian Amazon. Roofs thatched with *Lepidocaryum* leaves braided along split *Socratea* stems are highly appreciated and demanded by local inhabitants, due to their availability and freshness; as a result, both palms are an important source of cash income. Demand for *Lepidocaryum* roofs has increased, especially around the city of Leticia, due to population growth and tourism. Population size structure of both palms is similar to that reported in other places of the Amazon basin.

Methods: Data were collected in five indigenous communities north of Leticia, Amazonas department (Colombia). In two communities we used participant observation to collect information about extraction practices and management processes. At all five places, we also conducted semi-structured surveys among 10 harvesters and 54 households, to learn about the harvest, management, and marketing of both species. Population size structure was evaluated at El Zafire Biological Station, where we

selected 40 subplots of 0.01 ha for *Lepidocaryum* and 12 ha for *Socratea*.

Correspondence

Jaime A. Navarro López^{1*}, Rodrigo Bernal², Gloria Galeano^{3*}

¹Universidad ECCI, Bogotá, Colombia

²Reserva Natural Guadualito, Montenegro, Quindío, Colombia

³Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogotá, Colombia

*Deceased

*Corresponding Authors: jnavarrolop@gmail.com, rgbernal@gmail.com

Ethnobotany Research & Applications
19:49 (2020)

Results: Around 4000 harvestable individuals of *Lepidocaryum* and about six harvestable stems of *Socratea* were found per ha. Thatching a 48 m² house requires ca. 1 ha of a forest with *Socratea* and 0.81 ha with *Lepidocaryum*. The traditional management practice is to harvest all but the three

youngest leaves of *Lepidocaryum*, and selectively log the tallest individuals of *Socratea* (>15 m). We discuss the management practices of the involved species, as well as trade trends and resource supply in the area of Leticia.

Conclusions: We recommend maintaining and extending traditional management practices. Nonetheless, due to overexploitation near human settlements, it is also necessary to recover the populations of both species, to guarantee the supply of raw material and prevent this economic activity from becoming unfeasible.

Keywords: Arecaceae, harvest, non-timber forest products, shelter, trade.

Resumen

Contexto: las palmas *Lepidocaryum tenue* y *Socratea exorrhiza* proporcionan la materia prima para uno de los techos más preciados de la Amazonía colombiana. Los techos cubiertos con hojas de *Lepidocaryum* trenzadas a lo largo de tallos de *Socratea* rajados son muy demandados por los habitantes locales, debido a su disponibilidad y frescura; debido a esto, ambas palmas son una fuente importante de ingresos monetarios. La demanda de techos de *Lepidocaryum* ha aumentado, especialmente alrededor de la ciudad de Leticia, debido al aumento de la población humana y el turismo. Discutimos las prácticas de manejo de las especies involucradas, así como las tendencias comerciales y el suministro de recursos en el área de Leticia.

Métodos: los datos fueron obtenidos en cinco comunidades del norte de Leticia, Amazonas (Colombia). En dos de esas comunidades se utilizó observación participante para recolectar información de prácticas de extracción y procesos de manejo. En todas las comunidades desarrollamos entrevistas semiestructuradas entre 10 cosechadores y 54 dueños de casas para recolectar información acerca de la cosecha, manejo y comercialización de ambas especies.

Resultados: hallamos alrededor de 4000 individuos cosechables de *Lepidocaryum* y alrededor de seis tallos de *Socratea* por hectárea. Techar una casa de 48 m² requiere ca. 1 ha de bosque con *Socratea* y 0.81 ha con *Lepidocaryum*. La práctica de manejo tradicional es cosechar todas las hojas de *Lepidocaryum*, excepto las más jóvenes, y cortar de manera selectiva los individuos más altos de *Socratea* (>15 m).

Conclusiones: recomendamos mantener y extender estas prácticas de gestión tradicionales. Pero

también es necesario recuperar las poblaciones de ambas especies cerca de los asentamientos humanos donde se realizan cosechas intensivas, para garantizar el suministro de materia prima y evitar que esta actividad económica se vuelva inviable.

Palabras clave: Arecaceae, comercio, cosecha, productos forestales no maderables, vivienda.

Background

Among the many uses given to palms, their utilization as a source of building material is one of the most widespread, especially the use of leaves for thatching (e.g., Campos & Ehringhaus 2003, Paniagua-Zambrana *et al.* 2007, Johnson 2010, Macía *et al.* 2011, Cámara-Leret *et al.* 2017). Most palm leaves have some potential for thatching (Johnson 2010, Galeano & Bernal 2010), but only a few species have populations abundant enough to provide sufficient raw material for roofing multiple houses. The Amazonian palmlet *Lepidocaryum tenue* is ideal for roofing, because its leaves are small and highly durable (Mejía 1992, Navarro *et al.* 2011), the species forms large populations, and because it is the most abundant palm in the forest understory through a vast area of the Amazon (Voormisto *et al.* 2004, Balslev *et al.* 2010, Balslev *et al.* 2016).

On the other hand, the support onto which the leaves are braided is also of vital importance in making a roof, because its quality will impinge on the roof's useful life. The most commonly used thatch support in northwestern Amazonia comes from the split stems of the palm *Socratea exorrhiza*, which is found in a variety of forest types throughout the Amazon basin (e.g., Kahn & Mejía 1991, Voormisto *et al.* 2004). With these two palms, large tiles are produced, which are 3 m long and 1 m wide (with an effective roof coverage of ca. 0.6 m²), and are one of the main traditional roof materials in the Colombian and Peruvian Amazon (Mejía 1992, Vásquez & Baluarte 1998, Brokamp *et al.* 2011, Mesa & Galeano 2013, Gutiérrez 2020), and has become the favorite one in tourist sites (as lodges, small hotels and restaurants) around the city of Leticia, due to its freshness and beauty (Navarro *et al.* 2011).

Although the uses of both species for roofing have been documented (e.g., Bernal *et al.* 2011, Macía *et al.* 2011, Mesa & Galeano 2013, Salo *et al.* 2014, Gutiérrez 2020), as has their trade in Peru (Mejía 1992, Pyhälä *et al.* 2006, Warren 2008, Brokamp *et al.* 2011, Cotta 2015, Oñate *et al.* 2018), little is known about their management practices and their trade in Colombia, specifically in the vicinity of Leticia, where most of the market for this type of roof

is concentrated. The growing demand for *Lepidocaryum* roofs in this area has generated so much pressure on the populations of both species, that harvestable palms are increasingly farther away, and harvest effort is accordingly larger, leading to intensive or destructive harvesting practices, which can cause the local exhaustion of the resource (Navarro *et al.* 2011).

In this work, we document the population size structure of *Lepidocaryum tenue* and *Socratea exorrhiza*, and the local practices for their management, harvest, transformation, and marketing. Based on this information, we propose strategies for the sustainable management of both species.

Material and Methods

Study site

The study was carried out in the municipality of Leticia (Amazonas department, Colombia), in five indigenous communities located along the Leticia-Tarapacá road (4°12'S, 69°56' W; 4°04'S, 69°59'W), where *Lepidocaryum* tiles are marketed and used, and at El Zafire Biological Station (4°00'20"S, 69°53'55"W) where extensive populations of *Lepidocaryum tenue* and *Socratea exorrhiza* exist (Figure 1). Average annual rainfall in the area is 3315 mm and the average temperature is 25.8°C. The vegetation around the indigenous communities is composed of a matrix of mature forests mixed with scrub, secondary forests and slash-and-burn agricultural plots (locally called *chagras*). At El Zafire, the forest has not been harvested.

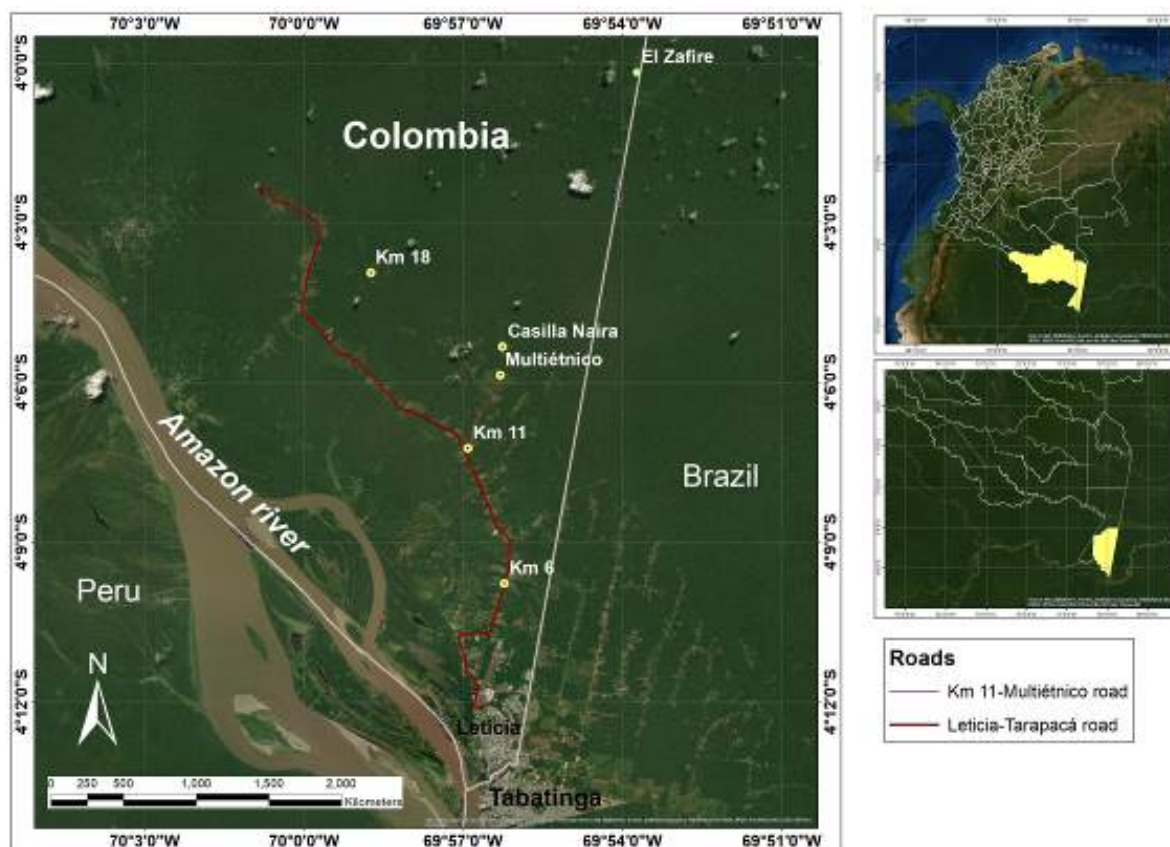


Figure 1. Location of the sites where management of *Lepidocaryum tenue* and *Socratea exorrhiza* was studied in the Colombian Amazon.

The villages in the area are inhabited mainly by Ticuna and Uitoto indigenous peoples, with a smaller proportion of Yucuna, Bora and Yagua, among others; there are also some mestizo and white settlers (Ortiz 2004, Tobón 2006). All of them traditionally use *Lepidocaryum* for roofing (Rodríguez 2006). Due to the proximity of the villages to Leticia and the easy access by road, forest products, including *Lepidocaryum* tiles, are commonly marketed. Most local forest products are

sold in Leticia, as this city is the regional center of economic activities (Riaño 2009, Dane 2016).

Study species

Lepidocaryum tenue (locally known as *caraná* near Leticia, or *irapay* in neighboring Peru) is a dioecious, cespitose palm with clonal growth by means of long stoloniferous rhizomes (Kahn & Mejía 1987, Navarro *et al.* 2011). It makes up extensive colonies in the forest understory, locally known as *caranales* or *manchales de caraná*. The species grows mainly on

terra firme, often associated with deep, well-drained white-sand soils (Kahn & de Granville 1992). It also grows (in lower density) on temporarily flooded and poorly drained soils (Kahn & Mejía 1987, Kahn & de Granville 1992). *Lepidocaryum tenue* has a wide distribution from western Venezuela to Brazil and Peru, from sea level to 500 m of elevation (Henderson *et al.* 1995).

Socratea exorrhiza (locally known as *zancona* in Leticia, and *cashapona* in neighboring Peru) is a monoecious, solitary palm with a stem up to 28 m in height and 18 cm in diameter (Henderson 1990, Henderson *et al.* 1995, Galeano & Bernal 2010). *Socratea* is remarkable by the prominent cone of stilt roots up to 3 m high, individual roots provided with short, conical spines (Galeano & Bernal 2010). It grows both in alluvial plains with poorly drained soils and in well-drained *terra firme* forests. The species has a wide distribution, from Nicaragua to Brazil, from sea level to 1000 m altitude (Henderson 1990, Henderson *et al.* 1995).

Data collection

We collected data between 2008 and 2012 in five villages north of Leticia: Casilla Naira, El Multiétnico, Kilómetro 6, Kilómetro 11 and Kilómetro 18. Three of these villages (Kilómetro 6, Kilómetro 11 and Kilómetro 18) are located along the Leticia-Tarapacá road, whereas Casilla Naira and El Multiétnico are at the end of a secondary road located between the community of Kilómetro 11 and the Tacana River (4°05'53.54"S, 69°56'21.02"W). In Casilla Naira and Kilómetro 18, we conducted participant observations at harvest sites, to learn about extraction practices and to document the management process from harvest to marketing. In all five villages, we also conducted semi-structured surveys among 10 harvesters (local experts) and 54 households, to learn about the harvest, management, and marketing of both species. The 54 households were selected taking into account that they had a building with caraná roof; 14 of the interviewed household members were women. The harvesters were selected among those mentioned by inhabitants of El Multiétnico and Kilómetro 11 during the survey. Four harvesters were from Kilómetro 11, three from Kilómetro 6, two from Kilómetro 18, and one from Casilla Naira; all of them were men.

To understand the population size structure of *Lepidocaryum* and *Socratea*, we used the permanent plots of El Zafire, where we recorded all individuals of *Lepidocaryum* in eleven 0.01 ha quadrants. Additionally, we used four other quadrants to record juveniles and 25 additional quadrants to record seedlings, in order to obtain a better sample of these size classes. For *Socratea*,

we recorded all individuals different from seedlings in 12 ha of a permanent plot (juveniles, subadults and adults), and all seedlings in 20 randomly selected 0.01 ha plots within those same 12 ha. The difference in size sample between both species is due to their contrasting abundances --whereas *Lepidocaryum* has up to 6000 harvestable stems per ha, for *Socratea* there are no more than 11 harvestable individuals in the same area. The sampled sites showed no signs of harvest.

For all individuals of both species, we recorded stem height, the presence of reproductive structures, and the number of leaves in the crown. For individuals of *Lepidocaryum* that did not have a developed stem, we counted the number of main veins in the youngest leaf, as described by Galeano *et al.* (2010). The above-mentioned features were used to establish size classes (Table 1). The population size structure of *Lepidocaryum* was defined according to Navarro *et al.* (2011). To define the size classes of *Socratea* we first defined three biological stages, seedling, juvenile, and adult, and we then used stem height to split juvenile and adult classes (see Table 1).

Results

Harvesting *Lepidocaryum tenue*

The first step for harvesting *Lepidocaryum* is to locate a suitable palm stand. A stand is deemed appropriate if at least 1000 leaves can be obtained from it. Leaf availability has decreased near Kilómetro 6, Kilómetro 11, and El Multiétnico villages, and nowadays harvesters must walk more than two hours for finding a suitable stand, whereas ten years ago palm stands could be found just 10-15 minutes walk away. Harvesters at Kilómetro 18 and Casilla Naira, on the contrary, state that there are still palm groves in good condition in their surroundings, so they do not need to walk more than 30 minutes to find the raw material for the roofs.

The extraction zones are communal territories, and most interviewees said that each family owns a forest area from which the leaves are taken. When leaves are lacking in their land, they ask permission from a neighbor or relative to harvest in theirs. Despite land tenure, it is common for people from other communities, reservations, or neighbors to harvest leaves in communal areas. As pointed out by harvesters, most illegal harvesting is done destructively, by cutting all leaves from a stem or just cutting the individual's crown. However, according to our observations, the landowners themselves also sometimes carry out such malpractices.

Leaves are harvested mostly from individuals with a developed stem (subadults and adults), but juveniles

individuals are also harvested sometimes, because they are abundant and provide large-enough leaves (see traits of each category in Table 1). However,

some harvesters claim that leaves from juveniles are more tender and, therefore, less durable.

Table 1. Size classes of *Lepidocaryum tenue* and *Socratea exorrhiza*, two palms used for thatching in the Colombian Amazon.

<i>Lepidocaryum tenue</i>		<i>Socratea exorrhiza</i>	
Class	Characters	Class	Characters
Clone	Asexually produced plant with bifid leaves		
Seedling	Sexually produced plant with bifid leaves	Seedling	Bifid leaves
Juvenile 1	Leaves with up to 18 veins	Juvenile 1	Stem < 1 m tall
**Juvenile 2	Leaves with more than 18 veins	Juvenile 2	Stem 1–5 m
*Subadult	Stem up to 50 cm tall	Juvenile 3	Stem 5–10 m
*Adult 1	Stem 50.1–100 cm tall, with evidence of reproduction	**Adult 1	Stem >10<15 m
*Adult 2	Stem 100.1–150 cm	*Adult 2	Stem >15<20 m
*Adult 3	Stem 150.1–200 cm	*Adult 3	Stem > 20 m
*Adult 4	Stem > 200 cm		

* Size classes traditionally harvested.

** Size classes harvested for commercial purpose.

Harvest is made by selecting the best leaves in a stem, grouping them on one side of the crown and cutting them with a sharp machete. If the stems are tall enough, they can be tilted without damage. When the leaves are intended for domestic use, it is customary to harvest only those palms with a well-developed stem and to select the best leaves of each stem (leaves with segments 50 cm or longer and petiole longer than 50 cm long), in most cases leaving three or more leaves on each stem (plus the spear leaf). When the harvesting is for marketing, small or broken leaves are also selected, and juvenile individuals are also harvested; in such cases sometimes all leaves in a stem are cut, and even the whole crown itself, is often cut. The process of leaf harvesting and bundling is shown in Figure 2.

Harvesting and bundling 1000 leaves takes 5-6 hours, not including the time needed to reach the harvest site. Cut leaves are stacked in piles to facilitate bundling. Once enough leaves have been collected (i.e., at least 1000 leaves), the leaf bundle (locally called *capillejo*) is assembled and tied up with leaflets of the palm *Oenocarpus bataua*, or with the long hanging roots of the hemiepiphytic aroid *Philodendron solimoesense*.

Individuals with a developed stem have 4-19 leaves ($X = 9.3$, $SD = 3.1$, $n = 449$); if three leaves were left in the crown, about 167 stems would be needed to form the 1000-leaf bundle. A bundle with that number of leaves weighs around 75 kg, the customary load carried by one person; some harvesters claim that they can make and carry packages with more than 1000 leaves, which weigh up to ca. 100 kg.

Harvesting *Socratea exorrhiza*

The leaves of *Lepidocaryum* are braided onto wooden strips (locally called *ripas* or *chontas*), obtained from the stems of the palm *Socratea exorrhiza*. For this purpose, adult palms taller than 15 m are harvested, size being considered the best indicator of a good palm for harvesting. Additional indicators to identify the best individuals, according to harvesters, are those with stilt roots taller than 2 m, and a black stem, which, they claim, indicates that the palm is old enough and will provide hard strips. Only the lower part of the stem is used for thatching, mostly the basal 8-9 m; above this height, the stem is too slender, and the strips would not support the weight of the leaves. Individuals with bent stems, or those that started to reproduce too low, are not highly valued, as their strips are either bent or too weak.

A palm taller than 15 m, with an average diameter of 10.5 cm ($SD = 1.5$, $n = 76$) will produce 2-3 pieces 3-4 m long each, and 7-11 strips 3-5 cm wide can be obtained from each piece, for a total of 14-33 strips. Width of the strips depends on the type of use: for the harvester's own house or for a communal house (*maloca*), strips 5 cm wide are used, whereas narrower strips (3 cm) are obtained for marketing.

When felling a palm, the stilt roots are cut first. Choosing the fall direction is essential, in order to avoid that the crown remains entangled in lianas or on other trees, which would delay work for up to one hour. Once the palm is felled, it is cut with an ax at the height of the upper roots, the 3-4 m logs are measured and cut again with a machete; because the stem at 3-4 m height is thinner, cutting with an ax can cause damage. To obtain the strips, a split is

made with the ax at one end of the log, and then another split at the required width, and leverage is then made with the ax blade for detaching the strip (Figure 3). Subsequently, each strip is taken by the opposite end to the one that was split, and the inner soft tissue is removed; one harvester claimed that the soft part will not detach easily if the process starts from the same end where the split was made,

thereby increasing the working time. Usually, only the strips from one half of the log are split, and the other half is hollowed out and used as a container for carrying the strips to the working site. The logs can also be split in half, using a stick as a wedge, avoiding that the stem pinches the ax.



Figure 2. Harvest of *Lepidocaryum tenue* near Leticia, Colombia. A, cutting; B, gathering; C-E, bundling; F, taking the leaf bundles home.

The time needed to fell a *Socratea* palm is 4-5 min, dimensioning it takes 8-12 min, and splitting and removing the soft inner part takes 18-30 min. The stems of *Socratea* are not very heavy and a single person can load the strips or sections of a palm

(without the soft part) to the working site. As with *Lepidocaryum*, local artisans claim that several years ago individuals of *Socratea* were found close to the communities, but now they must walk more than three hours in order to find any adult palms.



Figure 3. Extraction of *Socratea exorrhiza* stem strips near Leticia, Colombia. A, felling the palm; B-C, cutting and dimensioning, D, cutting the logs; E, splitting the logs; F, removing the inner, soft portion; G, taking the strips home.

Braiding the tiles

In the area around Leticia, each tile or section of a *Lepidocaryum* roof is called *pañó* or *peine*. Each tile is 3-4 m long, with a certain number of *Lepidocaryum* leaves woven on a strip of *Socratea* stem. The number of leaves for a 3 m tile is 95-132 ($X = 117$, $SD = 13.3$, $n = 30$), depending on the quality of the leaves or the tightness of the braiding. For braiding the tiles, *Lepidocaryum* leaves are taken one after the other, and the petiole is folded around the *Socratea* strip. Each leaf must be left with the blade in contact with the strip. The remaining portion of the petiole will then be bent over the previous 2-3 leaves, and the tip will be placed under the base of the

previous 3rd or 4th leaf. Each time a new leaf is placed, it is necessary to lift the previous 3-5 leaves, to put the new leaf under them; that guarantees that the tile lasts longer. Figure 4 shows the braiding process.

Lepidocaryum tiles have an additional appeal –the figures that can be made with the petioles. These are made to enhance the houses or *malocas*, but they require more effort and craftsmanship for their production. These fine tiles also require leaves with longer petioles (up to 80 cm). Two types of braiding are shown in Figure 4



Figure 4. Braiding *Lepidocaryum* tiles near Leticia, Colombia. A, Placing the *Lepidocaryum* leaves onto the *Socratea* strip and under previous leaves; B, bending the petioles around the *Socratea* strip; C, finishing the tile; D, lower face of the tile, where the petioles press the leaf segments; E, sun drying the tiles; F, two different kinds of braiding. This figure is in color in the electronic version.

The leaves should be braided when they are still green, so that the petioles are flexible and do not break when making the tile. Some craftsmen claimed that the newly woven tiles can be put on the roof when they are still green; however, most assured that it is better to let them dry in the sun for at least three days before placing them on the roof.

The time used to braid a *pañó* was 30-60 min for a 3 m tile. The production of some fine tiles may take more than 1 hour. According to several artisans, the elaboration of 100 tiles can take around 15 days,

including five days to harvest stems and leaves, and braiding ten tiles per day.

The production of tiles was usually made by just one member of the family, usually the father; however, sometimes his wife or children also participate. When the tiles are made for harvester's own houses, it is customary to call a *minga* (collective work) with family and friends, to accelerate the process. According to local interviewees, the ceilings of the large *malocas* were formerly made by the whole community in a great *minga*. On those occasions, the

craftsmen competed to make the tiles with the most beautiful braids, and it was an opportunity for the youth to learn the art of palm thatching.

Management

In terra firme forests, such as those of El Zafire, there were 6900-14700 stems of *Lepidocaryum* per ha ($X = 10190$, $SD = 2580$, $n = 11$), of which 2200-5900 ($X = 3950$, $SD = 1130$, $n = 11$) were harvestable. The population structure of *Lepidocaryum* shows that most of the individuals are concentrated in the

juvenile classes, followed by the harvestable adults (Figure 5A).

For *Socratea*, 4402 individuals were found per ha of *terra firme* forest, of which 2-12 were harvestable ($X = 6.2$, $SD = 3.1$, $n = 11$). The size structure of *Socratea* shows a typical inverted J shape, with a predominance of seedlings (98% of the individuals), indicating high regeneration of the species in this type of forest (Figure 5B).

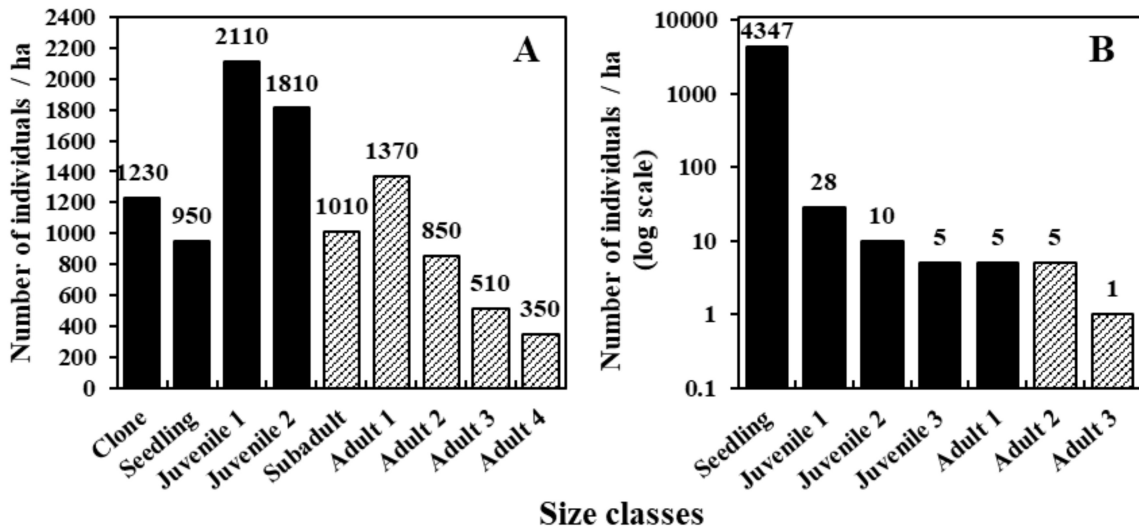


Figure 5. Average population size structure of *Lepidocaryum tenue* (A) and *Socratea exorrhiza* (B) on terra firme forests near Leticia, Colombia. Harvestable classes are hatched.

Management of *Lepidocaryum* consists basically in leaving 3-4 leaves in the crown of the individuals harvested (some people include the spear leaf therein). According to most interviewees, each site can be re-harvested after 3-4 years. For *Socratea*, the basic management is to cut the tallest palms. However, we have observed that, due to the high demand for roofs, harvesters sometimes cut down young palms that do not yet have a sufficiently thick and lignified stem.

In the communities studied, the average size of a house was 48.1 m² ($SD = 22.9$, $n = 23$). To roof a house of such dimensions, using a roof inclination of 45° (the minimum inclination for this type of roofing according to Hall, 1988), and keeping a distance of 15 cm between strips, would require approximately 164 tiles 3 m long, i.e., a total of ca 19,200 leaves. About 0.81 ha of *Lepidocaryum*-rich *terra firme* forest would be required to harvest that number of leaves. While for *Socratea*, if 4 cm wide strips are used, eight strips can be obtained from each log. If 9 m of the stem are used from each palm (three logs at 3 m each), then 24 strips can be obtained from a single palm. Thus, it would be necessary to harvest seven palms, which can be found in 1 ha of *terra firme*

forest. If 3 cm wide strips were used, 33 strips could be obtained from a palm, and only five palms would be required. If the strips are very narrow, however, they have a shorter life and usually cannot be reused.

In Colombia, harvest of both *Lepidocaryum* and *Socratea* is regulated by the "Statute of wild flora" (Corpoamazonia 2010), aimed at promoting the sustainable use of non-timber forest products. However, since 2010 up to 2014 no harvest permits had been granted for either species. This shows that there is ignorance about laws by the local inhabitants and that harvest of both palms continues to be practiced without any regulation. Artisans risk losing their products if they do not have the required permits.

Trade

Although *Lepidocaryum* thatching is mostly an activity for domestic use, there is also an active trade –the communities near Leticia sell the tiles for tourist sites in Leticia and neighboring areas, or to roof various types of constructions, like chicken coops. However, production of *Lepidocaryum* tiles is not a

permanent activity. Some interviewees stated that *Lepidocaryum* roofs are quite expensive, and they would replace them with zinc sheets, were the latter not so hot. This claim is due to the poor quality of many roofs that substantially reduce their useful life to less than two years.

The tiles were sold at the production sites, and transportation was paid by the buyers. In 2012, a 3 m *Lepidocaryum* tile cost COP 3000-5000 (USD \$1.7-2.8) and one 4 m long cost COP 7000 (USD \$3.9). An artisan working for one month in 2012 to produce 200 tiles would receive COP 600.000–1.000.000 (USD \$337.5-562.4) a figure above the legal minimum wage for that year (which stood at COP 566.700, USD \$318.7). In the neighboring Brazilian town of Tabatinga, just across the geometric border, we saw boats of five-meter long loaded of *Lepidocaryum* tiles brought from upriver in Peruvian territory. Thus, local trade on *Lepidocaryum* thatch involves a large area in the northern Amazon. *Lepidocaryum* thatch trade is mainly focused on tiles, but there is also a small leaf trade among villagers. In 2012, a leaf bundle could be sold for COP 50.000 (USD \$28.1), although costs might increase if the palm stands were too far away.

Discussion

Harvest

Although most informants stated that leaf harvesting should be done on adult individuals, market pressure pushes some artisans to harvest juvenile individuals; as shown by Navarro *et al.* (2011), this has negative effects on the population, especially when the harvest is destructive. On the other hand, the harvest of poor-quality leaves (including those with short blade and petiole) results in a shorter life of the tiles and the thatch, which in the short term increases the demand for tiles, and in the long run generates a higher pressure over the resource and may lead to bad harvest practices. Furthermore, the harvest pressure that raises with human population growth requires more leaves for the new houses, a problem already evident for *Geonoma deversa* in Peru (Flores & Ashton 2000), and *Pholidostachys synanthera* in Ecuador (Sirén *et al.* 2013, Salo *et al.* 2014). Bad harvest practices and the factors influence them can drive social and environmental problems, since that palms offer resources for a cheap roof to low-income communities, and can complement the revenues they receive (Flores & Ashton 2000, Salo *et al.* 2014)

Although traditional harvest practices for several palms state that it is necessary to leave several leaves in the palm crown to allow the palms to recover, harvesters often cut the whole crown (Flores & Ashton 2000, Sirén *et al.* 2014, Brokamp

et al. 2014, Salo *et al.* 2014), causing palm death and hence reducing abundance, growth and reproduction (Flores & Ashton 2000, Navarro *et al.* 2011, Brokamp *et al.* 2014), eventually jeopardizing the population after several harvest cycles.

As with *Lepidocaryum* leaves, the high demand for roofs and floors (*Socratea* is also important for making floors) is also causing not recommended practices in harvesting the stems of *Socratea*, leading to the extraction of individuals less than 15 m tall, which causes an accelerated reduction of the populations (Navarro *et al.*, unpublished data). Intensive harvest can lead to the exhaustion of local palm populations, as there appear to be no silvicultural practices associated to harvest, such as the planting of new individuals to replace the harvested ones.

Building

Depending on the leaf structure of the palm species used, the demand for thatching leaves is highly variable--whereas a house thatched with the palmate leaves of *Lepidocaryum tenue* requires ca. 395 leaves per square meter, one thatched with undivided leaves of *Geonoma macrostachys* in Ecuador needs only 57 leaves per square meter (Svenning & Macía 2002), and one thatched with pinnate leaves of *Pholidostachys synanthera* demands between 286-714 leaves per square meter (Sirén *et al.* 2013, Salo *et al.* 2014). Variation in the number of leaves used depends also on roof quality. As a result, it influences demand on the resource, and the area needed to obtain it. Roof quality, in turn, influences duration, which, according to some interviewees, can be up to 6 years. However, average durability is less than 3 years.

Due to the low durability, the scarcity of leaves in some places, and the closeness to cities, palm roofs are often replaced by more durable tiles (Brokamp *et al.* 2014, Gutiérrez 2020). This shift is often caused by government initiatives (Salo *et al.* 2014), leading, in some cases, to a loss of cultural resilience and indigenous autonomy (Salo *et al.* 2014, Gutiérrez 2020). Despite the change, if the leaves are abundant, many inhabitants prefer traditional roofs, at least in henhouses or kitchens, as we have seen in the rural area of Leticia, and as has been observed in Ecuador for *Phytelephas aequatorialis* roofs (Brokamp *et al.* 2014).

Management

The study evidenced the scarcity of *Lepidocaryum* leaves and *Socratea* stems in the vicinity of two villages (Kilómetro 6 and Kilómetro 11), mainly due to poor harvesting practices, such as cutting the stems or extracting all of the leaves from individuals

of *Lepidocaryum*, a malpractice used both by villagers and outsiders. A decrease of the resource, associated with poor harvesting practices, has also been documented in Peru, but it has been attributed mainly to the arrival of harvesters from outside of the communities (Álvarez Alonso *et al.* 2007, Raygada *et al.* 2007, Warren 2008, Álvarez & Shany 2012, Salo *et al.* 2013), or to changes in natural resource policy that increments *Lepidocaryum* extraction (L'Roe & Naughton-Treves 2014). While in the area around Leticia a traditional management rule exists for harvesting *Lepidocaryum*, deeming that "three leaves should be left in the crown", we found that for commercial purposes this rule is not followed. Commonly, all leaves are cut which can lead to stem death and cause population decrease (Navarro *et al.* 2011).

Additionally, other management and regulatory practices have been implemented in Peru for the extraction of leaves. In Loreto, poor harvesting practices have been reduced (Álvarez & Shany 2012), thanks to the support of harvesters by environmental authorities, the strengthening of artisan groups, and the introduction of simple and clear management rules, such as leaving five leaves per stem, shifting harvest areas, harvesting only mature leaves, and replanting in formerly harvested sites or transplanting juvenile individuals or sowing *Lepidocaryum* seeds (Álvarez Alonso *et al.* 2007, Raygada *et al.* 2007, Salo *et al.* 2014).

Finally, the use of several species for thatching could reduce pressure on *Lepidocaryum*. Some palms used for thatch (as *Lepidocaryum*) are more abundant in mature forest, whereas others thrive in secondary forest and still others grow better in modified systems. Promoting the use of an array of species will not only reduce pressure on a single species but will also result in a wider variety of thatch designs.

Harvest of adult *Socratea* stems in *terra firme* forests can lead to the exhaustion of populations (Navarro *et al.*, unpublished data), as evidenced by the current scarcity of stems for braiding tiles. Therefore, it is unlikely that the stem supply recorded by us will be maintained, unless silvicultural practices that encourage population growth are implemented. The density of *Socratea* stems found in this study is similar or higher than that found at sites in the Peruvian Amazon, with the exception of the seasonally flooded forest of the lower Ucayali River (Table 2). The variable density of *Socratea* in Peru and the high demand for tiles suggest that most *Socratea* strips may come from temporarily flooded forests such as those of the lower Ucayali. It is therefore a priority to make inventories in flooded forests near Leticia, to understand whether a similar trend exists in Colombia.

Table 2. Stem density of *Lepidocaryum tenue* and *Socratea exorrhiza* at several sites of the Peruvian Amazon, and near Leticia (Colombia). Figures for *Socratea* correspond to individuals larger than 10 m in height.

Species	Individuals per ha	Site	Reference
<i>Lepidocaryum tenue</i>	5353	Lower Ucayali (Peru)	Kahn & Mejía, 1991
	785	Iquitos-Pebas region	Vormisto <i>et al.</i> 2004
	5000	Allpahuayo-Mishana Reserve	Quevedo & Järlind, 2005
	1144	Iquitos region (Peru)	Kristiansen <i>et al.</i> 2009
	9536	Upper Ucayali (Peru), <i>terra firme</i>	Balslev <i>et al.</i> , 2010
	1252	Upper Ucayali (Peru), terraces	Balslev <i>et al.</i> , 2010
	6900 - 14700	Leticia (Colombia), <i>terra firme</i>	This study
<i>Socratea exorrhiza</i>	4	Lower Ucayali (Peru), floodplain forest	Kahn & Mejía 1990
	46	Lower Ucayali (Peru), seasonally flooded forest	Kahn & Mejía 1990
	6	Lower Huallaga (Perú), seasonally flooded forest	Kahn & Mejía 1990
	8	Lower Huallaga (Perú), seasonally flooded forest	Kahn & Mejía 1990
	1	Allpahuayo-Mishana Reserve, low terrce baja	Quevedo and Järlind 2005
	4.5	Allpahuayo-Mishana Reserve, low hills	Quevedo and Järlind 2005
	11	Leticia (Colombia), <i>terra firme</i>	This study

In Colombia, the impact of environmental regulations on the harvest of *Lepidocaryum* and *Socratea* seems to be minimal, judging from the absence of harvesting permit applications in the first four years after the law's enactment. Thus, Corpoamazonia,

the local environmental authority, is losing the opportunity of implementing the recommendations for inventorying palm stands and planning harvests, and of accompanying small harvesters in the process.

If the extraction of *Lepidocaryum* and *Socratea* is maintained without any effective management and control, it can lead to the local extinction of the resource, making this productive activity unviable in the medium and long term. The reduction of populations will not only affect the commercial activity, but will also affect local people, who traditionally use this type of roof, for which they need no cash. On the other hand, if the palm roofs become expensive as a result of their becoming trendy, this could affect low-income people, who would not be able to get it any longer, thus leading to inequality in resource access.

Trade

Although *Lepidocaryum* roofing is an important source of cash income for several families around Leticia, the demand and trade of this palm product in Colombia is not as significant as in Peru, where it is an essential activity for many inhabitants (Vásquez & Baluarte 1998, Mejía & Khan 1996, Baluarte & Vásquez 2000, Stagegaard *et al.* 2002, Pyhälä *et al.* 2006, Warren 2008, Navarro *et al.* 2011, Brokamp *et al.* 2011, Cotta 2015, Oñate *et al.* 2018). Especially in the area near Iquitos, hundreds of houses are thatched with *Lepidocaryum* (Brokamp *et al.* 2011, Salo *et al.* 2014, Brokamp 2015), and many of the non-timber forest product extractors are dedicated to the production of *Lepidocaryum* roofs (Vásquez & Baluarte 1998, Oñate *et al.* 2018) contributing significantly to family income (Pyhälä *et al.* 2006, Oñate *et al.* 2018).

The production of *Lepidocaryum* roofs, though occasional, is a vital economic activity that could generate an income comparable to the legal monthly minimum wage, if it were permanent throughout the year. In the area near Iquitos, for example, the average annual production of tiles per family is 300 (Álvarez Alonso *et al.* 2007), and for some communities this activity can equal the incomes received in Iquitos (Oñate *et al.* 2018), whereas for others it constitutes an important source of family income year around (L'Roe & Naughton-Treves 2014, Cotta 2015). Cash income from *Lepidocaryum* tile production could significantly improve the household economy in this region, where monthly cash income derived from other productive activities is much lower than the minimum wage (Rodríguez & Maldonado 2009), and where the income derived from forest products represents up to 30% of total income (Trujillo 2008).

Palm leaves of different species are traded along the Amazon basin, from local to regional scales (Brokamp *et al.* 2011, Smith 2015). Some *Geonoma* species are hardly used by small communities and

serve as a resource to supply family needs (Flores & Ashton 2000, Macía & Vivanco 2013), whereas others, such as *Pholidostachys*, *Phytelephas* or *Attalea* may have local trade (Salo *et al.* 2014, Smith 2015). However, only *Lepidocaryum* becomes so important at the regional level in the Peruvian Amazon, because of the demand generated by the city of Iquitos (Brokamp *et al.* 2011, Oñate *et al.* 2018). In any case, although the uses are local, the trade for all species provides extra economic resources for many families in forested areas, who do not have a salary. Some species can give good revenues, as is the case with *Lepidocaryum*, if good contracts are obtained, which can help to equate a minimum wage.

A study of the population dynamics of *Lepidocaryum* in the area (Navarro *et al.* 2011) showed that populations tend to grow, and that a moderate leaf harvest does not affect growth. This suggests that leaf supply near Leticia can be maintained, as long as the harvest is not intensive or destructive. Stem density of *Lepidocaryum* recorded in this study is higher than that found in the Peruvian Amazon (Table 2), where extraction pressure is higher, and where that commercial activity has been maintained for several decades. Thus, it could be expected that leaf supply in Colombia could be maintained for longer, if appropriate management plans were implemented.

Conclusions

The long-term extractive use of *Lepidocaryum* and *Socratea* as materials for thatching requires sound management practices, which are summarized here. For *Lepidocaryum*, at least the three youngest leaves (besides the spear leaf) must be left on each stem, and only stemmed individuals (subadults and adults) should be harvested. For *Socratea*, only the tallest individuals (>15 m) should be harvested. For both species, it is necessary to inventory the palm stands to determine the number of harvestable stems; harvest plots must be rotated in at least two-years shifts; nurseries should be established to propagate both species; *Lepidocaryum* plant must be planted in understory sites, where the species once existed, and small forest clearings, stubble or old *chagras* must be enriched with juvenile *Socratea* plants. In addition to these management activities, it is important to make good quality tiles, using leaves of appropriate dimensions (blade and petiole >50 cm) and strips ≥4 cm wide. Likewise, roofs must have a slope of at least 45°. The implementation of the above-mentioned measures, together with the technical support to artisans, will guarantee that this valuable forest resource and its associated productive activity will be sustainable in the long run. Finally, government institutions, primarily

Corpoamazonia but also universities and NGOs, must support communities to improve management practices, instead of setting up restrictions or police controls.

Declarations

List of abbreviations: Not applicable.

Ethics approval and consent to participate: All participants gave their prior consent knowing the reason for the study.

Consent for publication: Not applicable.

Availability of data and materials: The data was not deposited in public repositories.

Competing interests: The authors do not have any competing interests.

Funding: This paper was supported by the Research Directorate of the Bogotá Campus -DIB- of the National University of Colombia (Project No. 14366), by the EU-FP7-PALMS project (Project No. 212631) and by the "Francisco José de Caldas" Bicentennial Generation PhD Formation Program of Colciencias.

Authors' contributions: JANL carried out fieldwork, carried out data analysis and drafted the manuscript. GG and RB supervised the work and improved the manuscript. All authors read, reviewed and approved the final version of the manuscript.

Acknowledgments

We thank María Cristina Peñuela for facilitating work in the permanent plots of the El Zafire Biological Station, to Ángel Miguel, Chuti, Ever Kuiru and Juan Carlos Andoke for their valuable assistance in the field, and to Yisela Figueroa for the administrative support throughout the process.

Literature cited

Álvarez Alonso J, Araujo Tuesta A, Rojas Grández F. 2007. Sistematización de las experiencias de manejo de recursos en las comunidades locales de la RNAM. IIAP-BIODAMAZ, Iquitos, 80 p.

Álvarez J, Shany N. 2012. Una experiencia de gestión participativa de la biodiversidad con comunidades amazónicas. *Revista Peruana de Biología* 19:223-232.

Balick MJ. 1984. Ethnobotany of palms in the neotropics. *Advances in Economic Botany* 1:9-23.

Balslev H, Eiserhardt W, Kristiansen T, Pedersen D, Grandez C. 2010. Palms and palm communities in the upper Ucayali River Valley – a little-known region in the Amazon basin. *Palms* 54: 57-72.

Balslev H, Copete JC, Pedersen D, Bernal R, Galeano G, Duque Á, Berrio JC, Sánchez M. 2017. Palm diversity and abundance in the Colombian Amazon. In *Forest structure, function and dynamics*

in Western Amazonia. Edited by RW Myster. Wiley Blackwell, United Kingdom, 101-123.

Baluarte J, Vásquez M. 2000. El intercambio de productos forestales diferentes de la madera en el ámbito de Iquitos – Perú. *Folia Amazónica* 11:99-111.

Bernal R, Torres C, García N, Isaza C, Navarro J, Vallejo MI, Galeano G, Balslev H. 2011. Palm management in South America. *The Botanical Review* 77:607-646.

Brokamp G, Valderrama N, Mettelbach M, Grandez CA, Barfod A, Weigend M. 2011. Trade in palm products in North-western South America. *The Botanical Review* 77:571-606.

Brokamp G, Borgtoft-Pedersen H, Montufar R, Jácome J, Weigend M, Balslev H. 2014. Productivity and management of *Phytelephas aequatorialis* (Arecaceae) in Ecuador. *Annals of Applied Biology* 164(2):257-269.

Brokamp G. 2015. Relevance and Sustainability of Wild Plant Collection in NW South America: Insights from the Plant Families Arecaceae and Krameriaceae. Springer, Berlin, Germany, 217 p.

Cámara-Leret R, Faurby S, Macía MJ, Balslev H, Gödel B, Svenning JC, Kissling WD, Rønsted N, Salsis-Lagoudakis CH. 2017. Fundamental species traits explain provisioning services of tropical American palms. *Nature Plants* 3(2):1-7.

Campos MT, Ehringhaus C. 2003. Plant virtues are in the eyes of the beholders: a comparison of known palm uses among indigenous and folk communities of southwestern Amazonia. *Economic Botany* 57:324-344.

Corpoamazonia (Corporación para el Desarrollo Sostenible del Sur de la Amazonia). 2010. Resolución 0727 del 19 de julio de 2010. Estatuto de Flora Silvestre. "Aprovechamiento de productos forestales no maderables". 63 p. (http://www.corpoamazonia.gov.co/files/Reglamentacion_Definitiva.pdf). accessed on 1/21/2018.

Cotta JN. 2015. Contributions of local floodplain resources to livelihoods and household income in the Peruvian Amazon. *Forest Policy and Economics*, 59:35-46.

DANE. 2016. Informe de coyuntura económica regional. Departamento del Amazonas. Departamento Administrativo Nacional de Estadística, Bogotá.

Flores CF, Ashton PMS. 2000. Harvesting impact and economic value of *Geonoma deversa*, Arecaceae, an understory palm used for roof

- thatching in the Peruvian Amazon. *Economic Botany*, 54(3):267-277.
- Galeano G. 1992. Las palmas de la región de Araracuara. Tropenbos-Colombia. Bogotá, Colombia, 180 p.
- Galeano G, Bernal R. 2010. Palmas de Colombia. Guía de Campo. Editorial Universidad Nacional de Colombia, Bogotá, Colombia, 688 p.
- Galeano G, Bernal R, Isaza C, Navarro J, García N, Vallejo MI, Torres C. 2010. Evaluación de la sostenibilidad del manejo de palmas. *Ecología en Bolivia* 45(3):85-101.
- Gutiérrez MP. 2020. The Northwestern Amazon malocas: Craft now and then. *Journal of Material Culture*, 25(1):3-35.
- Hall N. 1988. Thatching: a handbook. Intermediate Technology Publications. London, UK, 55p.
- Henderson A. 1990. Areaceae. Part I. Introduction and the Iriarteinae. *Flora Neotropica*. New York Botanical Garden, New York, USA, 100 p.
- Henderson A, Galeano G, Bernal R. 1995. Field guide to the palms of the Americas. Princeton University Press. New Jersey, USA, 363 p.
- Johnson DV. 2010. Non-wood forest products 10 / Rev. 1. Tropical palms. 2010 Revision. FAO, Rome, Italy, 256 p.
- Kahn F, Mejía K. 1987. Notes on the biology, ecology, and use of a small Amazonian palm: *Lepidocaryum tessmannii*. *Principes* 31: 4-19.
- Kahn F, Mejía K. 1990. Palm communities in wetland forest ecosystems of Peruvian Amazonia. *Forest Ecology and Management* 33/34:169-179.
- Kahn F, Mejía K. 1991. The palm communities of two "terra firme" forest of Peruvian amazon. *Principes* 35:22-26.
- Kahn F, de Granville J-J. 1992. Palm in forest ecosystems of Amazonia. *Ecological Studies* vol 95. Springer-Verlag, Berlin Heidelberg, USA, 226 p.
- Kristiansen T, Svenning JC, Grandez C, Salo J, Balslev H. 2009. Commonness of Amazonian palm (Areaceae) species: Cross-scale links and potential determinants. *Acta Oecológica* 35:554-562.
- L'Roe J, Naughton-Treves L. 2014. Effects of a policy-induced income shock on forest-dependent households in the Peruvian Amazon. *Ecological Economics* 97:1-9.
- Macía MJ, Armesilla PJ, Cámara-Leret R, Paniagua-Zambrana N, Villalba S, Balslev H, Pardo-de-Santayana M. 2011. Palm uses in North-western South America: a quantitative review. *The Botanical Review* 77:462-570.
- Macía M, Vivanco M. 2013. Uksha *Geonoma macrostachys*. In *Palmas ecuatorianas: biología y uso sostenible*. Edited by R Valencia, R Montúfar, H Navarrete, H Balslev. Herbario QCA de la Pontificia Universidad Católica de Ecuador, Quito, Ecuador, 203-208.
- Mejía K, 1992. Las palmeras en los comercios de Iquitos. *Bulletin de l'Institut Français d'Études Andines* 21:755-769.
- Mejía K, Kahn F. 1996. Biología, ecología y utilización del irapay (*Lepidocaryum gracile* Martius). *Folia Amazónica* 8:19-28.
- Mesa LI, Galeano G. 2013. Usos de las palmas en la Amazonia colombiana. *Caldasia* 35: 351-369.
- Navarro JA, Galeano G, Bernal R. 2011. Impact of leaf harvest on populations of *Lepidocaryum tenue*, an Amazonian understory palm used for thatching. *Tropical Conservation Science* 4:25-38.
- Navarro JA. 2014. Dinámica poblacional de tres palmas utilizadas en construcción (*Lepidocaryum tenue*, *Socratea exorrhiza* e *Iriarteia deltoidea*): alternativas para su manejo sostenible en la Amazonia colombiana. Tesis de doctorado de la Universidad Nacional de Colombia.
- Oñate-Calvín R, Oviedo JL, Salo M. 2018. Forest resource-based household economy in the communities of the Nanay River Basin, Peruvian Amazonia. *Ecological Economics* 146:218-227.
- Ortiz MR. 2004. Los resguardos del municipio de Leticia en el sistema general de participaciones: ¿un instrumento viable hacia la descentralización? Tesis de Maestría, Universidad Nacional de Colombia, Sede Amazonía, Leticia, Colombia, 269 p.
- Paniagua-Zambrana NY, Byg A, Svenning J-C, Moraes M, Grandez C, Balslev H. 2007. Diversity of palm uses in the western Amazon. *Biodiversity and Conservation* 16:2771-2787.
- Pyhälä A, Brown K, Adger WN. 2006. Implications of livelihood dependence on non-timber products in Peruvian Amazonia. *Ecosystems* 9:1328-1341.
- Quevedo A, Järlind H. 2005. Inventario forestal participativo en la comunidad de "Anguilla" de la zona de Reserva Nacional Allpahuayo-Mishana. IIAP-BIODAMAZ, 63 p. (http://www.iiap.org.pe/biodamaz/faseii/download/literatura_gris/Inventario_Forestal_Participativo_Anguilla_RNAM.pdf) accessed on 01/02/2015.
- Raygada V, Rojas G, Álvarez J. 2007. Plan de manejo adaptativo de irapay para pequeños

extractores de la RNAM. IIAP-BIODAMAZ, Iquitos, Perú, 16 p.

Riaño Umabrila E. 2009. Leticia: Conectora de regiones. Revista Credencial Historia, 233.

Rodríguez G. 2006. Manejo de caraná (*Lepidocaryum tenue* Martius) en el municipio de Leticia Amazonas. Monografía para aspirar al título de Especialista en Estudios Amazónicos, Universidad Nacional de Colombia, Sede Amazonía. Leticia, Colombia, 57 p.

Rodríguez KJ, Maldonado JH. 2009. Importancia de los productos forestales no maderables en los hogares de Puerto Nariño (Amazonas, Colombia). Cuadernos de Desarrollo Rural 6:31-52.

Salo M, Sirén A, Kalliola R. 2014. Diagnosing wild species harvest: Resource use and conservation. Academic Press, London, UK, 494 p.

Smith N. 2014. Palms and People in the Amazon. Springer International, Cham, Switzerland, 500 p.

Sirén AH, Montúfar R, Gualinga J. 2013. Palma de wayuri *Pholidostachys synanthera*. In Palmas ecuatorianas: biología y uso sostenible. Edited by R Valencia, R Montúfar, H Navarrete, H Balslev. Herbario QCA de la Pontificia Universidad Católica de Ecuador, Quito, Ecuador, 135-144.

Stagegaard J, Sørensen M, Kvist LP. 2002. Estimations of the importance of plant resources extracted by inhabitants of the Peruvian Amazon flood plains. Perspectives in Plant Ecology, Evolution and Systematics 5(2):103-122.

Svenning JC, Macía MJ. 2002. Harvesting of *Geonoma macrostachys* Mart. leaves for thatch: an exploration of sustainability. Forest Ecology and Management 167(1-3): 251-262.

Tobón MA. 2006. La fórmula biodiversidad-cultura y el poder político en el extremo del Trapecio Amazónico colombiano. Universitas Humanistica 62:365-383.

Trujillo C. 2008. Entra selva y mercado: exploración cuantitativa de los ingresos en hogares indígenas. In: Imani mundo III. Gente, tierra y agua en la Amazonia. Edited by AI Buitrago & EA Jiménez. Universidad Nacional de Colombia, Sede Amazonia, Bogotá, Colombia, p.133-162.

Vásquez M, Baluarte J. 1998. La extracción de productos forestales diferentes de la madera en el ámbito de Iquitos, Perú. Folia Amazonica 9:69-92.

Vormisto J, Svenning J-C, Hall P, Balslev H. 2004. Diversity and dominance in palm (*Arecaceae*) communities in terra firme forests in the western Amazon basin. Journal of Ecology 92:577-588.

Warren A. 2008. Demographic effects of thatch harvest and implications for sustainable use of irapai palm (*Lepidocaryum tenue*, Mart.), by riverine communities in the Peruvian Amazon. PhD dissertation. Florida International University, Florida, USA, 197 p.