


## REVIEW

# Brazilian Amazonian palm-stem types and uses: a review

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## ABSTRACT

Palms may be an important source of renewable raw material to replace wood, however, the uses of the stems of native species of the Brazil are known only at the local or regional level. We carried out a literature review on the traditional knowledge of the uses of the stems of palm species native to the Amazon biome in Brazil, and related the types of uses with morphological characteristics of the stems. The review resulted in information on 45 species with solitary or cespitose stems, and six stem-size types: tall (15 species), medium-short (3), medium (5), small (17), acaulescent (1) and climbing (4). We found 80 indications of stem use in seven categories and 14 subcategories. A similarity analysis showed that, in general, tall, medium-short, medium, small ( $\geq 10$  cm in diameter) and climbing stem types, solitary or cespitose, are used for construction, furniture, handicrafts, utensils, tools and musical instruments. Only small stems ( $< 10$  cm diameter) are used to manufacture weapons for hunting and fishing, and climbing stems are used in the manufacture of ropes. Stems of *Socratea exorrhiza*, *Euterpe oleracea* and *Desmoncus polyacanthos* are the most frequently used to meet subsistence needs in traditional communities in the Brazilian Amazon. Our findings indicate that there is a potential for use of several native palm stems as sources for alternative materials in the manufacture industry and as sustainable income sources for Amazonian communities.

**KEYWORDS:** Arecaceae, alternative wood, new materials, riverine communities, sustainable development

## Tipos e usos dos caules de palmeiras na Amazonia brasileira: uma revisão

### RESUMO

As palmeiras têm sido consideradas uma importante fonte de matéria-prima lenhosa em substituição à madeira, contudo, os usos dos caules de espécies nativas do Brasil são conhecidos apenas em nível local ou regional. Realizamos uma revisão da literatura sobre o conhecimento tradicional dos usos dos caules de espécies de palmeiras nativas do bioma Amazônia no Brasil, e relacionamos os tipos de uso com as características morfológicas dos caules. A revisão resultou em informações sobre 45 espécies com caules solitários ou cespitosos, e seis tipos de tamanhos de caules: alto (15 espécies), médio a curto (3), médio (5), pequeno (17), acaulescente (1) e escandente (4). Encontramos 80 indicações de uso dos caules em sete categorias e 14 subcategorias. Uma análise de similaridade mostrou que, em geral, caules com portes altos, médios a curtos, médios, pequenos ( $\geq 10$  cm de diâmetro) e escandentes, solitários ou cespitosos, são usados para construções, móveis, artesanatos, utensílios, ferramentas e instrumentos musicais. Apenas caules de pequeno porte ( $< 10$  cm de diâmetro) são usados para fazer armas para caça e pesca, e os caules escandentes para confecção de cordas. Caules de *Socratea exorrhiza*, *Euterpe oleracea* e *Desmoncus polyacanthos* são os mais utilizados para atender às necessidades de subsistência em comunidades tradicionais da Amazônia brasileira. Nossos resultados indicam o uso potencial dos caules de diversas espécies nativas de palmeiras como fontes de materiais alternativos na indústria manufatureira e como fontes de renda sustentável para as comunidades amazônicas.

**PALAVRAS-CHAVE:** Arecaceae, madeira alternativa, novos materiais, comunidades ribeirinhas, desenvolvimento sustentável

## INTRODUCTION

There are about 378 species of 71 genera of palms (Arecaceae/Palmae) in Brazil, distributed in all Brazilian biomes. The greatest diversity is known from the Amazon region, where 148 native species have been listed (Soares *et al.* 2020). Several Amazonian species are endemic and under increasing pressure due to deforestation (Alvez-Valles *et al.* 2018).

Palms are the main source of natural resources for populations living in the Amazon region (Santos and Coelho-Ferreira 2012), satisfying subsistence needs in various categories of use, such as food, construction, handicrafts, fibers, medicine, cosmetics, textiles and biodiesel, among others (Zambrana *et al.* 2007; Macía *et al.* 2011; Bernal *et al.* 2011; Pennas *et al.* 2019). Most species are only known regionally or locally and therefore their traditional use and

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contribution to human well-being and the regional economy are unknown to the general public (Clement *et al.* 2005). This traditional knowledge is of fundamental importance for the conservation and sustainable exploitation of useful palms, supporting programs for the management of natural resources and implementation of economic development in local communities (Zambrana *et al.* 2007). Furthermore, woody monocots, prominently including palms, are increasingly being considered as a source of renewable raw material to replace eudicotyledonous and coniferous wood (Trindade and Máximo 2017; El-Mously *et al.* 2019), and as options for crop diversification to create investment opportunities with the generation of new products (Corandin *et al.* 2018).

Despite not forming actual heartwood, stems are among the most commonly used parts of palms, reportedly for construction, handicrafts and daily utensils, among other purposes (Vilhena-Potiguara *et al.* 1987; Miranda *et al.* 2001; Rocha and Silva 2005; Oliveira *et al.* 2006; Araújo *et al.* 2016). In this context, the objective of this review was to survey the recorded uses of stems of palm species native to the Brazilian Amazon and to relate uses to stem morphological types.

## MATERIAL AND METHODS

### Survey of palm species with recorded stem use

Palm species native to the Amazon biome in Brazil with some recorded use of its stem were surveyed in print and digital media. All phytophysiognomies occurring in the Brazilian Amazon were considered: *terra firme* forest, floodplain forest, swamp forest, ombrophyllous forest, riparian or gallery forest, savanna forest, *campina* (white-sand grass/shrublands), *campinarana* (white-sand forest), *restinga* (sandy coastal plain vegetation) and ironstone outcrops.

The survey of printed media involved scientific papers, dissertations, theses and books cataloged in the libraries of nine Brazilian institutions: Museu Paraense Emílio Goeldi (MPEG), Embrapa Amazônia Oriental (CPATU), Universidade Federal Rural da Amazônia (UFRA), Universidade Federal do Pará (UFPA) and Universidade do Estado do Pará (UEPA) in the northern state of Pará; Instituto Nacional de Pesquisas da Amazônia (INPA) in the state of Amazonas; and Instituto de Pesquisas Jardim Botânico do Rio de Janeiro (JBRRJ), Museu Nacional da Universidade Federal do Rio de Janeiro (MN/UFRJ) and Universidade do Estado do Rio de Janeiro (UERJ) in Rio de Janeiro state.

The digital survey was carried out using the following databases: Catálogo de Teses e Dissertações da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior ([www.catalogodeteses.capes.gov.br](http://www.catalogodeteses.capes.gov.br)); Google Scholar ([www.scholar.google.com.br](http://www.scholar.google.com.br)); JSTOR ([www.jstor.org](http://www.jstor.org)); Scielo ([www.scielo.br](http://www.scielo.br)); Scopus ([www.scopus.com](http://www.scopus.com)); Web of Science ([www.webofknowledge.com](http://www.webofknowledge.com)) and Empresa Brasileira de Pesquisa

Agropecuária ([www.embrapa.br/seb](http://www.embrapa.br/seb)). The following search terms were used: ethnobotany of palms, fibrous plants, stems of palms, palms products, uses of palms. Only citations from the Amazon biome in the Brazilian federal states of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins, as well as parts of the states of Maranhão and Mato Grosso, were considered.

The following information was extracted for each species of surveyed palm: species, local name, habit, stem type, use category, use subcategory, forms of use, distribution in the Brazilian Amazon, references and distribution in Brazil (Table 1). The uses of the stems surveyed in literature were classified in categories and subcategories according to Macía *et al.* (2011). The latter authors carried out a review on the use of palms in northern South America, and classified the ethnobotanical uses of specific plant parts into ten categories, each divided into subcategories. When the ethnobotanical information was not classifiable within any subcategory, it was assigned the subcategory 'other'. The compiled list of scientific names of species recovered from our survey was checked and updated, when necessary, using the lists of Flora do Brasil (2020) and SpeciesLink (2021). Recorded stem-use categories were mapped by state included in the Amazon biome based on the study areas in the literature sources, when provided.

Palm-stem types were defined according to Balslev *et al.* (2011), who classified tropical palm species of South America into eight forms of growth, based on maximum sizes of attributes such as leaf size, absence or presence of aerial stem and aerial stem length and diameter. Within each form of growth, the species are further classified as cespitose or solitary (Table 2).

### Statistical analysis

In order to evaluate the association between stem characteristics and uses, data of the stem-type, use categories and use subcategories (Table 1) were organized in a binary matrix of presence (1) and absence (0). The matrix was subjected to cluster analysis performed with the Vegan 2.5-7 package, in the R software (R Core Team 2021). Species with greater similarity in relation to the analyzed characteristics were grouped using the unweighted pair-group method with arithmetic mean (UPGMA) (Sneath and Sokal 1973) with the Jaccard coefficient.

## SPECIES WITH RECORDED STEM USE

We recovered 43 literature references with records of the use of stems of 45 species of native palms in the Brazilian Amazon (Table 1). The work of Miranda *et al.* (2001) had the highest number of cited palm species (24), followed by Lorenzi *et al.* (2010) (16), Miranda and Rabelo (2008) (16) and Shanley and Medina (2005) (7). More than 50% of the studies mentioned only one or two palm species regarding stem use.

**Table 1.** Stem type and use of palm species native to the Brazilian Amazon. Local name according to the citation source. Stem type: TS = tall stem; MS = medium stem; MSS = medium-short stem; SS = small stem; AS = acaulescent; CS = climbing stem. Habit: S = solitary; C = cespitose. Use categories (according to Macia *et al.* 2011): Constr = construction; Cultur = cultural, Environ = Environmental, Fuel, HuFood = Human food, UtenTool = Utensils and tools, Other = Other uses. Forms of use cited as in the original source. State: Brazilian Amazon state in which the use was reported. State acronyms: AC = Acre, AL = Alagoas, AM = Amazonas, AP = Amapá, BA = Bahia, CE = Ceará, DF = Distrito Federal, ES = Espírito Santo, GO = Goiás, MG = Minas Gerais, MS = Mato grosso do Sul, MT = Mato Grosso, PA = Pará, PE = Pernambuco, PI = Piauí, RJ = Rio de Janeiro, RO = Rondônia, RR = Roraima, RN = Rio Grande do Norte, SP = São Paulo, TO = Tocantins). Ns = Not specified. Acronyms in bold font are unconfirmed occurrences.

Species	Local name	Habit	Stem type	Use category	Use subcategory	Forms of use	Distribution in the Brazilian Amazon	References	Distribution in Brazil
<i>Acrocomia aculeata</i> (Jacq.) Lodd. ex Mart.	Macaúba	S	TS	Constr	Houses	Houses	PA, MA	24, 25, 26, 29	PA, BA, CE, MA, PI, DF, GO, MG, RJ, SP
					Other	Gutters to transport water, slats			
				HuFood	Food additives	Starch			
				UtenTool	Domestic	<i>Jirau</i> *			
<i>Astrocaryum aculeatum</i> G.Mey.	Tucumã	S	TS	Constr	Bridges	Bridges	AC, PA	8, 15, 22, 25, 26	AC, AM, PA, RO, RR, MT
					Houses	Houses, corrals			
				Environ	Fences	Fences			
				UtenTool	Domestic	Furniture (tables)			
					Hunting and fishing	Bows			
	Other	Handicrafts							
<i>Astrocaryum jauari</i> Mart.	Jauari	C	TS	Constr	Houses	Houses (floors)	AM, RR	3, 25, 26	AC, AM, AP, PA, RO, MA
				Cultur	Recreational	Musical instruments			
				UtenTool	Domestic	Furniture (chairs, tables)			
	Other	Handicrafts							
<i>Astrocaryum murumuru</i> Mart.	Murumuru	C	MSS	Constr	Houses	Houses	PA	8, 26	AC, AM, AP, PA, RO
<i>Astrocaryum rodriguesii</i> Trail	Murumuru de terra firme	S	TS	Constr	Houses	Houses	PA	25	AM, AP, PA
				UtenTool	Other	Handicrafts			
<i>Astrocaryum tucuma</i> Mart.	Tucumã do Amazonas	S	TS	Constr	Houses	Houses	AM	10	Ns
<i>Astrocaryum vulgare</i> Mart.	Tucumã do Pará	C	MSS	Constr	Bridges	Bridges	PA, MA	1, 23, 24, 25, 26, 38	AP, PA, TO, MA, GO
					Houses	Houses (walls), corrals			
				UtenTool	Domestic	Furniture (tables)			
				Other	Handicrafts				
<i>Attalea speciosa</i> Mart. ex Spreng.	Babaçu	S	TS	Constr	Houses	Houses (floors, walls), corrals	MA, MT	6, 7	AC, AM, PA, RO, TO, BA, CE, MA, PI, GO, MS, MT, MG
				Environ	Soil improvers	Organic fertilizer			
				UtenTool	Domestic	Furniture (shelves)			
<i>Attalea spectabilis</i> Mart.	Curuá	S	AS	Constr	Houses	Houses	AM	4	AM, AP, PA
				UtenTool	Hunting and fishing	Arrowheads			
<i>Bactris acanthocarpoides</i> Barb.Rodr.	Marajá	C	SS	UtenTool	Hunting and fishing	Arrowheads	Ns	26	AM, PA
<i>Bactris bidentula</i> Spruce	Marajá do iguapó	C	SS	UtenTool	Hunting and fishing	Arrowheads	Ns	26	AM, PA, MT
					Other	Handicrafts			
<i>Bactris brongniartii</i> Mart.	Marajá	C	SS	Constr	Houses	Houses (roofs, walls)	MA	26, 38	AC, AM, PA, RO, RR, MA, MT
					Other	Pillars, rafters			
				UtenTool	Hunting and fishing	Arrows			
<i>Bactris concinna</i> Mart.	Marajá	C	SS	UtenTool	Hunting and fishing	Arrows	Ns	26	AC, AM

Table 1. Continued.

Species	Local name	Habit	Stem type	Use category	Use subcategory	Forms of use	Distribution in the Brazilian Amazon	References	Distribution in Brazil
<i>Bactris gasipaes</i> Kunth	Pupunha	C	MS	Constr	Houses	Houses (floors, walls)	AM, PA	4, 12, 25, 39	AC, AM, PA, RO, MT
					Other	Pillars			
				Cultur	Recreational	Musical instruments			
				Environ	Soil improvers	Organic fertilizer			
				UtenTool	Domestic	Furniture (chairs, tables, modular panels)			
	Hunting and fishing	Bows, arrows, fishing traps							
	Other	Handicrafts (artefacts)							
<i>Bactris hirta</i> Mart.	Marajá	C	SS	UtenTool	Hunting and fishing	Arrows	PA	25, 26	AM
<i>Bactris macroacantha</i> Mart.	Marajá	C	SS	UtenTool	Other	Handicrafts	AM	26	AC, AM, PA, RO
<i>Bactris maraja</i> Mart.	Marajá	C	SS	Constr	Houses	Fishing corrals	AC, AM, RR, PA	3, 8, 26, 28	AC, AM, AP, PA, RO, RR
				UtenTool	Hunting and fishing	Bows, arrows, spears, weapons			
				Other	Handicrafts, shot gun cartridge removers				
<i>Bactris riparia</i> Mart.	Pupunharana	C	SS	UtenTool	Hunting and fishing	Bows, arrowheads	Ns	26	AC, AM
<i>Bactris simplicifrons</i> Mart.	Marajá	C	SS	UtenTool	Other	Handicrafts	Ns	26	AC, AM, AP, PA, RO, RR, MA
<i>Bactris tomentosa</i> Mart.	Marajazinho	C	SS	UtenTool	Other	Handicrafts	PA	31	AC, AM, AP, PA, MA
<i>Desmoncus giganteus</i> A.J.Hend.	Jacitara grande	C	CS	UtenTool	Other	Handicrafts	Ns	24	AC
<i>Desmoncus mitis</i> Mart.	Jacitara	C	CS	UtenTool	Domestic	Baskets	AC	8, 24	AC, AM, RO, MT
					Wrappers	Tobacco wrapping and latching			
					Other	Handicrafts, clothes-lines			
<i>Desmoncus orthacanthos</i> Mart.	Jacitara	C	CS	UtenTool	Domestic	Baskets, bags, fans, sieves, sousplats, <i>tipitis</i> **, furniture (chair backs, chair seats, couches)	PA	24, 27, 28, 35, 41	AC, AM, RR, RO, PA, AP, MA, AL, BA, PB, PE, ES, RJ
					Hunting and fishing	<i>Matapis</i> ***			
					Other	Handicrafts, wicker articles			
<i>Desmoncus polyacanthos</i> Mart.	Jacitara	C	CS	UtenTool	Domestic	Baskets, bags, <i>tipitis</i> **, furniture (chair backs, chair seats)	AC, AM, RO, RR, PA, MT	2, 7, 17, 24, 25, 26, 28, 31, 36	AC, AM, AP, PA, RR, AL, BA, CE, MA, PB, PE, RN, GO, ES, MG, RJ
					Other	Handicrafts			
					Rope	Various types of ropes			
<i>Euterpe catinga</i> Wallace	Açaí catinga	C	MS	Constr	Houses	Houses	Ns	24, 26	Ns
					Bridges	Bridges			
<i>Euterpe oleracea</i> Mart.	Açaí	C	TS	Constr	Houses	Houses (floors, walls)	AP, PA	1, 5, 13, 18, 19, 21, 25, 26, 28, 29, 31, 32, 41, 42	AP, PA, TO, MA
					Other	Beams, pillars, rafters, slats			
				Fuel	Firewood	Firewood			
				UtenTool	Domestic	<i>Jirais</i> *			

Table 1. Continued.

Species	Local name	Habit	Stem type	Use category	Use subcategory	Forms of use	Distribution in the Brazilian Amazon	References	Distribution in Brazil
<i>Euterpe precatoria</i> Mart.	Juçara	S	TS	Constr	Houses	Houses (floors, walls), huts, storage sheds	AC, AM, RR, PA, MT	3, 4, 7, 8, 16, 24, 25, 43	AC, AM, PA, RO
					Other	Gutters to transport water, beams, lattices			
				Environ	Fences	Fences			
				UtenTool	Domestic	Furniture (shelves, table-tops)			
<i>Geonoma deversa</i> (Poit.) Kunth	Ubim	C	SS	UtenTool	Hunting and fishing	Arrows	RR	3	AC, AM, AP, PA, RO, RR, MT
					Other	Shot gun cartridge removers			
<i>Hyospathe elegans</i> Mart.	Ubim-rana	C	SS	UtenTool	Hunting and fishing	Bows	Ns	24	AC, AM
<i>Iriartea deltoidea</i> Ruiz & Pav.	Paxiubão	S	TS	Constr	House	Houses (floors, walls)	AC, PA	2, 8, 15, 24, 42	AC, AM, RO, MT
					Transportation	Canoe bottoms			
					Other	Beams, posts			
				Cultur	Recreational	Musical instruments			
				Environ	Fences	Fences			
			UtenTool	Domestic	Utensils				
					Hunting and fishing	Bows, spears			
<i>Iriartella setigera</i> (Mart.) H.Wendl.	Paxiubinha	C	SS	Constr	House	Houses (floors, walls)	AM, PA	2, 24, 26, 36, 42	AM, PA, RO
				Cultur	Recreational	Musical instruments (flutes, trumpets)			
				UtenTool	Domestic	Utensils			
					Hunting and fishing	Fishing weapons, blowguns			
<i>Leopoldinia pulchra</i> Mart.	Piaçava	C	SS	Environ	Fences	Fences	AM	24, 25, 26, 42	AM, PA
					Soil improvers	Organic fertilizer			
				UtenTool	Domestic	Baskets			
<i>Mauritia carana</i> Wallace	Caraná	S	TS	UtenTool	Other	Handicrafts (artefacts)	AM	24, 26	AM, RR
<i>Mauritia flexuosa</i> L.f.	Miriti	S	TS	Constr	Bridges	Bridges, floating docks, posts, stilts	AC, AM, PA, RR, MT	8, 14, 15, 19, 21, 25, 30, 33, 34, 40	AC, AM, PA, RO, TO, BA, CE, MA, PI, DF, GO, MS, MT, MG, SP
					Houses	Houses (walls, roofs), corrals			
					Other	Gutters to transport water			
				Environ	Fences	Fences			
					Soil improvers	Organic fertilizer			
					Food Additives	Starch, sap			
			HuFood	Food Additives					
				UtenTool	Domestic	Furniture			
					Other	Splints for collecting rubber latex			
					Miscellaneous	Larvae ( <i>turus</i> )			
<i>Mauritiella armata</i> (Mart.) Burret	Caraná	C	MS	Constr	Bridges	Bridges	PA	1, 19	AC, AM, PA, RO, RR, TO, BA, CE, MA, PE, PI, GO, MT, MG
					Houses	Floors			
					Other	Pillars			
<i>Oenocarpus bacaba</i> Mart.	Bacaba	S	TS	Constr	Bridges	Bridges	AC, AM, PA, RR	3, 4, 5, 11, 25, 26	AC, AM, AP, PA, RO
					Houses	Houses (floors, roofs)			
					Other	Beams, posts, slats			
				Cultur	Cloth and accessories	Walking sticks			
				Environ	Fences	Fences			
					Hunting and fishing	Bows, arrows, harpoons, spears			
			UtenTool	Other	Handicrafts, tool handles, umbrella handles				

Table 1. Continued.

Species	Local name	Habit	Stem type	Use category	Use subcategory	Forms of use	Distribution in the Brazilian Amazon	References	Distribution in Brazil
<i>Oenocarpus bataua</i> Mart.	Patauá	S	TS	Constr	Bridges	Bridges	AC, AM, PA	4, 20, 25, 26, 43	AC, AM, PA, RO
					Houses	Houses			
				Environ	Fences	Fence slats, fence pillars, garden fences			
				UtenTool	Hunting and fishing	Bows, arrows			
			Other	Miscellaneous	Larvae ( <i>tapurus</i> )				
<i>Oenocarpus distichus</i> Mart.	Bacaba de leque	S	TS	Constr	Houses	Houses	PA	25, 26	PA, RO, TO, MA, GO, MT
<i>Oenocarpus mapora</i> H.Karst.	Bacabinha	C	MS	Constr	Houses	Houses (floors, walls), gates	AC	8, 24, 26, 43	AC, AM
				UtenTool	Other	Lattices			
<i>Oenocarpus minor</i> Mart.	Bacabinha	C	SS	UtenTool	Hunting and fishing	Bows, arrows, blowguns, spears	PA	25	AM, PA, RO
<i>Raphia taedigera</i> (Mart.) Mart.	Jupati	C	MSS	Constr	Houses	Houses	PA	9, 25	PA
<i>Socratea exorrhiza</i> (Mart.) H.Wendl.	Paxiúba	S	TS		Houses	Houses (floors, walls, roofs, window grids)	AC, AM, AP, PA, RR, MT	2, 3, 4, 5, 7, 8, 15, 18, 19, 21, 25, 26, 27, 28, 31, 36, 37, 42	AC, AM, AP, PA, RR, MA
				Constr	Transportation	Canoe floors			
					Other	Gutters to transport water, lattices			
				Environ	Fences	Fences			
				Cultur	Cloth and accessories	Walking sticks			
					Recreational	Musical instruments [flutes, drums, spears with rattle, <i>reco-recos</i> (percussion instruments), violas]			
				UtenTool	Domestic	Furniture ( <i>jiraus*</i> , shelves, sticks)			
	Hunting and fishing	Bows, arrowheads, spears, drills, blowpipes, fishing traps ( <i>cacuri</i> )							
	Other	Handicrafts							
<i>Syagrus inajai</i> (Spruce) Becc.	Inajá	S	MS	Constr	Bridges	Bidges	PA	1	AM, AP, PA, RR, MA
					Houses	Floors			
<i>Syagrus cocoides</i> Mart.	Piririma	S	SS	Constr	Houses	Houses	PA	24, 25, 26	AM, PA, TO, MA, PI, GO, MT
				UtenTool	Hunting and fishing	Bows			
<i>Wettinia augusta</i> Poepp. & Endl.	Paxiubinha de macaco	C	SS	Constr	Houses	Houses (floors, walls)	AC	24	AC

1-Almeida and Jardim (2012); 2- Alves *et al.* (2014); 3- Ammann (2014); 4- Anderson (1977); 5- Araújo and Lopes (2012); 6- Araújo *et al.* (2016); 7- Arruda (2013); 8- Campos and Ehringhaus (2003); 9- Carney and Hiraoka (1997); 10- Costa *et al.* (2005); 11- Cymerys (2005); 12- Cymerys and Clement (2005); 13- Cymerys and Shanley (2005); 14- Cymerys *et al.* (2005); 15- Farias *et al.* (2016); 16- Ferreira (2005); 17- Flores and Lima (2013); 18) Fonte *et al.* (2015); 19- Germano *et al.* (2014); 20- Gomes-Silva (2005); 21- Jardim and Cunha (1998); 22- Jardim and Stewar (1994); 23- Lima *et al.* (2013); 24- Lorenzi *et al.* (2010); 25- Miranda and Rabelo (2008); 26- Miranda *et al.* (2001); 27- Oliveira *et al.* (1991); 28- Oliveira *et al.* (2006); 29- Pinheiro *et al.* (2005); 30- Ribeiro (2010); 31- Rocha and Silva (2005); 32- Rodrigues *et al.* (2006); 33- Sander *et al.* (2018); 34- Santos and Coelho-Ferreira (2012); 35- Santos *et al.* (2016); 36- Smith (2015); 37- Smith and Plagnol (2016), 38- Souza (2010); 39- Trindade and Máximo (2017); 40- Valente *et al.* (2001); 41- Vilhena-Potiguara *et al.* (1987); 42- Wallace (2014); 43- Wallace and Ferreira (2016).

\* wooden frame used to store household utensils

\*\* woven compressible tube-like device used to extract the liquid component of fermented cassava

\*\*\* cone-shaped shrimp trap

**Table 2.** Growth forms of palm species native to South America, according to the classification by Baslev *et al.* (2011).

Size	Leaf (m)	Height (m)	Diametre (cm)	Habit
Tall	Ns	20-35	20-100	C, S
Medium-short	4-10	1-20	15-25	C, S
Medium	2-4	8-15	12-15	C, S
Medium/small	Ns	Ns	30-60	C, S
Small	Ns	0,1-8	0,4-12	C, S
Acaulescent (large)	4-8	Ns	Ns	S
Acaulescent (small)	< 2	Ns	Ns	S
Climbing	Ns	Ns	Ns	C

C = cespitose; S = solitary; Ns = Not specified

Knowledge on the uses of palm stems was retrieved from riverine, *quilombola* (settlements originating from runaway slaves), rubber tapper, family farmer, artisan and extractivist communities, as well as indigenous communities of the Yanomami tribe in the state of Amazonas (Anderson 1977), the Yawanawá and Kaninawá in the state of Acre (Campos and Ehringhaus 2003), the Ti Araçá in the state of Roraima (Ribeiro 2010) and the Karipuna in the state of Amapá (Fonte *et al.* 2015). Most studies were carried out in riverine communities. At the state level, most citations were from Pará (25), followed by Amazonas (13), Acre (12), Roraima (6), Mato Grosso (5), Maranhão (3) and Rondônia and Amapá with one citation each (Table 1).

The 45 surveyed palm species belong to the subfamilies Arecoideae and Calamoideae (Table 1). Arecoideae had the greatest number of representatives, with 41 species distributed in two tribes, six subtribes and 15 genera, four of which with spiny stems (Table 1). Calamoideae was represented by only four species belonging to one tribe, two subtribes and three genera (Table 1).

*Oenocarpus* Mart. and *Euterpe* Mart. were the genera with the highest number of species with stem-use citations relative to the total number of species known for the genus in the Brazilian Amazon (five of six species, and three of four species, respectively), followed by *Desmoncus* Mart. (four of nine species), *Astrocaryum* G.Mey (six of 21), *Bactris* Jacq. ex Scop. (11 of 35), and *Attalea* Kunth (two of 14) and *Syagrus* Mart. (two of six species) (Table 2). *Iriarteia deltoidea* was cited in an area of the Brazilian Amazon where there is no confirmed occurrence record of this species (Table 1).

The 45 cited species represent about 28% of the 161 palm species recognized for the northern region of Brazil, and 30% of the 148 species recognized for the Brazilian Amazon (Soares *et al.* 2020). In northwestern South America, information on the use of palm stems was retrieved for 59% of the 134 species occurring in the Amazon region (Macía *et al.* 2011). The record of use of *Iriarteia deltoidea* is evidence of its presence in the state of Pará (Alves *et al.* 2014), which expands its area of occurrence in Brazil. This finding is

relevant, as palms remain a poorly sampled group with little representation in Amazonian herbaria (Rocha and Silva 2005; Henderson 2011). Palms are frequently difficult to collect due to the presence of spines, the large size of vegetative and reproductive structures, the high and unbranched stems and to that individuals are frequently sterile (Anderson 1977; Miranda *et al.* 2001; Ammann 2014; Rocha 2017), resulting in that most records are field observations (Henderson *et al.* 1995; Miranda and Rabelo 2008).

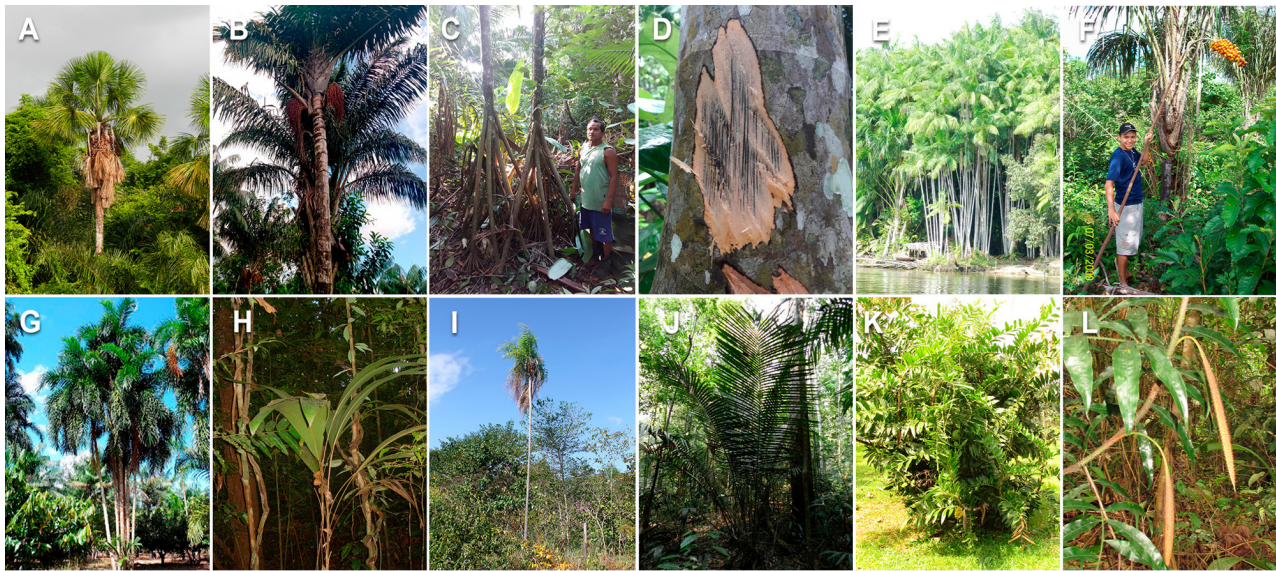
Traditional knowledge on the uses of Brazilian Amazonian palm parts, especially their woody or fibrous stems, has been investigated in local communities in the states of Pará and Amazonas (Anderson 1977; Vilhena-Potiguara 1987; Miranda *et al.* 2001; Rocha and Silva 2005; Oliveira *et al.* 2006; Santos and Coelho-Ferreira 2012; Germano *et al.* 2014; Santos *et al.* 2016). Publications for other parts of the biome are still rare (e.g., Flores and Lima 2013). Although indigenous peoples have broad and diverse ethnobotanical knowledge about the use of palms in the Amazon (Bernal *et al.* 2011; Macía *et al.* 2011; Wallace 2014; Smith 2015), few publications mentioned palm-stem uses by indigenous communities in the Brazilian Amazon (Anderson 1977; Campos and Ehringhaus 2003; Ribeiro 2010; Fonte *et al.* 2015). Most studies have focused on the subsistence, economic and sociocultural importance of palm species in riverine communities, which are more easily accessible (e.g., Jardim and Cunha 1998; Rodrigues *et al.* 2006; Santos and Coelho Ferreira 2011; Almeida and Jardim 2012; Lima *et al.* 2013; Germano *et al.* 2014; Araujo *et al.* 2016).

The surveyed literature generally did not present detailed information about the study areas or the characteristics of the palms, such as development stage or height and diameter of the used stems. In this sense, the use of the classification by Balslev *et al.* (2011), though preliminary, was useful, as it is based on very basic characteristics, allowing categorization in the absence of detailed information. More standardized and informative surveys will be necessary to account for the wider amplitude in forms of growth and stem architectures, and the plasticity resulting from the development in different types of soil, hydrology, temperature, topography, incidence of sunlight and disturbance levels (Kahn and de Graville 1992; Balslev *et al.* 2011; Salm *et al.* 2011; Muscarella *et al.* 2020).

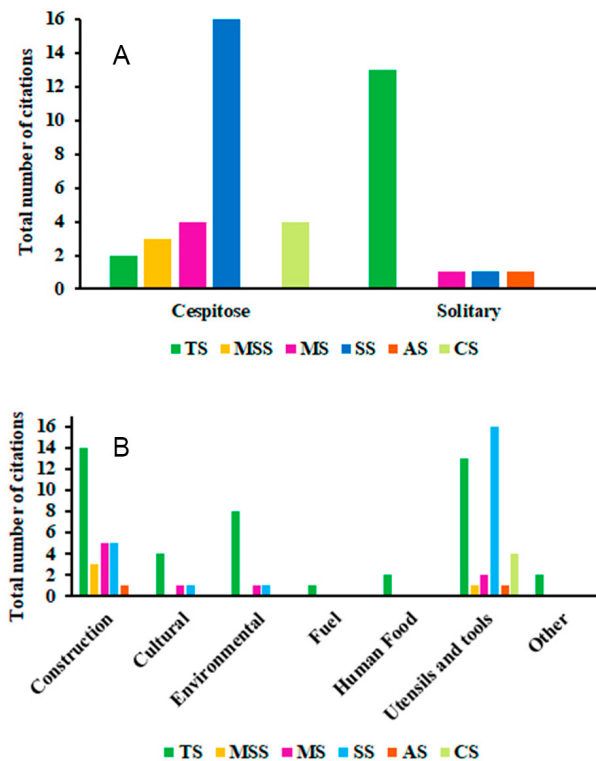
## STEM TYPES AND USES

The cited palm species have solitary or cespitose habit, with six types of stem-growth form (Figure 1; Table 1). The species with the greatest number of uses have cespitose stems (29 species, 64%) and are especially small palms (*Bactris*) or climber palms (*Desmoncus*) (Figure 2a; Table 1). Among species that do not branch, i.e., with solitary stems (16 species, 36%), the tall stem type was the most representative (Figure 2a; Table 1).

The stems were used mainly for utensils and tools (41 citations), construction (22), cultural (8), environmental uses



**Figure 1.** Types of stem of native palm species in the Brazilian Amazon. Stem-growth types according to Balslev *et al.* (2011). The images show: tall stem (A-E), medium-short stem (F), medium stem (G), small stem (H), small stem  $\geq 10$  cm in diameter (I), acaulescent (J), climbing stem (K-L); solitary (A-D, I-J); cespitose (E-G, K-L), with spines (F-H, K-L). Species: *Mauritia flexuosa* (A); *Oenocarpus distichus* (B); *Socratea exorrhiza* (C-D); *Euterpe oleracea* (E); *Astrocaryum vulgare* (F); *Bactris gasipaes* (G); *Bactris hirta* (H); *Syagrus cocoides* (I); *Attalea spectabilis* (J); *Desmoncus orthacanthos* (K); *D. polyacanthos* (L). Habitats: floodplain forest (A, E, C-D); terra firme forest (B, F, H, J, G, K-L) in the Pará state (Brazil); rocky area (ferricrete) in Conceição do Araguaia, Pará state (Brazil) (I). Credits: André Cardoso (A, E, H-J); the authors (B-D, K-L); Jorge Oliveira (F) and Julcéia Camillo (G).



**Figure 2.** Distribution frequency of stem types of the 45 species of native palm trees in the Brazilian Amazon recorded in this study, according to stem-growth form (A); and to the recorded categories of use (B). Stem-growth form (according to Balslev *et al.* 2011): TS = tall stem, MSS = medium-short stem, MS = medium stem, SS = small stem, AS = acaulescent, CS = climbing stem.

(5), human food (2), fuel (1) and other uses (1), for a total of 80 indications of use. Utensils and tools are manufactured with all six stem types of all size categories (Figure 2b; Table 1). Tall-stem types were the most used in all categories of use, except for utensils and tools (Figure 2b). Only the stems of tall, medium and small palms were reportedly used for making musical instruments, such as flutes, drums, *reco-recos* (scraper percussion instrument), spears with rattle, trumpets and violas. The most cited species include *Socratea exorrhiza* (Figures 1c-d; 3a) (18 citations), with a tall stem, *Euterpe oleracea* (Figures 1e; 3b-f) (13 citations), with a tall stem and *Desmoncus polyacanthos* (nine citations), with a climbing stem (Table 1). The only record of commercial use of stem products was for the climbing palms *Desmoncus orthacanthos* (Figures 1k; 3g-h) and *D. polyacanthos* (Figures 1l; 3i-l), in the form of handicrafts marketed in municipal markets, fairs, warehouses and specialised shops in the states of Pará and Roraima (Flores and Lima 2013; Santos *et al.* 2016).

The cluster analysis formed four distinct groups (Figure 4). The first group contained only one solitary tall species that is used for construction. The second group comprised tall, medium and acaulescent palms with solitary stems also used for construction, environmental uses, utensils and tools, except for one species that is only recorded as used for utensils and tools (*Mauritia carana*). The third group was formed by cespitose, small palms (10 species of *Bactris*) and climbing palms (four species of *Desmoncus*), which were used, respectively, for handicrafts (arrowheads) and handicrafts, utensils and fishing traps, except for four species



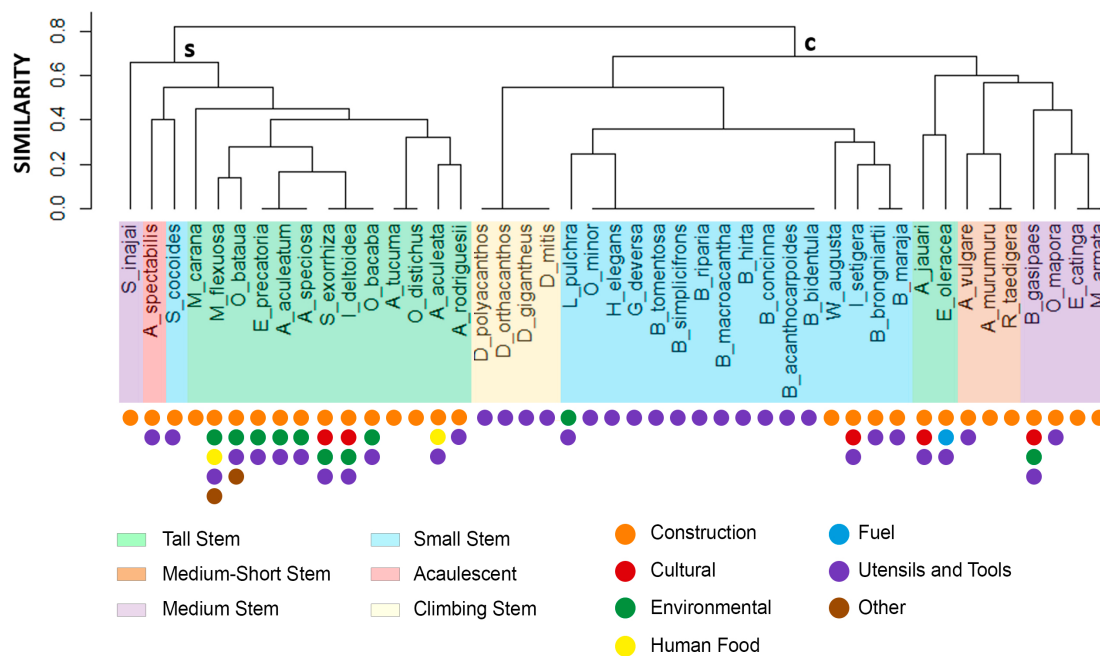


**Figure 3.** Uses of stems of native palm species in the Brazilian Amazon. Fishing traps: *cacuri* (A) in the Tocantins River, Pará state (Brazil); *matapi* (G). Construction: house (B); walls (C-D); floor (E); roof (arrow) (F) on Cotijuba Island, Pará state. Domestic utensils: bag (H); basket (I); fan (J); sieve (K) on Marajó Island, Pará state; cylindrical tube press (*tipiti*) (L) in Santo Antonio de Itapucú, Manaus state (Brazil); bowl (M) in Belém, Pará state. Furniture: tables (N-O). Organic fertilizer for orchids (P) in Terra Santa, Pará state. Stem-growth form (according to Balslev *et al.* 2011): TS = tall stem cespitose (A) or solitary (B-F, M, P); MS = medium stem (N-O); CS = climbing stem (G-L). Species: *Socratea exorrhiza* (A); *Euterpe oleracea* (B-F); *Desmoncus orthacanthos* (G, H); *D. polyacanthos* (I-L); *Oenocarpus bataua* (M); *Bactris gasipaes* (N-O); *Astrocaryum aculeatum* (P). Credits: Nigel Smith ([www.animalsanimals.com](http://www.animalsanimals.com)) (A) and Springer International Publishing (L); the authors (B-H, M); Sueyla Bezerra (I-K); Instituto Nacional de Pesquisas da Amazônia (N); Henrique Borçato (O); João Batista (P).

that were also used in construction: *Bactris bronhiatitii* (roofs and walls), *Bactris maraja* (fishing corrals), *Iriartella setigera* (floors and walls) and *Wettinia augusta* (floors and walls). The fourth group was composed of tall, medium-short and medium cespitose palms used for construction, utensils and tools, except for four species that were exclusively cited for construction (*Astrocaryum murumuru*, *Euterpe catinga*, *Raphia taedigera* and *Mauritia armata*). One species was used for firewood (*Euterpe oleracea*) and another as organic fertilizer

(*Bactris gasipaes*). In the first group, two species of tall-stem palms were used for starch (*Astrocaryum aculeata* and *Mauritia flexuosa*) and two for larvae food (*turus*) (*Mauritia flexuosa* and *Oenocarpus bacaba*). Five species distributed in the three largest groups were used for manufacturing musical instruments (*Astrocaryum jauari*, *Bactris gasipaes*, *Iriartea deltoidea*, *Iriatella setigera* and *Socratea exorrhiza*) (Figure 4; Table 1).

Despite being broad-scaled, our analysis indicated that species with both solitary or cespitose stems are employed in



**Figure 4.** Dendrogram resulting from a cluster analysis of stem characteristics and uses of 45 palm species native to the Brazilian Amazon with recorded traditional uses of the stem. C = cespitose; S = solitary.

all use categories, although specific stem types are associated with specific forms of use. In particular, small cespitose stems of *Geonoma deversa*, *Hyospathe elegans*, *Iriartea setigera*, *Oenocarpus minor* and ten species of *Bactris* were used by indigenous peoples to make hunting tools such as blowgun, bows, arrows, harpoons and spears for being hard but flexible (Miranda *et al.* 2001; Campos and Ehringhaus 2003; Miranda and Rabelo 2008; Lorenzi *et al.* 2010). Cespitose climbing stems of *Desmoncus* are used to make baskets, ropes and various utensils, such as *tipitis*, an indigenous technology found only in the Brazilian Amazon, developed to remove the toxic liquid from bitter cassava (*Manihot esculenta* Crantz) (Carney and Hiraoka 1997; Smith 2015). *Desmoncus polyacanthos* fibers are considered more flexible and resistant than those of other species used to make *tipitis*, such as the petiole of *Ischnosiphon obliquus* (Rudge) Körn (Marantaceae) and the leaves of *Mauritia flexuosa* and *Oenocarpus bacaba* (Miranda *et al.* 2001; Wallace 2014; Smith 2015). The fibrous climbing stems of *Desmoncus* are used in a similar way as Asian rattan (Uhl and Dransfield 1987), and are the only type of stems commercialized in northern Brazil, as household utensils and decoration (Flores *et al.* 2013; Santos *et al.* 2016). Yet, its potential for industrial use remains little explored (Miranda *et al.* 2001). In fact, the uses of many species of palm trees are not recorded in the literature (T. Kikuchi, pers. obs.), such as the tall stems of the Patauá palm (*Oenocarpus* sp.), which are used to manufacture utensils that can be found in craft stores and fairs (Figure 3m), highlighting the need for further

studies that focus on ethnobotanical knowledge of useful palm species in the Amazon region (Macía *et al.* 2011).

The stems of tall, medium-short and medium, solitary or cespitose palms are the most valuable for construction and production of utensils, accessories, tools and handicrafts, due to the resistance and workability of their wood (Anderson 1977; Miranda *et al.* 2001; Miranda and Rabelo 2001). Stems of acaulescent, medium-short and small types are less valuable and used only as an alternative when there is a shortage of more suitable species (e.g., *Attalea spectabilis*) (Anderson 1977), or when certain species are locally abundant (e.g., *Astrocaryum vulgare*, *Bactris brongniatii*, *B. maraja*, *Iriartella setigera* and *Oenocarpus minor*) (Souza *et al.* 2010; Jardim and Cunha 1998). Locally abundant, resistant species are also associated with a higher number of use citations (Germano *et al.* 2014), both in floodplain and *terra firme* environments, such as *Astrocaryum aculeata*, *A. aculeatum*, *A. jauari*, *A. rodriguesii*, *A. tucuma*, *A. vulgare*; *Attalea speciosa*, *Bactris gasipaes*, *Desmoncus polyacanthos*, *D. giganteus*, *D. orthacanthos*, *D. mitis*, *Euterpe catinga*, *E. oleracea*, *E. precatoria*, *Iriartea deltoidea*, *Leopoldinia pulchra*, *Mauritia flexuosa*, *Mauritiella armata*, *Oenocarpus bacaba*, *O. bataua*, *O. mapora*, *Raphea taedigera*, *Syagrus cocoides*, *S. inajai*, *Socratea exorrhiza* and *Wettinia augusta* (e.g., Anderson 1977; Jardim and Cunha 1998; Carney and Hiraoka 2003; Ferreira 2005; Lorenzi *et al.* 2010; Miranda and Rabelo; Almeida and Jardim 2012; Araújo *et al.* 2016; Wallace and Ferreira 2016). The lack of records on some species, such as *Mauritia carana*, is attributed to the difficulty

in harvesting these palms, which have been replaced as raw material over the years in construction and manufacture of utensils by industrialized materials (Rocha and Silva 2005; Germano *et al.* 2014; Smith 2015).

Only the stems of *Astrocaryum jauari*, *Bactris gasipaes*, *Iriartea setigera*, *Iriartea deltoidea* and *Socratea exorrhiza* were mentioned for the manufacture of musical instruments, especially by indigenous Kaxinawá in Acre state (Campos and Ehringhaus 2003). The wood of these species probably has the anatomical, physical and mechanical properties to provide ideal resonance features. These species were also reported in most other use categories, showing their importance to meet the basic subsistence needs of traditional communities in the Brazilian Amazon (Santos and Coelho-Ferreira 2012; Germano *et al.* 2014).

In the environmental use category, stems were used to make organic fertilizer (Figure 3p), fences and enclosures for vegetable gardens and gardens (Lorenzi *et al.* 2010; Germano *et al.* 2014). In the fuel category, wood from *Euterpe oleracea* is used for heat bricks (Miranda *et al.* 2001). In the human food category, sap, and starch similar to the sago used for porridge are obtained, respectively, from the stems of *Acrocomia aculeata* and *Mauritia flexuosa* (Miranda *et al.* 2001; Miranda and Rabelo 2008). In the category of other uses, it was mentioned that the wood from rotten stems of *Mauritia flexuosa* and *Oenocarpus bataua* that were in contact with water from floodplains or rivers, are consumed by molluscs called *туру*, which, in turn, are used as a food source by many riverine communities (Miranda *et al.* 2001; Gomes-Silva 2005). The use of palm stems as a source of larvae of *Rhyncophorus palmarum* (Coleoptera), which are used for human consumption, is the most cited in the other use category in the Amazon of Colombia, Ecuador, Peru and Bolivia (Macía *et al.* 2011). More forms of use for the stems of many palm species could probably have been registered in the utensils and tools category if they had been described in detail by the citing authors beyond generic terms such as “handicrafts” and “artifacts”.

In the western Amazon, the stems of *Bactris gasipaes*, *Iriartea deltoidea*, *Oenocarpus bataua*, *O. mapora* and *Socratea exorrhiza* were the most used by traditional peoples, especially indigenous peoples, in various categories of use, such as construction, cultural, environmental uses, fuel, human food, medicines and veterinary medicine, utensils and tools and other uses (Macía *et al.* 2011). Among these species, Bernal *et al.* (2011) described the stems of *Euterpe oleracea*, *Iriartea deltoidea*, *Socratea exorrhiza* and *Desmoncus polyacanthos* as the most important for construction and crafts in South America, but their uses are still restricted to local or regional domestic consumption. The stem uses of these same species were also the most cited for the Brazilian Amazon.

The traditional knowledge on the uses of palm species contributes to the conservation of palm-trees and to devise

sustainable alternative sources of income for local communities (Thoma *et al.* 2016), and provides an invaluable information source for prospection of new materials and biotechnological applications. Among current studies on industrial applications of palm-stem products, coconut palm (*Cocos nucifera* L.) stems have been used in the production of biocomposites for partial or total replacement of conventional building materials such as steel, concrete and bricks (González *et al.* 2019), in addition to stems of *Astrocaryum aculeatum* and *Bactris gasipaes* (Figure 3n-o), that have potential for the development of new products for the furniture industry (Miranda and Rabelo 2008; Trindade and Máximo 2017). The formulation of public policies is necessary to systematize the knowledge on the use of Brazilian Amazonian palm species and to promote the rational use and appreciation for products generated from the woody or fibrous palm stems, in all cases ensuring the conservation and sustainability of the extraction.

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