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Original Article

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Palm (Arecaceae) Communities in the Brazilian Atlantic Forest: a Phytosociological Study

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ABSTRACT

The aim of this study was to improve our understanding of the structure and composition of native palm communities in the Brazilian Atlantic Forest. This study was carried out at "Parque Estadual da Serra Furada" (PAESF), a protected area located in southern state of Santa Catarina. A palm community survey was carried out in Dense Ombrophilous Forest in five 20 m × 100 m sampling units, totaling 1ha. All palm individuals were measured, totaling 11,183 plants, belonging to four genera and five species: *Bactris setosa* Mart., *Euterpe edulis* Mart., *Geonoma gamiova* Barb.Rodr., *Geonoma schottiana* Mart. and *Syagrus romanzoffiana* (Cham.) Glassman. *Euterpe edulis* was the most common species, contributing the most to all phytosociological parameters; however, relatively few large individuals were found. Our study demonstrates the limitations of traditional forest surveys that ignore smaller diameter palm species and highlights the importance of the role of this group in the floristic diversity, ecosystem function, environmental services and carbon dynamics.

Keywords: biodiversity, conservation area, *Euterpe edulis*, forest inventory, Palmae, phytosociology, Santa Catarina.

1. INTRODUCTION

Palms belong to one of the largest plant families (Arecaceae) and represent a vital element of forest ecosystems, in terms of both ecological and economic importance (Reitz, 1974; Soares et al., 2014; Elias, 2018; Elias et al., 2016, 2018, 2019). With abundance of nutritious fruits and seeds, palms provide an essential resource for tropical forest frugivores (Zona & Henderson, 1989; Andreazzi et al., 2009; Galetti et al., 2013; Vinholes, 2018). In addition, palms are key components of the forest structure, and can be found in all forest strata (canopy understory), although many tropical species have been extensively collected by humans, for both timber and non-timber uses (Ubessi-Macarini et al., 2011; Elias & Santos, 2016; Elias et al., 2019).

Research on palm community structure in Brazil is relatively rare compared to other plant groups (Fisch & Gomes, 2015) and is mostly limited to studies focused on the Cerrado (Campos et al., 2017) and Amazon domains (Salm et al., 2015). Furthermore, while studies on forest structure and composition in the Atlantic Forest are common (Colonetti et al., 2009; Portella & Santos, 2014; Bosa et al., 2015); their methodologies, especially the inclusion criteria, often overlook important components of the forest structure, excluding some palm species due to their particular growth habit.

A better understanding of the palm population structure and dynamics is critical, as reduced densities and species loss due to forest fragmentation are important basic structural changes to palm communities, altering food chains and compromising the availability of basic resources (Carvalho et al., 2010).

The present work describes the structural characteristics (absolute and relative frequency; absolute and relative density; absolute and relative dominance; and Importance Value Index) of palm communities in a fragment of Dense Ombrophilous Forest at the “Parque Estadual da Serra Furada” (PAESF), southern Santa Catarina.

2. MATERIAL AND METHODS

2.1. Study area

The “Parque Estadual da Serra Furada” (PAESF) is located between Orleans and Grão Pará, two municipalities in the southern part of the Brazilian state of Santa Catarina (Figure 1). Historically, the area now occupied

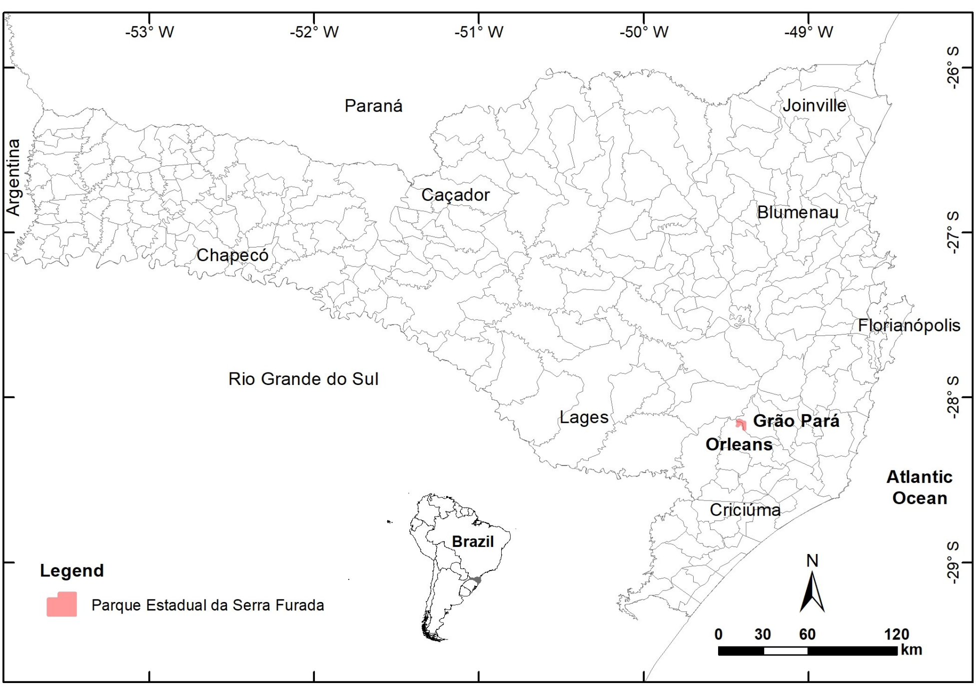

Figure 1. “Parque Estadual da Serra Furada” (PAESF) located between Orleans and Grão Pará, in the southern part of Santa Catarina, Brazil.

by PAESF experienced unsupervised timber extraction and human disturbance until the creation of the park on June 20, 1980 (Decree No 11.233; Guislon et al., 2017). Hunting and collection of economically valuable species were widespread and led to the loss of much of the original biodiversity. Subsistence livestock farming and logging were widely practiced before the creation of the park and substantially altered the forest structure (Guislon et al., 2017). The vegetation of the study area presents high diversity of tree species, distributed across a mosaic of heterogeneous habitats, and includes species such as *Alchornea triplinervia* (Spreng.) M. Arg., *Ocotea catharinensis* Mez., *Actinostemon concolor* (Spreng.) Müll.Arg. and *Guapira opposita* (Vell.) Reitz (Guislon et al., 2017).

The Köppen climate classification for the PAESF region is humid subtropical with no defined dry season and hot summers (Cfa), with average annual temperature varying from 17.0 °C to 19.3 °C at lower altitudes, and balmy summers (Cfb) with average annual temperature ranging from 13.8 °C to 15.8 °C at higher altitudes (Alvares et al., 2013). Average annual rainfall ranges from 1,300 mm to 2,500 mm (Alvares et al., 2013). The PAESF terrain is rugged, characterized by craggy areas and steep valleys with altitudes from 400 to 1480 m. The vegetation in the park is classified as Dense Ombrophilous Montane and High-Montane Forests (IBGE, 2012). In terms of geology, PAESF is characterized by extensive rock areas, such as siltstones, shales and sandstones included in the following lithostratigraphic classifications: São Bento Group, represented by diabase intrusion and by Serra Geral and Botucatu formations; Passa Dois Group, composed of Rio do Rastro, Terezina, Serra Alta and Irati formations; and Guatá Group, with non-glacial sediments and coal layers, composed of the Palermo Formation (IBGE, 2012).

2.2. Data collection

A palm community survey was carried out in Dense Ombrophilous Forest within five 20 m × 100 m sampling units (SU), or plots, totaling 1ha (Figure 2). The first sampling unit (A) was installed five meters from the forest edge in an area with history of intense exploitation by past residents and located close to PAESF headquarters. The second sampling unit (B) was installed

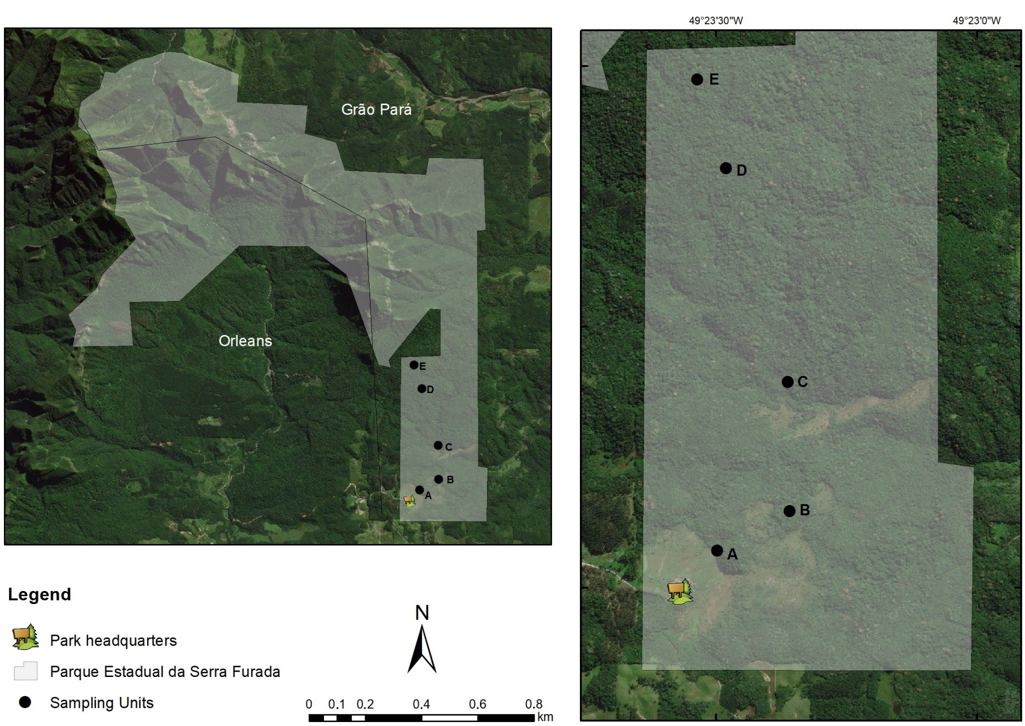

Figure 2. Sampling Unit (SU) locations within the “Parque Estadual da Serra Furada” (PAESF) boundary, located between municipalities of Orleans and Grão Pará, Santa Catarina, Brazil.

within the forest interior on sloping ground with little history of human intervention. The third sampling unit (C) was installed nearby streams and waterfalls and surrounded by rugged terrain. The fourth and fifth sampling units (D and E) were located in selectively logged forest at higher altitudes and far from any water bodies. Sampling units ranged in altitude from 470 to 650 m (Guislon et al., 2017). All palms from seedlings to adults were measured and identified in each plot. Height at the top of leaf crown was measured using a laser measure tape (Bosch GLM 40), and Diameter at Soil Height (DSH) of each palm was measured using a digital caliper (MTX – 150mm).

2.3. Data analysis

To analyze the horizontal and vertical structure of PAESF palm populations, the DSH distribution (Diameter at Soil Height) and height classes separated into 15 size classes based on Sturges (1926) were examined.

Data were standardized, and non-metric multidimensional ordination methods (NMDS) (Clarke, 1993) and the Bray-Curtis index were used to determine associations and distinct groups among SUs using species abundance as variable. Analysis of similarity (ANOSIM) (Clarke, 1993) was then applied with 999 permutations to determine significance of assigned groups. All palm species were included in these analyses.

To characterize the horizontal structure of each group, as determined by NMDS and ANOSIM, Importance Value (IV) was calculated, which is the sum of the relative frequency, density and dominance values for each species. Finally, the species that most contributed to differences between groups were identified using analysis of similarity (SIMPER) (Clarke, 1993). Statistical analyses were run in the R computing environment (R Development Core Team, 2018).

3. RESULTS AND DISCUSSION

Overall, 11,183 individual palms belonging to four genera and five species were surveyed: *Bactris setosa* Mart., *Euterpe edulis* Mart., *Geonoma gamiova* Barb.Rodr., *Geonoma schottiana* Mart. and *Syagrus romanzoffiana* (Cham.) Glassman. This high palm abundance was directly related to our methodology, which included all individuals, regardless of size. Recently, Fisch & Gomes (2015) reviewed sampling methods and floristic and structural parameter calculations across six palm community studies in different vegetation types. Among studies, only one calculated dominance, which was based on palms with DBH ≥ 2 cm, thus excluding small stature and stemless palms and underestimating the true extent of the palm community (Elias et al., 2018). Generally, forest inventories exclude trees with DBH ≤ 2 cm, but their diverse growth habits, including reproductively mature stemless and small stature specimens, dictate a more inclusive methodology for studying the composition and structure of palm communities and forests containing palms.

This study included all palms regardless of size and evaluated population stratification across 15 size classes defined based on the formula of Sturges. C1, C2 and C3 classes corresponded to more than 90% of sampled individuals, demonstrating the dominance of young and short-stature individuals and depicting an “inverted j” pattern (Table 1), typical of natural populations that present high *in locus* regeneration (Rocha, 2004). The same pattern was reported for *E. edulis* (Reis et al., 1996) and several other neotropical palms growing in Santa Catarina (Elias et al., 2019).

C10 class also included many individuals and is mainly composed of *E. edulis* palms, which grow 10-12 m in height. Field observations confirmed that these individuals are reproductive, showing signs of flowering and fruiting. Reitz (1974) also observed fertile individuals within this size class in Santa Catarina. In contrast, *E. edulis* individuals from the initial classes showed high mortality rate, following the “inverted j” pattern, with only 5.5% and 1.2% in C1 class, reaching the second and third size classes, respectively. This high mortality rate is linked to genetic potential, the microenvironment and intra and interspecific competition (Reis et al.,1996).

Bactris setosa, *G. gamiova* and *G. schottiana* exhibited lower abundance compared to *E. edulis* and were distributed among fewer height classes. As understory species, these palms rarely grow over 3.5 meters in height (Elias et al., 2018). These species show signs of flowering and fruiting at heights above 1.24 m in the second size class.

All *Syagrus romanzoffiana* palms were included in the smallest size class (C1). This palm is a large arborescent palm, rarely found in PAESF, but known for its high environmental plasticity (Elias et al., 2016). The concentration of smaller individuals found here suggests that *S. romanzoffiana* is beginning to colonize forest communities in the park, probably due to the presence of new seed dispersers (Giombini et al., 2009).

The distribution of DSH classes presented pattern similar to height class distributions (Table 2). The three smallest classes (<52.8 mm) corresponded to more than 98% of sampled individuals and represented more than 35% of the basal area within the community, but smaller individuals also demonstrated high mortality rate (Swaine et al., 1987).

Our findings highlight loss of information with the exclusion of smaller diameter individuals – a common practice in plant population studies. For palms in particular, this restrictive methodology excludes meaningful information regarding reproductive and ecologically important understory plants that fail to meet minimum size requirements. By including all palms, this study ensured that smaller diameter and stemless palms were sampled to better understand the

Table 1. Palm distribution by height classes (m) for all palms sampled in five 20 m × 100 m sampling units within PAESF, Santa Catarina, Brazil.

Class	Height (m)	Bac.set	Eut.edu	Geo.gam	Geo.sch	Sya.rom	RA
C1	(0.04-1.24)	58	9244	1019	51	8	92.82
C2	(1.24-2.43)	11	245	115	11	0	3.42
C3	(2.43-3.63)	3	60	73	8	0	1.29
C4	(3.63-4.83)	2	12	12	0	0	0.23
C5	(4.83-6.03)	0	10	0	0	0	0.09
C6	(6.03-7.22)	0	72	0	0	0	0.64
C7	(7.22-8.42)	0	11	0	0	0	0.10
C8	(8.42-9.62)	0	12	0	0	0	0.11
C9	(9.62-10.82)	0	8	0	0	0	0.07
C10	(10.82-12.01)	0	126	0	0	0	1.13
C11	(12.01-13.21)	0	8	0	0	0	0.07
C12	(13.21-14.41)	0	1	0	0	0	0.01
C13	(14.41-15.61)	0	1	0	0	0	0.01
C14	(15.61-16.80)	0	1	0	0	0	0.01
C15	(16.80-18.00)	0	1	0	0	0	0.01

Table 2. Palm distribution by DSH classes (mm) for all palms sampled in five 20 m × 100 m sampling units within PAESF, Santa Catarina, Brazil.

Classes	DSH (mm)	Bac.set	Eut.edu	Geo.gam	Geo.sch	Sya.rom	RA	RBA
C1	(1.0-18.3)	54	9137	629	25	8	88.11	9.28
C2	(18.3-35.5)	14	425	464	27	0	8.32	16.31
C3	(35.5-52.8)	4	99	99	8	0	1.88	9.50
C4	(52.8-70.1)	2	56	21	9	0	0.79	8.57
C5	(70.1-87.3)	0	15	3	1	0	0.17	2.97
C6	(87.3-104.6)	0	7	0	0	0	0.06	1.64
C7	(104.6-121.9)	0	7	1	0	0	0.07	2.59
C8	(121.9-139.1)	0	14	0	0	0	0.13	6.08
C9	(139.1-156.4)	0	17	0	0	0	0.15	9.21
C10	(156.4-173.7)	0	13	1	0	0	0.13	9.39
C11	(173.7-190.9)	0	10	1	0	0	0.10	9.49
C12	(190.9-208.2)	0	4	0	0	0	0.04	3.98
C13	(208.2-225.5)	0	4	0	0	0	0.04	4.72
C14	(225.5-242.7)	0	1	0	0	0	0.01	1.34
C15	(242.7-260.0)	0	3	0	0	0	0.03	4.92

Bac.set = *Bactris setosa*; Eut.edu = *Euterpe edulis*; Geo.gam = *Geonoma gamiova*; Geo.sch = *Geonoma schottiana*; Sya.rom = *Syagrus romanzoffiana*; RA = relative class abundance; and RBA = relative basal area.

role of these palms in the structure and dynamics of the Atlantic Forest community (Fisch & Gomes, 2015).

3.1. Distribution on sampling units

Palms occurred throughout all SUs; however, ordination analysis identified two distinct palm communities, separating SU (A) from all others (B, C, D, and E) (Figure 3). Differences were related to past land use history. Before PAESF was officially demarcated, SU (A) experienced heavy exploitation – mainly the harvest of *E. edulis* palm heart. Even after demarcation, forest reserves were still plagued by illegal harvesting, a common practice in Santa Catarina (Gasper et al., 2011). For example, Silva & Fisch (2012) reported illegal palm heart extraction in protected areas of the "Parque Estadual da Serra do Mar" in Ubatuba, along the northern coast of the state of São Paulo.

SUs (B, C, D and E) were grouped together despite different intervention histories and distinct environmental contexts. One of the main reasons for this procedure was the considerable distance of each SU from the park boundary and difficult access to these areas. ANOSIM also confirmed the separation of SUs into the same two distinct groups (R=0.80; *P*=0.001): environments with high intensity exploitation (A) were significantly different from those with low impact exploitation (B, C, D and E).

Relative frequency, density, dominance, and importance values showed no clear differences among the four SUs (B, C, D and E), while absolute palm density in SU (A) was, on average, five times lower than in the other SUs. This contrast reflects land use history, especially the extraction of *E. edulis* stems for palm heart and the exploitation of other economically valuable species, which altered luminosity and the presence of propagules in the area, reducing the abundance of species typical to these environments, as observed in other forest fragments of Santa Catarina (Gasper et al., 2011).

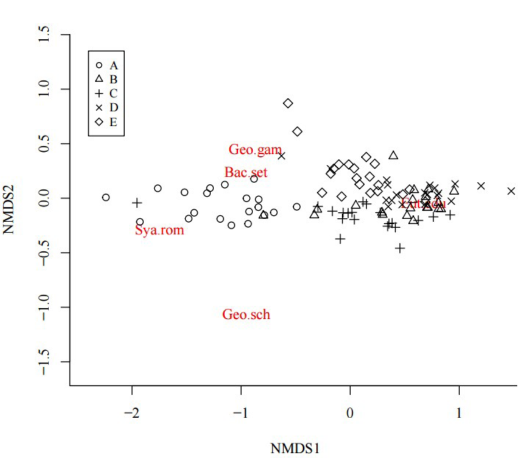

Figure 3. Multidimensional non-metric scaling for sampled palm species, according to the different Sampling Units (A, B, C, D, and E). Stress: 0.044 (2 dimensions).

SIMPER analysis pointed *E. edulis* as key for distinction among environments, corresponding to 84% of dissimilarity, followed by *G. gamiova* (14%). In addition, *E. edulis* presented the highest IVI across all SUs (Table 3). This species dominates all layers of the forest strata and at times, it appears monodominant. Reitz (1974) also emphasized the importance of *E. edulis* in the Dense Ombrophilous Forests of Santa Catarina, and our results corroborate Oliveira et al. (2014), who identified *E. edulis* as the most abundant palm species of Ubatuba, state of São Paulo.

Geonoma gamiova was also important to the palm community surveyed here. In total, 1219 individuals of this thin-stemmed species were recorded in nearly all SUs. *Geonoma gamiova* was spared during PAESF's logging period, due to its use as a non-timber forest product, such as rope and roofing that crafted from leaves (Reitz, 1974). The species has few environmental restrictions (Oliveira et al., 2014) and is regularly distributed throughout the Dense Ombrophilous Forest understory (Henderson, 2011; Elias et al., 2018).

Bactris setosa and *G. schottiana* occurred at low densities with only 74 and 70 individuals, respectively. Both species are selective in terms of habitat conditions. The rugged terrain found within PAESF does not provide ideal establishment conditions for *B. setosa*, which prefers wet soils, nor for *G. schottiana*, which develops better at higher altitudes (Reitz, 1974; Elias et al., 2018).

Syagrus romanzoffiana was the least abundant palm species in PAESF, with only 12 individuals all shorter than 1.2 m. This large arborescent palm can reach 15 m and shows natural regeneration inside the forest, especially in forest gaps. The dispersion of *S. romanzoffiana* seeds into PAESF originates from only a few seed sources, although mammal feces containing many seeds are frequently found. We believe that with time, *S. romanzoffiana* will become increasingly common in PAESF, as well as throughout the state of Santa Catarina (Elias et al., 2016).

Table 3. Palm community composition parameters, ordered by Importance Value Index, for species sampled at "Parque Estadual da Serra Furada" (PAESF), Santa Catarina, Brazil.

Environment with high levels of exploitation (Sampling Unit A)							
Species	**AF**	**RF**	**AD**	**RD**	**ADO**	**RDO**	**IVI**
Euterpe edulis	100	48.78	1800	89.11	0.08	65.56	203.45
Geonoma gamiova	75	36.59	190	9.41	0.03	25.94	71.93
Bactris setosa	15	7.32	15	0.74	0.00	3.06	11.12
Geonoma schottiana	10	4.88	10	0.50	0.01	5.39	10.76
Syagrus romanzoffiana	5	2.44	5	0.25	0.00	0.05	2.74
Total	**205.00**	**100**	**2020**	**100**	**0.12**	**100**	**300**
Environment with low levels of exploitation (Sampling Units B, C, D and E)							
Species	**AF**	**RF**	**AD**	**RD**	**ADO**	**RDO**	**IVI**
Euterpe edulis	100	39.41	11815	87.69	3.04	79.04	206.13
Geonoma gamiova	95	37.44	1476.25	10.96	0.71	18.39	66.78
Bactris setosa	40	15.76	88.75	0.66	0.03	0.68	17.10
Geonoma schottiana	12.5	4.93	85.00	0.63	0.07	1.87	7.43
Syagrus romanzoffiana	6.25	2.46	8.75	0.06	0.00	0.03	2.56
Total	**253.75**	**100**	**13473.75**	**100**	**3.84**	**100**	**300**

AF = Absolute Frequency; RF = Relative Frequency; AD = Absolute Density; RD = Relative Density; ADO = Absolute Dominance; RDO = Relative Dominance; IVI = Importance Value Index.

4. CONCLUSIONS

Euterpe edulis dominated PAESF palm communities; however, relatively few large palms were found. Considering high mortality rates in smaller size classes, this scarcity of reproductive individuals compromises the continuity of the population and the ecosystem services they provide. On the other hand, *Bactris setosa*, *G. gamiova* and *G. schottiana* exhibited lower abundance compared to *E. edulis*, mainly due to their narrow habitat requirements, but significantly contributed to the diversity and biomass of the overall palm community.

Past land use history and the collection of *E. edulis* stems for palm heart left a lasting negative result on palm communities found within PAESF. Future management plans and conservation initiatives in this area should take into account the importance of this palm and its fragility in the forest.

The abundance of palms recorded in our survey at PAESF demonstrates the limitations of traditional forest surveys that ignore smaller diameter species (DBH ≤ 2 cm). The exclusion of shorter height understory palms leads to a misrepresentation of the true forest community, and we suggest that forest ecology studies use less restrictive criteria for palms in order to avoid underestimating the role of this group in the floristic diversity, ecosystem function, environmental services and carbon dynamics.

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