



Revista Brasileira de Geografia Física

Homepage: <https://periodicos.ufpe.br/revistas/rbgfe>



A pioneering community in dunes: does anthropization modify floristic composition?

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Artigo recebido em 30/06/2019 e aceito em 24/12/2019

RESUMO

A zona costeira do Piauí tem sido fortemente impactada nos últimos anos pela intervenção antrópica – processos urbanísticos, turismo predatório, descarte inadequado de resíduos sólidos – principalmente sobre as áreas de dunas. Os impactos negativos refletem nos estratos vegetais, dentro os quais se destacam as formações herbáceas, alterando sua estrutura e dinâmica, comprometendo o equilíbrio do ecossistema. Assim, este estudo avaliou as diferentes formações herbáceas em dunas em estado de conservação e antropização, assim como, identificou a diversidade de espécies presentes nos dois ambientes, as espécies dominantes, comuns e indicadoras de efeitos antropogênicos. A pesquisa procedeu na cidade de Luís Correia, litoral do Piauí, nas proximidades das praias do Coqueiro e Macapá, onde foram realizadas as coletas das dunas antropizadas e conservadas, respectivamente. Foi empregado o método de parcelas, totalizando 200 parcelas em 4 dunas. O material vegetal foi coletado, identificado e incorporado em herbário. Nas dunas antropizadas, foi encontrado um total de 12 espécies, distribuídas em 11 gêneros, correspondentes à 11 famílias. Já nas dunas não antropizadas, foi possível obter um total de 23 espécies, distribuídas em 20 gêneros, correspondentes à 13 famílias. As dunas se caracterizaram pela formação de campos. As famílias mais representativas foram Fabaceae e Poaceae. As espécies mais significativas quanto à sua dominância, foram *Richardia grandiflora* Britton, e *Euploca polyphylla* (Lehm) J.I.M. Melo & Semir, sendo consideradas indicadoras de efeitos de antropização, utilizadas em estudos de anatomia foliar, onde foi possível a identificação de estruturas que permitem a sua adaptação à ambientes de restinga. Este estudo contribuiu para o conhecimento da diversidade botânica de herbáceas em dunas do litoral piauiense, fornecendo dados para subsidiar pesquisas subsequentes de fisiologia e anatomia de espécies indicadoras de antropização.

Palavras-chaves: anatomia foliar, antropização, fitossociologia, herbáceas, restinga.

ABSTRACT

The coastal zone of Piauí has been heavily impacted in recent years by anthropic intervention - urban processes, predatory tourism, inadequate disposal of solid waste - mainly on the dune areas. The negative impacts reflect in the vegetal strata, in which the herbaceous formations stand out, altering its structure and dynamics, compromising the balance of the ecosystem. Thus, this study evaluated the different herbaceous formations in dunes in a state of conservation and anthropization, as well as, identified the species diversity present in both environments, the dominant species, common and indicative of anthropogenic effects. The research was carried out in the city of Luís Correia, on the coast of Piauí, near the beaches Coqueiro and Macapá, where the plant samples were collected in the anthropized and preserved dunes. The plots method was used, with 200 plots in 4 dunes. The plant material was collected, identified and incorporated in herbarium. In the anthropic dunes, a total of 12 species were found, distributed in 11 genera, corresponding to 11 families. In the non-anthropic dunes, it was possible to obtain a total of 23 species, distributed in 20 genera, corresponding to 13 families. The dunes were characterized by the formation of fields. The most representative families were Fabaceae and

Poaceae. The most significant species for their dominance were *Richardia grandiflora* Britton, and *Euploca polyphylla* (Lehm) J.I.M. Melo & Semir, being considered indicators of anthropization effects, used in foliar anatomy studies, where it was possible to identify structures that allow their adaptation to restinga environments. This study contributed to the knowledge of the herbaceous botanical diversity in dunes of the Piauí coast, providing data to support subsequent researches on the physiology and anatomy of species indicative of anthropization.

Keywords: leaf anatomy, anthropization, phytosociology, herbaceous, restinga.

Introduction

It is noticeable that coastal areas have been suffering in recent years from strong anthropogenic intervention, reflected mainly by the constant growth of coastal development processes, both in Brazil and in other parts of the world (Silva et al. 2018). This disorderly process intensifies the concentration of human activities and the unsustainable and non-rational use of the natural resources present in these regions.

The physiognomy of the coastal zones is formed by ecosystems and clusters of natural elements of restinga environments, characterized by the presence of dunes of different sizes, both movable and fixed, herbaceous fields, fields formed by fruticeta, high and low forests, among others (Santos-Filho et al., 2015).

Dunes are usually coastal formations resulting from the action and interaction of three basic elements: winds, vegetation and sediments. The onshore wind carries the sand particles behind and along the shoreline, and when they encounter an obstacle, tend to accumulate, leading to different patterns of shapes and sizes (Pinheiro, 2009; Silva et al., 2018). When transported and accumulated, these dunes can be of two types: I) movable, when there is a lack of vegetation or obstacles that allow the displacement of the sand particles by long distances from the shoreline; II) fixed, when the formation of a vegetation occurs and fixes the sedimentation already accumulated, causing the dune to stop moving forward (Moura-Fé, 2008; Araújo et al., 2016). When consolidated, the dunes have environmental functions that are important for the environment, because they act as natural barriers, preventing the direct action of the sea on the coast, they function as habitats for several species of fauna and flora characteristics of this environment, as well as tourism attractions in certain places (Araújo et al., 2016, Mesquita et al., 2018). Therefore, the dunes become a formation of high importance for the environment, and, thus, making their preservation necessary.

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Brazil and in other parts of the world (Silva et al. 2018). This disorderly process intensifies the concentration of human activities and the unsustainable and non-rational use of the natural resources present in these regions.

From the different types of plant strata found in dunes, herbaceous formations are the main ones, which play a fundamental role in the sedimentary control of coastal environments, reducing erosion episodes and flooding (Silva et al., 2016). This stratum is in subjection to stress levels due to several factors, mainly soil nutrient deficiency, low organic matter content and a wide range of humidity and temperature related to strong winds (Santos et al., 2000). This ecosystem has gradually suffered a series of impacts that alter its dynamics and compromise its equilibrium (Santos & Medeiros, 2003; Oliveira & Sousa, 2011; Arulmoorthy and Srinivasan, 2017), it is caused mainly by anthropic actions that alter vegetation physiognomy and structure regions.

The northern coast of Northeast Brazil has more mobile dunes compared to the eastern coast, confirming its frequent occurrence on the coast of Piauí, since it is in a dry climate region (Santos-Filho et al., 2013). The strong wind, and the lack of humidity of the air, remove the water from the sand particles carried by wind along the shoreline, entering more and more to the coast.

Based on this premise, the coast of Piauí does not escape this rule, since its coast has been strongly negatively impacted by a cluster of actions and ecologically inadequate choices, especially on the dune areas. One of the main attractions of this area is tourism, where these in great flow, has been changing the physiognomy of the dunes of the region, mainly by the incorrect disposal of solid residues, that agglomerate in the dunes and end up polluting the environment (Souza & Silva, 2015).

For this reason, the present work evaluated herbaceous formations in dunes in a state of conservation and anthropization, as well as, identified the diversity of species present in both environments, the dominant species, common and indicative of anthropization.

Material and Methods

Study area

The study area comprises the city of Luís Correia (PI), near the beaches Coqueiro and Macapá, where the flora samples were collected in the anthropic and non-anthropogenic dunes, respectively (Figure 1). Luís Correia is the county of Piauí most visited by tourists, located in the coordinates -02 ° 52 '45'S and 41 ° 40' 01'W, it has an area of 1,071,276km², a population of 28,406 inhabitants, with an average altitude of 10m above

sea level, and annual average rainfall of 1172mm, (IBGE, 2010). The soil of this region is formed by marine quartz sands, dystrophic quartz sands and eutrophic alluvial soils (Santos-Filho et al., 2013), dated from the Quaternary (IBGE, 2010). The climate is considered tropical Aw type, according to the classification of Köppen and Geiger (Peel et al., 2007), with some coastal variations, with an annual average of 27.4 ° C (IBGE, 2010).

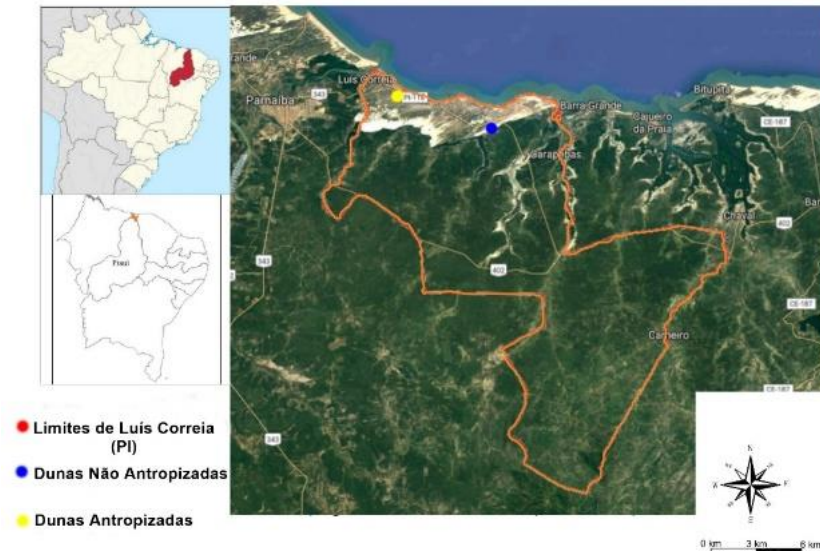


Figure 1 – Geographical location of the county of Luís Correia, Piauí, Brazil, evidencing the dunes used in this study. Source: prepared by the authors

Methodological procedures

The botanical collection followed the methodology of plots proposed by Munhoz & Araújo (2011), where the percentage of coverage of individuals found in each plot in the dune surveyed were recorded. This reporting took into account only those individuals whose stems or rhizomes were inserted within the plot, even if, in case of creeping plants, their posterior portion to the stem was outside the plot area.

The study comprised four dunes, two of which suffered anthropogenic processes, because

they were located in urban areas, with many occupations of residences, vehicular traffic and grazing of animals; and two dunes located far from the urban environment, with the minimum of anthropic interference, being considered non-anthropic.

The anthropic dunes are located near Coqueiro beach and the unpopulated dunes were selected near the access of Macapá beach, as shown in Table 1 below.

Table 1. Location of the dunes surveyed, Luís Correia, Piauí, Brazil.

Location	Dunes anthropized		Dunes not anthropized	
	Dune 1	Dune 2	Dune 3	Dune 4
Latitude	02°53.377'	02°53.397'	02°55.850'	02°55.893'
Longitude	041°37.356'	041°37.350'	041°30.498'	041°30.504'
Altitude	06m	06m	07m	09m

Source: prepared by the authors

The collection of the botanical material was carried out and processed, according to the vegetable taxonomy procedures proposed by Mori et al. 1989, with composition of exsiccates to serve as testimonial material of the present research, according to Vouchers registered in Table 1. The botanical material was identified by means of taxonomic identification keys and by comparison of existing specimens in the Graziela Barroso Herbarium (TEPB) (TROPEN) of the Universidade Federal do Piauí (UFPI), located in the Nucleus of Environmental Sciences studies - Núcleo de Referências em Ciências Ambientais do Trópico Ecotonal do Nordeste (TROPEN). The plants were classified in the APG IV system (APG, 2016), updating the names of the taxa based on the MOBOT website 2018, (APG, 2016). The identified materials were inserted in the herbarium Graziela Barroso. An application for botanical collection authorization was made to ICMBio, through the SISBIO system, and was approved by No. 59173-2, thus allowing botanical material to be obtained for analysis and to serve as a testimony of the research.

For phytosociological sampling, the plots method proposed by Munhoz & Araújo 2011, was used. In each dune, five transects with 100m length each were drawn, perpendicular to the sea line, with 10m distance between each transect. At each transection, 10 plots of 1m² (1x1m), 10m apart, were positioned alternately (random) along the transect, with 50 plots in each dune, totaling 200 (two hundred) plots, similar to the work of Pereira et al. 1992, to obtain data about plant species found closest to the edge of the beach. For the study sample, the herbaceous vegetation was considered as a plant that does not present woody stem in all its extension, do not have large amounts of lignin, and can be easily cut (Gonçalves & Lorenzi, 2011). The following phytosociological parameters were calculated: absolute plant cover, absolute and relative frequency, importance value and density (Mueller-Dombois & ElleMBERG, 1974; Pereira et al., 1992 and Menezes & Araújo, 1999). Calculations were made using Excel software from the Office 2013 package. Sorensen's similarity index (Ss) was also calculated to verify the degree of similarity between occurrences of species on the dunes.

The statistical verification was done using the Student's t test to determine the existence of a significant difference, considering the Absolute Frequency of the herbaceous cover between the

dunes sampled. The BioEstat package, Version 5.3, was used for the calculation.

The anatomic analyzes of two species with greater representativeness were carried out in the research, in order to identify possible adaptations that these species had to survive in these environments. Each individual was collected and fixed in FAA (50% formaldehyde, acetic acid, 50% ethyl alcohol, I: I: 18, v / v) and stocked in 50% ethanol, following the methodology established by Johansen 1940. The preparation of the slides followed the Kraus & Arduin 1997, standards, where the material was hand sectioned with the aid of sharp razor blades, and cross-sections of the plant organs were obtained. The sections were clarified in 50% sodium hypochlorite solution (NaClO) for a period of approximately six minutes. After the clarification process, the material was rinsed in sterile distilled water to start the staining process of the vegetable tissue was carried out. In which 0.5% basic fuchsin and 0.5% Astra blue were used, then the material was placed in a slide with 50% glycerinated gelatin and sealed with clear nail polish (Kraus & Arduin, 1997). After assembly of the slides, they were analyzed under an optical microscope and photographed.

Results and discussion

Phytosociology of the herbaceous stratum

In the sampling carried out on the anthropic dunes (DuA), a total of 12 species were found, distributed in 11 genera, corresponding to 11 families. In the sampling of the non-anthropic dunes (DuNA), 23 species were found, distributed in 20 genera, corresponding to 13 families (Table 2).

Table 2 - List of species identified in the anthropic and non-anthropic dunes of the coast of Piauí.
 DuA1 - anthropized dune 1; DuA2 - anthropized dune 2; DuNA3 - unanthropized dune 3; DuNA4 - dune not anthropized 4.

Family / Species	DuA1	DuA2	DuNA3	DuNA4
Amaranthaceae				
<i>Alternanthera brasiliana</i> (L.) Kuntze	X	X		
<i>Alternanthera littoralis</i> Beauv. Ex Mog.	X	X		
Boraginaceae				
<i>Euploca polyphylla</i> (Lehm) J. I. M. Melo & Semir	X	X	X	X
Commelinaceae				
<i>Commelina erecta</i> L.	X		X	X
Convolvulaceae				
<i>Ipomoea pes-caprae</i> (L.) R. Br.	X	X	X	X
Cyperaceae				
<i>Cyperus articulatus</i> L.	X	X		
<i>Remirea maritima</i> Aubl.	X	X		
Euphorbiaceae				
<i>Chamaesyce hyssopifolia</i> (L.) Small	X	X	X	X
Fabaceae				
<i>Chamaecrista racemosa</i> (Vogel) H. S. Irwin & Barneby	X	X		
<i>Chamaecrista ramosa</i> (Vogel) H. S. Irwin & Barneby	X	X	X	X
<i>Senna obtusifolia</i> (L.) H.S. Irwin & Barneby		X		
<i>Aeschynomene brasiliana</i> (Pois.) DC.	X	X		
<i>Macroptilium atropurpureum</i> (Sessé & Moc. Ex. DC.) Urb.	X	X		
Malvaceae				
<i>Sida galheirensis</i> Ulbr.	X			
Não identificada 1			X	
Nyctaginaceae				
<i>Boerhavia coccinea</i> Mill.			X	X
Passifloraceae				
<i>Passiflora foetida</i> L.				X
Poaceae				
<i>Aristida setifolia</i> Kunth.	X	X		
<i>Eleusine</i> sp 1		X		
<i>Paspalum maritimum</i> Trin.	X	X	X	X
<i>Pennisetum setosum</i> Raddi.	X	X		

Não identificada 2			X	X
Rubiaceae				
<i>Borreria verticillata</i> G. Mey	X	X		
<i>Richardia grandiflora</i> Britton.	X	X	X	X
Turneraceae				
<i>Turnera subulata</i> Sm.	X		X	X
<i>Turnera ulmifolia</i> L.	X	X		
Violaceae				
<i>Hybanthus calceolaria</i> (L.) Schulze-Menz	X	X		

Source: prepared by the authors

The physiognomy characterization of the region is similar to one of the classes proposed by Silva & Britez 2005, where it was classified as a field formation, characterized by the predominance of herbaceous species, whether they are erect, cespitosas, creeping and / or rhizomatous et al., 2017). Santos-Filho et al. 2010, proposed a new classification for the characterization of Silva and Britez (2005), based on the peculiarities presented by the Piauí coast, which differs from the other restinga regions of the northeastern coast, since Piauí has a coastline that is between two recent geological formations: areas formed by quartz sands from the Quaternary period, and established areas of Barrier formation, from the Tertiary age. The authors also established that the characterization of the dune phytogeography is due to the degree of vegetation cover (open or closed) and to the area's flood regime (flooded or non-flooded), as well as herbaceous and fruticeta fields.

As for the number of species, Fabaceae and Poaceae were the best represented families (five species each), followed by Amaranthaceae, Cyperaceae, Malvaceae and Turneraceae (two species each). Similar result was found by Amaral & Lemos 2015, regarding the two main families of

herbaceous species found in restingas of the coast of Piauí. Similar results were found by Medeiros et al. 2010, where one of the three families with the largest representation of species on the coast of Alagoas was Fabaceae (four species).

From the two most representative families, Fabaceae is always present as one of the species with the highest occurrence of species in the floristic listings of the Northeastern coast, as seen in areas of Paraíba (Oliveira Filho, 1993; Maroja et al., 2018); Pernambuco et al. 2004, and Almeida Jr. et al. Rio Grande do Norte (Almeida Jr. et al., 2006); Bahia (Viana et al., 2006); Ceará (Silva et al., 2008; Santos-Filho et al., 2011); Alagoas (Medeiros et al., 2010); Piauí (Santos-Filho et al., 2013, 2015); (Almeida Jr. et al., 2017, Lima & Almeida Jr., 2018), and Maranhão (Amorim et al., 2016, Araujo et al. Sergipe (Oliveira et al., 2013, Oliveira et al., 2018).

Student's t-test showed $p = 0.0180$ ($p \leq 0.05$), showing a significant difference between the absolute frequency of species between anthropic dunes and non-anthropic dunes, as can be seen in Figure 2.

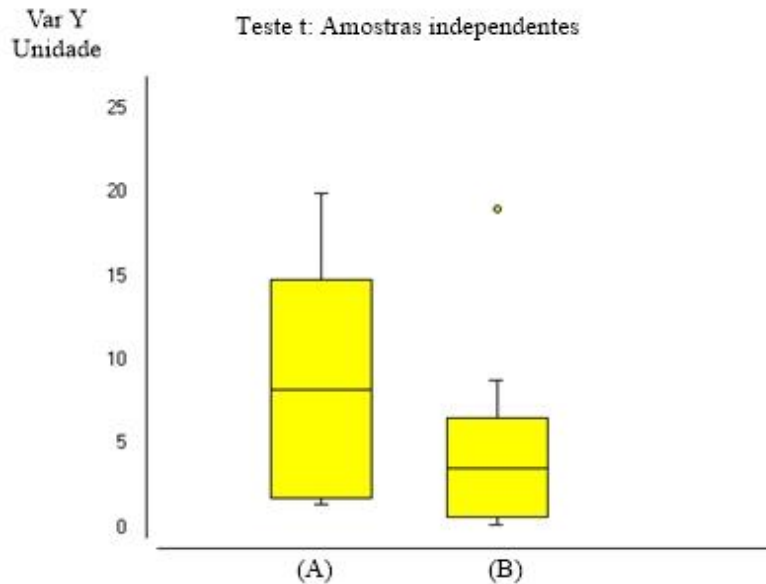


Figure 2. Box-plot demonstrating the differences in the absolute frequency of the species of the non-anthropogenic dunes (A) in relation to the anthropic dunes (B).

Source: prepared by the authors

The Sorensen Index (Ss), a binary coefficient that qualitatively compares species similarity along an environmental gradient (Wolda, 1981), was used to identify the similarity of species among the studied dunes. The result varies from 0 to 1, in that the closer to 1 is the result, the greater the species similarity.

$$Ss = \frac{2c}{a + b}$$

Where: a - number of species in non-anthropized dunes; b - number of species in the anthropic dunes, and; c - number of species in common in both cases.

$$Ss = \frac{2c}{a + b} \rightarrow Ss = \frac{2 \times 8}{23 + 12} \rightarrow Ss = 0.45$$

The species similarity among the dunes is Ss = 0.45, that is, although there is a diversity of species in each region, there are still a number of these, which are found in both cases, which means the dunes possess physiognomies and constitutions are very similar, being considered of low diversity. Similar data were found by Oliveira et al. 2018, in a study in the Caatinga, where they found in their results a total of H' = 0.40 in the Shannon-Wiener index, also for similarity, considering low diversity between herbaceous areas of Sergipe restinga in relation to the other Northeastern states. Miranda et al. 2007 has already found a greater similarity

among species, being H' = 0.88 between anthropic and non-anthropic areas, for a restinga area of Rio Grande do Norte.

In order to analyze the structural parameters, the following data were calculated: absolute coverage (AC), absolute frequency (FA), relative frequency (FR) and importance value (VI), as shown in Table 3 for non-anthropic dunes, and Table 4 for anthropic dunes. The importance value index (VI) followed the standards described by Pereira et al. 1992, and Menezes & Araújo 1999, where the VI was made from the sum of absolute coverage and relative frequency.

Table 3 - Phytosociological parameters of the species occurring in the non-anthropic dunes.

CA - Absolute coverage (%); FA - Absolute frequency (%); FRD3 - Relative frequency of dune 3 (%); FRD4 - Relative frequency of dune 4 (%); VID1 - Value of importance of dune 3 (%); VID2 - Value of importance of dune 4 (%).

Species	CA	FA	FRD3	FRD4	VID3	VID4
<i>Aeschynomene brasiliana</i> (Poir.) DC.	0,19	1,6	0,36	2,65	0,22	1,57
<i>Alternanthera brasiliana</i> (L.) Kuntze	0,98	2,4	0	4,55	0	3,78
<i>Alternanthera littoralis</i> P. Beauv.	4,75	1,12	0,27	12,5	0,27	11,38
<i>Aristida setifolia</i> Kunth	0,04	0,2	0	0,38	0	0,25
<i>Borreria verticillata</i> G. Mey	1,89	6,4	3,6	8,33	3,6	6,05
<i>Chamaecrista racemosa</i> (Vogel) H.S. Irwin & Barneby	1,29	6,2	4,32	7,2	4,32	4,83
<i>Chamaecrista ramosa</i> (Vogel) H.S. Irwin & Barneby	0,67	2	1,44	2,27	1,44	1,4
<i>Chamaesyce hyssopifolia</i> (L.) Small	3,45	8,8	11,15	4,92	11,15	2,82
<i>Commelina erecta</i> L.	0,03	0,6	1,08	0	1,08	0
<i>Cyperus articulatus</i> L.	0,01	0,2	0	0,38	0	0,2
<i>Eleusine</i> sp	0,07	0,4	0	0,76	0	0,49
<i>Euploca polyphylla</i> (Lehm) J. I. M. Melo & Semir	3,96	7,6	5,04	9,09	4,97	7,78
<i>Hybanthus calceolaria</i> (L.) Schulze-Menz	0,39	2,2	2,88	1,14	1,89	0,65
<i>Ipomea pes-caprae</i> (L.) R. Br.	4,77	6	6,83	4,17	8,48	3,53
<i>Macropitilium atropurpureum</i> (Sessé & Moc. ex DC.) Urb.	1,85	5,2	7,55	1,89	6,02	1,18
<i>Paspalum maritimus</i> Trin	5,9	8	8,27	6,44	7,95	7,85
<i>Penisetum setosum</i> Raddi.	3,54	7,4	4,32	9,47	3,7	8,38
<i>Remirea maritima</i> Aubl.	4,49	5,8	7,91	2,65	8,8	2,39
<i>Richardia grandiflora</i> Britton	29,78	19	16,19	18,94	26,77	33,55
<i>Senna obtusifolia</i> (L.) H.S. Irwin & Barneby	0,03	0,2	0	0,38	0	0,24
<i>Sida galheirensis</i> Ulbr.	0,13	0,4	0,72	0	0,53	0
<i>Turnera subulata</i> Sm.	0,36	2,4	2,52	0	1,73	0
<i>Turnera ulmifolia</i> (L.)	1,66	4,2	7,55	1,89	5,51	1,49

Source: prepared by the authors

Table 4: Phytosociological parameters of species occurring in anthropic dunes.

CA - Absolute coverage (%); FA - Absolute frequency (%); FRD1 - Relative frequency of dune 1 (%); FRD2 - Relative frequency of dune 2 (%); VID1 - Value of importance of dune 1 (%); VID2 - Value of importance of dune 2 (%).

Species	CA	FA	FRD1	FRD2	VID1	VID2
<i>Boehavia coccinea</i> Mill.	2,06	5,8	5,79	6,05	4,16	4,40
Não identificada 1 (Poaceae)	0,60	1,6	0,83	2,42	0,59	1,80
<i>Chamaecrista ramosa</i> (Vogel) H.S. Irwin & Barneby	29,50	20	20,66	20,16	33,14	25,10
<i>Chamaesyce hyssopifolia</i> (L.) Small	0,80	4,8	5,79	4,03	3,30	2,63
<i>Commelina erecta</i> L.	15,68	18,6	19	18,95	20,11	18,98
<i>Euploca polyphylla</i> (Lehm) J. I. M. Melo & Semir	12,78	15,6	16,12	15,73	13,68	18,64
<i>Ipomoea pes-caprae</i> (L.) R. Br.	6,94	7,2	4,96	9,68	4,39	11,84
<i>Paspalum maritimum</i> Trin	5,51	11,2	15,7	7,26	13,19	5,35
<i>Passiflora foetida</i> L.	0,64	14	0,00	2,82	0,00	2,23
<i>Richardia grandiflora</i> Britton	1,63	4,8	7,02	2,82	4,78	2,23
Não identificada 1 (Malvaceae)	1,43	4,6	0,41	8,87	0,22	6,28
<i>Turnera subulata</i> Sm.	1,01	3,8	3,72	4,03	2,42	2,75

Source: prepared by the authors

It can be verified that in both dunes, dominant species have occurred, being *Richardia grandiflora* Britton and *Euploca polyphylla* (Lehm) J. I. Melo & Semir, thus affirming that even in anthropic processes, these species can adapt to the changes occurring in the environment. Regarding the vegetation cover, in both cases, more than 70% coverage of the plots were verified.

The species identified in the anthropic dunes had a total of 74% similarity to those found by Amorim et al. 2016, who also studied anthropized dunes. In non-anthropic dunes, the species had 80% similarity to those found by Araújo et al. (2016) in the same situation, thus indicating that species such as *Euploca polyphylla* (Lehm) J. I. M. Melo & Semir, *Richardia grandiflora* Britton, *Turnera subulata* Sm, and *Chamaecrista ramosa* (Vogel) H.S. Irwin & Barneby, can be considered indicators of anthropogenic effects. Maroja et al. 2018, also obtained the same species in anthropized environments in Paraíba; Almeida Jr. et al. 2017 in Maranhão; Santos-Filho et al. 2015, in Piauí; Sacramento et al. 2007, and Zickel et al. 2007, in Pernambuco; Viana et al. (2006) in Bahia; Santos-Filho et al. 2011, in Ceará and Oliveira et al. 2013, in Sergipe. These studies show that some of these

species are present in several northeastern coastal areas, both in the Eastern Northeastern Coast and the North Northeastern Coast.

Regarding the value of importance (VI), it was observed that in the anthropic dunes, three species were of greater importance for the research, since they reached high values compared to other species, which are: *C. ramosa*, *Commelina erecta* L., and *E. polyphylla*. In the unpopulated dunes, the species with the highest value of importance (VI) were: *R. grandiflora*, *E. polyphylla* and *Chamaesyce hyssopifolia* (L.) Small. Of these species, two are constantly mentioned in several floristic works of restinga of the northeastern coast, being *R. grandiflora* and *E. polyphylla*, being able to demonstrate that these species have significant adaptations to establish themselves in dune environments.

Anatomical adaptations in response to environmental conditions

Some species in order to survive in restinga regions, which have low nutrients, high light intensity, high temperatures, among other environmental factors, they develop strategies for their adaptation to the environment where they are

inserted. The species *R. grandiflora* and *E. polyphylla* are found in large quantities in dune environments, being able to serve as a model of indicative species able to adapt in the middle of these factors.

When performing the foliar anatomy, it was observed that these species have some structures that facilitate their survival and maintenance in dune environments, such as the presence of trichomes throughout their leaf blade (Figure 3A). Gomes et al. (2009) indicate that these structures are present in several species of plants, being more present in herbaceous and sub-shrubs, serving as protection against herbivores. Francino et al. 2006, further reinforce that in addition to protection against predators, trichomes also serve to reduce the loss of plant water. For species that are in open spaces and with high luminous intensity, as is the case of dunes, these functions of trichomes become essential for their adaptation and maintenance in the environment.

It has also been observed that the stomata are smaller than the cells of the epidermal wall, and are positioned below the level of epidermal cells (Figure 3B). Silva et al. 2003, point out that stomata have different sizes and may be larger or smaller than epidermal cells, where their size is related to the water stress that the plant passes through. The analyzed species are in an

environment with high temperature, therefore, little amount of water is retained in their leaves. Barros 2013, shows that the smaller stomata are usually protected by the cuticle, which is a possible adaptation so that they do not lose much water in their evapotranspiration process.

In both species, the presence of the Kranz anatomy (Figure 3C) occurred, which is present in plants that perform C4 type photosynthesis, usually grasses and small plants. It consists of the mesenchymal parenchyma cell layer, the sheath of the bundle and the vascular bundle (Apezato-da-Gloria & Carmello-Guerreiro, 2006). As shown by Frank-de-Carvalho et al. 2010, this structure is mainly linked to the physiological processes of the plant, allowing a greater concentration of CO₂ in its leaves, facilitating the process of plant growth. Martins et al. 2008, demonstrate that plants with *Kranz* anatomy can adapt in regions with low availability of nutrients or saline soils, because in their physiological process, it decreases the amount of nutrients that the plant needs to survive.

The identification of these structures, as shown by Frank-de-Carvalho et al. 2010, and Barros et al. 2013, show that the plants generate processes of changes in their structures, so that adaptations to the different environmental conditions occur.

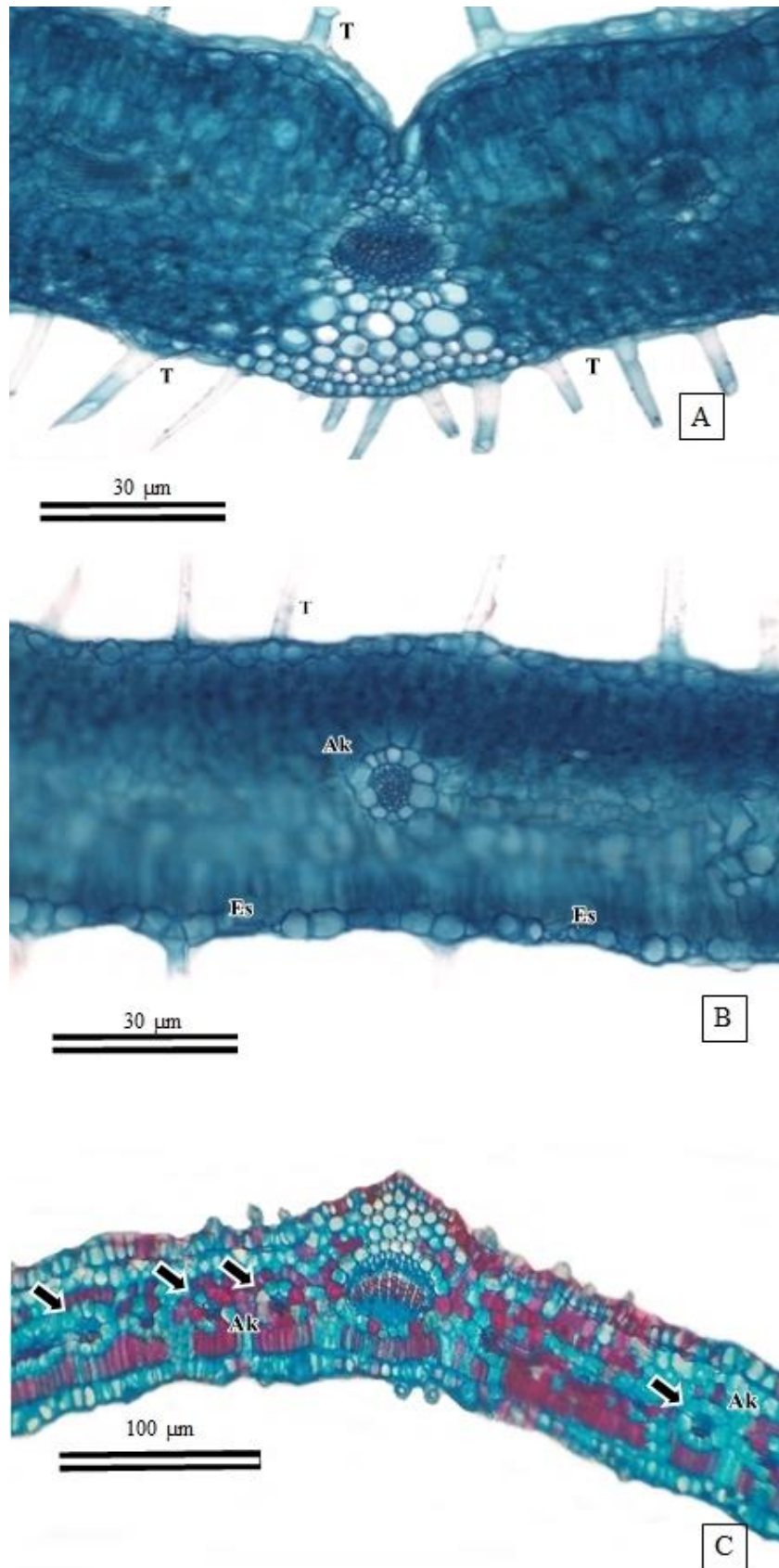


Figure 3: Anatomical sections of leaves of *R. grandiflora* (A / B) and *E. polyphylla* (C). T - Trichomes; Ak – Kranz Anatomy; Es - Stomata; Arrows - Kranz Anatomy.
Source: MOURA, M. R. B. 2019

Conclusion

This study contributed to the knowledge of the botanical diversity of dunes in the Northeastern coast, the structural relationships of the community of herbaceous plants that colonize the soil layer of the dunes and cooperate with the future establishment of other plant species with higher level of requirements of organic matter in the soil.

The study was extremely important to understand which species dominate the dune colonization process. We understand that dunes in regions with greater human influence, there is a strong reduction in the number of species, causing diversity to occur, proving that those species presented in anthropized dunes are more resistant to human presence. The results of the leaf anatomy allowed the understanding of some aspects of the adjustment process

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The floristic of herbaceous species can subsidize management actions and indications of species for planting, for the immobilization of mobile dunes that enter in the communities living surround them.

Acknowledgements

The authors are grateful for the Coordination of Superior Level Staff Improvement (CAPES), for the provision of research grant. To the professors of the Masters degree program in Development and Environment (MDMA), from the Universidade Federal do Piauí (UFPI), for providing subsidies for the development of the research.

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