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Wind Zoning and Sediment Transport in the PARNA Wind Corridors area of Jericoacoara, Ceara, Brazil

Zoneamento Eólico e Transporte dos Sedimentos na área dos Corredores Eólicos do PARNA de Jericoacoara, Ceara, Brasil.

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Abstract: The study analyzed the behavior of sediment transport in the Beach Zone located between Praia do Preá and Jericoacoara in the Jericoacoara National Park - PARNA. The physical limitations of in situ measurements of sediment transport on beaches, mainly longitudinal, restrict studies in these environments to the subaerial part. Sediment trap methods were chosen, with 04 collection and measurement campaigns being carried out for reconnaissance, carried out between July 2019 and February 2022, where eleven trap points were delimited, comprising the beach sectors and the wind corridors of transportation and feeding of Duna Por do Sol (DPS). Three sediment traps were used for each collection point, spaced 5.00 meters apart. With the results obtained, eolic-sedimentary zoning was carried out, presenting the processes and effects of the local wind dynamics (erosion and sedimentation), understanding how the morphological dynamics of the area occur and correlating it with possible scenarios, essential elements for the planning that aimed at mitigating impacts and requalification of the area in the medium and long term, resulting in a project that will try to stop the sediment balance deficit in the DPS, contributing to its recovery in volume and area, with the installation of sets of Wind Current Guide Structures (EGCE).

Keywords: Zoning; Wind Transport Corridors; Current Guides.

Resumo: O estudo analisou o comportamento do transporte de sedimentos na Zona de Praia localizada entre a Praia do Preá e de Jericoacoara no Parque Nacional de Jericoacoara – PARNA. As limitações físicas de medições in situ do transporte de sedimentos em praias, principalmente o longitudinal, restringem os estudos nestes ambientes à parte subaérea. Foram escolhidos os métodos de armadilhas de sedimentos, sendo realizadas 04 campanhas de coleta e medição, para o reconhecimento, realizadas entre julho de 2019 a fevereiro de 2022, onde se delimitou onze pontos das armadilhas, compreendendo os setores da praia e os corredores eólicos de transporte e alimentação da Duna Pôr do Sol (DPS). Foram utilizadas 3 armadilhas de sedimentos para cada ponto de coleta, distanciados entre si em 5,00 metros. Com os resultados obtidos, foi realizado um zoneamento eólico-sedimentar, apresentando os processos e efeitos da dinâmica eólica local (erosão e sedimentação), entendendo como ocorre a dinâmica morfológica da área e correlacionando-a com possíveis cenários, elementos essenciais para o planejamento que objetivasse a mitigação dos impactos e requalificação da área a médio e longo prazo, resultando em um projeto que tentará cessar o déficit do balanço sedimentar na DPS contribuindo para a sua recuperação em volume e área, com a instalação dos conjuntos de Estruturas Guias de Corrente Eólica (EGCE).

Palavras-chave: Zoneamento; Corredores de Transporte Eólico; Guias de Corrente.

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1. Introduction

This work studied the wind sedimentary system of Jericoacoara and its coastal dynamics analyzing the processes and effects of local environmental dynamics (erosion, sedimentation, pollution, landscape degradation, land use and occupation, infrastructure, tourist demand, and environmental impacts) that pointed to a complex environmental and structural situation in the area. The study attempted to understand the morphological dynamics of the area and correlate it with possible scenarios, which were essential elements for planning, aimed at mitigating impacts and requalifying the area in the medium and long term.

The work aimed to quantify the record of low sediment accumulation in the eolian feature called Duna Pôr do Sol (DPS) over the last 20 years. Possible urban interventions were also investigated as one of the decisive factors in this short-term environmental transformation. An attempt was made to integrate the description of studies and surveys in the area with the perspectives of appropriate solutions.

2. Methodology

The study area is in the PARNA (National Park) of Jericoacoara in Ceara (Figure 1) and the aeolian sedimentary system is characterized by the presence of a promontory and the action called “headland bypassing dune field” (CASTRO, 2002), or that is, the transport of sediments from a beach to the East (Preá – Jericoacoara) to a beach to the West (Jericoacoara).

Using remote sensing tools, geoprocessing, and numerical modeling, the present work aims to quantify the rate of dune movement over water resources, urban areas, and vegetation of the Jericoacoara Environmental Protection Area in this coastal segment, making it possible to define prohibition zones subject to burials.

To experiment, we carried out the field campaign, under normal atmospheric conditions and in less rainy periods. Measuring instruments were used in the field, including a German Freiberger Prazision Mechanik compass, camera, and Professional Instruments CE Anemometer, in addition to 30 cumulative sediment traps.

These traps accumulate all the material transported through a vertical section, consisting of a PVC tube 1m long and 4” (inches) in diameter, with two vertical openings on opposite sides, the front one is 70cm long x 1cm wide. width and the back 70cm long x 2.5cm wide. The traps integrate all transport along the vertical. The 1.0 m tube is driven 30 cm into the ground, leaving 70 cm exposed to the winds.

The exposed part has two longitudinal openings, the first allows air to enter and the second located in the opposite portion of the tube, is covered by a mesh (nylon screen) to avoid the effect of air tightness. The difference in velocity/pressure gradient between the two openings generates a downward circular flow that throws the transported particle to the bottom of the tube, storing this volume of sand.

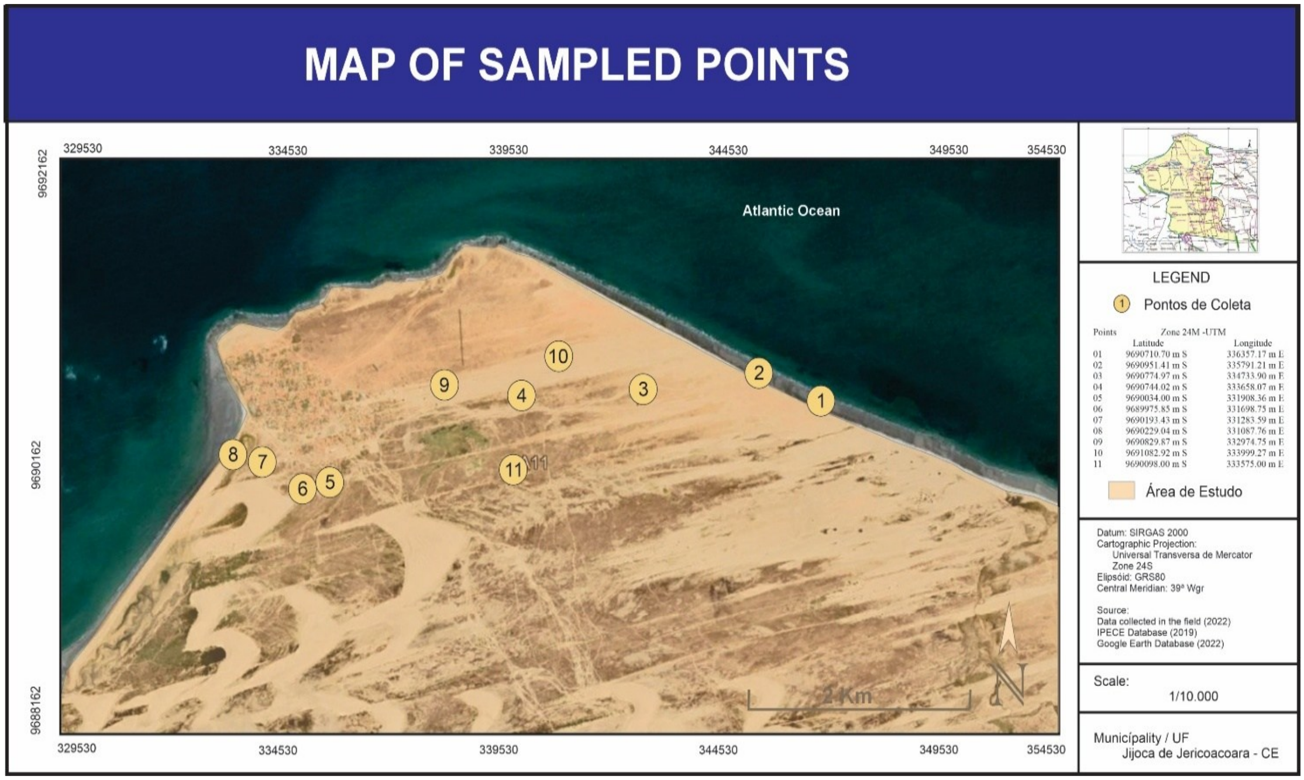

Figure 1 – Map of Sampled Points.
Source: Authors (2019).

During the field stages, a set of 30 traps was used, which were positioned in 10 locations along the wind-sedimentary corridor, as shown in Figure 01, with the duration of these traps being initially noted concerning accumulation levels. The idea of working with this type of trap basically consists of obtaining the wind transport rate.

Three traps were used for each collection point, 5.00 meters apart, as shown in figure 02. The mooring point, measuring latitude and longitude, is in the trap called B.

Wind direction measurements were carried out with the aid of a compass to identify the preferred wind direction to fix the pair of wind traps.

The time of setting and removing the traps, the duration they spent collecting sediments, the speed of the winds with the aid of an anemometer, in addition to the collection of samples from each cycle analyzed, were noted, with everything being noted on the field records, as shown in the table 01.

The criteria observed were: distance from natural or artificial obstacles, avoiding the interference of these obstacles in the results; longitudinal distribution, and positioning about the same transverse axis.

The collector opening was always positioned facing the preferred wind direction, measured perpendicular to the ripple marks present on the sandy surface of the studied terrain. To calculate the volume of sediment transported to recover the DPS, the linear correlation of r2=0.87 was adopted, that is, 87%, where sediment transport (g/s/m) grows linearly with the increase in wind speed (m/s).

For each sampling station, an estimate was made regarding the volume transported, using the methodology carried out by Maia (1998), where the values of the weight of the samples taken from the traps, collection time, opening of the traps, and the density of the sand in the area, sediment transport values are obtained. The weight of the sediments must be transformed into kg, as well as the opening of the traps must be transformed into a linear meter, in addition to measuring time in seconds.

The wind transport process refers to the wind's ability to shape the earth's surface, where it can transport or deposit materials, such as erosion factors. Wind corridors are responsible for the transport of sediments, forming the local landscape, with wind transport presenting some main processes. This differentiation is mainly due to the size of the grain to be transported, the energy of the wind, and the existence or not of obstacles. There are the processes of Suspension, Saltation, and Drag or Rolling.

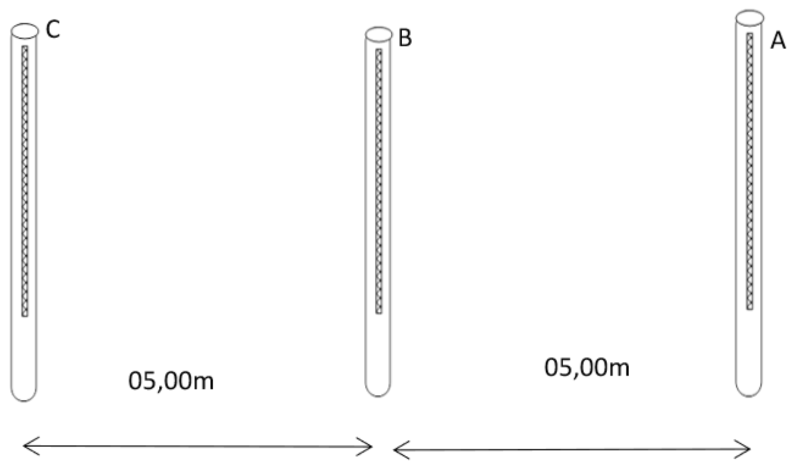

Figure 2 – Arrangement of Sediment Traps.
Source: Maia et al. (1988).

The integration traps used during the experiments have an accumulation capacity of around 270cm^3, which corresponds to a sediment weight of between 435 and 480 grams, indicating a density of the order of 1.6gr/cm^3. These values were used to measure the volumes of sediment transported in the wind-sedimentary corridor.

3. Results

On sandy beaches, deposition, and erosion processes are controlled by a dynamic balance that involves three main components: quantity and type of available sediment, physical energy along the coast, and changes in sea level (Davis, 1985) apud Masselink and Short (1993). On a short-term scale (years and decades), without the influence of relative sea level variations, the sediment stock contained on a beach can be defined as the volume of sediment within the beach and that moving across the beach, and in a given stretch of beach corresponds to the result of the balance between the addition and removal of sediments (Rosati, 2005).

The sediment balance fluctuates over a certain period, mainly under the influence of storms. While the sediment stock can be quantified, the supply rate for a time interval is very difficult to calculate, mainly due to the uncertainties existing in the calculation of longshore drift, and thus interferes with the total amount of sediment involved in the sediment balance.

The surplus occurs due to the greater addition and less removal of sediments. On the other hand, the deficit occurs due to greater removal and lesser addition of sediments. The first process results in the advancement of the beach line by the deposition of sediments, and the second, is the retreat or erosion of the beach line.

Regarding sediment transport, considering the analysis of captures from sediment traps deployed in the study area, situations are demonstrated that simulate how sediment transport is occurring in the wind corridors and in the study area.

Maia (2001) reports that dune migration depends on their size, varying in an inverse relationship. Barcan dunes on Jericoacoara Beach migrate at a rate of 17.5 m/year, while sand sheets do so at 10.0 m/year. This dependence highlights the existence of equilibrium in the dune field, that is, through constant wind transport and migration according to its volume. The aggregate transport of sediment obtained with the migration of barcan dunes was on the order of 78 m^3/m/year on Jericoacoara beach.

The volume of sediment captured in a period of 1 hour, with 1.0m traps, was used for the calculations, resulting in a density of 0.00081g/m^3, with a median Wind Speed of 8.9m/s, the main and secondary direction of the winds, in the area, being E and ENE, the Average Granulometric fraction of 0.062 mm, and the gain and loss of elevation in the beach strip of 5.0 to 8.0 meters, presented results in the order of 0.000539g/m^3, demonstrating an annual volume deficit of around 69,716.138m^3/year, in the DPS.

As an example, we will use the first sample A01 from 07/30/2019, where 50.30g was obtained in 19,620 seconds. It has already been reported that the opening of the sediment collection traps is 1.0cm, which must be transformed into a linear meter. The weight of the sample must also be transformed into kilograms (Kg), so 0.0503 x 100 (Kg/m(linear)), we will have 5.03Kg/m. This value will be divided by the time in seconds of accumulation in the trap (5.03/19,620), presenting the result in Kg/m.s., then transformed into Kg/m.month (0.0002563 x 3,600 x 24 x 30 = 664, 51 kg/m.month).

Finally, divide the value found by the density of the sand. The value used for the density in the area was 1.6g/cm^3, (it is observed that the density of quartz is in the range of 2.65g/cm^3, and the porosity of the sand is between 38 and 43%), so we have as result (664.51 Kg/m.month / 1.6 / 1,000) = 0.415 m^3/m.month of sediment transport.

The appropriate use of management in a coastal zone implies the need to know and understand the natural and anthropogenic agents that act in a given area, responsible for the dynamic processes and for controlling their evolution over a given time.

Table 1 – Measurement of Sediment Transport at the sampled points.

LOCAL Jericoacoara		TIME		SEDIMENT TRAPS		SEDIMENT TRANSPORTATION	
DATE	POINT SHIFT	DURATION IN THE FIELD	DURATION IN SECONDS	SAMPLE WEIGHT (g)	SAMPLE WEIGHT (Kg)	1,6g/cm^3 (sand density) m^3/m.mês	POINT SHIPPING AVERAGE m^3/m.mês
30/07/2019	A 01 Morning - Afternoon	05:27	19.620	50,30	0,0503	0,415	0,415
30/07/2019	A 01 Afternoon - Night	15:49	56.940	40,90	0,0409	0,116	0,116
05/02/2020	A 01 Morning - Afternoon	05:07	18.420	120,30	0,12030	1,058	1,058
05/02/2020	A 01 Afternoon - Night	14:09	50.940	80,20	0,08020	2,550	2,550
16/09/2020	A 01 Morning - Afternoon	03:30	12.600	4,40	0,00440	0,565	0,3701
16/09/2020	A 01 Morning - Afternoon	03:30	12.600	2,20	0,00220	0,282	
16/09/2020	A 01 Morning - Afternoon	03:30	12.600	2,05	0,00205	0,2635	
16/09/2020	A 01 Afternoon	02:05	7.500	5,11	0,00511	1,10376	1,1769
16/09/2020	A 01 Afternoon	02:05	7.500	1,58	0,00158	0, 34128	
16/09/2020	A 01 Afternoon	02:05	7.500	0,95	0,00095	2,052	
17/09/2020	A 01 Night	06:44	24.240	ND	0	0	0
17/09/2020	A 01 Night	06:44	24.240	ND	0	0	
17/09/2020	A 01 Night	06:44	24.240	ND	0	0	
21/02/2022	P 01 Afternoon	08:15	29.700	23,23	0,02323	2,027	0,6768
21/02/2022	P 01 Night	11:25	41.100	ND	0	0	
22/02/2022	P 01 Morning - Afternoon	11:25	41.100	08,97	0,00897	0,00353	
30/07/2019	A 02 Morning - Afternoon	05:36	20.160	730,20	0,73020	5,86767	5,86767
30/07/2019	A 02 Afternoon - Night	15:39	56.340	600,00	0,60000	1,7,524	1,72524
05/02/2020	A 02 Morning - Afternoon	04:56	17.760	630,20	0,63020	5,74844	5,74844
05/02/2020	A 02 Afternoon - Night	14:14	51.240	850,52	0,85052	2,68899	2,68899
16/09/2020	P 02 Morning - Afternoon	03:20	12.000	208,12	0,20812	2,8096	4,7075
16/09/2020	P 02 Morning - Afternoon	03:20	12.000	418,00	0,4180	5,6430	
16/09/2020	P 02 Morning - Afternoon	03:20	12.000	420,00	0,4200	5,6700	
16/09/2020	P 02 Afternoon	02:05	7.500	3,50	0,00350	0,0756	0,23178
16/09/2020	P 02 Afternoon	02:05	7.500	2,40	0,00240	0,05184	
16/09/2020	P 02 Afternoon	02:05	7.500	4,69	0,00469	0,101304	
17/09/2020	P 02 Night	06:38	23.880	0,20	0,00020	0,001356	0,005265

LOCAL Jericoacoara		TIME		SEDIMENT TRAPS		SEDIMENT TRANSPORTATION	
DATE	POINT SHIFT	DURATION IN THE FIELD	DURATION IN SECONDS	SAMPLE WEIGHT (g)	SAMPLE WEIGHT (Kg)	1,6g/cm^3 (sand density) m^3/m.mês	POINT SHIPPING AVERAGE m^3/m.mês
17/09/2020	P 02 Night	06:38	23.880	0,55	0,00055	0,003731	
17/09/2020	P 02 Night	06:38	23.880	1,58	0,00158	0,01071	
21/02/2022	P 02 Afternoon - Night	08:08	29.280	20,25	0,02025	0,112	
21/02/2022	P 02 Afternoon - Night	17:40	63.600	0,8	0,0008	0,00203	0,1003
22/02/2022	P 02 Morning - Afternoon	10:56	39.360	45,5	0,0455	0,187	
30/07/2019	P 03 Afternoon	05:56	21.360	720,00	0,720	5,4606	5,4606
30/07/2019	P 03 Afternoon - Night	15:46	56.760	640,00	0,6400	1,82663	1,82663
05/02/2020	P 03 Afternoon	04:55	17.700	822,00	0,8220	7,52338	7,52338
05/02/2020	P 03 Afternoon - Night	14:21	51.660	740,00	0,7400	2,32055	2,32055
16/09/2020	P 03 Afternoon	03:20	12.000	576,00	0,5760	7,776	
16/09/2020	P 03 Afternoon	03:20	12.000	780,00	0,7800	10,53	6,78375
16/09/2020	P 03 Afternoon	03:20	12.000	151,50	0,1515	2,04525	
16/09/2020	P 03 Afternoon	04:00	14.400	126,40	0,1264	1,422	
16/09/2020	P 03 Afternoon	04:00	14.400	762,00	0,7620	8,5725	5,5458
16/09/2020	P 03 Afternoon	04:00	14.400	590,50	0,5905	6,6431	
17/09/2020	P 03 Night	06:23	22.980	345,00	0,3450	2,4321	
17/09/2020	P 03 Night	06:23	22.980	598,00	0,5980	4,2157	2,6765
17/09/2020	P 03 Night	06:23	22.980	196,00	0,1960	1,3817	
21/02/2022	P 03 Afternoon - Night	08:20	30.000	9,0	0,009	0,0486	
21/02/2022	P 03 Afternoon - Night	17:40	63.600	ND	0	0	0,0325
22/02/2022	P 03 Morning - Afternoon	10:52	39.120	12,0	0,012	0,049	
30/07/2019	A 04 Afternoon	05:32	19.920	904,00	0,904	7,35180	7,35180
30/07/2019	A 04 Afternoon - Night	15:52	55.560	1.050,00	1,050	3,06155	3,06155
05/02/2020	A 04 Afternoon	04:32	16.320	834,00	0,8340	8,27867	8,27867
05/02/2020	A 04 Afternoon - Night	14:28	52.080	950,00	0,9500	2,9550	2,9550
16/09/2020	P 04 Morning	03:05	11.100	904,00	0,9040	13,1935	
16/09/2020	P 04 Morning	03:05	11.100	825,00	0,8250	13,0184	13,0767
16/09/2020	P 04 Morning	03:05	11.100	892,00	0,8920	13,0183	
16/09/2020	P 04 Afternoon	04:08	14.880	830,00	0,8300	9,0363	
16/09/2020	P 04 Afternoon	04:08	14.880	902,00	0,9020	9,8201	8,1508
16/09/2020	P 04 Afternoon	04:08	14.880	514,00	0,5140	5,5960	
17/09/2020	P 04 Night	06:15	22.500	802,00	0,8020	5,7744	
17/09/2020	P 04 Night	06:15	22.500	588,00	0,5880	4,2336	4,8408
17/09/2020	P 04 Night	06:15	22.500	627,00	0,6270	4,5144	
21/02/2022	P 04 Afternoon	07:00	25.200	72,00	0,072	0,462	

LOCAL Jericoacoara		**TIME**		**SEDIMENT TRAPS**		**SEDIMENT TRANSPORTATION**	
DATE	**POINT SHIFT**	**DURATION IN THE FIELD**	**DURATION IN SECONDS**	**SAMPLE WEIGHT (g)**	**SAMPLE WEIGHT (Kg)**	**1,6g/cm^3 (sand density) m^3/m.mês**	**POINT SHIPPING AVERAGE m^3/m.mês**
21/02/2022	P 04 Night - Morning	13:40	49.200	ND	0	0	0,211
22/02/2022	P 04 Morning - Afternoon	10:40	38.400	41,00	0,041	0,172	
29/07/2019	A 05 Night	16:00	57.600	12,30	0,0123	0,03459	0,03459
30/07/2019	A 05 Morning	07:58	28.680	8,20	0,00820	0,04631	0,04631
05/02/2020	A 05 Afternoon	04:30	16.200	10,30	0,01030	1,030	1,030
05/02/2020	A 05 Night	14:30	52.200	13,20	0,01320	0,4096	0,4096
16/09/2020	P 05 Morning	03:05	11.100	2,62	0,00262	0,03823	0,04519
16/09/2020	P 05 Morning	03:05	11.100	3,09	0,00309	0,04509	
16/09/2020	P 05 Morning	03:05	11.100	3,58	0,00358	0,05225	
16/09/2020	P 05 Afternoon	04:40	16.800	1,88	0,00188	0,01813	0,01119
16/09/2020	P 05 Afternoon	04:40	16.800	1,60	0,00160	0,01543	
16/09/2020	P 05 Afternoon	04:40	16.800	ND	0	0	
17/09/2020	P 05 Night	05:30	19.800	ND	0	0	0
17/09/2020	P 05 Night	05:30	19.800	ND	0	0	
17/09/2020	P 05 Night	05:30	19.800	ND	0	0	
21/02/2022	P 05 Afternoon - Night	07:00	25.200	5,3	0,0053	0,0034	0,00676
21/02/2022	P 05 Night - Morning	11:23	40.980	1,2	0,0012	0,0047	
22/02/2022	P 05 Morning - Afternoon	09:35	34.500	26,00	0,026	0,0122	
29/07/2019	A 06 Night - Morning	16:32	59.520	2,00	0,0020	0,00544	0,00544
30/07/2019	A 06 Morning - Afternoon	08:17	29.820	ND	0	0	0
06/02/2020	A 06 Morning	06:27	23.220	6,00	0,0060	0,04186	0,04186
06/02/2020	A 06 Afternoon - Night	16:35	59.700	ND	0	0	0
16/09/2020	P 06 Afternoon	03:00	10.800	0,85	0,00085	0,01275	0,0290
16/09/2020	P 06 Afternoon	03:00	10.800	ND	0	0	
16/09/2020	P 06 Afternoon	03:00	10.800	4,95	0,00495	0,07425	
16/09/2020	P 06 Afternoon - Night	04:40	16.800	2,07	0,00207	0,001996	0,2973
16/09/2020	P 06 Afternoon - Night	04:40	16.800	7,18	0,00718	0,006923	
16/09/2020	P 06 Afternoon - Night	04:40	16.800	ND	0	0	
17/09/2020	P 06 Night	05:30	19.800	ND	0	0	0
17/09/2020	P 06 Night	05:30	19.800	ND	0	0	
17/09/2020	P 06 Night	05:30	19.800	ND	0	0	
21/02/2022	P 06 Afternoon - Night	07:04	25.440	29	0,029	0,0184	0,0147
21/02/2022	P 06 Night - Morning	11:12	40.320	9,5	0,0095	0,00381	
22/02/2022	P 06 Morning - Afternoon	11:50	42.600	58,0	0,058	0,0220	
29/07/2019	A 07 Afternoon	02:00	7.200	3,20	0,00320	0,072	0,072

LOCAL Jericoacoara		**TIME**		**SEDIMENT TRAPS**		**SEDIMENT TRANSPORTATION**	
DATE	**POINT SHIFT**	**DURATION IN THE FIELD**	**DURATION IN SECONDS**	**SAMPLE WEIGHT (g)**	**SAMPLE WEIGHT (Kg)**	**1,6g/cm^3 (sand density) m^3/m.mês**	**POINT SHIPPING AVERAGE m^3/m.mês**
29/07/2019	A 07 Night	14:48	53.320	3,51	0,00351	0,0106	0,0106
30/07/2019	A 07 Morning - Afternoon	08:44	31.440	2,12	0,00212	0,0109	0,0109
06/02/2020	A 07 Morning	06:22	22.920	ND	0	0	0
06/02/2020	A 07 Afternoon	16:22	58.920	3,31	0,00331	0,00910	0,00910
16/09/2020	P 07 Morning	02:50	10.200	3,15	0,00315	0,0500	0,03863
16/09/2020	P 07 Morning	02:50	10.200	0,70	0,00070	0,01111	
16/09/2020	P 07 Morning	02:50	10.200	3,45	0,00345	0,05479	
16/09/2020	P 07 Afternoon	04:35	16.500	2,83	0,00283	0,02778	0,01367
16/09/2020	P 07 Afternoon	04:35	16.500	0,40	0,00040	0,00393	
16/09/2020	P 07 Afternoon	04:35	16.500	0,95	0,00095	0,00932	
17/09/2020	P 07 Night	05:30	19.800	ND	0	0	0
17/09/2020	P 07 Night	05:30	19.800	ND	0	0	
17/09/2020	P 07 Night	05:30	19.800	ND	0	0	
21/02/2022	P 07 Afternoon - Night	06:35	23.700	1,8	0,0018	0,0123	0,1289
21/02/2022	P 07 Night - Morning	11:10	40.200	ND	0	0	
22/02/2022	P 07 Morning - Afternoon	08:45	31.500	72,8	0,0728	0,3744	
29/07/2019	A 08 Afternoon	02:00	7.200	220,00	0,2200	4,95	4,95
29/07/2019	A 08 Night - Morning	14:50	53.400	580,00	0,5800	1,7595	1,7595
30/07/2019	A 08 Morning - Afternoon	08:30	30.600	312,00	0,3120	1,65	1,65
06/02/2020	A 08 Morning - Afternoon	06:20	22.800	320,00	0,3200	2,27	2,27
06/02/2020	A 08 Afternoon - Night	15:25	55.500	734,00	0,7340	2,1424	2,1424
16/09/2020	P 08 Morning -Afternoon	02:40	9.600	33,45	0,0345	0,582	7,778
16/09/2020	P 08 Morning -Afternoon	02:40	9.600	580,27	0,58027	9,7921	
16/09/2020	P 08 Morning -Afternoon	02:40	9.600	768,00	0,7680	12,960	
16/09/2020	P 08 Afternoon - Night	04:35	16.500	101,15	0,10115	0,9931	1,9039
16/09/2020	P 08 Afternoon - Night	04:35	16.500	212,00	0,2120	2,08145	
16/09/2020	P 08 Afternoon - Night	04:35	16.500	268,60	0,206860	2,63716	
17/09/2020	P 08 Night	05:20	19.200	96,00	0,0960	0,8100	1,3050
17/09/2020	P 08 Night	05:20	19.200	196,00	0,1960	1,65375	
17/09/2020	P 08 Night	05:20	19.200	172,00	0,1720	1,45125	
21/02/2022	P 08 Afternoon - Night	08:40	31.200	132,00	0,132	0,685	0,876
21/02/2022	P 08 Night - Morning	10:10	36.600	ND	0	0	
22/02/2022	P 08 Morning - Afternoon	08:20	30.000	360,00	0,360	1,944	
30/07/2019	A 09 Morning - Afternoon	05:43	20.580	730,00	0,7300	5,7463	5,7463
31/07/2019	A 09 Afternoon - Night	07:50	28.200	560,00	0,5600	3,2170	3,2170
06/02/2020	A 09 Morning - Afternoon	06:30	23.400	760,00	0,7600	5,2615	5,2615

LOCAL Jericoacoara		**TIME**		**SEDIMENT TRAPS**		**SEDIMENT TRANSPORTATION**	
DATE	**POINT SHIFT**	**DURATION IN THE FIELD**	**DURATION IN SECONDS**	**SAMPLE WEIGHT (g)**	**SAMPLE WEIGHT (Kg)**	**1,6g/cm^3 (sand density) m^3/m.mês**	**POINT SHIPPING AVERAGE m^3/m.mês**
06/02/2020	A 09 Afternoon - Night	15:03	54.180	660,00	0,6600	1,97342	1,97342
16/09/2020	P 09 Afternoon	02:15	8.100	786,00	0,7860	1,5720	1,04690
16/09/2020	P 09 Afternoon	02:15	8.100	52,45	0,05245	0,10490	
16/09/2020	P 09 Afternoon	02:15	8.100	732,00	0,732	1,46400	
16/09/2020	P 09 Afternoon - Night	03:45	13.500	278,00	0,2780	3,3360	1,6046
16/09/2020	P 09 Afternoon - Night	03:45	13.500	10,60	0,01060	0,12720	
16/09/2020	P 09 Afternoon - Night	03:45	13.500	112,55	0,11255	1,35060	
17/09/2020	P 09 Night	05:10	18.600	171,70	0,17170	1,49545	0,5596
17/09/2020	P 09 Night	05:10	18.600	7,40	0,00740	0,06445	
1709/2020	P 09 Night	05:10	18.600	13,65	0,01365	0,11888	
30/07/2019	A 10 Morning - Afternoon	05:30	19.800	940,00	0,9400	7,6909	7,6909
31/07/2019	A 10 Afternoon - Night	17:45	63.900	860,00	0,8600	2,1802	2,1802
06/02/2020	A 10 Morning - Afternoon	06:00	21.600	870,00	0,8700	6,525	6,525
06/02/2020	A 10 Afternoon - Night	15:20	55.200	820,00	0,8200	2,4065	2,4065
16/09/2020	P 10 Afternoon	02:05	7.500	890,00	0,8900	19,2240	19,6272
16/09/2020	P 10 Afternoon	02:05	7.500	940,00	0,9400	20,3040	
16/09/2020	P 10 Afternoon	02:05	7.500	896,00	0,8960	19,3536	
16/09/2020	P 10 Afternoon - Night	03:22	12.120	712,00	0,7120	9,5168	11,2544
16/09/2020	P 10 Afternoon - Night	03:22	12.120	925,00	0,9250	12,3638	
16/09/2020	P 10 Afternoon - Night	03:22	12.120	889,00	0,8890	11,8826	
17/09/2020	P 10 Night	05:05	18.300	610,35	0,61035	5,4031	4,0471
17/09/2020	P 10 Night	05:05	18.300	360,20	0,36020	3,1886	
17/09/2020	P 10 Night	05:05	18.300	401,00	0,40100	3,5498	
21/02/2022	P 10 Afternoon - Night	06:25	23.100	122,00	0,122	0,855	0,337
21/02/2022	P 10 Night - Morning	12:20	44.400	ND	0	0	
22/02/2022	P 10 Morning - Afternoon	09:20	33.600	32,00	0,032	0,157	
21/02/2022	P 11 Afternoon - Night	07:00	25.200	6,4	0,0064	0,041	0,0178
21/02/2022	P 11 Night - Morning	11:30	41.400	ND	0	0	
22/02/2022	P 11 Morning - Afternoon	10:00	36.000	2,8	0,0028	0,0126	

Source: Authors (2022).

The collection stations at points 01 and 02, which are on the beach, have better transport during the Afternoon period, followed by the Morning. At night, the detected transport is very low, with some traps not showing sediment capture. At night there is lower temperature, and higher humidity, therefore there is a reduction in wind speed and consequently less sediment transport.

Another important observation at these stations, which are located in the berm zone, on the east coast, is the coarse sediments found, indicating great energy from the work of currents and waves (longshore drift) that can initiate an erosive process on these beaches.

The stations at points 03 and 04, which are aligned with the central wind sediment transport corridor, towards Papai Noel Dune (DPN), presented the highest accumulation of sediment in the traps in the Morning period, with a value of 13.0767 m^3.m.month, higher than that reported by Maia (2001). It was observed that the alignment of the point coincides with the access trail to Vila de Jericoacoara, where motor vehicle traffic is intense, resulting in the movement of sediment and consequent transport. This traffic influenced the movement of sediments into the traps. The area where the collection stations were placed represents the Active Deflation Surface. The Afternoon period showed a continuation of sediment accumulation, this period being the one with the best results. At night, there are few catches.

Points 05 and 06 are located close to the arrival of Papai Noel Dune, being distributed at intervals of 250 meters, and are the collection points with the lowest sediment transport rates, in all periods. It is important to emphasize that in 12 measurements no sediment accumulation was detected in the traps deployed. The area is used as pasture for livestock by the local population. This area is representative of the Stabilized Deflation Surface.

The traps placed at points 07 and 08 showed small sediment transport values, mainly in the Morning and Afternoon periods. At night, the amounts captured in the traps are negligible. Point 08 has better transport, possibly being influenced by sediments from Papai Noel Dune.

The best average sediment transport values are in the alignment of points 09 and 10, which corresponds to the first aeolian sediment transport corridor, which was sectioned by Vila de Jericoacoara. Due to this fact, Pôr do Sol Dune no longer receives the amount of sediment that would balance the existing deficit. The best transport values are in the Afternoon and after Morning periods. At point 09, there is less transport, possibly due to this corridor being sectioned by the buildings of Vila de Jericoacoara, which created an Accumulation Zone, where sediments are also removed. This area is used by the Municipality of Jijoca de Jericoacoara, irregularly, to complete the level of existing streets and alleys, when the town experiences disruptions due to large floods, as seen in 2020 and December 2021, which practically excavate all the sediments deposited in these streets and alleys, transporting them to the beach area.

Another point observed is that part of this area that we call the Accumulation Zone is located in the area where there is licensing for archaeological research. Sediment collection point 09 was deactivated in the last field.

Collection Station 11 was located in the wind sediment transport corridor that directs of Arraia Dune, with low transport being observed, even during the day, with Afternoon having the best transport.

As verified, in all collection stations, the night period presents the lowest values of sediment transport, in relation to the day, quite possibly due to the decrease in wind speed, except when there are gusts of wind, caused by the decrease in the temperature and the effects of atmospheric pressure.

As we know, temperatures are decisive factors regarding the intensity levels of atmospheric pressure. Chemically speaking, when substances are colder, the molecules group together, and when substances are hotter, the molecules move apart, that is, when temperatures are less high, the air molecules come together, becoming denser, therefore, heavier, increasing the pressure. When temperatures rise, particles move apart, the air becomes less dense and the pressure decreases. Wind can be considered moving air.

Wind transport is directly influenced by these variants, by atmospheric pressure, humidity, solar incidence, and temperature. As already mentioned in this work, in regions with greater solar incidence and temperature, atmospheric pressure (SST – Sea Surface Temperature) changes and increases, causing greater wind speed and, consequently, greater sediment transport. Sediments begin transport at speeds of 3.2 m/s. In the area, the dry period, which runs from August to December, represents the period in which the effective feeding of the aeolian sediment transport corridors and dune fields occurs and, consequently, a higher migration rate.

The Jericoacoara wind sedimentary system in Ceara is characterized by the presence of a promontory and the action called "headland bypassing dune field". In this continental strip, the beach, located to the East, Praia da Trilha do Preá, the sediments cross the promontory area mainly due to the preferential direction of the winds, almost from E-W, and arrive at the inlet to the underside, on Jericoacoara beach, refeeding the beach strip and dunes and carrying out the coastal crossing or bypass.

As can be seen from the Sampled Points Map (Figure 1) and the Wind Sedimentary Zoning Map (Figure 3), the main aeolian sediment transport corridors are represented by the sampled points, point 09 and point 10, which we will call corridor 01, and by the sampled points point 03 and point 04, corridor 02.

The study showed mobility in the wind sediment transport corridors called 02, of 13.0767 m^3/m.month, during the day, located at sampled point 04, on 09/16/2020, being the second-best measured point of sediment transport. As already reported, these points (03 and 04) coincide with the access trail to Vila de Jericoacoara, where motor vehicle traffic is intense, and with this, there is sediment movement and consequent transport. Point 10 on 09/16/2020, presented 19.6272 m^3/m.month during the day.

Corridor 01:
The average for point 09 demonstrated the following values:
Point 09 (Daytime) with the transport of 3,415 m^3/m.month;
Point 09 (Night) with the transport of 1,916 m^3/m.month;
Monthly average: 2,665 m^3/m.month.
The average of point 10 demonstrated the following values:
Point 10 (Daytime) with the transport of 11,281 m^3/m.month;
Point 10 (Night) with the transport of 2,767 m^3/m.month;
Monthly average: 4,511 m3/m.month.
Corridor 01 with an annual average of 31.98 m^3/m.year,
Corridor 02:
The average of point 03 demonstrated the following values:
Point 03 (Daytime) with the transport of 6,328 m^3/m.month;
Point 03 (Night) with the transport of 1,714 m^3/m.month;
Monthly average: 4,021 m^3/m.month.
The average of point 04 demonstrated the following values:
Point 04 (Daytime) with the transport of 9.215 m^3/m.month;
Point 04 (Night) with the transport of 2,767 m^3/m.month;
Monthly average: 5,991 m^3/m.month.
Corridor 02 with an annual average of 60.07 m^3/m.year,

The average transport of aeolian sediments at the other points showed small transport values. At sampled points 01 and 02, which are located on the beachfront area between Preá and Jericoacoara, the average value of 0.795 m^3/m.month was measured at Point 01, and at Point 02 the value of 2.634 m^3/m. month, which shows that transport in this area is small. In field observations, it was verified that the area is undergoing erosion processes, and the grains are medium to fine sand, requiring high wind speeds for transport. The area still suffers from the constant movement of motor vehicles.

At points located in the Stabilized Deflation Plain, sediment transport values were almost zero. Point 05 presented a monthly transport average of 0.226 m^3/m.month. Point 06 presented a monthly average of 0.0776 m^3/m.month and point 07 had a sediment transport value of 0.040 m^3/m.month. This area is used as pasture for livestock by the local population, being representative of the Stabilized Deflation Surface and soil modification, with the creation of small mounds of land vegetated by grasses, which obstruct the transport of sediments. In this area, the transport of aeolian sediments is almost non-existent (maximum of 2.72 m^3/m.year), being 28 times lower than the measured 78 m^3/m/year in Jericoacoara (Maia, 2001), demonstrating that the entire system suffered interference and as a consequence presents a high sedimentation deficit in the studied area.

Sampled point 08 is influenced by Papai Noel Dune, with transport towards Pôr do Sol Dune, even so, it presents an average sediment transport value of 3,080 m^3/m.month, much lower than that measured by Maia in 2001.

As observed in the field, sediment transport is greater throughout the day, which is influenced by temperature, atmospheric pressure, humidity, and solar incidence.

There is a difference between potential transport and actual transport. To analyze potential transport, there must be sand available, loose, and with a particle size that supports transport due to the incident wind speeds. The real transport, measured in the field, suffers from other conditions, such as places where the sediments already have medium to coarse grain size, therefore, they have the potential for transport, but the wind speed does not have the efficiency and energy for this transport, so the actual transport is smaller than the potential transport (final conditions) of the ideal situation. This fact is seen in the studied area mainly in the Active Deflation Plain with erosion.

In transport corridors, there are places where sediment transport is greater, mainly due to wind speed, the existence or absence of vegetation, and obstructions, so where there are no such interventions, there is a higher wind speed and a greater possibility of transport.

4. Aeolian-Sedimentary Zoning

Initially, an attempt is made to characterize the natural and anthropogenic causes that determined the sediment deficit in the DPS area. The work in question focuses on presenting wind-sedimentary zoning, through field measurements, trying to understand the factors that paralyzed or reduced sediment transport through wind corridors, whether the same, natural or anthropic, in order to predict adequately what happened in these areas.

The studied area is inserted in the domain of Cenozoic sedimentary deposits, according to the morpho structural classification established by Souza/1988 (Meireles, 2011), consisting of Tercio-Quaternary exposures of the Barreiras Formation, represented by outcrops in places with strong deflation (erosion wind) and the cliffs that emerge on the Preá Trail.

The coastal plain covers Praia de Jericoacoara and practically the entire coastline of the area, except Serrote, constituting a strip of land with beach and post-beach sectors, dune fields with mobile and fixed dunes, deflation corridors and wind transport, phreatic and interdune lagoons. The geomorphological features of the coastal plain most studied in relation to the area of this research project are the beach strips, the dune fields, and the existing fluviomarine plain.

With the survey and analysis of data collected in the field and through a bibliography of the area under study, the identification of sensitive areas was carried out and the zones were defined, resulting in the characterization of the geoenvironmental units, represented by the Beach Range, Mobile Dunes, Fixed Dunes, Freatic Lagoons, Fluviomarine Plain, Wind Deflation Plain and Serrate, with details of these environmental units being carried out, especially those most related to the dominant wind processes in the region.

Considering the project objectives and environmental management, special attention was paid to the Wind Deflation Plain and the dune field that surrounds the Pôr do Sol, Papai Noel, and Arraia dunes.

After integrating all the data obtained and from the perspective of local environmental dynamics, mainly sedimentary and erosion processes, the following Wind-Sedimentary Units were delimited: Mobile Dunes - Accumulation Zone; Active Wind Deflation Plain; Stabilized Wind Deflation Plain, and Wind-Sedimentary Corridor.

In the Wind-Sedimentary Zoning Map, geoprocessing techniques, digital cartography, and the use of LIDAR images were used to map the area of the wind sediment transport corridors that should feed sediments to the Pôr do Sol and Papai Noel Dunes, located in PARNA of Jericoacoara, obtaining a general understanding of the processes that influence the DPS, in addition to the work and field surveys carried out on this dune and its wind-driven sediment transport corridors.

With this delimitation, the Wind-Sedimentary Zoning Map was created, which involves the entire area of the research project (Figure 3) and also indicates the preferred and local directions and directions of the winds, which should guide the actions to be designed in the focused environmental management.

The average wind speed was measured in the field, using a Professional Instruments CE anemometer, where the average for each collection point is presented in Table 1. After analyzing the field data, four groups of speeds were represented, with the largest speed range between 8.9m/s and 9.5m/s, located around point P10, speeds ranging from 7.5m/s to 8.8m/s around points P9, P3 and P2, speeds with ranges between 6.7m/s to 7.4m/s, along points P1 and P4 and the range with values ranging from 5.2m/s to 6.6m/s along points P5, P6, P7, and P8. Some gusts with values of up to 14.0 m/s were observed. Justified values, due to the region's dry period. For the Pôr do Sol Dune Recovery Project, we will use these ranges of values for mathematical analyses.

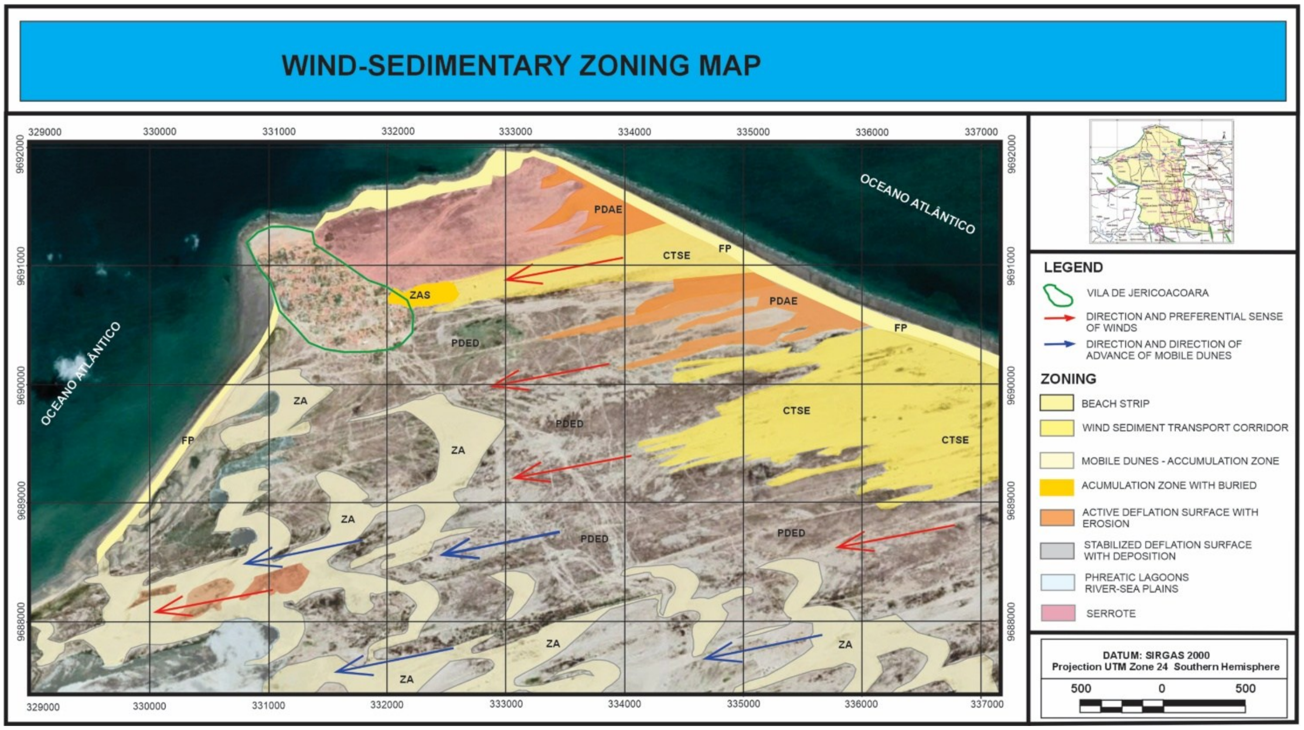

Figure 3 – Wind-Sedimentary Zoning Map.
Source: Authors. (2022).

The Eolian-Sedimentary Zoning Map used geoprocessing techniques, digital cartography and the use of LIDAR images to map the area of the wind sediment transport corridors that should feed the Pôr do Sol and Papai Noel Dunes, located in the Jericoacoara PARNA, obtaining a general understanding of the processes that influence the DPS, in addition to the field work and surveys carried out on this dune and its wind sediment transport corridors.

5. Conclusions and Recommendations

The area covers a beach strip above the tide line and below the bed of the Trilha do Preá, with a length of 740m, between the bar of an intermittent stream with no official name and the main climb of the main trail (road) that connects Praia do Preá and Vila de Jericoacoara, which has a large availability of sediment. This is the area where sediment transport begins to carry the sand from the beach to the entrance of the wind-sedimentary corridor that still supplies the Jericoacoara dune field, in an incipient way. It is a narrow portion of the beach, more or less inclined, varying in width between 1 and 10 meters in the sections with rocks (Serrote region and foot of Pôr do Sol Dune), and between 4 and 30 meters (in the stretch of beach at Trilha do Preá), depending on the type of tide and the time of low and high tides.

The system is characterized by the presence of a promontory and the action called "headland bypassing dune field". The sediments are blocked and diverted to the continent by the presence of the promontory (Serrote). It is also in this area that you will find the largest number of access trails to the village, coming from the headquarters of the municipality of Jijoca de Jericoacoara, the coastal lagoons, and the municipality of Cruz. The area is characterized by being an area connecting mobile or fixed dunes to their feeding areas, in the case of the study area the beach strip is located to the east (Trilha do Preá).

The sediments, coming from the stretch area and beach berm, are intercepted by Ponta de Jericoacoara and form the largest individual dune field in the State. The area is characterized by a large field of mobile dunes, and for this dune field to form, an area of sediment movement was necessary from the beach strip, this area is called the Active Deflation Plain. It has this name because it is an area with flatter topography, with great wind influence. In this region, wind corridors can be observed, with high wind speeds, where the sand that forms the mobile dunes in the region can be seen.

The study of wind transport was based on tests using sediment traps of the type that accumulate all the material transported through a vertical section, these measurements being associated with simultaneous measurements of wind direction and speed.

The value of the dune formation potential represents, when negative, the removal of sediments from the beach to the interior of the continent, while positive represents the migration of sediments in a “headland bypass dune field” type process. In this case, the beach is replenished by wind transport. On the other hand, the stretches of the coast whose positions present greater angles correspond to those where wind transport occurs almost parallel to the coastline, which justifies the permanence of sediments close to the beach, often forming frontal dunes, which help in the maintenance of coastal stability.

In places with greater intensity of frontal winds and high aridity, such as in the segment of the beach strip between Preá and Jericoacoara, there is great availability of sediments, through wind-sedimentary corridors where wind transport takes place (in sheets and cords) to the accumulation zones and where they constitute large mobile dune bodies.

There was a decrease in the length of the aeolian sediment transport corridors and the volumes transported in these aeolian-sedimentary transport bands due to several factors, including human interference, artificial obstructions, the addition of fixing vegetation cover with a gradual reduction in sand volumes along its route, from the beach to the dunes, as well as the existence of many trails for vehicle circulation, which results in a random dispersion of sand along the erosion grooves created on these trails in several directions different from the natural transport corridor.

The study showed mobility in the aeolian sediment transport corridors much lower than that pointed out by Maia (2001), presenting in the aeolian sediment transport corridor 01 (to the north), represented by sampled points 09 and 10, a rate of 31. 98 m^3/m.year, these points represent the corridor obstructed by the Village of Jericoacoara. In corridor 02, represented by sample points 03 and 04, a transport rate of 60.07 m^3/m.year, these points (03 and 04) coincide with the access trail to Vila de Jericoacoara, where motor vehicle traffic is intense, and as a result, there is movement of sediment and consequent transport. At points located in the Stabilized Deflation Plain, sediment transport values were almost zero (maximum of 2.72 m^3/m.year), being 28 times lower than the measured 78 m^3/m/year in Jericoacoara (Maia, 2001), demonstrating that the entire system suffered interference and as a consequence presents a high sedimentation deficit in the studied area.

The reactivation of wind corridors necessarily involves actions such as the installation of EGCE – Wind Current Guide Structures, to divert sediment transported and accumulated in accumulation zones, to redirect them to supply these corridors and be transported to the accumulation areas of Papai Noel Dune and Pôr do Sol Dune.

A complete Environmental Education action is also necessary, with a zoning of use of the areas, mainly regarding extensive livestock farming and vehicle trails that exist in the PARNA of Jericoacoara.

References

ALEXANDER, J.; BRIDGE, J. S.; CHEEL, R. J.; LECLAIR, S. F. Bedforms and associated sedimentary structures formed under supercritical water flows over aggrading sand beds. Sedimentology, v. 48, p. 133-152, 2001.

AQUINO, Mariana Correia; MORAIS, Jáder Onofre de; SOARES, Raquel Cavalcante. Análise do Balanço Sedimentar na Praia do Futuro, Ceara, Brasil. In: XIII Simpósio de Geografia Física Aplicada, Viçosa – MG, 2009.

ARAUJO, N. Jericoacoara. Editora Minerva, 1987.

BARRA, O. A. O. L.; ARRUDA, A. G. F.; VASCONCELOS, Fábio Perdigão; CASEMIRO, M. B.; AMARAL, D. N. Aspectos legais de proteção à zona costeira no Brasil e seus desdobramentos no litoral do estado do Ceara. Estudios Socioterritoriales, v. 23, p. 83-100, 2018.

BRIDGE, J.; DEMICCO, R. Earth Surface Processes, Landforms, and Sediment Deposits. Cambridge University Press, 2008.

CARVALHO, A. M. de; SALES, V. de C. Contribuição do Transporte Eólico no Processo de Evolução da Linha de Costa. Mercator, Fortaleza, v. 15, n. 2, p. 105-115, abr./jun., 2016.

CASTRO, J. W. A.; ÀVILA, C. A.; GONÇALVES, R. J. O sistema de dunas oblíquas do litoral norte de Cabo Frio, Estado do Rio de Janeiro. In: Simpósio Nacional de Geomorfologia, 4, São Luís. Anais... São Luís: UGB, 2002. p. 23.

CASTRO, J. W. A.; DIAS, F. F.; RANGEL, F. E.; MIGUEZ, A. I. P. Taxa de Transporte de Sedimento Eólico em Dunas Costeiras Obliquas do município de Cabo Frio – Estado do Rio de Janeiro. In: II Congresso sobre Planejamento e Gestão das Zonas Costeiras dos Países de Expressão Portuguesa IX Congresso da Associação Brasileira de Estudos do Quaternário II Congresso do Quaternário dos Países de Língua Ibérica.

DAVIS, R. A. Beach and nearshore zone, in Coastal sedimentary environments. New Springer-Verlag, New York, 1978.

DAVIS, R. A. Coastal Sedimentary Environments. Springer-Verlag, New York, 1985.

DAVIS Jr., R. A. Regional Coastal Morphodynamics Along the United States Gulf of Mexico. Journal of Coastal Research, v. 13, n. 3, p. 595-604, 1997.

GURGEL JR, J. B.; MEIRELES, A. J. A.; GURGEL, G. A. S. Abordagem Geológica Ambiental em uma área submetida a processos erosivos costeiros na praia do Pecém - São Gonçalo do Amarante, Ceara Brasil. IV Congresso da Associação Brasileira de Estudos do Quaternário, São Paulo, 5 à 8 de Julho de 1993.

GURGEL JR, J. B.; MEIRELES, A. J. A.; GURGEL, G. A. S. Avaliação das Condições de Degradação Ambiental pelo Avanço do Mar na Praia do Pecém - Litoral Norte do Estado do Ceara. Uma Proposta de Estudo. 3º Encontro Nacional de Estudos sobre o Meio Ambiente - ANAIS V.2, 1991.

GURGEL JR, J. B.; GURGEL, G. A. S. Plano de Sustentabilidade do Projeto de Recuperação e Estabilização da Praia e Encostas, do Programa de Proteção Ambiental, do Projeto Aldeia da Praia, Secretaria Municipal de Turismo de Fortaleza – SETFOR, na Cidade de Fortaleza/CE, 2014.

GURGEL JR, J. B. Complementar com elaboração e execução do projeto serviluz.

ICMBio - Instituto Chico Mendes de Conservação da Biodiversidade. Avaliação Ecológica Rápida e Analise da Unidade de Conservação - Plano de Manejo do Parque Nacional de Jericoacoara. Brasília, 2011.

MAIA, L. P. Procesos Costeros y Balance Sedimentario a lo Largo de Fortaleza (NE Brasil): Implicaciones para una Gestioan Adecuada de la Zona Litoral. Unpubl. Ph.D. Thesis, Faculty of Geology, University of Barcelona, 1998.

MAIA, Luís Parente et al. Dynamics of coastal dunes at Ceara State, Northeastern Brazil: dimension and migration rate. Arquivos de Ciências do Mar, Universidade Federal do Ceara, Fortaleza, v. 34, p. 11-22, 2001.

MASSELINK, G.; SHORT, A. D. The effect of the tide range on beach morphodynamics and morphology: a conceptual beach model. Journal of Coastal Research, v. 9, n. 3, p. 785-800, 1993.

MEIRELES, A. J. A. Geodinâmica dos Campos de Dunas Móveis de Jericoacoara/CE-BR. Mercator - Revista de Geografia da UFC, v. 10, n. 22, p. 169-190, maio-agosto, 2011.

PEREIRA FILHO, N. S. Análise da Dinâmica Espaço-Temporal (1973 A 2014) das Dunas de Jericoacoara, Ceara, Brasil. Dissertação de Mestrado, Coordenação do Programa de Pós-Graduação em Geografia da UFC, Novembro, 2014.

ROSATI, J. D. Concepts in Sediment Budgets. Journal of Coastal Research, v. 21, n. 2, p. 307-322, 2005.

SILVEIRA, A. P.; VASCONCELOS, F. P.; SALES, V. C. C. Análise da Evolução Temporal e da Dinâmica Sedimentar da Duna Pôr do Sol, em Jericoacoara, Ceara, Brasil. Revista da Casa da Geografia de Sobral (RCGS), v. 21, p. 656-673, 2019.

SOUZA, M. J. N. Contribuição ao estudo das unidades morfoestruturais do Estado do Ceara. Revista de Geologia da UFC, Fortaleza, n. 1, p. 73-91, jun. 1988.

SOUZA, M. J. N. O Litoral Leste do Estado do Ceara: potencialidades e limitações de uso dos recursos naturais das unidades geoambientais. In: Zenilde Baima Amora. (Org.). O Ceara: enfoques geográficos. 1 ed. Fortaleza: FUNECE, 1999, v. p. 11-24.