Monitoring methods of dunefield susceptible to human activities in the Nísia Floresta area, eastern coast of the State of Rio Grande do Norte, Brazil

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Abstract

The coastal area of northeastern Brazil shows a wide range of dunefields, which were formed during the Holocene and Pleistocene periods. In the eastern coast of the Rio Grande do Norte State (RN), these aeolian provinces are characterized by older (stabilized by vegetation) and young (without vegetation) dunefields. They cover a large coastal zone, which forms important aquifers that supply water to several coastal cities, including Natal, the capital of the state. This coastal area is also characterized by the tourism industry, which is considered one of the most important financial resources and means of employment generation. Despite this importance, no study has been carried out concerning the impact of tourism activities in this area. Because of this, the aim of this work is to present a monitoring method of the coastal dunefields in the town of Nísia Floresta, Brazil, including the periodical identification of internal geometries of dunes with GPR profiling, and external geometries of dunes using a Geodesic GPS. The study area is characterized by SE-NW-trending dunefields. They are composed of blowouts, blowout dunes, and interdune areas, which have been modified by human occupation and off-road vehicle driving. The data permits the analysis of depositional and erosional controls and relates it to the reference of the Dunas Park, a conservation area near the town of Nísia Floresta.
Keywords: coastal dunes, monitoring method, GPR, GPS.

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1 Introduction

Coastal dunes form a dynamic system, occurring on the coastlines where the texturally adequate sediments are abundant [1]. Coastal dunes are of great importance from a geological point of view. They constitute a natural defender of the wave action, and they have an ecologic importance because they present native species. Because of their dynamism, these systems suffer constant changes. When susceptible to anthropic action, they become vulnerable. Examples are the Mediterranean coastal dunes, 75% of which were destroyed principally by tourism activities [2, 3]. Therefore, it is necessary to improve the knowledge of these areas in order to try to minimize possible impacts caused by these activities.

In Rio Grande do Norte, In Rio Grande do Norte, there are abundant coastal dunefields characterized by two geomorphologic units: vegetated dunes (or Pleistocene dunes) and dunes without vegetation (or Holocene dunes). Particularly in Natal (capital of Rio Grande do Norte) and nearby area, dunes have a relevant function in groundwater capitation, and they are responsible for recharging the principal aquifer that supplies the region [4]. Thus, the preservation of this ecosystem is important, as these places are intensively exploited by tourism, which can lead to future environmental degradation. Based on this idea, this work proposes some methods for monitoring the coastal dunefields, which will permit both the analysis of the external surface of these deposits and the investigation of subsurface, using geodesic GPS and GPR (Ground Penetration Radar), respectively. Works using the integration of both techniques described above have been developed previously [5, 6]. The Nísia Floresta area, chosen to be evaluated for environmental impact is used as a road for dune buggy driving. The acquired data is compared with data from the Dunas Park preservation area where it is not allowed vehicles entrance and edifications construction.

2 Regional setting and research context

Two fields were selected for the development of this work; both situated on the eastern coast of Rio Grande do Norte, separated by a distance of about 33 km, fig. 1. The reference area is an environmental conservation unit, located in Dunas Park, Natal, capital of Rio Grande do Norte. The impacted study area is on Búzios Beach, in Nísia Floresta. They are very similar areas, presenting the same patterns of winds (NW) and the same geologic/geomorphologic context. The active dunes are characterized by blowouts and blowout dunes, besides interdune areas. In these places, there are also nebkas fields and shadow dunes along the blowouts. Data obtained by the climatologic station of the Federal University of Rio Grande do Norte (UFRN) show that between 1983 and 2005, the annual average temperature ranged between 22.8ºC and 29.4º, with average air-relative humidity of 80%. The winds are predominantly NW, with average velocity of 4.4 m/s. The period from August to October presents the major velocities, which reach 5.09 m/s, whereas the period from March to May offers the lower velocities, which reach a minimum of 3.69 m/s.

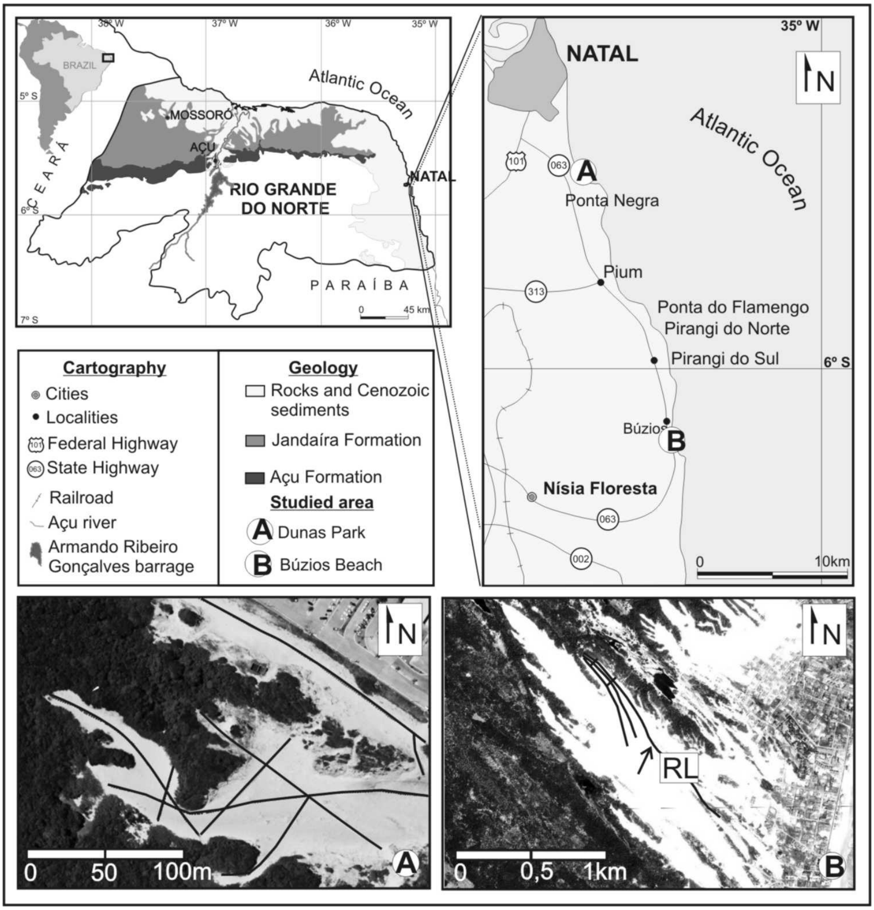

Figure 1: Map of study area. A. Blowout analyzed in Dunas Park, showing eight lines of GPR [7] acquired in April of 2004 (aerial photograph, 1999). B: Blowout at Búzios Beach (Ikonos Image, 2002), showing the six collected lines in May 2004. RL corresponds to the Reference Line acquired in two periods (May 2004 and April 2005), which permitted a multitemporal analysis of the geophysical data. The arrow indicates a detail mesh carried out in April of 2005. For more explanation, see item 4.

The pluviosity is characterized by a range of values, reaching a minimum of 858.2 mm in 1993 and a maximum of 2,500mm in 1986. These data are valid for both areas, as they are close to one to another.

3 Methods

Before the use of georadar in sedimentology, the characterization of the internal structures of dunes was made through natural field exposures and cutting trenches. They gave restricted information, since the deepness of the trench was controlled by the level of the local water table [8]. Thus, the use of the GPR technique fills this gap, becoming more efficacious in determining stratigraphic architecture and the body's geometry, as it was able to reach a maximum depth of 57 m in some cases [9]. Moreover than this, GPR is important to help the development of dunes-model migration. In this research, RAMAC equipment of MALA Geosciences, 100 and 200 MHZ antenna, was used, fig. 2. Software GRADIX (version 1.11) and RADAN (version 4.0) were used for GPR-image processing. Geodesic GPS and total station were used for topography correction.

Figure 2: Data acquisition, using an antenna frequency of 100 MHZ. The equipment was carried manually (A) and fixed to quadricycle (B) using antenna frequency of 200 MHZ.

The geodesic GPS played an important role in the research, considering that it permitted the generation of digital elevation models (DEM). The Real Time Kinematics GPS (RTK) was used for high-precision positioning in real time. The results can present subdecimal precision [10]. This technique requires the presence of a reference station and a mobile station. The reference station involving two segments. One segment is represented by (i) a transmitter radio and its respective antenna, and (ii) a "legant" antenna and a "legacy" receptor. A mobile station, called a rover, is in fact a GPS with a Hyper system, allowing the communication with a base and a collector for data storage. The attributes x, y, and z can be collected at each point or in a continued mode. At Búzios Beach, the rover was fixed to the quadricycle, making the process of data survey faster than usual, fig. 3a. On the other hand, at Dunas Park, where vehicle traffic is prohibited, control points were acquired with a rover transported manually, fig. 3b. The software GOCAD was used for three-dimensional visualization of the information collected in the field.

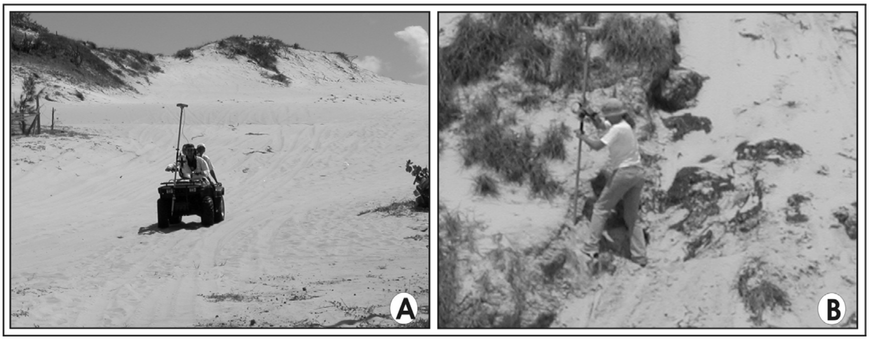

Figure 3: Aspects of the use of rover for acquisition of the digital elevation model. A: Mobile Station of the GPS attached to the quadricycle at Búzios Beach dunes. B: Mobile Station transported at Dunas Park.

4 Results

4.1 GPR

At Búzios Beach dunefield, six GPR lines were acquired in May 2004, including the reference line, fig. 1. These lines permitted the distinction of four radar faces, as presented as follows: R1) reflectors with maximum depth of 20º related to dune foresets; R2) plain-parallel reflectors associated to dune blowout; R3) mounded reflectors, related to the preservation of small dunes; and R4) plain-parallel reflectors attributed to the presence of sand sheets, fig. 4. Another data survey in April of 2005 was done in the same local of the reference line, with a special section chosen for details. The interpretation of this section, fig.5, permitted the identification of three reflectors. The deepest one, around 23 m, was correspondent to the water table (WT). The other reflectors, with a relatively steep inclination angle, were attributed to a migration of blowout that eroded the previous surface. One difference that was observed in lines of GPR acquired in distinct periods was easily identified in the blowout dunes. The erosional surface, which separates the deposits of crestal reworking of dune blowout (with plain-parallel reflectors) of the other types of deposits, reached major depths in the last collected data. It indicates that blowout dunes, in the analyzed segment, experienced a period of deposition, fig. 6.

At the Dunas Park area, the same pattern of radar faces was observed based on the analysis of eight lines of GPR. This was justified by the fact of the dunes being geomorphologically similar to dunes in areas characterized by corridor-type blowouts, which were described at Búzios Beach [7]. However, no evolutional consideration about the dunes' internal structure for Dunas Park can be established yet, since only one field campaign was carried out with GPR for this area [7].

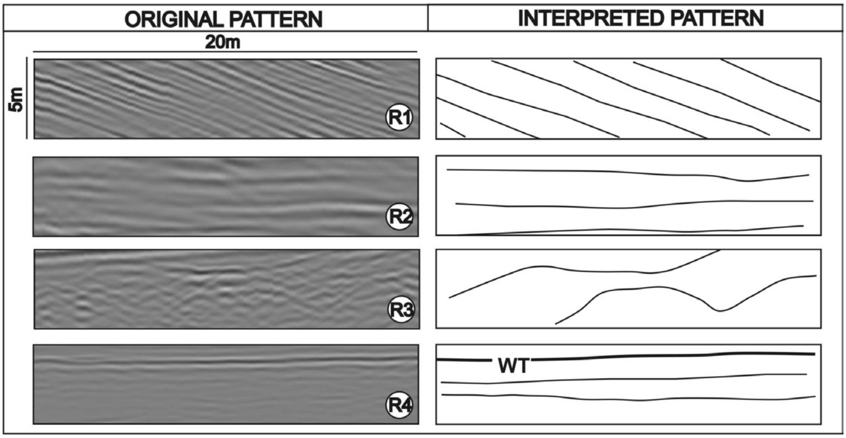

Figure 4: Visualization of radar faces observed in the dune profiles (see text for explanation). In R4, the strongest reflection corresponds to the water table (WT).

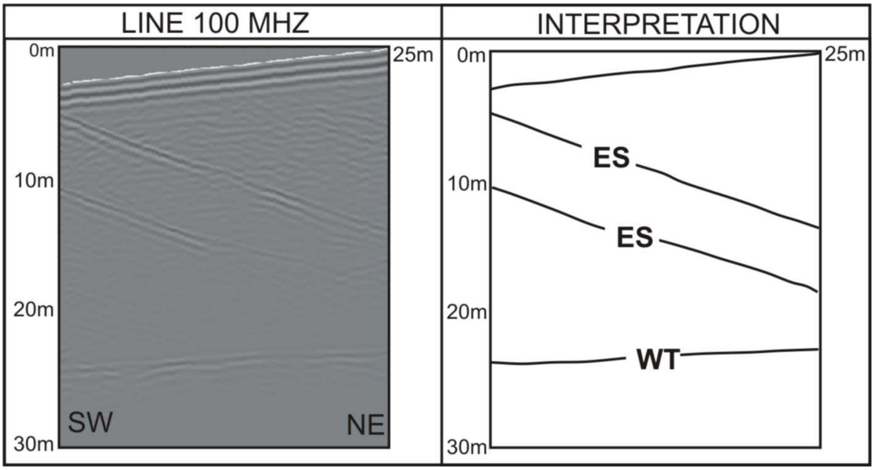

Figure 5: Example of GPR line obtained from a detail section. The first two reflectors correspond to erosional surface (ES). The deepest reflector corresponds to the water table (WT).

4.2 Geodesic GPS

Multitemporal topographic data collection was done with a geodesic GPS for both studied areas. Two surfaces were obtained at Dunas Park (April 2004 and October 2005; fig. 7a) and three surfaces were obtained at Búzios Beach (May 2004 and April and October 2005; fig. 7b). It must be emphasized that the first

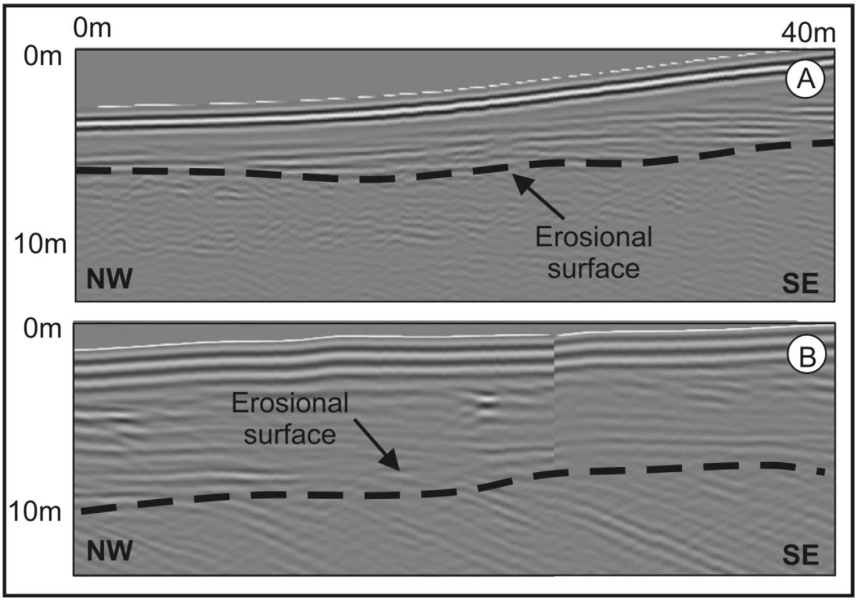

Figure 6: Part of the GPR line acquired at Búzios Beach blowout dune. A: Data survey carried out in April 2004, in which could be observed, around 5 m deep, the erosional surface that separates the deposits of reworking of the blowout dune (characterized by plain-parallel reflectors) from other deposits. B: Data survey realized in April 2005, making evident erosional surface around 10 m. In this case, below the erosional surface, deposits of dune migration are observed showing typical high angle reflectors.

topographic data survey with GPS (for both areas) was done between April and May 2004. This last period coincided with the lowest average rates of wind velocity in the area. The last data survey, done in October, 2005 also in both areas, is characterized by the presence of strong winds, which contributes to major aeolian transport.

At Búzios Beach, when the three generated surfaces were analyzed, fig. 7b, we observed places that were subjected to notorious erosion in blowout dune and blowout. This change in morphology can happen because of natural migration of the blowout or because of erosive events, and there is not a conclusive response to this yet. But it is correct to affirm that the urbanization with residence constructions along the blowouts constitutes possible obstacles for the sediment supply from the coast. Another factor that must be analyzed is that the last surface was obtained during a period of strong winds, which consequently contributes to the increase of sediment transport.

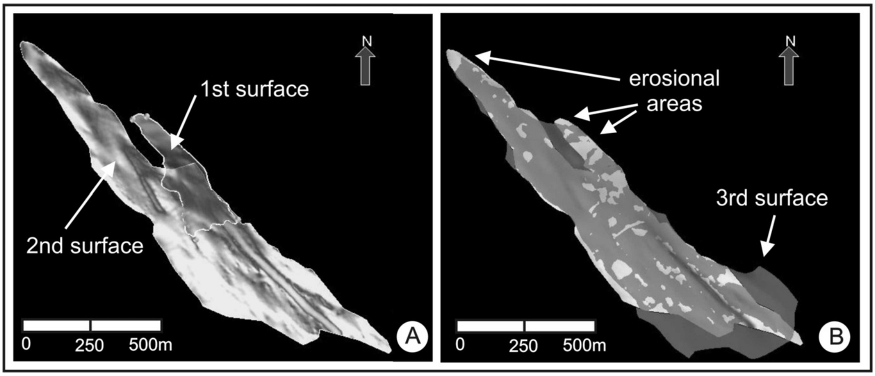

Figure 7: Generated DEMs for the blowout at Búzios Beach. A: Superposition of the first two generated surfaces (May 2004 and April 2005). B: Superposition of three generated surfaces, in which the light regions correspond to the places that presented erosion.

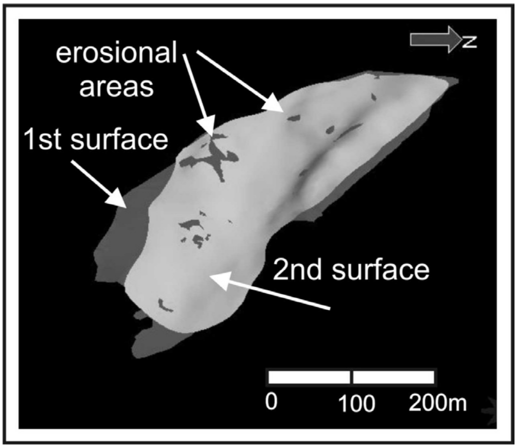

Figure 8: Superposition of both generated surfaces for the blowout at Dunas Park (April 2004 and October 2005), showing few places of erosion (darker tone).

At the Dunas Park, it is possible to recognize a major tendency toward deposition in the 19-month period of analysis, fig. 8. The results show few places under erosion, despite the existence of a road close to the park. It is important to note that for purposes of environmental conservation, vehicle traffic or urban constructions is not permitted in the area. This area, compared to Búzios Beach, is more protected from anthropic action.

5 Conclusions

Integrated methods were presented here for the monitoring of coastal dunes with geologic and geophysics techniques. It is important to emphasize that the continue monitoring of this area with geodesic GPS and GPR can give good answers related to dunefield evolution, which is susceptible to anthropic action. Another benefit is the possibility of acquiring parameters that could further its sustainable use.

The relief changes observed in the dunefield at Búzios Beach (mainly erosion) could be related to intensive tourism activity. On the other hand, at the Dunas Park preservation unit during the same period of analyses, deposition largely exceeds erosion. Detailed wind studies for both dunefields are also necessary to evaluate changes in the efficiency of the aeolian transport.

Acknowledgements

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