Journal of Coastal Research	SI 48	64-68	III SCCG (Proceedings)	Spain	ISSN 0749-0208

Characterization of the contemporary aeolian sediment dynamics of Boa Vista (Cape Verde)

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ABSTRACT

HERNÁNDEZ, L. and SUÁREZ, C., 2006. Characterization of the contemporary aeolian sediment dynamics of Boa Vista (Cape Verde), *Journal of Coastal Research* SI 48 (Proceedings of the 3rd Spanish Conference on Coastal Geomorphology), 64-68. Las Palmas de Gran Canaria – Spain, ISSN 0749-0208

This article presents a preliminary characterization of the contemporary aeolian sediment dynamics of the island of Boa Vista (Cape Verde Archipelago). Preliminary results suggest that the entire island represents an integrated aeolian/marine sediment transport system involving transport around and across the island under the influence of the Trade Winds. Human interference in the sediment transport system has been noted and recommendations for future development to take account of natural dynamics are presented.

ADITIONAL INDEX WORDS: *aeolian sedimentary dynamics, Boa Vista, Cape Verde*

INTRODUCTION AND STUDY AREA

The aim of this paper is to undertake a provisional characterization of the contemporary aeolian sedimentary dynamics of Boa Vista (Cape Verde) (Figure 1) for the purpose of providing information on the possible impacts of future tourist development of the island.

The island of Boa Vista is located in the Archipelago of Cape Verde, at 16 º 10’ N and 23 º 65’ W, only 620 km from the African continent. The island is almost circular, approximately 30 km in diameter, and has a surface area of 634 km^2. Given that the maximum altitude of the island is less than 400 m, it is not possible to trap the moisture from the clouds that accompany the prevailing NE trade winds and the island consequently has a very arid climate.

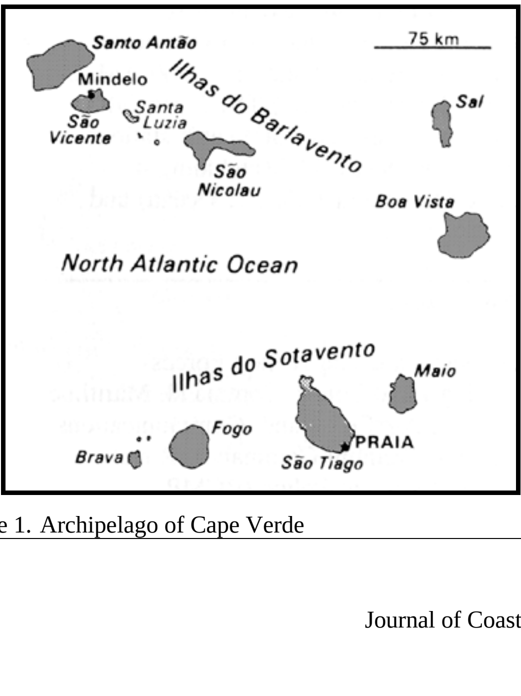

Figure 1. Archipelago of Cape Verde

The island is composed of volcanic rocks (basalts, phonolites, trachytes) deposited at different stages in the formation of the island. In the eastern islands of Cape Verde material dating back to the initial formation of the Atlantic Ocean has been identified, although eruptions took place up to the Miocene, (SERRALHEIRO et al., 1974). This older material appears principally in central and eastern parts of the island, and in the latter sector forms covers an area that spreads from north to south, and includes the island’s highest peak (Roque Estancia, 387 meters high).

Carbonate sedimentary deposits, formed during the Pliocene and the Quaternary, of both continental and marine facies, are also widely represented in the island. At present, calcareous materials occupy a wide area, particularly on the coast, where they form platforms at an altitude of over 100 meters (CASTANHEIRA AND CARDOSO, 1988). Carbonate dunes or large stabilized dunes are found nearby.

Boa Vista’s current coastline is 104,6 km long, of which 55 km (52%) is sandy. The rest of the coast is steep, and is made up of differing materials and forms including deeply eroded volcanics (principally in the east), alluvial and marine sediments, forming wide expanses of calcarenites and ancient carbonate-cemented aeolian landforms in the south and west (Figure 2).

Vegetation is limited to species adapted to the island’s arid conditions and the land is subjected to intense grazing. The dominant species are annual plants, together with shrubs adapted to the arid conditions, such as *Launaea malanostigma*, *Phoenix atlantica*, *Tamarix canariensis* and *Acacia albida* can be found in the most humid areas of the island, whereas *Zygophyllum waterlotii*, *Zygophyllum fontanesii*, *Frankenia ericifolia* and others occur in the sandy mobile areas (CASTANHEIRA & CARDOSO, 1988). *Prosopis sp.*, a species introduced in the 1970s by UNESCO in order to guarantee food for cattle and wood

Figure 2. Carbonate-cemented dunes at Varandinha's beach

for human consumption, is particularly widespread throughout the island.

In 2000 the island's population stood at 4206 inhabitants, just 1% of the country's total population. The island's population density is 6.70%, although large areas are practically uninhabited, since most of the population lives in the capital, Sal Rei (2024 inhabitants in 2000), and in some other dispersed nuclei, such as Rabil or Joao Baptista. The principal economic activities of the population have, up until recently, been agriculture, cattle farming and fishing, although in recent years tourist-related services have grown significantly. The construction of tourist-related infrastructure has also increased. These new activities have given rise to an important migratory movement, and today the island of Boa Vista receives migratory workers from other places, principally from the neighbouring sub-Saharan African countries.

In this context the Government of the Republic of Cape Verde has designed a planning programme for the tourist development of the island of Boa Vista to establish not only the number of beds to be created but also the location of new urban nuclei and related installations, such as ports or highways. The Government has established a few urban development priority zones, all of which are located along the western coast of the island, where some of the best beaches, including Chave (in the west) and Santa Monica (in the south) are situated.

METHODOLOGY

Given the aim outlined above, the analysis of the sedimentary dynamics of the island of Boa Vista was carried out by means of a multiscale analysis. The starting point was the analysis of an image from the Enhanced Thematic Mapper sensor (ETM) of the Landsat-7 satellite, taken on January 5, 2001, and available in the database of Global Land Cover Facility (GLCF) of the Institute for Advanced Computer Studies of the University of Maryland (USA). In conjunction with this image, we have used the photographs taken during a KLM photogrammetric flight on October 29, 1991, to a scale of 1/15.000, commissioned by the Government of the Republic of Cape Verde. Finally, information was gathered on the ground during two field work campaigns, the first of which took place in February, 2004 (as part of the field studies undertaken for the Strategic Tourist Development Plan for the Island of Boa Vista), and the second in August, 2005.

The use of geographical information technology has allowed the geomorphologic analysis to be compared with the original format of the territorial planning document (PASKOFF, 1993). Thus processes related to aeolian sedimentary dynamics were studied across the whole island, using remote sensing techniques and the interpretation of aerial photographs (MCKEE, 1979; GOUDIE et al., 1981). The information treated in this way has enabled us, with the support of field work, to undertake the classification of the aeolian deposits in terms of morphology and general transport features (PYE AND TSOAR, 1990; NICKLING, 1994).

RESULTS

In terms of the electromagnetic spectrum, the highest level of water reflectivity occurs in bands of visible light, although the signal captured by a sensor over this cover varies according to fluctuation in the parameters of the water: increases in turbidity, related to sediment content, produce increased signals (BHARGAVA & MARIAM, 1990). These variations can be highlighted by carrying out simple colour composition exercises on the lowest values of the visible bands of the satellite image. Figure 3 shows that most of the sand contributions received by the island of Boa Vista come from its northern marine platform, consistent with the principal vector of marine transport from the NE, determined by the currents and the trade winds, which leads to the accumulation of sediments on the north coast. However, because the northeastern sector of this coastline is steep, the sands either do not accumulate, or do not penetrate more than a few hundred meters inland. Thus, the greatest aeolian sand transport towards the interior of the island, favored by the lack of topographic impediments, is produced along the northwestern coast of Boa Esperança (Figure 4: 1). This contrast is observable along the whole coastline of the island, with sands penetrating inland more easily along the western coast than along the eastern coast. This ease of access produces a large volume of sandy sediments in transit, mobilized by the wind, in the western coastal sector of the island, that generate a continuous dune field (from north to south). The low topography in the eastern sector also makes it possible for sands to reach the interior of the island giving rise to dune fields that occupy smaller surface areas than those located in the west.

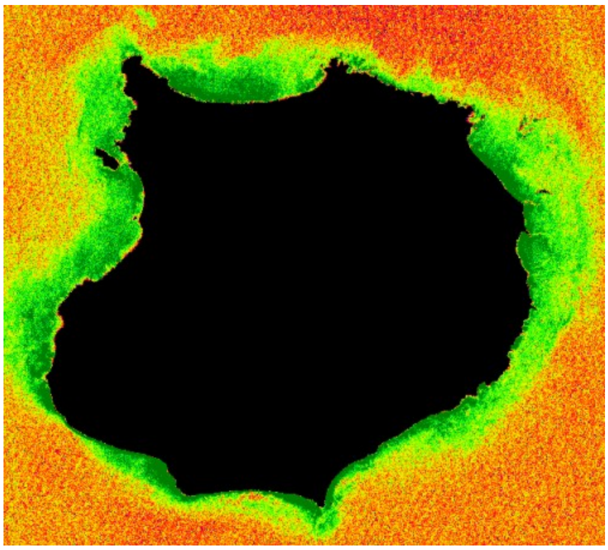

Figure 3. Color composition of the lowest values of the visible bands of the Landsat-ETM image

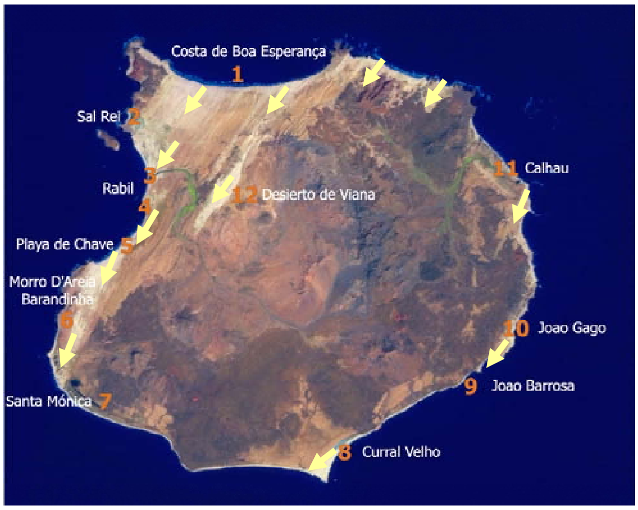

Figure 4. Principal sand fields of Boa Vista, and arrows indicating the direction of aeolian transport

Following the simulation of the theoretical path of the flow of sediments originating from the island's northwestern platform, we could say that they are transported NE-SW (Figure 4: 2) to Carlota's beach (Figure 4: 3). Nevertheless, a significant quantity of sands penetrating in the east of the Coast of Boa Esperança enters across the land above sea level, avoiding topographic impediments and forming Viana's Desert (Figures 4: 12).

Regarding the quantity of sediments mobilized, the landforms of the principal flow in the first sector (from Coast of Boa Esperança to Sal Rei) are characterized by the presence of sandsheets and nebkhas (Figure 5). Some obstacles of anthropic origin are also observed, such as alignments of palm leaves, intended to reduce aeolian sediment transport. The number of such obstacles increases closer to Sal Rei, the capital of the island, which is located close to Carlota's beach (Figure 4: 3). Thus aeolian transport of sediments in the surrounding area is almost totally prevented. Alignments of *Prosopis sp*. also manage to trap large volumes of sand, thanks to its wide root system (SANDYS-WINSCH AND HARRIS, 1994) (Figure 6).

Close to Carlota's beach, the only indications of contemporary aeolian sediment mobility are ripples. Nevertheless, in the recent past, sediments arrived at this beach in the form of large dunes. These dunes are today stabilized by vegetation, and marine erosion has steepened their leading edge (Figure 7). In this sector the seawater flows into former interdune hollows, and penetrates inland with each tide cycle. Once the aeolian sediments reach the sea again, they are once again exposed to the currents and waves, which transport them towards the south. Nonetheless, some residual bedforms guarantee the continuity of the sedimentary transport by land: a set of barchan dunes approximately three meters high has managed to cross the mouth of Rabil ravine, in which there is a coastal lagoon (Figure 4: 4; Figure 8), reaching the north sector of Chave's beach for (Figure 4: 5).

Figure 6. Alignments of *Prosopis sp* (right) impede the aeolian sedimentary dynamics in the vicinity of Sal Rei (left)

Chave's Beach is accumulative in nature, since it receives sediments from two sources (i) the barchan dunes that cross the mouth of Rabil ravine and (ii) the sea. These conditions facilitate the generation of transverse dunes (Figure 9). The path of the sediments across this wide dune field is affected in the south by the presence of a topographical high (Morro de la Areia, 167 m high). Thus, while some of the sediments are sent back to the sea, others are transported around the eastern side of this feature (Figure 4: 6). This gives rise to a transfer of sand in the form of barchan dunes, and transverse dunes at the distal end of the transport pathway (Figure 10).

At the coast, some sediment is deposited sea, but some transported eastward, principally by the longshore drift, generating a wide beach called Santa Monica (Figure 4: 7; Figure 10). It is

Figure 5. Aeolian deposits on the Coast of Boa Esperança

Figure 7. Steep dune on Carlota's beach

Figure 8. Barchan dunes between Rabil ravine (in the north) and Chave's beach (in the south)

reasonable to assume that these sediments also reach Curral Velho (Figure 4: 8), depending on the variations in wind, currents and waves throughout the year.

In the south of the island, between Santa Monica and Curral Velho, the sand transport paths that encircle the island converge, having followed either the route explained above along the western coast, or having travelled along the east coast. Fields of coastal dunes, such as Joao Barrosa (Figure 4: 9) accumulate at this convergence. For this reason the longest beaches of the island are in the south, with the longshore drift playing a fundamental role in their development (Figure 10).

Figure 9. Aerial view of dune field and Chave's beach

Figure 10. Aerial view of sediments exit to the sea at Santa Monica

CONCLUSIONS

The information set out above, yield several conclusions regarding the aeolian sedimentary dynamics of the island of Boa Vista. They are as follows:

1. The sandy sediments of Boa Vista are of marine origin.
2. The sediments are transported to land above sea level only across those low coasts which are free from topographic obstructions and lie perpendicular to the NE-SW direction.
3. The aeolian sedimentary transport occurs in a NE-SW direction and is determined by the trade winds.
4. The path of the sands across the land above sea level, is determined by natural factors (such as the presence of topographic accidents), and human factors (where sand is stabilized by vegetation).
5. Continuity in aeolian sedimentary transport between the

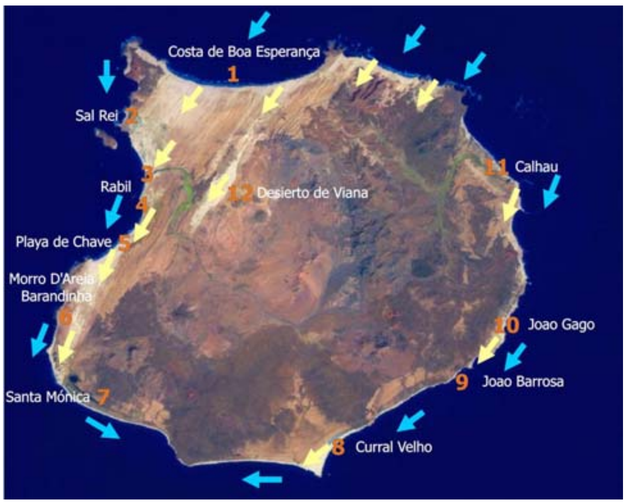

Figure 11. Theoretical model of marine/aeolian sedimentary transport for the island of Boa Vista

north and the south of the island along the different dune fields along the western coastline has been detected.

We also deduce the existence of an important sedimentary marine transport path from N-S, which surrounds the island and which is driven by the prevailing winds and currents. The existence of this sediment transport by the longshore drift has been detected at Chave's beach, on the west, as well as in the south of the island, where it gives rise to long beaches such as Santa Monica.

Given the above findings, we reach the provisional conclusion that all the dune fields on Boa Vista form a part of a single marine/aeolian sedimentary system (Figure 11). In this respect, the island of Boa Vista could represent a theoretical model of sedimentary dynamics in islands of similar characteristics.

RECOMMENDATIONS FOR PLANNING

Bearing in mind these conclusions, and with a view to the tourist development foreseen for this island in the near future, it is necessary to stress the vulnerability of the fields of coastal dunes particularly given their sensitivity to the construction of buildings and infrastructure, due to the ensuing obstruction of sand transport. Buildings act as traps for sediments moving towards the interior of the dune systems. Even when the offending buildings are demolished, the effects of these traps remain evident for a long time (PASKOFF AND OUELATI, 1991; PASKOFF, 1998).

In the case of the island of Boa Vista, the interference of human activities in the sedimentary dynamics is already evident around the capital, Sal Rei. It may also be assumed that significant interference will take place if tourist installations are to be built in the vicinity of the presently mobile sand systems.

Moreover, it is important to consider the island’s sedimentary dynamics as a whole, given that any installations built along the western coast of the island could have serious consequences for the sand dynamics, and consequently for the permanency of the beaches located in the south of the island.

We propose, therefore, the development of urban development plans that anticipate this obstruction of the sediments. Detailed study should be undertaken of the interactions between installations, such as ports and dikes, and sedimentary dynamics. Finally, we reiterate and support the idea raised in the Strategic Tourist Development Plan for Boa Vista of protecting the whole island’s coastline by classifying it as the National Park of the Sands of Boa Vista.

ACKNOWLEDGEMENTS

The information summarized in this paper comes from a report carried out by the authors of the Strategic Tourist Development Plan for the Island of Boa Vista. This plan was directed by the architect J. M. Alonso Fernandez-Aceytuno, who understood the importance of the aeolian sedimentary dynamics of the island, and consequently proposed that the coastline be protected as an emblematic element in future tourist development planning. The English translation of this paper has been revised by Heather Adams, ULPGC.

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