SHORT-TERM CHANGES AND LONGSHORE TRANSPORT ON A STEEP FINE SAND BEACH: THE EXAMPLE OF THE ITAMARACÁ ISLAND, NE BRAZIL

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RESUMO

O objetivo deste trabalho foi de avaliar as relações em curto prazo entre o transporte dos sedimentos ao longo da linha de costa de Itamaracá e o seu avanço ou recuo, identificar tendências sazonais e avaliar as mudanças morfológicas. São apresentados os perfis topográficos coletados em seis praias na Ilha de Itamaracá, Pernambuco, NE do Brasil. Estes perfis foram construídos a partir de dados mensais coletados pela monitoração anual das praias de novembro 2003 a outubro 2004. Estas praias apresentam os seus gradientes baixos (2° a 5°) e são compostas de material sedimentar do tipo areia fina. O balanço sedimentar total determinado para a Ilha de Itamaracá foi negativo, na ordem -133.37 m^3/m para todas as praias nos meses estudados. De uma maneira geral, as praias são impactadas por processos da erosão. A deriva litorânea em Itamaracá é de sul para norte. Em algumas praias, estruturas rígidas foram construídas perpendiculares a linha de costa, tanto por proprietários de casas como por imobiliárias, sem supervisão técnica. Estas estruturas rígidas inibem o deslocamento dos sedimentos para o norte. A deriva litorânea, os influxos dos rios, e as areias fornecidas do mar fizeram somente uma contribuição pequena aos sedimentos nas praias de Itamaracá. Os fatores associados com a ocupação de áreas de praia e as intervenções feitas no sul da ilha “para conter o recuo da linha de costa” são também responsáveis para agravar a erosão de algumas praias.

Palavras chave: Erosão costeira, transporte litorâneo, Ilha de Itamaracá, processos deposicionais, NE Brasil.

ABSTRACT

The objective of this work was to evaluate the short-term relationships between the transport of sediments along the Itamaracá coastline and its advance or retreat, identifying seasonal trends and evaluating the morphological changes. This paper presents the topographical profiles collected for six beaches in Itamaracá island, Pernambuco State, NE Brazil. These profiles were constructed from monthly data collected by one year monitoring of the beaches from November 2003 to October 2004. These beaches have shallow gradients (2° to 5°) and are composed of fine sand-sized material. The whole sedimentary balance determined for the island of Itamaracá was negative, in the order of –133.37 m^3/m for all beaches during the months studied. Overall, the beaches are impacted by erosional processes. The littoral drift in the island of Itamaracá occur from south to north. In some beaches, rigid structures have been built perpendicular to the shoreline by house owners, without technical supervision. These rigid structures hind the northward displacement of sediment. Alongshore drift, river influxes, and sands supplied from the sea have made only a small contribution to sediments on the beaches of Itamaracá island. Factors associated with occupation of beach areas and the interventions made to the south of the island “to contain the coastline retreat” are also responsible for aggravating the erosional rate of some beaches.

Keywords: Coastal erosion, longshore transport, Itamaracá island, depositional processes, NE Brazil

INTRODUCTION

The term 'beach', in the geological sense, can be used to express the accumulation of sediments of continental and/or biological origin, consisting predominantly of sand particles, which can be eroded easily by waves. These deposits comprise the terrestrial sediments delivered to the coast by rivers, sediments produced by the erosion of coastal landforms by waves, and marine sediments that have been reworked from offshore deposits onto the coast (Wright and Short, 1984; Bryant, 1985, Bauer and Allen, 1995, Hughes *et al.*, 1997).

According to Suguio (1992), the beach is the area neighboring an aqueous body, which is usually composed of sandy material or, more rarely, of gravel and shells of mollusks and other organisms. It extends from the level of the medium low tide to the line of permanent vegetation or to where the landscape changes, for instance to cliffs or dunes.

Therefore, the beach is considered to be the area that is affected by sea processes, such as winds, currents, tides, and waves, being the area under land and sea influence. In terms of long-term changes, the beaches of northeastern Brazil are suffering more from the action of erosive processes than from depositional processes (Chaves, 1991; Duarte, 1995; Dominguez, 1999; Vasconcelos *et al*., 2001; Neves, 2003; Oliveira *et al*., 2003; Bittencourt *et al*., 2005). In Pernambuco State, as on the whole northeastern coast, the problem of beach erosion is worsening, with urban beaches suffering the most intense shoreline retreat.

Demographic growth has forced the increasing use of coastal areas. Major erosion problems have occurred where buildings have been erected on parts of sandy beach systems that are subject to natural phases of erosion.

According to Dominguez (1990), coastal erosion is a problem for humans when they build some types of fixed objects, such as highways, buildings, and other types of permanent constructions in the path of coastline retreat. Dominguez (1990) or He also, affirms that erosion is in some circumstances caused by humans, because if an area close to the coastline had no human occupation, the problem would not exist.

In northeastern Brazil, waves are gentler during the summer season because the winds blow with less intensity and tend to deposit sands on the higher parts of the beach. During the winter, winds of greater intensity generate larger waves with more energy, and sands tend to be removed from the higher parts of the beach. They are transported toward the foreshore zone, accumulating under the bar form,This configuration tends to be reversed in the summer, when there is a balance between erosion and deposition in this part of the beach.

The collection of short- and long-term beach profiling data is the first step in understanding complex beach processes. This information, combined with ocean current and wave data, may allow scientists to understand better how fast and why our beaches are changing (Duncan, 1964; Kroon and Masselink, 2002; Dolique and Anthony, 2005; Anfuso and Javier-Gracia, 2005; Kokot *et al*., 2005).

According to Hoefel (1998), the transverse profile of a beach varies with the gain or loss of sand, which results from the relationships between the energy of waves, in semiannual changes. This is because of seasonal cycles of winter and summer, and the morphological characteristics of the beach profile are associated with the energy conditions during each season.

The physical balance of the beach depends on the relationship between the contribution of sediments and the capacity for coastal transport. When the amount of available sand in the beach system is greater than can be transported by coastal agents, the beach will tend to accumulate sand and increase in area. Otherwise, there will be erosion and consequently a retreating coastline.

Moura (2000) suggests that the problem of erosion results from the conflict between natural processes and human activity. The solution to the problem is linked to the issue of soil use in coastal areas. In other words, coastal erosion is the result of an imbalance between the natural hydrodynamic conditions and changes to the beach environment made by humans.

This paper presents the topographical profiles collected for six beaches on Itamaracá island, Pernambuco State, NE Brazil. These profiles were constructed from monthly data collected by one year monitoring of these beaches from November 2003 to October 2004.

The profiles show how the beach topography changed from month to month, and over the course of the a year. Itamaracá island presents environmental problems related mainly to disordered urban expansion, occupation of the beach zone, coastal tourism developments, and the pollution of hydric resources.,

Changes in the shoreline of Itamaracá island have also occurred over a range of time scales. It is important to distinguish between short-term changes in the coastline and long term coastal erosion. This work integrates a research project that includes studies of the erosion history, large scale coastal behavior, and the reef record, to develop a comprehensive model of coastal system evolution with the goal of further enhancing our predictive capabilities regarding shoreline stability in Pernambuco State.

The objective of this work was to evaluate the short-term relationships between the transport of sediments along the Itamaracá coastline and its progradation or retreat, identifying seasonal trends and evaluating the morphological changes.

REGIONAL SETTING

Itamaracá island is located in the northern littoral of Pernambuco State, northeastern Brazil, 40 km north of Recife, between latitudes 7°41´S and 7°48´S, and longitudes 34°49´W and 34°53´W (Figure 1). Its limits are the municipal districts of Vicência (north) and Itapissuma (west), Igarassu (south), and the Atlantic Ocean (east). It is separated from the continent by a geological fault designated *Santa Cruz* because it is located in the channel of the same name.

The Santa Cruz Channel is an elongated U-shaped channel that is connected to the south Atlantic ocean at both ends. It receives fresh water from six small rivers with a combined fresh water discharge of 1 m^3/s in the dry season and 56 m^3/s in the rain season (Medeiros and Kjerfve, 1993 and 2005).

At the southern end of the island, there is a sandy bank designated *Coroa do Avião* (Crown of the Airplane, Figure 2). This sandy bank is 560 m long and 80 m wide. The origin of this sandy bank is linked to coastal transport. The sediments transported by coastal drift find a hydraulic barrier formed by the currents flowing from the southern mouth of the Santa Cruz channel. Thus, the sediments originating from alongshore transport are deposited, adding sediment to the *Coroa do Avião*. To the east of *Coroa do Avião* stand other minor banks of sand that experience constant current changes because of the hydrodynamic processes of this area.

Sandy sediments formed predominantly of quartz do not reach the beaches of the island but accumulate at the limit of the flow discharge at the southern mouth of the Santa Cruz channel. The line of beach rocks parallel to the coast also contributes to the fact that the sandy sediments do not reach the platform edge (Lira, 1992).

Over the last 20 years, the island of Itamaracá has been subjected to more dynamic use and occupation. The urban and rural activities on the island have had an important impact on the social and economic development of the region. In the coastal areas, urban activities prevail over rural ones. Tourism has motivated increasing occupation of extensive areas for recreation, and this motive is the main cause of the urbanization of Itamaracá island (Morais, 2000).

The occupation of the seafront, mainly related to tourist activity, is creating a parallel urbanization axis on the coast. This occupation of the coastal area is occurring with great speed and in a disordered way, increasing problems such as erosion and sedimentation in many parts of the beaches.

The Urbanization Development Degree (UDD) for the coastal area of the municipal district of Itamaracá was determined by Morais (2000), using the parameters defined by Esteves and Finkl Jr (1998), according to the criteria shown in Table 1.

Table 1 – Parameters used for determination of Urbanization Development Degree (UDD).

Urbanization Development Grade (UDG)	High, > 60% coastal area occupied
	Intermediate, >30% and < 60% coastal area occupied
	Low, < 30% coastal area occupied

According to Morais (2000), the occupation of the land of the Itamaracá coastal area is linked directly to the Urbanization Development Degree, according to Table 02.

The coastal area of Itamaracá Island is sheltered by a line of beach rocks (Figure 1)

Table 2 – Extension and urbanization at the beaches of the island of Itamaracá.

Beach	Area (m2)	Urbanization area (%)	UDD
Forte Orange	1.239.969	16	Low
São Paulo	1.282.320	54	Intermediate
Forno da Cal	2.115.665	42	Intermediate
Pilar	1.513.214	62	High
Jaguaribe	520.131	72	High
Sossego	1.445.816	6	Low

parallel to the coast and locally called 'mar-de-dentro' or 'the inside sea' (Kempf, 1967–1969).

Chaves (2000) studied recent beach rock cementation mechanisms at Itamaracá Island and proposed a model that suggests that the origin of the beach rocks is related to the amount of sand deposited on and removed from the beach area.

MATERIAL AND METHODS

Topographic profiles

The purpose of the beach profile is to define the morphology of the beach to determine the response of this environment to wave dynamics. These profiles supply information about the main factors that control the profile gradients, such as waves, sediments, and wave–sediment interactions. Beach profiles vary seasonally and as the wave climate changes over the long term, in response to the pressures of erosion and accretion. Taking a series of profiles along a beach and repeating this profile measurements allows us to determine the behavior of the entire beach in terms of shoreline recession and volumetric sand loss.

The methodology used to obtain the beach profiles was optimized by Emery (1961) and is commonly applied in studies of coastal dynamics. The profiles were always drawn at low tide, and their locations were defined by the varied morphological characteristics of the several beaches that compose Itamaracá island.

The benchmarks (BM) of the profiles were established in places of easy access. The absolute altitude was calculated with the software Maré based on the maximum tide when the shoreline reached the highest part of the beach. The geographic coordinates used are the Universal Transverse Mercator (UTM) coordinates in the 25M zone. The volume of sediments was calculated with the software Surfer based on the different results of the topographic profiles, with the month of November 2003 used as the reference. The results are expressed in cubic meters per linear meter (m^3/m).

Along the coast of Itamaracá island, six beaches were chosen for the systematic topographical measurements in monthly basis from November 2003 to October 2004. The six beaches were selected for the study based on the variations between erosion and sedimentary deposition.

RESULTS

All the beaches studied in Itamaracá island have shallow gradients (2° to 5°) and are composed of fine sand-sized material. The beaches are dissipative, according to Wright and Short (1983). Figure 03 shows the results of the studied topographic profiles. From south to north, they are: Fort Orange (01), São Paulo (02), Forno da Cal (03), Pilar (04), Jaguaribe (05), and Sossego (06), a total of six stations (Figure 1).

Profile 1: Fort Orange beach

The benchmark (BM) of Profile 1 is located at latitude 9136149 N and longitude 0297122 E (UTM – 25M) at the base of the Fort Orange south wall (Figure 4A). The beach gradient is 3° and the BM is 3.165 m. The profile direction is 165 Az.

The beach envelope presents a complex configuration, with significant variations among the profiles drawn over 12 months. In the first six months of sampling, the morphology of the beach alternated between months of erosion and months of deposition. In the last six months,

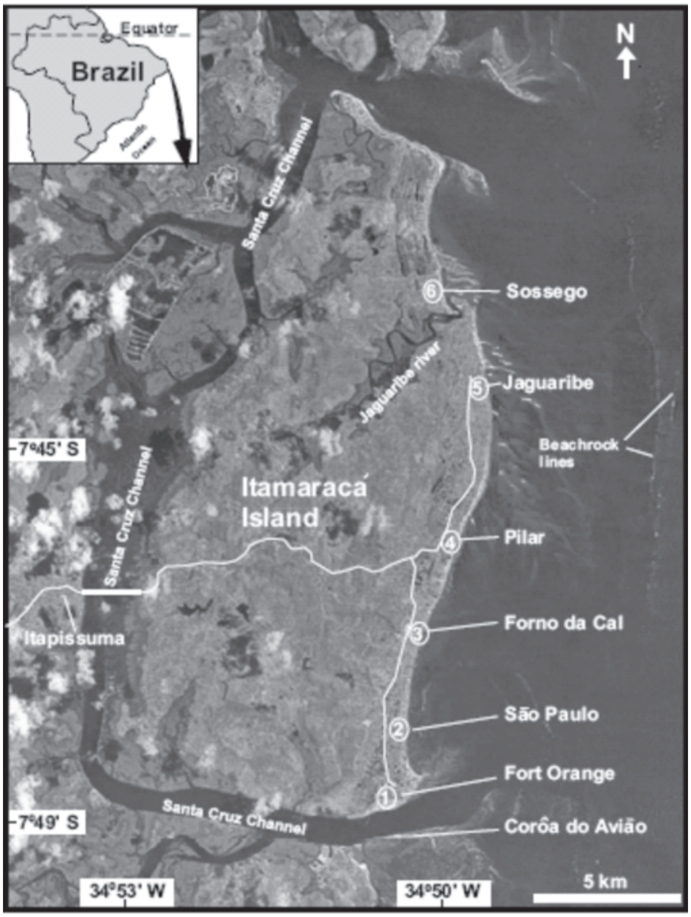

Figure 1 – Itamaracá island and location of data collect stations.

the erosive action was outstanding in June, shortening the beach profile. In October, it changed to depositional processes. The sedimentary balance calculated for the period of 12 months had a positive value of 15.18 m^3/m, which confirms that the deposition of sediments is greater than their erosion on Fort Orange beach (Figure 3 A). There are many free blocks of rock in front of the Fort wall

Profile 2: São Paulo beach

Profile 2 is located at latitude 9140259 N and longitude 0297959 E (UTM – 25M) on a rock edifice (Figure 4B) in front of the Iate Club of Itamaracá. There are also many free blocks of rock in front of the artificial platform that was built to protect the club. The beach gradient is 4° and the BM is 1.33 m.

The profile direction is 130 Az. The beach of São Paulo suffered intense erosive processes during the first six months of sampling. The strong erosive activity was quite evident, produced by the continuous action of waves that reached directly to the beach face, because of this problem the profile was very narrow. During the months

Figure 2 – Coroa do Avião *(Crown of the Airplane), Itamaracá, Pernambuco. Now, base of studies of Federal Rural University of Pernambuco. Island sandbank formed in the last 50 years. See localization in Figure 1.*

of May to October 2004, the erosive activity on the beach was still apparent. In August, the profile was very narrow, because of the activity of the high tide, which practically covered the whole beach face. The sedimentary balance at São Paulo beach calculated from 12 months of sampling data was negative, in the order of – 42.72 m^3/m, confirming the tendency to erosion (Figure 3 B).

Profile 3: Forno da Cal beach

This profile is located at latitude 9141759 N and longitude 0298448 E (UTM – 25M) at a distance of 3 km north of Profile 1 (Figure 4C). The benchmark (BM) is located in front of a house built in the berm area. A wide sandy beach 100 m wide is observed, with a steep sloping berm at the shore face. The beach gradient is 2° and the BM is 3.185 m.

In the months of November, December, February, March, and April, the behavior of the sedimentary package showed some alternation of deposition and erosion. In January, erosive activity was verified on the berm. This was associated with the rains of January, which moved the sediments from higher parts of the beach toward the foreshore area. In May and September, there were more expressive sedimentation deposits, but in October, the wave action was great enough to cause erosive activity. Thus, the sedimentary balance on Forno da Cal beach was negative, at –7.71 m^3/m (Figure 3 C).

Profile 4: Pilar beach

Profile 4 is located at latitude 9144033 N and longitude 0298790 E (UTM – 25M). A street has been built between the houses and the beach, limiting the backshore zone

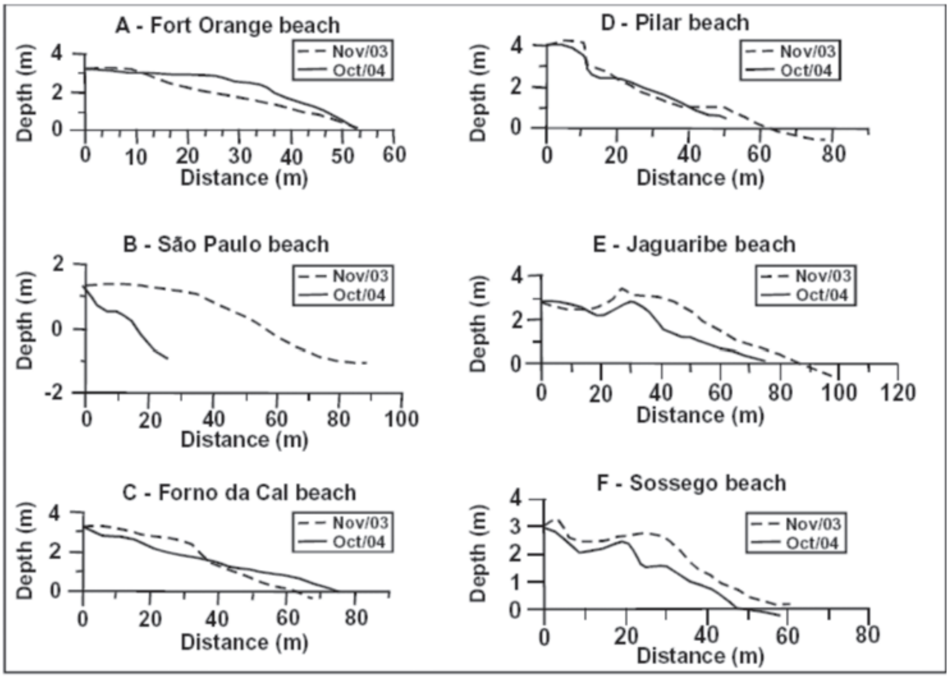

Figure 3 – Beach profiles studied at the Itamaracá island in November of 2003 and Octuber 2004. A: Forte Orange, B: São Paulo, C: Forno da Cal, D: Pilar, E: Jaguaride, F: Sossego.

(Figure 4D). The beach gradient is 3° and the BM is 3.955 m.

More erosive activity was observed in March and a period of depositional processes in February. In July, intense depositional activity was observed along the whole extent of the profile, whereas during the other months, erosion and deposition were almost balanced. The sedimentary balance of Pilar's beach is negative, but it is very subtle, at just –14.1 m^3/m, showing linear descent (Figure 3 D).

Profile 5: Jaguaribe beach

Profile 5 is located at latitude 9145369 N and longitude 0298542 E (UTM – 25M) at Jaguaribe beach. Similar to Profile 3, this is a sandy beach 110 m wide, with a steeply sloping berm at the shoreface (Figure 4E). Coastal vegetation occurs on the berm. The beach gradient is 3° and the BM is 2.81 m.

At station 5, the berm was stable with coastal vegetation in all the months studied. However, particularly in the month of January, a decrease in the longitudinal profile was confirmed, which modified the higher part of the profile. During the months of May to October, the beach profile was altered with displacement of the sandy banks along the foreshore area. February 2004 was the period with the largest amount of deposition, at 31.23 m^3/m, and the month of January had strong erosive activity of –36,5 m^3/m. This result for January was probably associated with the rains in that month, which were very intense for the whole coast of the State of Pernambuco. The negative sedimentary balance for

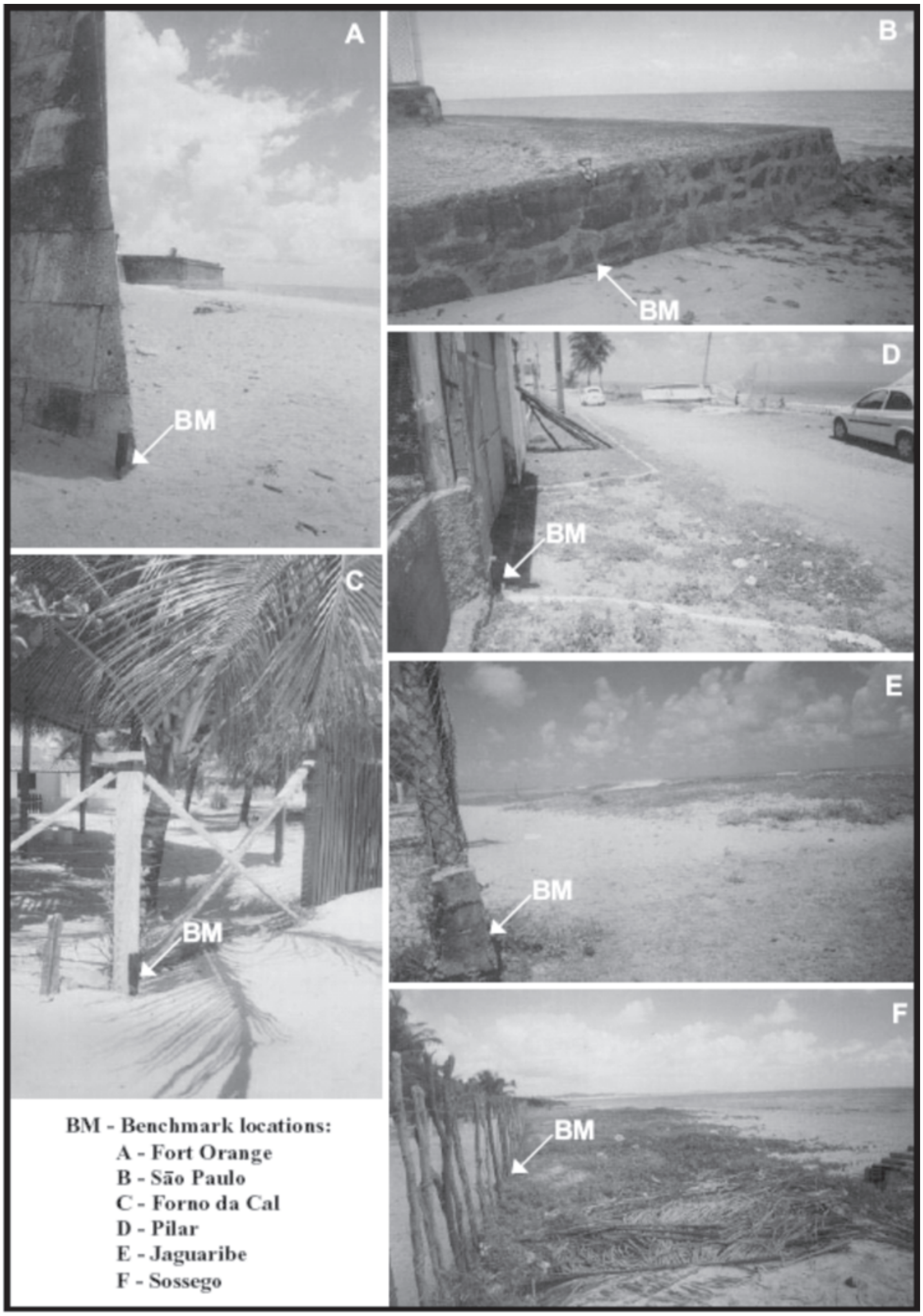

Figure 4 – Location of the stations in the studied beaches of Itamaracá island.

Jaguaribe beach confirms that it is subject to erosive processes. During the study period, the sedimentary balance was in the order of –54.53 m^3/m (Figure 3 E).

Profile 6: Sossego beach

This profile is located at latitude 9146294 N and longitude 0297957 E (UTM – 25M) at Sossego beach, north of Itamaracá island (Figure 4F). This is also a wide sandy beach, 110 m wide, with coastal vegetation on the berm. The beach gradient is 5° and the BM is 2.90 m.

The morphology of this profile presents a stable berm and several sandy banks in the area of the underwater beach (Figure 1). Only in January did this area suffer erosive activity. In May and June, the morphology changed from a depositional phase to an erosive phase. The sedimentary balance of Sossego beach was –30.49 m3/m, characterizing an erosive tendency for this area (Figure 3 F).

The distribution pattern of sediments on each beach displays a constant behavior of erosion or deposition, but the complexity of the beaches and their different processes have influenced their morphologies.

Table 3 shows that the beach profiles present independent morphodynamic behaviors. In other words, the erosion or deposition observed in one profile is not repeated in the other profiles. Only in August was it possible to verify an erosive pattern for all the beaches studied.

The whole sedimentary balance calculated for Itamaracá island was negative, at –133.37 m^3/m for all of the beaches during the period oh this study. Overall, the beaches are impacted by erosion processes. The beaches are constituted of quartz sands. In the Fort Orange and Sossego profiles, halimeda grains and fragments of mollusks were observed, perhaps related to the proximity of the southern mouth of the Santa Cruz Channel

Table 3 – Sediment deposition or erosion at the six studied beaches in the island of Itamaracá.

	Forte Orange	São Paulo	Forno da Cal	Pilar	Jaguaribe	Sossego
Nov/03	Reference	Reference	Reference	Reference	Reference	Reference
Dec/03	Erosion	Erosion	Deposition	Deposition	Deposition	Deposition
Jan/04	Erosion	Deposition	Erosion	Deposition	Erosion	Erosion
Fev/04	Deposition	Erosion	Deposition	Deposition	Deposition	Deposition
Mar/04	Deposition	Deposition	Erosion	Erosion	Erosion	Erosion
Apr/04	Erosion	Erosion	Deposition	Deposition	Deposition	Deposition
May/04	Erosion	Deposition	Deposition	Erosion	Deposition	Deposition
Jun/04	Erosion	Deposition	Erosion	Erosion	Erosion	Erosion
Jul/04	Deposition	Erosion	Deposition	Deposition	Deposition	-
Aug/04	Erosion	Erosion	Erosion	Erosion	Erosion	-
Sept/04	Deposition	Deposition	Deposition	Deposition	Erosion	-
Oct/04	Deposition	Erosion	Erosion	Erosion	Erosion	-

and the Jaguaribe river, respectively. The rigid structures, especially those built perpendicular to the beach, hind the northward transport of sediment.

CONCLUSIONS

The beaches of Itamaracá island have shallow gradients (2° to 5°) and are composed of fine sand-sized material. The coastal drift on these beaches is from south to north. On some beaches, rigid structures have been built perpendicular to the shoreline by house owners, without technical supervision. These rigid structures hinder the northward displacement of sediment. Alongshore drift, river influxes, and sand supply from the sea have made only a small contribution to the sediments of the beaches of Itamaracá Island. Factors associated with the occupation of the beach areas and the interventions made to the south of the Island "to contain the coastline retreat" are also responsible for aggravating the erosion of some beaches.

These beach profiles of Itamaracá island indicate that between November 2003 and October 2004, the beaches were submitted to erosion. Analysis of future data (what type of data?) should indicate whether these beaches experience more erosion in the winter and whether sand is being accreted back onto the beach during the summer. The erosion of the beaches of Itamaracá island may take the form of long-term losses of sediment or merely the temporary redistribution of coastal sediments. Long-term data should provide a variety of information, including whether there is a net gain or loss of sand over the years, what impact storms have on the beaches, and how seawalls and other engineering structures affect the beaches.

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