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# Analysis of the coastal and environmental hydrodynamics of the Areia Preta beach in Natal/RN

# Análisis de la hidrodinámica costero y ambiental de la playa de Areia Preta en Natal/RN

# Análise da hidrodinâmica costeira e ambiental da praia de Areia Preta em Natal/RN

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## Abstract

The objective of this work to understand the causes of coastal erosion through characterization of environment, determining beach profiles and hydrodynamic analysis, with the main methods for understanding coastal process. The spatial clipping of this research comprises a point, located on the urban beach Areia Preta, zone east of the city of Natal, capital of Rio Grande do Norte eastern coast of the state. A methodology consisted of bibliographic survey, environmental characterization, topographic survey transverse to the beach in the compartments of the post-beach foreshore and ante-beach through the methodology of "Stadia" Birkemeier (1918) and data collection method hydrodynamics based on the methodology of the Mueher (2011), and addition to records photographs.

**Keywords:** Coastal erosion; Areia Preta /RN; beach profile; hydrodynamics analysis.

## Resumen

Este trabajo tiene como objetivo comprender las causas de la erosión costera a través de la caracterización del ambiente de playa, determinando perfiles de playa y análisis hidrodinámico como principales métodos para comprender los procesos costeros. El foco espacial de esta investigación es un punto ubicado en la playa urbana de *Areia Preta*, costa este de la ciudad de

Natal, capital del Estado de Rio Grande do Norte. La metodología científica aplicada consistió en estudio bibliográfico, caracterización ambiental, levantamiento topográfico transversal a la playa en los compartimientos *backshore, foreshore* y *foreshore*, utilizando la metodología *Birkemeier "Stádia"* (1981) y recogida de datos hidrodinámicos respaldados en la metodología de *Mueher* (2011), además de registros fotográficos

**Palabras clave:** Erosión costera; Areia Preta/RN; perfil costero; análisis hidrodinámico.

**Resumo**

O objetivo desse trabalho é buscar compreender as causas da erosão costeira através da caracterização do ambiente praial, determinando perfis praiais e análise hidrodinâmica, com os principais métodos para compreender os processos costeiros. O recorte espacial dessa pesquisa compreende um ponto, localizado na praia urbana de Areia Preta, zona leste da cidade do Natal, capital do Rio Grande do Norte, litoral oriental do estado. A metodologia consistiu de levantamento bibliográfico, caracterização ambiental, levantamento topográfico transversal à praia nos compartimentos do pós-praia, estirâncio e antepraia, através da Métodologia da "Stádia" Birkemeier (1981) e coleta de dados hidrodinâmicos baseado na metodologia de Mueher (2011), além de registros fotográficos.

**Palavras-chave**: Erosão costeira; Areia Preta/RN; perfil praial; análise hidrodinâmica.

## Introduction

The coastal zone (CZ) is a dynamic space and is in constant transformation, resulting from the interaction of natural processes and also from the impacts of human action. Several ecosystems that change between mangroves, beaches, dune fields, estuaries, among other environments, make up this spatial cut. Thus, the ZC is considered an environment of significant natural wealth (DIAS E OLIVEIRA, 2013, p. 372).

Since the middle of the 20th century, the coastal zone has been seen as the area where there is the greatest population concentration and the most intense appropriation of its natural resources. This pressure causes several problems, among which coastal erosion stands out, causing damage both to the environment and to local human activities. Taveira-Pinto, F., Rosa-Santos, P., Fazeres-Ferradosa, T. (2021), say that: The consequent anthropogenic pressures, motivated by the various socioeconomic activities, favored the expansion of the instability of coastal habitats and ecosystems, promoting the expansion of coastal erosion.

Coastal erosion is a global phenomenon, intensified by the action of winds, waves, tides and other forces of nature, in addition to being affected by anthropic activities that increasingly weaken the environment (OLIVEIRA, 2017). For Morais (2009), the expansion of the urban area in the coastal environment has stimulated significant changes in the geomorphology and dynamics of its processes, contributing to spread relevant impacts to the natural environment. Upward urbanization in these environments has led to new forms of consumption, causing strong pressure on all ecosystems (MORAIS, 2009).

The importance of this work resides in the fact that the advance of the sea brings social and economic inconveniences to coastal populations. In this way, monitoring through research is established as an adequate tool to monitor and establish guidelines and preventive tools against the advance of the sea.

Given the above (Muehe, 2006), he speaks of the need to develop a specific diagnosis for each situation, whose objective is to point out the causes, so that mitigating and coastal management measures can be taken. Well, according to Birth. D.R (2020), the protection of the coastal zone, its proper use as well as respect for monitoring must be in the conscience of specialists, politicians and its residents and visitors. It is noted that the lack of sensitivity, inspection and inadequate appropriation of the coastal environment compromise its balance, causing impacts that may be irreversible (BAPTISTA, M., & BERNARDES, D. 2021).

In this perspective, some works were carried out in Natal, highlighting the works of Diniz (2002), Cunha (2004), Araújo (2006), Nunes (2008), Nunes (2011), Nunes (2012), Chacon (2013), Medeiros (2015) and Maciel et al. (2016) among others.

One of the problems that affects the coastal zone around the globe is coastal erosion. In Brazil this phenomenon is no different, there are beaches with very severe erosion processes which require emergency recovery or containment measures

(SOUZA, 2009). Natal-RN is also no exception to this reality, there are many beaches that are subject to erosion processes. The causes of this erosion in many stretches of the coast of the state, as pointed out by Vital et al (2006), are related to the reduced fluvial input of sediments and the loss of sediments to the mainland. However, the integrated management policies for coastal zones in Brazil are still in the initial stages, whether in relation to the problem and its causes, territorial planning, coastal containment/protection works (structural or not), project financing or to studies of scenarios that can guide investments (SOUZA, 2009).

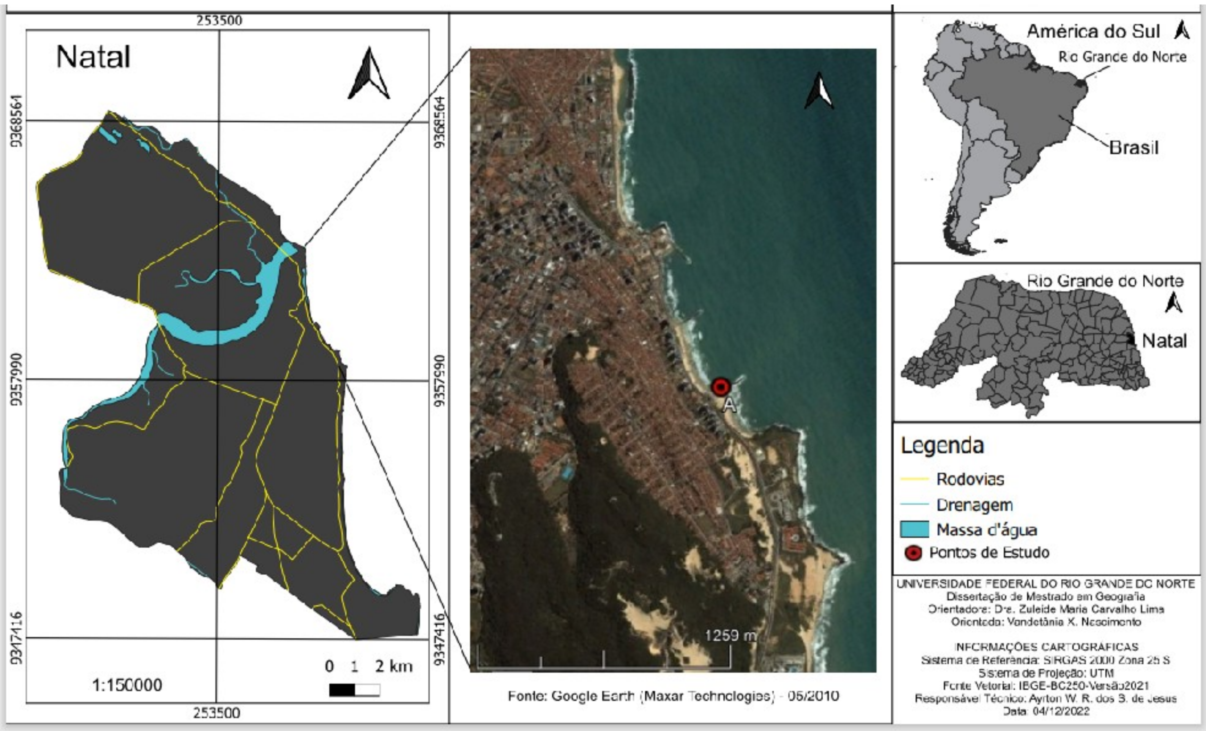
The objective of this work is to seek to understand the causes of coastal erosion through the characterization of the beach environment, topographic survey and hydrodynamic analysis, these being the main methods used here to understand coastal processes, having as universe of this research the beach of Areia Preta, located in Natal, capital of Rio Grande do Norte.

According to Lima (2013), the coastal zone of Natal/RN presents vulnerability linked to environmental changes caused by natural and anthropogenic factors. Thus, by comparing the data collected in February, June and October 2022, it was possible to analyze the coastal dynamics and its causes and consequences.

**Characterization of the study area**

The area under analysis is located on the eastern coast of the state of Rio Grande do Norte and comprises the urban beach of Areia Preta, located between the coordinates 5º 47'28.54 South latitude and 35º 11'10.95'' West longitude in the zone east of the city of Natal, (map 1).

Map 1- Areia Preta Beach – Natal - RN




Source: prepared by Ayrton W.R dos S de Jesus, 2022. Based on the IBGE-BC250 database - 2021 version. Fonte:

The climate of the area is the Tropical type, with an average annual temperature above 26°C and low annual amplitude (NIMER, 1989), the precipitation index varies between 700 mm and 1500 mm (EMPARN, 2017), with a rainy season influenced by the displacement of the ITCZ (Intertropical Convergence Zone) between May and June, and intense drought between the months of September and December. According to Vital et al (2006) and Amaro et al (2021), in this sector of the Brazilian coast, changes in the coastline are dominated by waves and modified by tides, originating reflective and intermediate beaches. The prevailing winds in the study area have a southeasterly direction for most of the year, followed by easterly winds (Cunha, 2004).

The geology of this area is marked by tertiary-Quaternary deposits of the Barreiras Formation, ferruginous sandstones, beach sandstones, eolic and marine sediments. The Tertiary-Quaternary deposits of the Barreiras Formation are constituted, according to Cunha (2004), by layers of clastic deposits, with diversified granulometry between quartz pebbles and consolidated sands with varied colors.

Another characteristic of these rocks that make up the Barreiras formation, according to Maciel (2020), are a reddish color with ferruginous cementation and weak diagenesis, with horizons that can expose oxidation-reduction. Specifically in the study area, the geological deposits of the Barreias Formation are highlighted (ferruginous sandstones, beach sandstones and eolic and marine sediments).

On the coast of Natal, according to Cunha (2004 Apud Nunes, 2011), the predominant vegetation is composed of 3 strata: herbaceous, shrubby and arboreal species. It can be said that these formations are of the secondary type since the original vegetation was destroyed by man. Currently, the vegetation is composed of cultivated plants combined with little regeneration of natural vegetation.

According to Alves (2009), the vegetation found on the dunes and beaches has a predominance of creeping formations settled on quartz and marine sediments such as herbaceous species: (beach parsley) Ipomea pescaprae, (sand grass) Panicum racemosum, (goat beard grass) ) Sporobolus virginicus, and (pirrixiu) Iresine porucaloides. While low-sized vegetation is found in past dunes such as (jatobá) Hymenaea sp, (imbaúba) Cecropia sp, and (pau-darco) Caesalpina sp etc.

In the study area, the present vegetation is composed of undergrowth such as (beach parsley) Ipomea pescaprae, (sand grass) Panicum racemosum, (pirrixiu) Iresine portucaloides, in addition to (coconut trees) Cocos nucifera L and (castanhola) Terminalia catappa.

**Methodological and technical procedures**

The methodology consisted of three stages, pre-field, field and cabinet. In the pre-field stage, a bibliographical survey was carried out, definition of the monitoring point and data collection about the area. In the field stage, environmental characterization was carried out, cross-beach topographic survey in the backshore and foreshore compartments, using the Birkemeier "Stádia" Methodology (1981) (panel 1). The collection of hydrodynamic data was also carried out based on the methodology of Mueher (2011). Images from Google Earth (Maxar technologies) were used, with reference system SIRGAS 2000 Zona 25S projection system: UTM vector source: IBGE-BC250- 2021 version and photographic records.

The field stages were held on February 2, June 16 and October 24, 2022 on Areia Preta beach, during full moons and new moons (high tide). The topographic profile was carried out at the point denominated as point A. This profile was chosen because this point is located before an artificial promontory (spike) that dampens the strength of the coastal current favoring the deposition of sediments in the impact with the spigot, which works as protection.

**Panel 1 -** Topographic profile (A); wave height (B); Wave period (C) current velocity (D)**.**


Source: Author's field file. Photos: Nascimento, (February to June 2022).

For the data analysis of the results of the profiles, the differences in level between the points were used, which were measured through readings in horizontal sights with a topographic level and a ruler, then these data were processed in the Excel software, the quotas of the targeted points were calculated. and made the graphics.

To measure the wave height, Thales' theorem was used based on the similarity of triangles. Twelve consecutive waves were measured, the two most discrepant waves were eliminated and the arithmetic mean of the remaining values was obtained. To measure the wave period, a stopwatch and two beacons were used. An observer looks at the two beacons and counts 10 periods of 11 waves, then eliminates the highest and lowest value of the period and calculates the arithmetic mean of the remaining values. To carry out the calculations of the speed of the coastal current, the formula of Bonjorno and Ramos (1992) was used, ◎V=◎S/◎T, where ◎V corresponds to the speed, ◎S is the variation of the course and ◎T is the time variation.

**Results and discussion**

The practical work began with the environmental characterization, where we observed the presence of frontal dunes on strong anthropic densification initiated according to Silva (2016), since the 20th century, causing the waterproofing of the natural system of natural drainage and subsurface of rainwater. This anthropic densification over areas of ancient dunes that influences the flow of rainwater has interfered with leaching. The lack of adequate sewage has led to pollution of the beach environment in all compartments, which during the most intense rains can cause the collapse of barriers and dunes at a given time, making the beach unsuitable for bathing.

In the study area itself, the existence of natural and artificial headlands (spike) was verified (panel 2), the latter has generated a great anthropic interference in the three compartments of the beach, post-beach, foreshore and foreshore. Anthropogenic interference is also related to the strong presence of bathers and traders.

Panel 2- Natural and man-made headland.


Source: Author's field file. Photos: Nascimento, (jun, 2022).

The backshore presented a variation of the extension of its width of 7.5 m. February having its greatest width of 20 m and the smallest in October with 12.5 m. As for the vegetation found, it is characterized by the presence of grasses, beach grass, coconut trees and others. In relation to the sediments seen in the post-beach, they were of medium granulometry, with the presence of heavy minerals identified only in the month of October. It was also noted the presence of trash cans distributed along the beach, even so, polluting materials such as plastic, glass and organic waste were found. It was noticed that the post-beach compartment is quite small, even so, the existence of many social dynamics was visualized (tents, commerce, signaling and also widely used for sports activities).

The pulley presented a variation of 25.2 m in the extension of its width, with its maximum width in the month of October with 70 m and the smallest in the month of June with 44.8 m. The inclination of this compartment varied between 3 and 5 degrees. In relation to the sediments of this compartment, it is possible to affirm that in the three months observed, the sediments had medium granulometry presenting heavy minerals. We also identify polluting materials such as plastics and organic waste. Spreading line and runoff marks (striations and gutters) were also visualized. Runoff marks form from surface erosion caused by a thin stream of water flowing over sandy sediments (MENDES, J.C, 1984). Another observation was the presence of ferruginous sandstones from the Barreiras formation, which undergo erosive processes and form potholes that present living organisms as shown in (photo. 1). On the foreshore, the sediments identified were of fine granulometry. The anthropic interference is due to the spike and the waves of the plunging type.

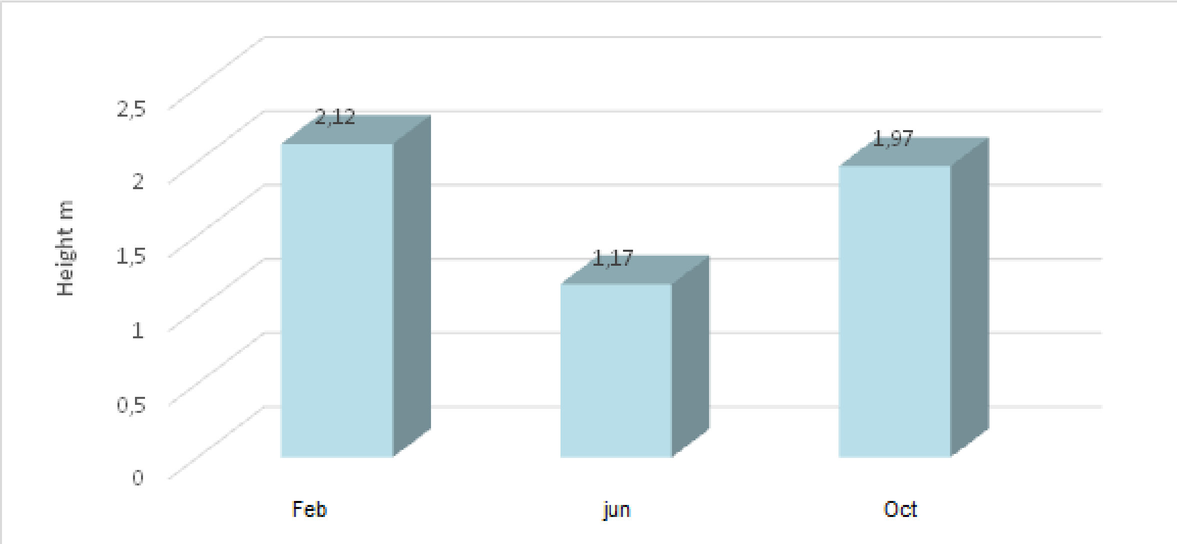
Photo 1 - Ferruginous sandstones with potholes (erosive features).

Source: Author's field file. Photos: Nascimento, (jun, 2022).

Through the analysis of data referring to the three fields studied, a parameter was defined to characterize the beach environment. Likewise, we analyzed the hydrodynamic data for comparison.

The wave height is a parameter that represents the wave energy to be dissipated in the strand. This height depends on the strength of the wind blowing over the marine aquatic mass towards the beach and the morphological typology of the sea floor. In the months studied there was a variation in wave height. In February and October, the wave height presented a value of around 2 (two) meters, while in June this value was reduced by half, as shown in (graph 01). This is due to the seasonality of the coastal wind regime in the RN, which in February and October is more intense. (INMET, 2022).

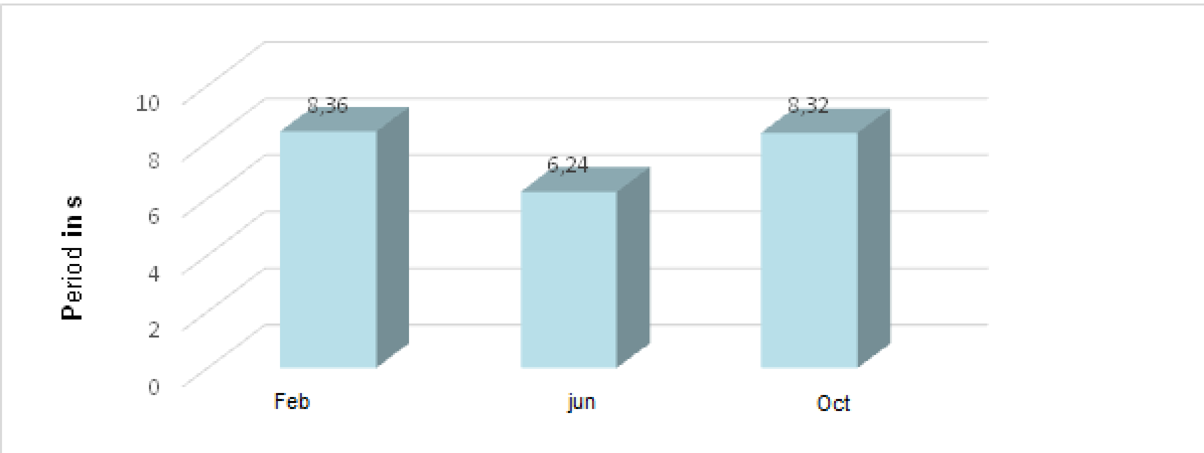
Graph 1- Wave height at point A- Areia Preta beach




Source: Author's field file. Nascimento, (jun, 2022).

The wave period is influenced by the speed and direction of the winds, favoring the understanding of the intervals and distances of the generation of longitudinal waves. In the three months of the study, the period of the waves showed a low change, with values in the range of 6 to 9 seconds, as shown in (graph 2). The shortest wave period is registered in June, due to a low intensity in the frequency of the winds, as mentioned in the previous topic. This month it becomes evident that the lower the wave height, the slower the transition from one wave to the next.

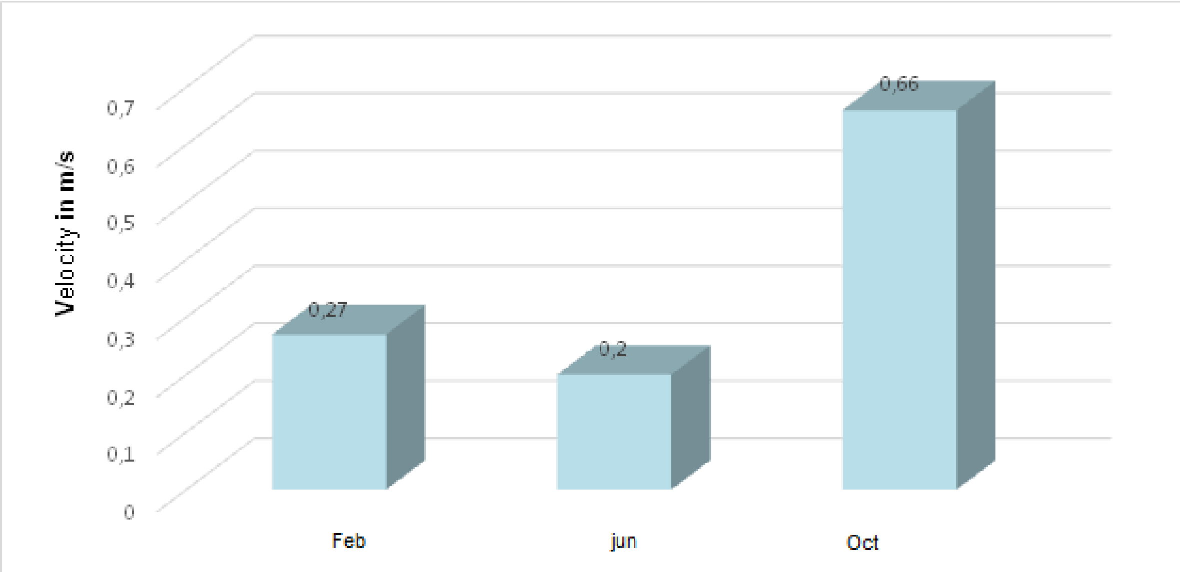
Graph 2 - Period of wave point A- Areia Preta beach




Source: Author's field file. Nascimento, (jun, 2022).

The current velocity, as shown in (graph 03), was lower in the months of February and June, reaching a minimum velocity of 0.27 m/s and 0.2 m/s, respectively. This indicates that in these two months there was less sedimentary transport, while in October the current was faster, showing greater sedimentary transport.

Graph 3 - Current velocity point A- Areia Preta beach

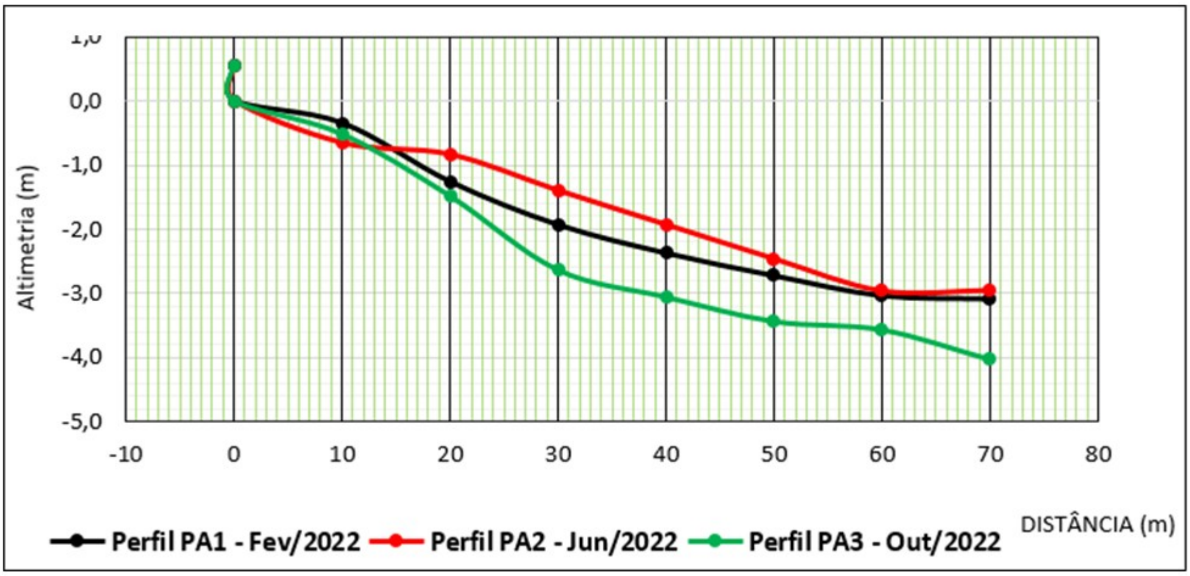



Source: Author's field file. Nascimento, (jun, 2022).

Taking as a reference the analysis of the beach profile to understand how the process of entry and exit of sediments along the beach takes place, showing erosive characteristics or not (COELHO, Victor Hugo Rabelo et al 2012). Thus, the beach profile is considered by (Chaves, 2000) as the result of the interaction between wave action and coastal drift currents, and the volume of sediments, as well as its granulometry. Beach profiles change over time, either seasonally as the wave climate changes, or for longer periods, in response to erosion or deposition pressures (Chaves, 2005).

The purpose of creating a profile in this work was to understand the process of erosion and deposition, making it possible to compare them according to the period of each one, based on the month of February, as shown in (graph 4).

Graph 4 - Topographic profiles steps 1-2-3 point A




Source: Author's field file. Nascimento, (jun, 2022).

It is noticed that there was a significant change in the profile when comparing the months of February and June with October, in this month beach erosion was greater. The profile results, shown in (graph 4), are in accordance with the classic results evidenced in Bascom, (1953) and Shepard and Inman (1950), as cited by Carvalho, B. C (2019), where it is said that waves with less energy contribute to the formation of the berm and progradation of the beach face towards the sea, forming a steeper profile. In Graph 04 it can be seen that in June the slope on the beach face was higher, which corroborates the wave height data shown in (Graph 1). The wave height in June compared to February and October was the one with the lowest value (lower energy) compared to the other months studied. It is known that more energetic beaches have erosive tendencies, which may locally lead to material and social damage.

## Final considerations

The present research showed how a field research in coastal geomorphology is carried out, conducted through environmental characterization, hydrodynamic analysis and analysis of the beach profile, collected in three different periods.

In the three fields, a significant amount of polluting materials was identified in the backshore and foreshore, evidenced by the presence of traders and beach users. Great anthropic interference resulting from the installation of the spike. Sandstone beaches with marmites (erosive features). We verified that changes in the profile are related to seasonality and that waves with less energy contribute to the formation of the berm and progradation of the beach face towards the sea, forming a steeper profile.

Finally, this research is configured as a set of information that can serve as a basis for environmental managers in ordering and planning the coastal environment affected by erosion problems, since the disorderly use and appropriation of this environment can cause environmental instability that it can often be irreversible.

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Author 1: Elaboration, discussion of results, bibliographic research, text review.
Author 2: Research orientation, Selection of materials and final analysis of results.