

## ENVIRONMENTAL ANALYSIS AND LEGAL BASES FOR COASTAL AREA EVALUATION: THE SEIXAS BEACH SAMPLE – PB

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**Abstract:**

The present work aims at performing an environmental analysis focused on the current legislation applied to Seixas Beach, located in the southern littoral of João Pessoa city, in the State of Paraíba – Brazil. In this coastal zone as well as in other littoral areas of Brazil and Paraíba, natural processes linked to anthropogenical activities have increased coastal erosion, changing significantly the local scenery. This study identified the eminent necessity of applying technical measures that may promote area conservation or the mitigation of present-day erosive processes. Among the implications of disorderly occupation in this coastal space, we observe marked erosion on the coastline that has caused serious socio-economical and landscape damages. Another characteristic of this littoral zone are the elements of civil infrastructure built on permanent preservation areas, including the Average High Tide Line (Marine Line). This fact violates the current environmental legislation in Brazil and contributes noticeably to the degradation of the area.

**Keywords:** Seixas Beach, João Pessoa, coastal erosion.

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## INTRODUCTION

In most recent decades, the coastal areas in Brazil have been the scenery of countless problems, which have shown, under various aspects, how this environment is unstable, dynamic and susceptible to changes that derive from socio-environmental damages. Such effects, that come to be seen in the landscape caused by the intense urban occupation, which frequently occur not as a result of any study or previous planning, produce the insertion of an environmental pressure for which the area is not geologically prepared.

In the case of Seixas Beach, we aimed to investigate the effects of a series of problems, common to littoral zones, undergone by this coastal environment in the latest years, among which we name: coastal erosion, native beach vegetation degradation, irregular occupation along the coast and engineering works for containment of coastal erosion. Coastal environments tend to be spaces of an intense touristic speculation, mainly because of the attractions and entertainment that these spaces usually offer. Under this perspective, it is important to implant adequate actions of planning and for conservation, in order to mitigate the processes that cause the degradation of these spaces.

In this context, due to the limit stretch between the continents and the oceans, coastal regions come to constitute areas where there is the occurrence of an intense exchange of energy and material from the Earth's crust. These regions have been invaded, in worldly scale, by the rapid population increase, which constitute one of the straightforward consequences of the economic development (Souza and Suguio, 2003).

Thus, coastal areas tend undoubtedly to be propitious spaces for problems caused by coastal erosion. These problems also have been observed in different places in the world, what makes this question a global nature phenomenon, but they are exacerbated in underdeveloped or under developing countries, where environmental legislations are incipient or are not properly applied by the authorities.

According to Muehe (2006), among the most frequent causes of erosion or coastal propagation, there is the alteration in the amount of sediments that are washed over parallel to the coastline. Another approach that has lately been broadly observed points out to the anthropic intervention in the mechanisms that supply sediments to the marine environments, as being the factor that exacerbates and affects intensely the erosive dynamics on the coastal zones. Under this view, Muehe (2006) affirms that the risks of erosion are increased proportionally to the increase of littoral occupation, mainly around the great cities.

Faria (2005) conclude that Brazilian beaches have been eroded due to the anthropic or natural causes, and even a combination of the two, without signs of a

general marine transgression. If the level of the sea is really coming higher, as many European and American scientists are postulating, the effect is not visible yet on the Brazilian coast or there are not sufficient data about it to corroborate the hypothesis on the sea level elevation in Brazil.

Faria (2005) affirmation comes from data collected from the monitoring of 19 distinct beaches on Brazilian littoral, which have not undergone any changes on their coastal profile for the past four decades. This finding is worth observing, because, on Seixas Beach, the anthropic intervention has been the principal exacerbating factor for landscape degradation and for the retention of sediments that should supply the adjacent beaches.

## THE LOCALIZATION OF THE STUDY AREA

Seixas Beach, the far east sector of Brazilian littoral, is located in João Pessoa, the capital of Paraíba State (Fig. 1), covers a geographical mark that involves the most eastern continental point of both Americas, whose limits are defined in the south by Penha Beach and in the north by Cabo Branco Beach.

### Atmospheric Aspects and Oceanographic Pattern

The predominant climate in the area is tropical, hot and humid, typical on northeastern littoral, with relatively high air humidity (average 80%). The rains occur with annual average rainfall that ranges between 1.400 and 1.800mm a year and are more regular during the months of October and in winter, mainly between the months of April and June. During the other months, there is rainfall decrease, but there is no occurrence of dry months. The average temperatures vary from 22°C in winter to 30°C in summer (INPE, 2014).

According to Nimer (1979), the main atmospheric circulation systems that work in this area are: "the Earth Equatorial Forest (MEA), the Intertropical Convergence Zone (ZCIT), the Atlantic Polar Front (FPA) and undisturbed chains of eastern Europe – easterly waves (EW)", where air from the Alisios of SE is predominant. Therefore, the winds of Southeast Quadrant 160° are the predominant generating trains of oblique waves on the coastline, producing with this a chain of littoral driftnets that steers S – N, carrying on a sediment transport to this same direction.

### Geomorphological Characterization

Seixas Beach is a morphological littoral unit present on the geomorphological coastal compartment made of unconsolidated sandy sediments. This sandy material has as its principal source the sandy-clay sediments badly consolidated Barreiras Formation that are found in the rear part of this beach Seixas Beach as well as it

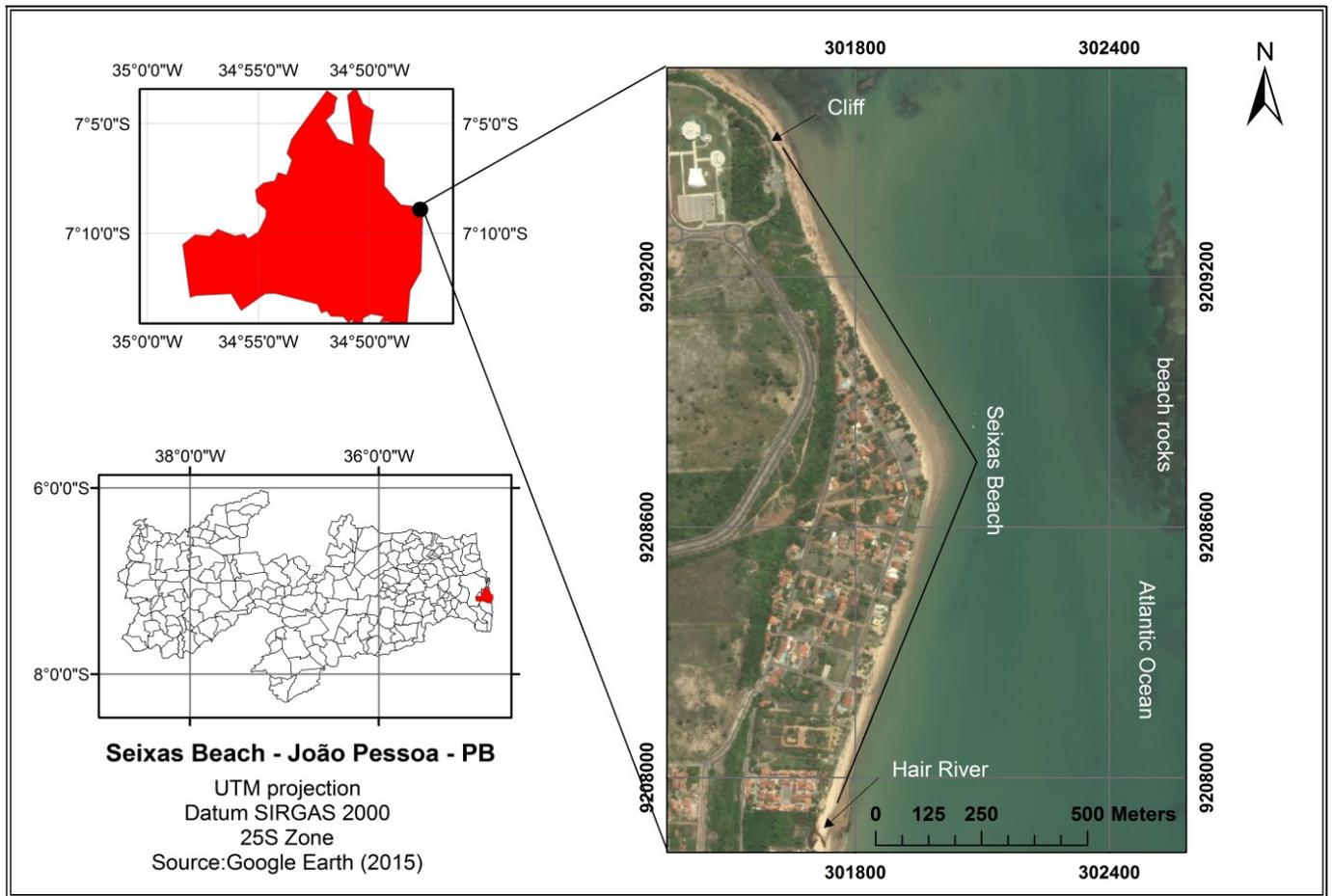


Fig. 1 Geographical location of Ponta do Seixas.

homonym suburb are inserted in marine terraces of Holoceno and, in its sector near the coastline, on the coastal flat land. The formation of the Seixas suburb as a whole is intimately linked to a variation of the sea level in the Holoceno, where the marine apex has reached about 5 meter above the present-day sea level at 5.100AP (Suguio et al., 2005). After maximum transgressive lag, the sea retreated in temporal stages, leaving littoral ridges produced by opportune events. Therefore, all the suburb is settled down on these littoral ridges that were uncharacterized for the planting of streets and houses.

An important aspect of the area geomorphology is the proximity between the Coastal Tableland, formed predominantly by Barreiras Formation, with the Holocene marine terraces, where the suburb is settled. The maximum width between the base of the coastline low plateau is only 300m. This morphology promotes an urban concentration within a fragile geology and unconsolidated sediment environment.

The terraces and flat lands may have several classifications (marine, continental, lacustrine, among others). In the case, the studied area is a marine terrace that extends from the foot of an inactive cliff to the marine flat land, where there is the present-day marine action through waves, tides, and littoral drift current. These shapes of the relief (terrace and marine flat lands)

form a field where natural and anthropic processes have significantly modeled the morphology of the area, producing a landscape vulnerable to socio-environmental risks.

Among the geomorphological units that delimit the sector that covers Seixas Beach (Fig. 2a), there are: the Cabelo River in the south (Fig. 2d), whose outfall is degraded by the presence of constructions, mainly on the bed of the river in the north of the canal (Fig. 2c); and Cabo Branco Cliff in the north (Fig. 2b), that, due to the constant landslides caused by the action of the syzygy tide waves on its foot, has undergone uneventful periods of intervention in the perimeter access.

On the shallow continental plateau (shoreface), in front of Seixas Beach, there is a rocky reef, whose formation is defined by Suguio (1998) as fragments of quartz cemented with calcite, representing a stage of littoral evolution in which, after its formation, may have occurred a coastline retreat. This formation, though many times identified as coral reefs, does not have its origin linked to coral organisms; therefore, it is a typical rocky feature. This rocky morphology affects significantly the wave intervention and dissipation that has the average height of about 0.5 meter in the area (Reis, 2008).

The beach rocks are evidences of paleobeaches, factor that proves how coastal environments are

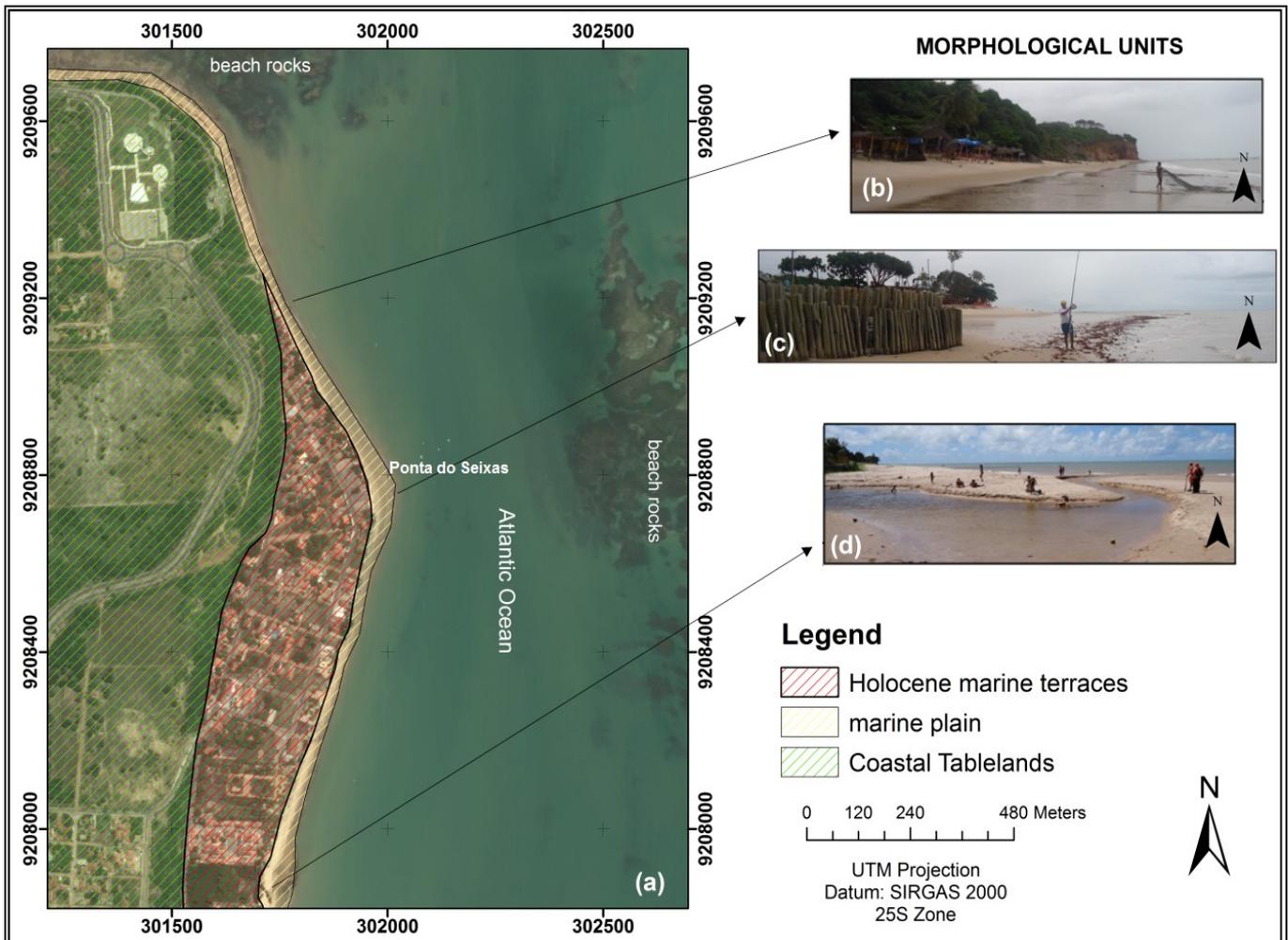


Fig. 2 Main morphological units present in the surroundings of the study area

dynamic and how they have undergone changes over the recent geological time. For Muehe (2006) and Ab’Saber (2005), these formations are propitious sectors for biogenic activities, where coral colonies and calcareous algae may settle down, forming front barriers in relation to the beach, that influence significantly the waves pattern.

It is also important to highlight that the waves work as main modeling agents of coastal morphology, whose action is intensified in the period when there is the association of high syzygy tides (2,7m in the littoral of Paraíba) with strong winds and storm events. In these moments, great modifications in the coastal morphology is observed as well as the intensification of erosive processes.

The morphology of a beach is the reflex of the incidence, size, and interval of the wave trains. The presence of coastal rocks interferes, substantially, in the wave pattern that comes to the beach. Therefore, for a right characterization of the morphology and composition of the beach sediments one should consider the presence or the absence of beach rocks in the surroundings (Fig. 3). On Seixas Beach, the morphology is highly linked to the presence of beach

rocks, what turns the immersed and submerged coastal environment much more complex and dynamic, factors that cannot in any way be neglected in doing any engineering work.

**MATERIALS AND METHODS**

For the development of this work, it was adopted the methodological approach proposed by Libault (1971), who defined the following level of analyses:

- Compilatory: data collect of pertinent requisites for the research, in this case, satellite images, photographic reports, works related to the area and sediment samples;
- Correlatory: step for information comparisons in order to establish significant correlations for the development of the work. In this fase, it is important to verify whether the data are significant or not.
- Semantic: step in which the previous verifications are submitted to analysis by a process of transformation that may help make logical decisions.
- Normative: when the results are shown in the form of models of reality, of planning, environmental characterization, among others.

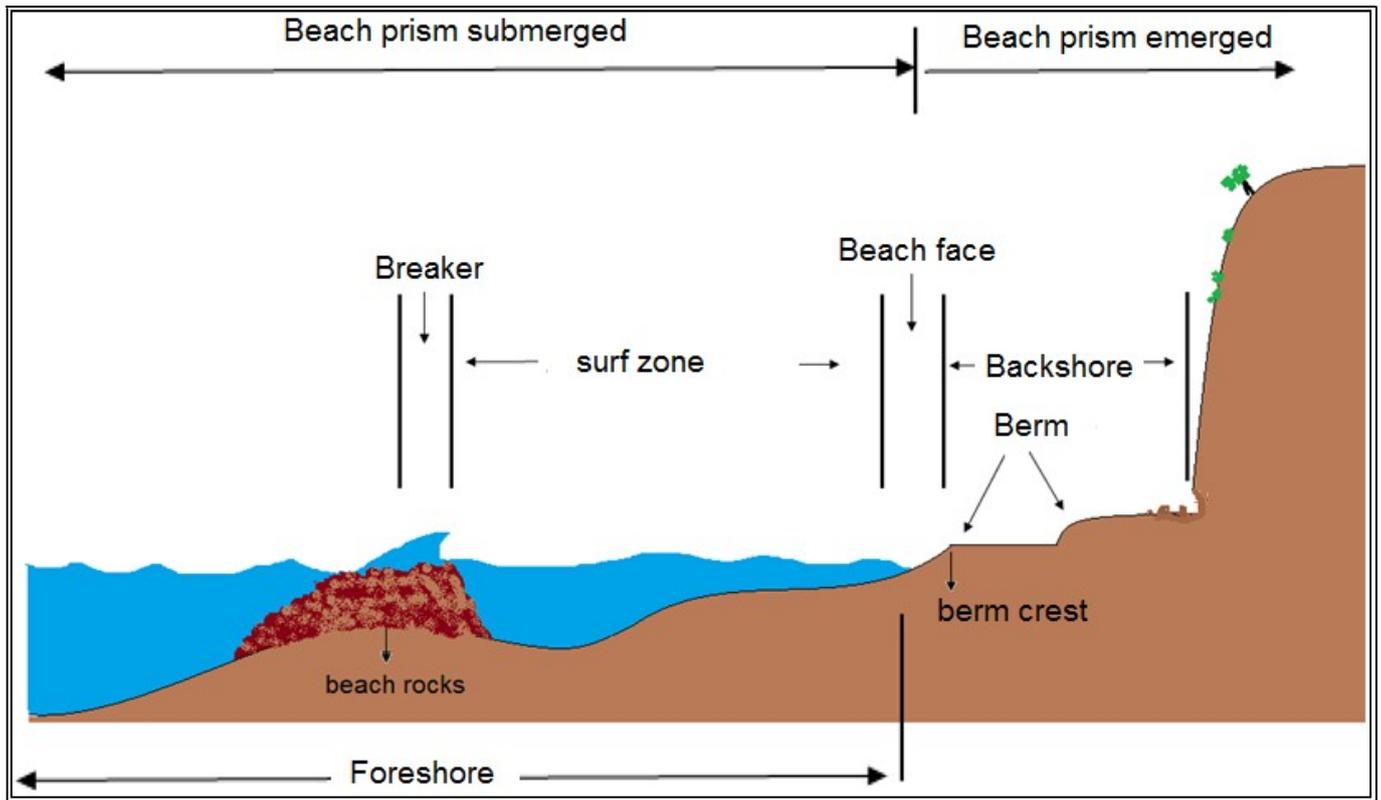


Fig. 3 Schematic profile of the onshore and offshore morphology of the area

For the elaboration of maps, the georeferencing of images from Google Earth, from the years of 2005 and 2015, in a SIG (Geographic Information System). Firstly, the study area and its surroundings were defined by the use of an image of 2015, so that we could have a better characterization of the morphologic compartments present in the area chosen (Coastal Tablelands, marine terraces, and marine flat land). Then, the evolution of the coastal erosion was delimited through the images of 2005 and 2015, obtaining numbers close to the erosive process advance in the study area.

In the field, samples of the sediments taken from distinct points were collected and photographic records of the sectors were made, where coastal erosion caused severe impacts to constructions and infrastructure close to the coastline. Also, photographic records of the containment works of the erosive process were made (riprap with calcareous rock).

In the lab, the samples of the sediments collected were submitted to a wash over with distilled water in order to extract water-soluble salts and, afterwards, they were dried in a autoclave at 70°C. After drying of each sample, a new weighing was made and then a solution of HCl at 10% was added for the burning and carbonate elimination present in each sample. After total carbonate elimination, the samples were weighed again and, then, it was possible do verify the percentage of terrigenous sediments (continental origin) in relation to carbonate sediments (marine origin).

The following step consisted in submitting the samples to a *rotap* (sieve shaker) with a set of sieve opening: 2.00mm, 1.00mm, 0.500mm, 0.250mm, 0.0125mm, 0.063mm, and 0.032mm, according to the traditional method of sieving described by Suguio (1973), obtained the parameters proposed by Folk and Ward (1957) related to the size of the grains and to the distribution of sand fractions, silt/clay of Shepard (1954). Through the granulometric analysis, we search to characterize the size of sediment grains, as well as to get preliminary information about the coastal environment and the percentage of terrigenous and biogenic contribution for the area.

## RESULTS AND DISCUSSIONS

About the erosive processes occurred on the coastline studied, it was possible to examine and quantify precisely the beach sectors where the erosive process is more intensified. These erosive processes have been visibly increased due to a series of improper constructions made on Average High Tide Line (Marine Line). In some higher social stratum construction and, therefore, of higher value added, containment works of erosive process are observed, not taking totally into consideration oceanographical pattern, geological and geomorphological characteristics of the area as well as the current legislation. Basically, these works consist of ripraps of calcareous rock, supported by wooden stakes (Fig. 4)

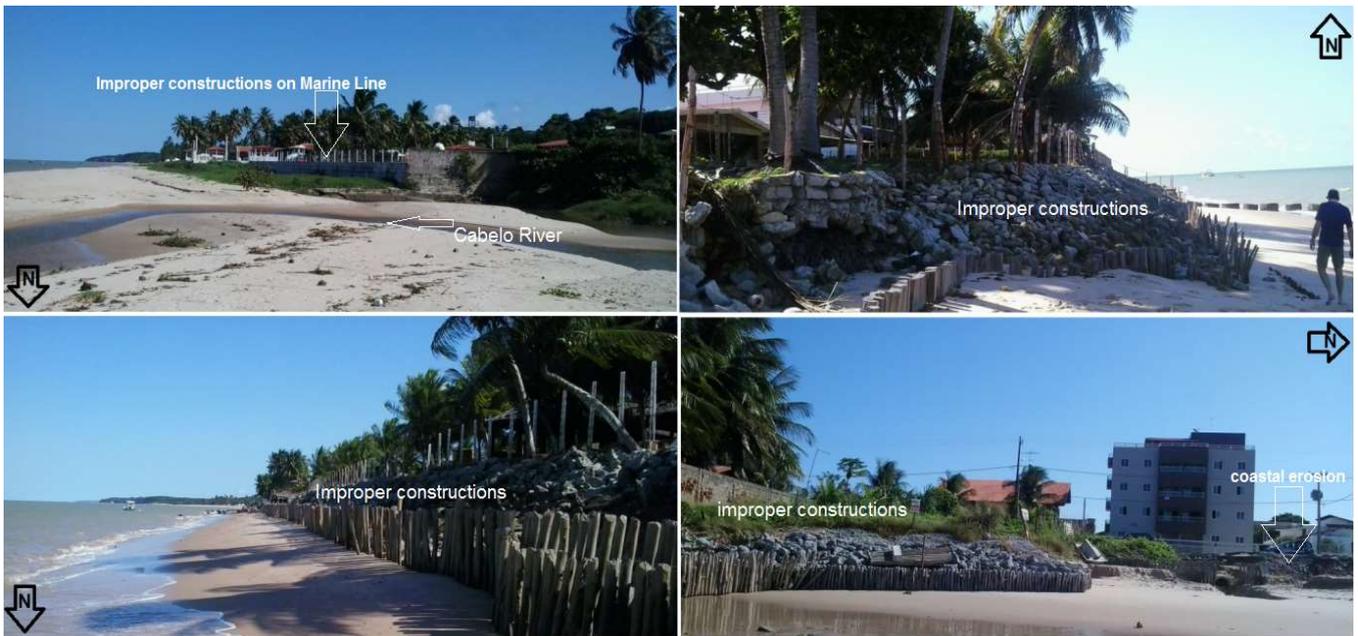


Fig. 4 Aspects of containment works built at housing on Seixas Beach

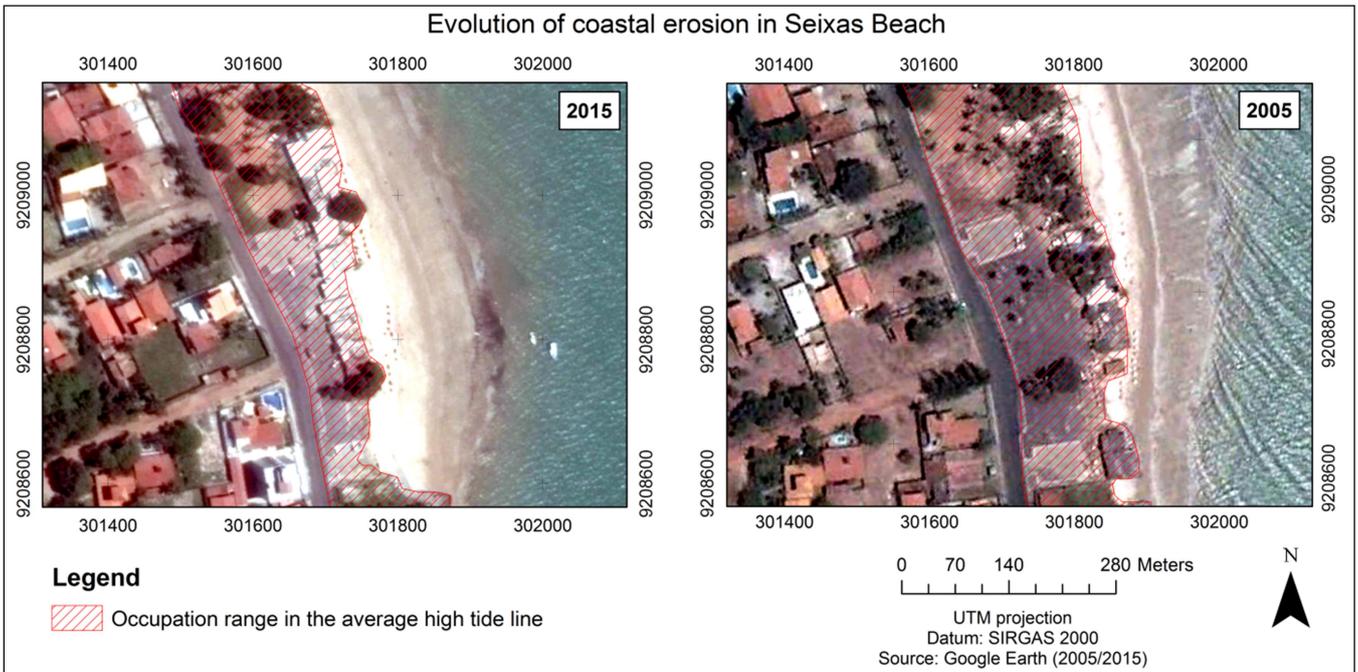


Fig. 5 Coastal erosion evolution in the stretch of Ponta do Seixas between the years of 2005 and 2015.

These works for coastal erosion containment come to influence directly on the coastal drift current that, due to the prevailing incidence of quadrant winds SE, steers S – N. In this situation, there is the preservation of properties in the rear part of the engineering work and a coastal erosion extension immediately after its north sector (Fig. 5). As an example, it is observed through the oblique aerial photograph a long riprap and, exactly, by end of it an accelerated process of coastal erosion, where several constructions have already been

destroyed and a part of a local car park. The observation made from satellite images have shown a loss of about 258m<sup>2</sup> of urban infrastructure on the coastline due to the erosion (Figs 5–6).

This situation confirms how the local landscape needs technical planning. A proof of it is seen in the material used to build the breakwater, where the containment barriers built are made of wooden stake and sediment rocks (predominantly calcareous) in the limit zone of berm (Fig. 6).



**Fig. 6** Aerial photograph of Seixas beach. Source: a) Available in SPU (2013); b) Furrier et al., 2007.

It is worth highlighting that the use of the calcareous rock is an inadequate procedure for containment works on the beaches, once its karst composition promotes the chemical dissolution, process that, due to the dynamic imposed by the coastal environment, turns to be considerably accelerated, making it necessary the periodical reposition of material, because of the worn-out caused by exogenous factors working in the area.

#### Area analysis face to the environmental legislation

Within the effort to understand the environmental situation of the studied area, it is relevant to analyse the physical environment under the light of the established norms that recommend the environmental preservation as well as the human settlement in the geographical space; mainly because, on Brazilian littoral, it is common to find problems aggravated by the lack of authorities surveillance and the violation of current legislation in relation to the coastal urban occupation, what, many times, result in the aesthetic degradation and environmental contamination of both the coast and the marine environment.

For these reasons, it is necessary to observe some parameters regulated by Law nº 6.938/1981 (Environment National Policies - PNMA) in order to understand whether in the studied area there is some plausible form of coastal zone management, according to Article 2º the PNMA, which has as the objective the preservation, improvement and recovery of the environmental life quality, with the aim of assuring, in the country, conditions for socioeconomically development, for national safety interests and for the protection to human life dignity (BRASIL, 1981).

In this view, the following principles that belong to the Law mentioned here were stressed: (i) IV – ecosystem protection, with the preservation of representative areas; (ii) VII – environmental quality status monitoring; (iii) IX – protection of areas threatened with degradation; (iv) X – environmental education for all levels of teaching, including community education, in order to enable them for an active participation in the defense of the environment.

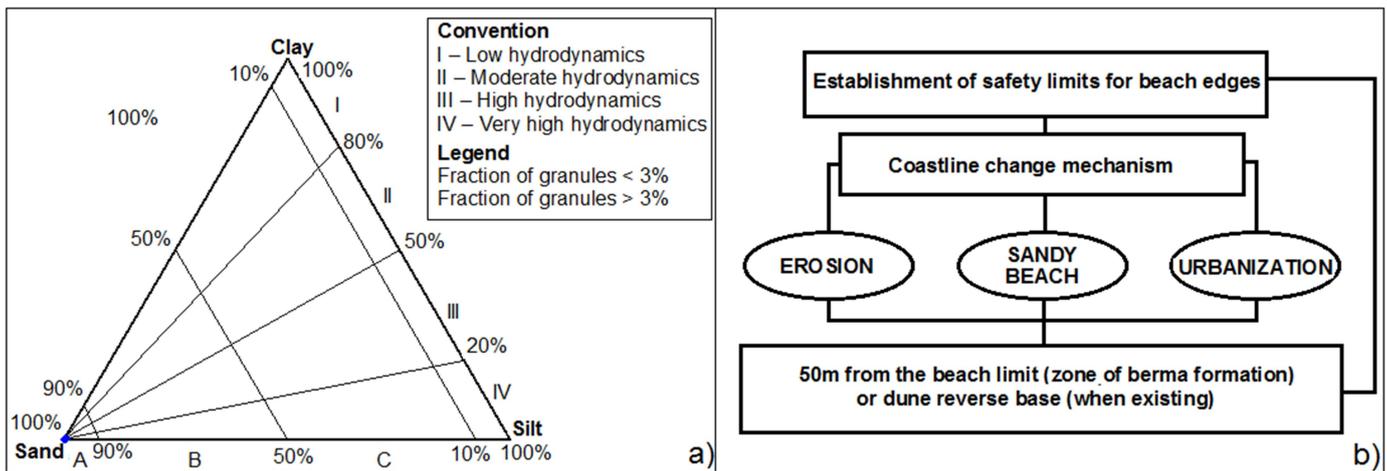
Thus, considering the fact that the examined area is under strong anthropic intervention, it is observed clearly that it surely exemplifies the total violation of the items mentioned, belonging to the Law (PNMA). Therefore, this area turned to be a space where the legal norms were not respected, thus contributing to the process of local landscape degradation.

Such conclusions are confirmed by the Article 3º of Law nº 6.938/1981, which define as “degradation of environmental quality the adverse change of the environmental characteristics” (section II) that result somehow in activities that generate adverse conditions to social and economic activities, which affect unfavorably the biota (according to subparagraphs “b” e “c” of section III).

The studied sector presents a coastal flat land densely occupied by houses, bar-rooms, recreational associations, and other civil works, that, according to the measurements taken, violate the articles of Law nº 7.661/1988, of the National Plan of Coastal Monitoring (PNGC); for according to article 10: “The beaches are public heritage for the people’s common use, being assured, always, free access to them and to the sea, in any direction and sense, except for the parts of national safety interest or included in areas protected by specific legislation” (BRASIL, 1988).

In accordance with the article above mentioned, it is observed in the area total violation of the current legislation, which can be proved by field records taken in the area, for according to § 1º of Article 10: “The urbanization or any form of soil use on the Coastal Zone that prevents or hinders access assured by the *caput* of this Article is not permitted” (BRASIL, 1988).

In this view, Muehe (2006) lists several criteria that establish limits for the monitoring of coastal zones, mainly those where unconsolidated sediments prevail, as it is the example of Seixas Beach. For this author, it is essential that, in the establishment of the protection zones on the beaches, the evolutionary tendency (geological and chronological time) should be considered, once these environments are stable and extremely dynamic and, because of this, any kind of



**Fig. 7(a)** Granulometric variation and hydrodynamics of the area according to the Pejrup’s criteria (1988), and **(b)** Schematic session elaborated from Muehe’s proposal (2006)

construction should be prohibited in the area, mainly those in perimeters likely influenced by the waves and with coastal erosion history.

On Seixas Beach, during the analyzed period, the granulometric of beach sediments indicated the prevalence of average sand for the stretch from the Cabelo River and Ponta dos Seixas (53%), and fine sand for the stretch of Cabo Branco Cliff (57%). These beach sediments discard the river competence in the sand supply in this area, because the only river found there presents a small flow rate.

The hydrodynamic pattern of the area corroborate Davis Jr. e FitzGerald (2008) that stress the fine sediments as characteristic of low energy wave environments, whereas the sand size sediments tend to accumulate in high energy wave environments. In this perspective, it is observed the existence of predominantly fine sediments, in a low energy wave area. However, the hydrodynamic pattern examined (**Fig. 7a**) is shown high, in contrast to the sediments analyzed and to the wave pattern verified. This contrast indicates conspicuously that the hydrodynamic pattern is strongly linked to a great anthropic intervention on coastline, mainly in erosion containment.

We highlight the need of redefine a minimum range of protection and maintenance so that we can try to establish the equilibrium of coastal environment similarly to the one proposed by Muehe (2006) (**Fig. 7b**) and also supported by the current legislation, once the present-day morphological characteristic are linked to the total absence of previous planning, natural characteristic ignorance and total violation of the current legislation.

Thus, considering the legal and technical assumptions here presented, it was defined the following stretch situation covers Seixas Beach:

a) Narrow marine flat land is intensely occupied due to the urbanization process, making a scenery

visibly affected by erosion caused and intensified by human intervention.

b) Riprap construction with no evidence of planning and with the use of inadequate material, made of calcareous block and wooden stake, that has exacerbated even more the dynamic equilibrium of coastal face, degrading the landscape.

c) Coastline bordered by constructions of houses, bar-rooms and recreational clubs, violating the current legislation and preventing the natural sediment mobilization.

d) Strong interference in marine hydrodynamics due to an intense disorderly human occupation.

**CONCLUSION**

We come to the conclusion that the process of coastal space occupation that covers Seixas Beach brings strong implications that results in: landscape degradation, lack of planning for the soil use and occupation, and coastal flat land disorderly occupation caused by inadequate infrastructures in extremely dynamic areas and not in accordance with the current legislation.

Thus, effective solutions should be taken in order to mitigate the effect of deterioration found in this coastal zone, ensuring effectively an adequate occupation that do not cause damage both to society and to the environment. Therefore, it is indispensable that such solutions should take place by the means of an integrating action among society, scientific community, and authorities, so that technical, financial and human efforts come to be conjoined, in order to contain the negative impacts caused in a fragile and extremely dynamic environment, as it is the coastal flat land.

In short, we highlight that such measures should be planted in order to promote the recovery and preservation of this environment, for the analysis of the area has shown a series of socio-economical negative consequences, due to the lack

of planning as well as the legal violations. Thus, it is necessary an urgent intervention on the part of the authorities, in order to promote an adequate spatial organization and try to establish a dynamic equilibrium in a vulnerable and susceptible environment of touristic importance.

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