



## COASTAL PROTECTION OF THE CITY OF BEIRA IN MOZAMBIQUE: ASSESSMENT AND MITIGATION PROPOSALS

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### SUMMARY

This research is the result of quantitative research that aims to propose sustainable ways of protecting the coastal zone to reduce the negative effects of coastal erosion in the City of Beira, based on a prior assessment. To understand the research data, the methodology consisted of bibliographical research, documentary research, direct observation and survey with employees of the Municipal Council and residents of the neighborhood of Praia Nova, Ponta – Gêa, Palmeiras and Macuti, with a sample of 215 participants . Based on statistical analysis, the research found that the natural cause of coastal erosion is rain, global warming and rising sea levels, while anthropogenic causes were the destruction of coastal vegetation and dunes; Sustainable natural measures include the planting of mangroves and casuarina trees, while artificial measures include the construction of breakwaters, walls and groins. Given the relevance of the study, it is suggested that the municipality makes efforts with the government and cooperation partners to obtain financing for the construction of a wall starting from Praia Nova to the Wedding Palace area; The city council must make efforts to rehabilitate mainly breakwaters close to spillways, and train its employees in coastal protection and disaster risk management. It should also develop lectures involving the community, on the causes and consequences of climate change, global warming and erosion.

**Key words:**Coastal protection. Causes. Consequences. Mitigation

### ABSTRACT

The present research is the result of a quantitative research that aims to propose sustainable ways of protecting the coastal zone to reduce the negative effects of coastal erosion in the City of Beira, starting from a previous evaluation. For the perception of the research data, the methodology consisted of bibliographical research, documentary research, direct observation and inquiry with employees of the Municipal Council and residents of the neighborhood of Praia Nova, Ponta - Gêa, Palmeiras and Macuti, with a sample of 215 participants. From the statistical analysis, the research found that the natural cause of coastal erosion is rain, global warming and the rise in sea level, while the anthropogenic causes were found to be the destruction of coastal vegetation and dunes; sustainable natural measures include the planting of mangroves and casuarinas, while artificial measures include the construction of breakwaters, walls and spurs. Given the relevance of the study, it is suggested that the municipality make efforts with the government and cooperation partners in order to obtain funding for the construction of a wall from Praia Nova to the area of the Wedding Palace; The city council must make efforts to rehabilitate breakwaters close to water outlets in particular, and train its employees in coastal protection and disaster risk management. It should also develop lectures involving the community, on matters about the causes and consequences of climate change, global warming and erosion.

**Keywords:**Coastal protection. Causes. Consequences. Mitigation

### 1. INTRODUCTION

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In recent years, the city of Beira has progressively suffered coastal erosion. This phenomenon aggressively threatens the submersion of the city, due to the fact that it is located below the average sea level. The phenomenon has a natural and anthropogenic origin. The combined effect of the lack of resources and the satisfaction of basic survival needs leads to the exploitation or misuse of available resources.

Due to the above, there are findings made in neighborhoods located in the coastal area of the City of Beira, which in recent years has suffered from erosion. The fury of the waters continually and progressively destroys the walls built in colonial times, thus allowing them to escape to the mainland. In turn, it is causing the collapse of houses, streets, trees and other important infrastructure located

near the coast. Existing experiences in combating or mitigating erosion in the country show that the actions implemented are often of a corrective nature, with few cases of preventive measures for this phenomenon. In these interventions, it is common to attack the problem where it most manifests itself without, however, attacking the origin by identifying and minimizing the causes. Therefore, asking about the structural and non-structural measures that must be implemented to reduce the effect of coastal erosion in the city is essential.

Sabino's study (2023), entitled "*Survey of governmental and non-governmental initiatives to protect the Coastal-Marine System of Southeastern Brazil*", had the purpose of identifying and discussing government and NGO actions related to the coastal-marine system in the Southeast region of Brazil, taking into account their purposes when they were developed and implemented in the national territory. The research found that NGOs played a significant role in leading a greater number of initiatives for the conservation of the coastal-marine system. The state of Rio de Janeiro stood out for investing more in these initiatives, including beach cleaning, environmental education and studies to help with preservation. On the other hand, there is less emphasis on conservation actions in the state of Minas Gerais, despite the importance of the coast for the region. Through this survey, it was possible to verify the engagement of different actors in the search for effective solutions and actions to preserve this important ecosystem.

This article aims to propose sustainable ways of protecting the coastal zone to reduce the negative effects of coastal erosion in the City of Beira, based on a prior assessment. The specific objective was to identify the main causes of coastal erosion in the most affected areas of the City of Beira; characterize the anthropogenic and natural causes of coastal erosion, and propose structural and non-structural measures for the control and prevention of coastal erosion in the aforementioned City. The object of study is the professionals from the Municipality of Beira, the population residing in the coastal areas of Chaimite (Praia Nova-Gharawapadja), Ponta-Gêa, Palmeiras and Macúti, with a total of 215 participants. Direct observation, comparative method and survey were adopted, as the fundamental techniques for data collection, and the statistical technique for analysis. However, the research is expected to have an immeasurable social impact as, with it, communities can be involved and motivated to abandon practices that alter the coastal natural ecosystem, focusing on the care and maintenance of local biodiversity.

### 1.1 Anthropogenic and natural causes of coastal erosion

Coastal erosion is a natural process that affects a large part of the world's beaches and, basically, occurs when the rate of sediment removal is greater than the rate of deposition. There are countless factors that cause this imbalance, such as: storms, rise in relative sea level, lack of sediment source, currents parallel to the coast, among others. Erosion in a coastal area becomes problematic when it becomes a severe and permanent process along the entire beach or in sections of it, threatening areas of ecological and socioeconomic interest (SOUZA, 2005). Under these conditions, it is called coastal erosion (reaching headlands, rocky shores and cliffs) or beach erosion (when it only refers to beaches).

In the classification of factors that cause erosion we can find two categories, namely anthropogenic and natural. According to Melo and Rosemeri (2004), anthropogenic causes include the trampling of dunes which, destroying the vegetation cover, leads to the appearance of wind shears and facilitates oceanic overtopping; the increase in runoff due to irrigation, which generally causes very strong erosion and intensifies the phenomena of damming; improvised roads and the construction of buildings on top of cliffs, which increase the loads exerted and induce vibrations leading to falling blocks and mass movements; sand mining (which completely destroys natural forms and often leaves depressed areas that are flooded during storms and leads to the intensification of erosion, causing very high local retreats of the coastline, sometimes caused by a single storm); poor territorial and urban planning, deforestation for construction and for the use of wood fuel and other purposes; movement of vehicles, machinery and trampling in places where civil construction works are taking place; felling of mangroves, casuarinas and other types of vegetation with an important role in coastal protection.

These and many other actions degrading natural forms deprive the coast of an intrinsic defense capacity that was conferred on it by such forms. It should be noted that the contributions of all these factors contribute to the occurrence of erosion both in the coastal area and inland, thus causing the loss of

physical destruction of the coast and habitats. According to Micoa (2007), the implementation of rigid or flexible structures, parallel or transversal to the coastline, interferes with the circulation pattern of coastal currents, as they modify the wave incidence angle, altering the beach profile and sedimentary balance. , generally intensifying erosion processes. Also, the transformation of areas of mangroves, river and lagoon plains, swamps and floodable areas into land for urbanization and anthropogenic activities; changes in the drainage pattern. Therefore, factors cause an imbalance in the regional sediment balance, because the source of sediment decreases, consequently increasing erosion processes on the coast.

Among the natural causes of coastal erosion are the force of wind and/or storms; the force of sea waves; precipitation; the increase in atmospheric temperature; the increase in the content of greenhouse gases in the atmosphere; the melting of ice in the polar regions; the morphodynamics of the beach: low-energy dissipative, being more susceptible to erosion, exhibiting low temporal and spatial variability, and the rise in sea level: in a short period of time, due to the combined effects of astronomical, meteorological and oceanographic phenomena when the passage of cold fronts(SOARES; ANGULO and LESSA, 1997).

## 1.2 Impacts of coastal erosion

Coastal erosion, as well as soil erosion, in general, has the same impacts, as the removal of soil by erosion causes the following problems:

The) *Environmental and Social Impacts*:in relation to the marine physical environment and Overall, the potential impacts are: Impacts on the bathymetry and circulation of the bay, and on coastal erosion; dispersal of re-suspended sediment, and increase in estuary water turbulence. Therefore, these direct and indirect impacts are generated during the dredging operation and deposition phase (MAPARAGEM, 2005; CONSULTEC, 2007);

B) *Ecological Impacts*:The main ecological impacts derived from erosion coastal according to CONSULTEC (2007) are: reduction in the rate of photosynthesis; reduced ability of P. monodonse shrimp to bury due to increased turbes; increased productivity due to increased nutrient availability; contamination of aquatic fauna, namely M. meretrix clams, as a result of resuspension of toxic materials in the water column, and suffocation of benthic organisms and juvenile M. monoceros shrimp, as a result of dredged dumping. It is important to emphasize that these are direct and indirect impacts generated during the dredging operation and deposition phase.

w) *Socioeconomic Impacts*:Still according to Consultec (2007), in socio-economic activities, the potential impacts predicted are mostly positive, such as: impacts on fishing; Impacts on the rehabilitation of the city's structure, and Impacts on port activity. The negative impacts are related to maritime traffic and impacts on fishing.

d)

## 1.3 Protection measures against coastal erosion

Coastal erosion results from the effect of tides. Therefore, this type of erosion is controlled through the construction of defense infrastructures that absorb the energy of sea waves in the contact area with the coast. According to Scherer (2001), the most common solution in urban areas is the construction of breakwaters placed along the seafront to dissipate part of the energy of sea waves, fixing dunes to stabilize the soil and building walls with logs. of trees. Other protection measures used to control coastal erosion consist of placing sandbags held in place by wooden stakes.

Heavy coastal engineering works are implemented to allow the retreat of the coastline, which is induced by the rise in sea level, the decrease in sediment supply, anthropogenic degradation actions on the coast and port jetties, generally functioning as supplementary inductors

of intense coastal erosion (OLIVEIRA, 1999). Consequently, they are also largely responsible for the accelerated retreat of the coastline. Despite the name by which they are known, coastal protection works do not, as a general rule, aim to protect the coastline. Typically, such works are constructed to protect property, whether public or private. These are, fundamentally, "curative" works carried out, in general, on an urgent basis, that is, they aim to eliminate or locally mitigate a "disease": coastal erosion that threatens or begins to damage poorly located properties. Works designated as "coastal protection" are generally of three types: transverse works (jetties, groins); adherent longitudinal works (walls, riprap), and non-adherent longitudinal works (detached works, breakwaters).

Vegetation in coastal protection makes all the difference. Casuarinas, for example, in coastal protection teira, contain the coastline, that is, they prevent the coastline from moving progressively closer to the continent; during storms, particles are retained in the area by reducing wind speed towards continental areas; in the coastal zone they are used in restoration programs for degraded habitats, due to their strong adaptive character in relation to other species of coastal plants (VANDLER, 2005).

For the Author, IBIDEM, the mangrove performs several natural functions of great ecological and economic importance, among which the following stand out: protection of the coastline: the vegetation performs the function of a barrier, acting against the erosive action of waves and tides, as well as in relation to winds; retention of sediment carried by rivers: due to the low hydrodynamism of mangrove areas, the charged particles precipitate and add to the substrate. Such sedimentation enables the occupation and propagation of vegetation, which makes it possible to stabilize the muddy vase from the root system of the mangroves; purifying action: the ecosystem works as a biological filter in which aerobic and anaerobic bacteria work with organic matter and the mud promotes the fixation and inertization of contaminating particles, such as heavy metals; area of nutrient concentration: located without estuarine zones, mangroves receive nutrient-rich waters from rivers, mainly, and the sea. Combined with this favorable location, the vegetation has high productivity, being considered the main source of carbon in the ecosystem. For this reason, mangrove areas are rich in nutrients; renewal of coastal biomass: as areas of calm, shallow waters rich in food, mangroves present ideal conditions for reproduction and development of young forms of various species, including those of economic interest, mainly crustaceans and fish. They therefore function as true natural nurseries; areas for feeding, sheltering, nesting and resting birds: the species that occur in this environment can be endemic, closely linked to the system, visitors and migratory, where mangroves act as important maintainers of biological diversity. However, the vegetated region, as it is hydrodynamically calmer, favors the deposition of sediments or serves as a feeding and breeding area for fish and birds.

Dunes also play a fundamental role in preventing floods, preventing saline intrusion into the water table and aquifers (dune ranges are important deposits of drinking water), protecting the beach strip against coastal erosion processes, protecting interior lands against the effects of storms (SANTOS, 2001). According to SANTOS (2001), dunes promote the recycling of nutrients and polluting substances, to stabilize sediments and maintain natural drainage, including the preservation of resident and migratory fauna associated with sandbanks, finding food availability and safe places to nest. and protect yourself from predators.

## 2 METHODOLOGY

### 2.1 Study area

The study area is located in the city of Beira. Beira is located approximately 1190 km north of Maputo, in the center of the Indian Ocean coast. It is a port city on the Mozambique Channel. The municipality has an area of 633 km<sup>2</sup>, an average altitude of 14 meters above sea level and is located at the coordinates: *19° 50' South and 34° 51' East*.

Figure 1: Geographical Framework of the City of Beira



Source: Adapted from Google Earth. 2023.

## 2.2 Search classification

**Regarding the approach:** To carry out the research, the qualitative-quantitative approach was used. The qualitative was subjective and consisted of data analysis, without numerical interpretations. In the quantitative approach, numerical interpretation was used as a basis for collected data (BOENTE and BRAGA, 2004).

**Regarding the objectives:** The research is classified as exploratory and descriptive. It is exploratory because it consisted of collecting qualitative data on the effects of erosion in the coastal area of the City of Beira, as well as quantitative data on the number of residents of the coastal area and employees of the Municipal Council, assigned to the Construction and Urbanization Council. It is descriptive because it used research methods and techniques to describe the main causes and effects of erosion in the coastal zone of the City of Beira.

## 2.3 Data collection methods (or techniques)

**Bibliographic method:** According to GIL (2002), a bibliographic method is considered when created from already published material, consisting mainly of books, periodical articles and other sources of knowledge search. The method consisted of collecting and reading relevant bibliography related to the topic under study. This consultation allowed the exploration of the various theories and works of other authors to scientifically support the research.

**Direct Observation Method:** Direct observation is a method characterized by the fact that the researcher observes without making any analysis of his observations MARTINS and LINTZ (2000). The author traveled to the neighborhoods located in the coastal area of the city, which are part of the study area (Chaimite - Praia Nova, Ponta-Gêa, Palmeiras and Macúti) to observe *on site* the main causes and effects of coastal erosion in those neighborhoods.

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**Documentary research:** According to COSTA (2006), using this technique, documents are analyzed to describe and compare uses and customs, trends, differences and other characteristics of a given problem or phenomenon through written or unwritten documents (regulations, laws, films, videos, slides, photographs). Therefore, this technique consisted of consulting the council's stance and environmental regulations on coastal use and protection.

**Inquiry:** The survey technique consists of a questionnaire carried out through a set of questions asked by the researcher to the researched group (MARTINS and LINTZ, 2000). This technique was used to collect information and determine the knowledge of communities living in the city's coastal zone regarding the causes, effects and extent of erosion on their living conditions. The questions also served to

obtain factual information, in accordance with the objectives of the questions asked, despite all of them having to administer questions to individuals.

## 2.4 Data analysis method

**Statistical method:** The method consists of the analysis and interpretation of numerical data in order to make the research results closer to the real causes of the phenomenon studied (REIS, 1996). Analyzes using statistical techniques helped to quantify the information collected using survey. In this research, this method consisted of the analysis, interpretation and quantification of data collected through surveys in the neighborhoods covered by the research, which allowed the creation of graphs and tables presented in the work.

## 2.5 Population and sample

Population is defined as “the set of animate or inanimate beings that have at least one characteristic in common” (LAKATOS and MARCONI, 2002). For this research, residents of the coastal area (Praia Nova, Ponta-Gêa, Palmeiras and Macúti) and employees of the construction and urbanization council at the Municipal Council were covered. The sample was purposeful because it was based on information or characteristics chosen by the researcher as relevant to the research. 215 individuals participated, including 200 families living in the coastal area of the City of Beira and 15 employees of the Municipal Council.

## 3. RESULTS AND DISCUSSION

### 3.1 Interview with Municipal Council employees

#### 1.1.1 About coastal erosion in the city of Beira

Regarding question one (1), 33% agree that the occurrence of rain, strong winds and global warming are the natural causes of erosion, 47% do not agree and 20% say they do not know. According to Soares; Angulo and Less (1997), the force of the wind and/or storms, the force of sea waves, precipitation, increased atmospheric temperature, and others are considered to be the main natural causes of coastal erosion. If so, most employees have little knowledge about the natural causes of coastal erosion and this result may be combined with the fact that there is little discussion around this matter in that institution.

From question two (2), 60% stated that anthropogenic activities, linked to sand extraction, destruction of dunes, mangrove forest and vegetation are the causes of coastal erosion, while 27% responded negatively. No less important, 13% consider that they do not know. Analyzing the results, it can be considered that most employees state that coastal erosion results from sand extraction, destruction of dunes, mangrove forest and vegetation. Of the anthropogenic causes, Melo and Rosemeri (2004) indicate, among others, the trampling of dunes (which destroys the vegetation cover, favors the appearance of wind cuts and facilitates ocean overtopping), the increase in runoff due to irrigation (which causes, generally, very strong erosion and intensifies the phenomena of embankment) and improvised roads and the construction of buildings on top of the cliffs (which increases the loads exerted and induces vibrations leading to falling blocks and mass movements).

6 In question three (3), 80% consider that the consequences of coastal erosion are the invasion of sea water into the city, reduction of the habitable area, 13% do not consider it and 7% say they do not know. Regarding the marine and coastal physical environment, the potential impacts are: impacts on the bathymetry and circulation of the bay, and on coastal erosion, dispersion of re-suspended sediments and increase in the turbidity of the estuary water (MAPARAGEM, 2005; CONSULTEC, 2007). From the results, it can be stated that the majority of employees show that they have some knowledge about the consequences of coastal erosion.

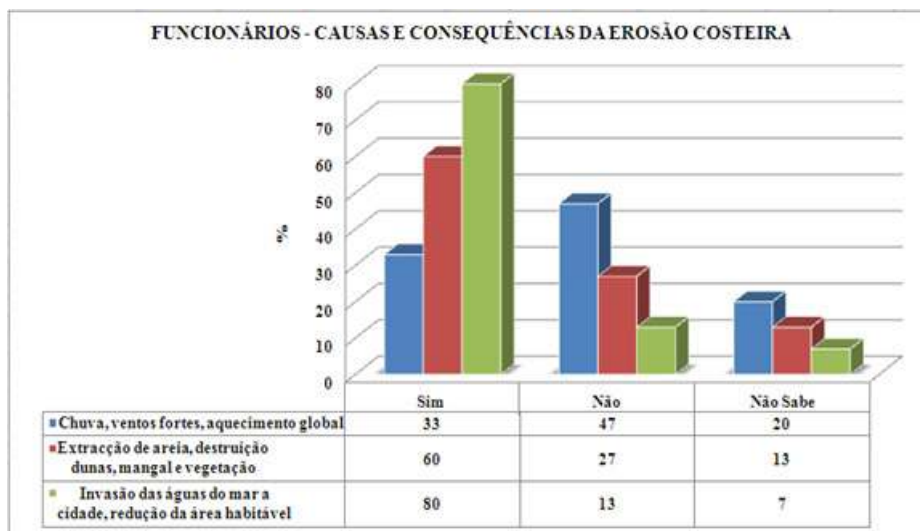


Figure 2: Data regarding coastal erosion in the City of Beira  
Source: Authors, 2023

### 3.1.2 Protection of the coastal zone of the City of Beira

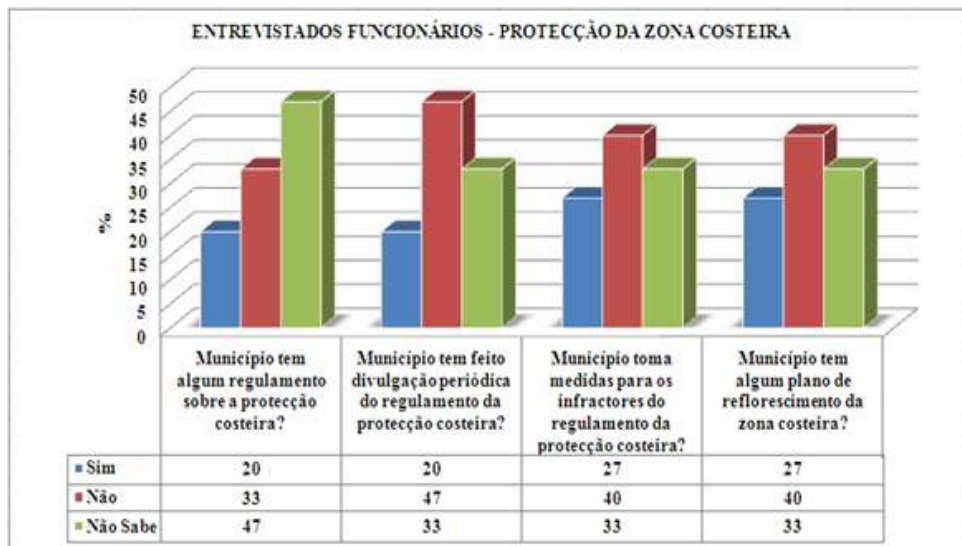
For question one (1), 20% believe that the municipality has some regulation on coastal protection, 33% do not and 47% say they do not know. Most employees state that they are not aware of the existence of a regulation on coastal protection in the municipality. This may mean that the employee does not have knowledge about coastal protection based on the existing document.

Regarding question two (2), 20% responded positively that the municipality has regularly published the coastal protection regulations, 47% responded negatively and 33% said they did not know. Therefore, most interviewees state that the municipality has not published the regulations on coastal protection. In Chapter VI of the Environmental Law in Mozambique of the year 2011, there is the heading “Rights and Duties of Citizens”, which begins in article 19 and goes up to article 24, in which they define- rights and duties, some of them already constitutionally enshrined, which are fundamental to the defense of the environment and the protection of citizens.

Regarding question three (3), 27% say that the municipality takes measures for violators of coastal protection regulations, 40% do not say so and 33% think they do not know. According to the results, it can be said that most employees responded negatively. However, Chapter VII of the Environmental Law in Mozambique from the year 2011, talks about “Responsibility, Infractions and Sanctions”, which goes from article 25 to article 27, including some solutions for civil, criminal or misdemeanor nature, which aim to combat aggressions occurring in the environment or through the environment. This could mean that the municipal council does not have this regulation, or if it does, it is not within the domain of employees.

For question (4), 27% believe that the municipality has a plan to reforest the coastal area, 40% say that there is no plan and 33% say they do not know. Melo and Rosemeri (2004), among the anthropogenic causes, mention deforestation, which greatly contributes to coastal erosion. The lack of a plan according to the majority (40%) may be an indicator of the local existence of the Environmental Law in the Municipality of Beira.

Figure 3: Data relating to Coastal Zone Protection in the City of Beira



Source: Authors, 2023

### 3.2 The survey addressed to residents of the coastal area - Beira

#### 1.1.1 Natural causes of coastal erosion in the city of Beira

At **New Beach**, for question one (1), 50% say that the natural cause of coastal erosion is rain. In question two (2), 36% say it is the wind. For question three (3), and without someone to indicate global warming. For question four (4), 14% consider rising sea levels. Soares; Angulo and Lessa, (1997) also point out, in addition to precipitation, the melting of ice in polar regions, a rise in sea level in a short period (due to the combined effects of astronomical, meteorological and oceanographic phenomena when cold fronts pass). However, the result may indicate that the knowledge that residents have may be combined with the fact that in recent years that area has been suffering violently from the effects of coastal erosion, as a large part of the fishermen's camps are partially or completely destroyed, and despite other associated factors.

For **Ponta-Gêa**, in question one (1), 24% consider that the natural cause of coastal erosion is rain. In question two (2), 26% say it is the wind. For question three (3), 30% say it is global warming. In question four (4), 20% argue that it is the rise in sea levels. Most respondents point to global warming. These results may be associated with the visible effects resulting from the rise in sea level, the effects of which have been plaguing that region, such as Soares; Angulo and Lessa (1997) indicate it as one of the natural causes of coastal erosion.

In the **Palm trees**, in question one (1), 24% say that the natural cause of coastal erosion is rain. In question two (2), 22% say it is the wind. For question three (3), 26% consider global warming. At question four (4), 28% say it is rising sea levels. However, in Palmeiras, most respondents say that rising sea levels are the natural cause of coastal erosion, followed by those who consider global warming. According to these respondents, when sea levels rise, the waters tend to exceed the coastline, threatening to invade the continent. Therefore, they drag sand, thus causing the silting of some drains. This fact means that a large part of the roots of plants and vegetation along the beach remain uncovered, thus contributing to the massive fall of trees, destruction of vegetation and the consequent increase in the coastline.

For **Macúti**, of the respondents, in question one (1), 22% say that the natural cause of coastal erosion is

rain. In question two (2), 28% consider it to be the wind. In question three (3), 18% say it is global warming. In the last question (4), 32% argue that it is the rise in sea levels. Analyzing the responses, it can be considered that the majority state that the natural cause of coastal erosion is the increase in sea level, followed by those who consider the wind.

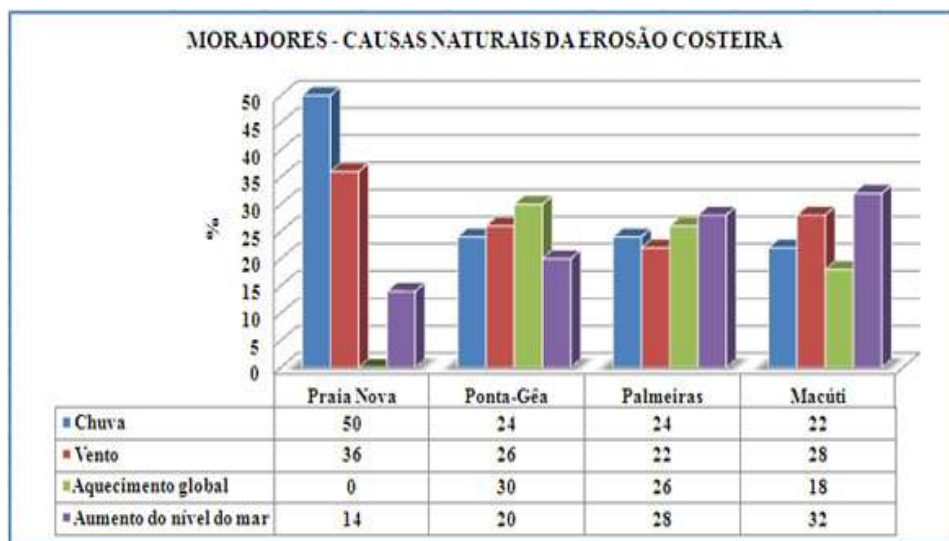


Figure 4: Data referring to the natural causes of coastal erosion  
Source: Authors, 2023

### 3.2.2 Anthropogenic causes of coastal erosion - Beira

At **New Beach**, regarding the first question (1), 28% consider sand extraction to be the anthropogenic cause of erosion. For question two (2), 24% say it is the destruction of dunes. In question three (3), 48% say it is the destruction of coastal vegetation. Observing the results, most argue that the destruction of coastal vegetation is an anthropogenic cause of coastal erosion.

For **Ponta-Gêa**, of those covered by the survey, in question one (1), 32% say that the anthropogenic cause of coastal erosion is sand extraction. In question two (2), 26% say it is the destruction of dunes. In question three (3), 42% support the destruction of coastal vegetation. It can be said that most claim that the anthropogenic cause of erosion is the destruction of coastal vegetation. This result may be combined with the fact that in recent years there has been a massive destruction of the vegetation that guaranteed natural protection against coastal erosion.

In the **Palm trees**, in question one (1), 34% state that the anthropogenic cause of coastal erosion is sand extraction. In question two (2), 26% consider it to be the destruction of dunes. In question three (3), 40% say it is the destruction of coastal vegetation.

For **Macúti**, in question one (1), 28% state that the anthropogenic causes of coastal erosion are sand extraction. In question two (2), 40% say it is the destruction of dunes. In question three (3), 32% say it is the destruction of vegetation. It may be that residents are unaware of the importance of dunes in protecting the coast (which serve as a natural barrier against the invasion of sea water and sand into inland areas and are home to biological diversity).

For Melo and Rosemeri (2004), among the anthropogenic causes it indicates the trampling of the dunes; sand explorations; poor territorial and urban planning, deforestation for construction and utilization of wood fuel and other purposes; movement of vehicles, machinery and trampling in places where civil construction works are taking place; felling of mangroves, casuarinas and other types of vegetation with an important role in coastal protection.

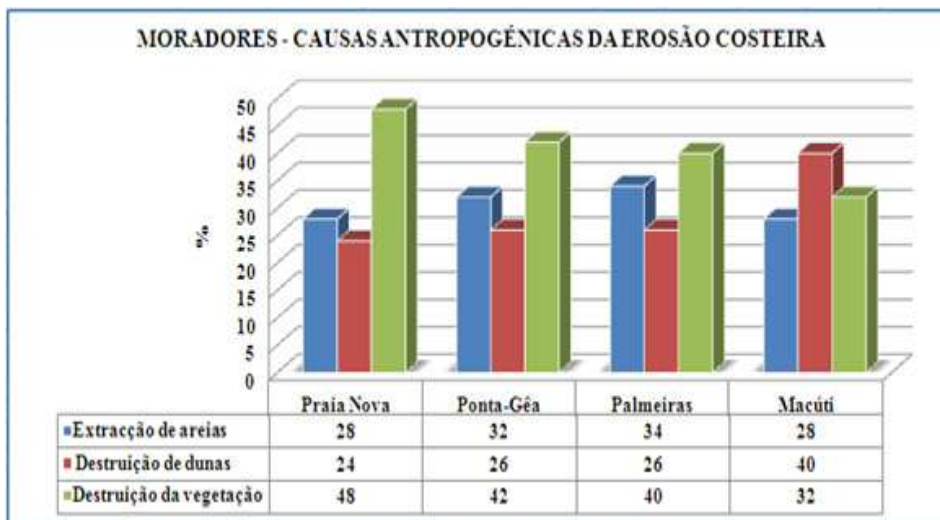


Figure 5: Anthropogenic causes of coastal erosion - Beira  
Source: Authors, 2023

### 3.2.3 Natural measures against coastal erosion - Beira

To the **New Beach**, in question one (1), 34% say that the natural measure of protection against coastal erosion is mangrove plantation. In question two (2), 26% support the planting of casuarina trees. In question three (3) 18% state that it is planting another type of vegetation. In question four (4), 22% say it is the formation of dunes. Most respondents defend the planting of mangroves as a natural measure to stop coastal erosion. The study by Vandler (2005) highlights the mangrove from the point of view of the various natural functions of great ecological and economic importance, highlighting among which, the protection of the coastline, retention of sediment carried by the river, purifying action, such as area of nutrient concentration, renewal of coastal biomass and, as feeding, shelter, nesting and resting areas for birds. This analysis must be combined with the fact that in the past that area had a vast area of mangroves that played a role in protecting the coastal area.

To the **Ponta-Gêa**, of the respondents, in question one (1), 38% stated that the natural measure of protection against coastal erosion is the planting of mangroves. In question two (2), 30% say it is the planting of casuarina trees. For question three (3), 14% defend the planting of another type of vegetation. In question four (4), 18% consider it to be the formation of dunes. As with Praia Nova, most respondents consider the replacement of mangroves as a measure to stop coastal erosion.

Us **palm trees**, in question one (1), 24% argue that the natural measure of protection against coastal erosion is mangrove plantation. In question two (2), 32% say it is the casuarina plantation. In question three (3), 24% state that it is the planting of another type of vegetation. In question four (4), 20% consider it to be the formation of dunes. Observing the results, it can be said that most respondents point to the planting of casuarina trees as a natural measure for coastal protection. Vandler IBIDEM, when he talks about the importance of coastal vegetation, such as casuarina trees, which in coastal protection, contain the coastline, that is, they prevent the coastline from progressively approaching the continent; During storms, they retain particles in the area by reducing wind speed in areas of the continent, and are even used in restoration programs for degraded habitats, due to their strong adaptive nature in relation to other species of coastal plants. These results may be combined with the fact that the media report cases of coastal erosion in the city of Beira, as in that area

There are still some casuarina trees, but in the meantime, there is no trace of mangroves.

For **Macúti**, in question one (1), 28% say that the natural measures to protect against coastal erosion are mangrove plantations. In question two (2), 32% say it is the casuarina plantation. For question three (3), 16% argue that it is the planting of another type of vegetation. In question four (4), 24% consider it to be the formation of dunes. In this neighborhood, most respondents consider the planting of casuarina trees as a natural measure of protection against coastal erosion. The result may be associated with the fact that in the leisure area on the beach, further accelerated the effects of the water.

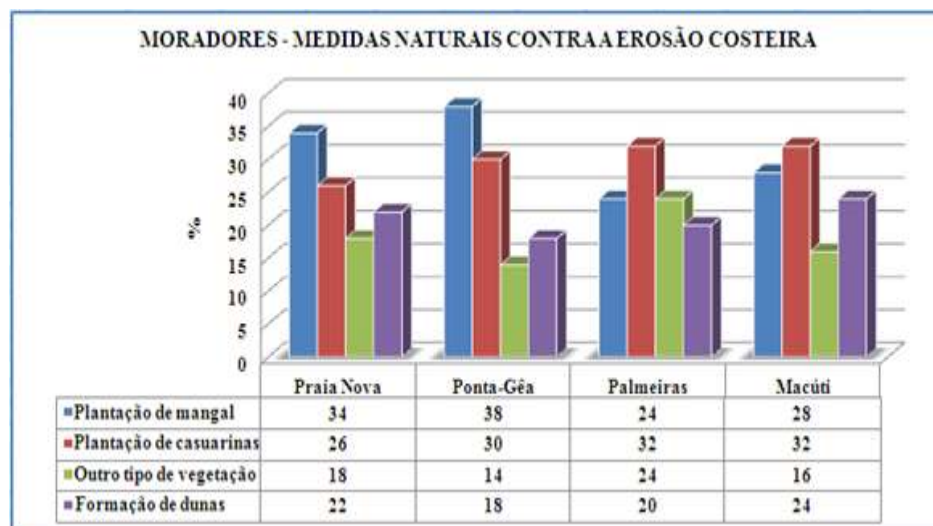


Figure 6: Data referring to natural measures against coastal erosion  
Source: Authors, 2023

### 3.2.4 Artificial measures against coastal erosion

In the area of **New Beach**, in question one (1), 20% consider the construction of jetties as an artificial coastal protection measure. In question two (2), 24% support the construction of spurs. In question three (3), 30% say it is the construction of breakwaters. In question four (4), 26% say it is the construction of walls. Most respondents defend the construction of breakwaters as an artificial coastal protection measure. According to Scherer (2001), the most common solution in urban areas is the construction of breakwaters placed along the seafront to dissipate part of the energy of sea waves, fixing dunes to stabilize the soil and building walls with logs. of trees.

At **Ponta-Gêa**, of the respondents, in question one (1), 24% argue that the artificial measure against coastal erosion is the construction of jetties. In question two (2), 28% consider the construction of spurs. In question three (3), 22% say it is the construction of breakwaters. In question four (4), 26% say it is the construction of walls. Most respondents consider the construction of spurs. However, when the upstream part of the groins is completely filled with sand, the littoral drift volumes in the downstream sector are not reestablished, as, due to the shape of the new coastline imposed by the groin, the drift currents are deflected offshore, sand is deposited at depths that inhibit its frequent remobilization (SANTOS, 2001).

In the area of **Palm trees**, in question one (1), 20% say that the artificial measure against coastal erosion is the construction of jetties. In question two (2), 24% support the construction of spurs. For question three (3), 26% consider the construction of breakwaters. In the last question (4), 30% say it is the construction of walls. Most residents of Palmeiras support the construction of walls. And, according to Consultec (2007), this construction has two functions, namely, modifying local oceanographic conditions, in order to make the entrance to the port and the port area itself safer, and modifying the conditions of sedimentary dynamics, in order to establish navigation channels and minimize siltation.

In this sense, the result in this neighborhood may be associated with the fact that a few years ago, the neighborhood was aggressively affected by coastal erosion, which caused the submersion of breakwaters and/or groynes, leading to the partial destruction of the beach fence wall. .

At the **Macúti**, in question one (1), 22% say that the artificial measure against coastal erosion is the construction of jetties. In question two (2), 28% support the construction of spurs. For question three (3), 24% consider the construction of breakwaters. In question four (4), 26% say it is the construction of walls. In this area, most respondents support the construction of spurs. The result may be associated with the characteristics of the neighborhood and the thought that the spurs reduce the strength of the waters, causing the sand to concentrate in high regions of the beach, minimizing the invasion of waters towards the mainland, as Santos (2001), states.

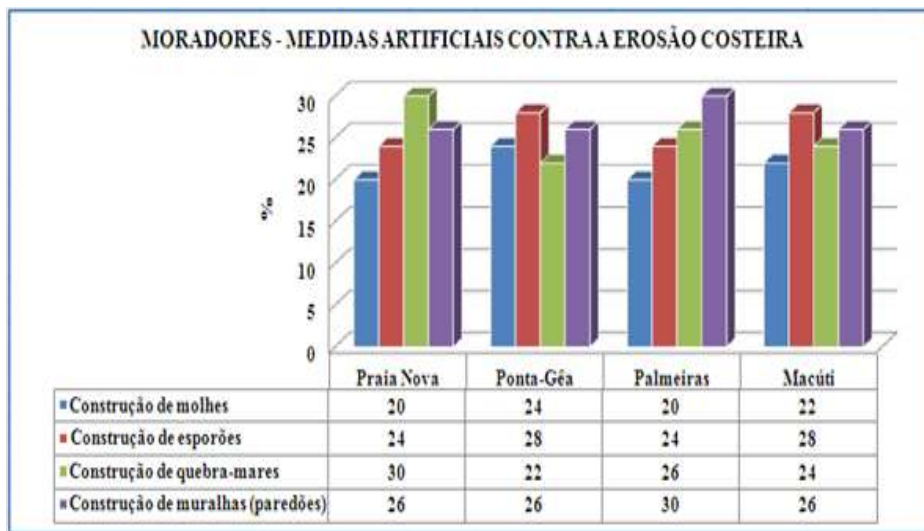


Figure 7: Data referring to artificial measures against coastal erosion  
Source: Authors, 2023

## 5 CONCLUSION

This article aims to propose sustainable ways of protecting the coastal zone to reduce the negative effects of coastal erosion in the City of Beira, based on a prior assessment. In general, participants demonstrated an interest in contributing to the study, which led to the following conclusions being reached:

Professionals from the Municipality of the City of Beira do not consider the occurrence of rain, strong winds and global warming to be natural causes of coastal erosion (47%), but rather anthropogenic activities linked to sand extraction, destruction of dunes, forest mangrove and vegetation (60%). They consider the consequences of coastal erosion to be the invasion of sea water into the city and a reduction in the habitable area (80%);

Furthermore, the majority do not know that the municipality has any regulation on coastal protection (47%), and are unaware that the institution has regularly published the aforementioned regulation (47%), as well as unaware that the municipality takes any measures for the violators of the regulation (40%) and much less agree that there is a plan to reforest the coastal zone (40%);

From the surveys carried out, it was found that the natural cause of coastal erosion is rain, with a greater impact in the Praia Nova area (50%), global warming, with a greater impact in the Ponta - Gêa area (26%) , rising sea levels, with the greatest impact in the Palmeiras (28%) and Macúti (32%) areas;

Anthropogenic causes include the destruction of coastal vegetation, with the greatest impact in the Praia Nova area (48%), Ponta - Gêa (42%) and Palmeiras (40%). The destruction of the dunes is one of the no less important causes, and the impact is felt in the Macuti area (40%);

Sustainable natural measures to mitigate coastal erosion include the planting of mangroves, in the area of Praia Nova (34%) and Ponta - Gêa (38%), and the planting of casuarina trees in the area of Palmeiras (32%) and Macúti ( 32%);

Sustainable artificial measures to mitigate coastal erosion in the City of Beira include the construction of breakwaters in the Praia Nova area (30%), the construction of walls in the Palmeiras area (30%), and the construction of groins in the Ponta zone - Gêa (28%) and Macuti (28%).

Given the relevance of the research, the Municipality must prepare a proposal for a specific regulation on coastal protection to be submitted to the municipal assembly and subsequently disseminated to employees and for residents of the city of Beira; the Municipality should make efforts with the government and cooperation partners to obtain financing for the construction of the wall; the city council must make efforts to rehabilitate mainly breakwaters close to spillways; the municipal council must train its employees in coastal protection and disaster risk management; It must also develop campaigns involving the community, particularly those residing in the project area, on the causes and consequences of climate change, global warming and erosion.

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