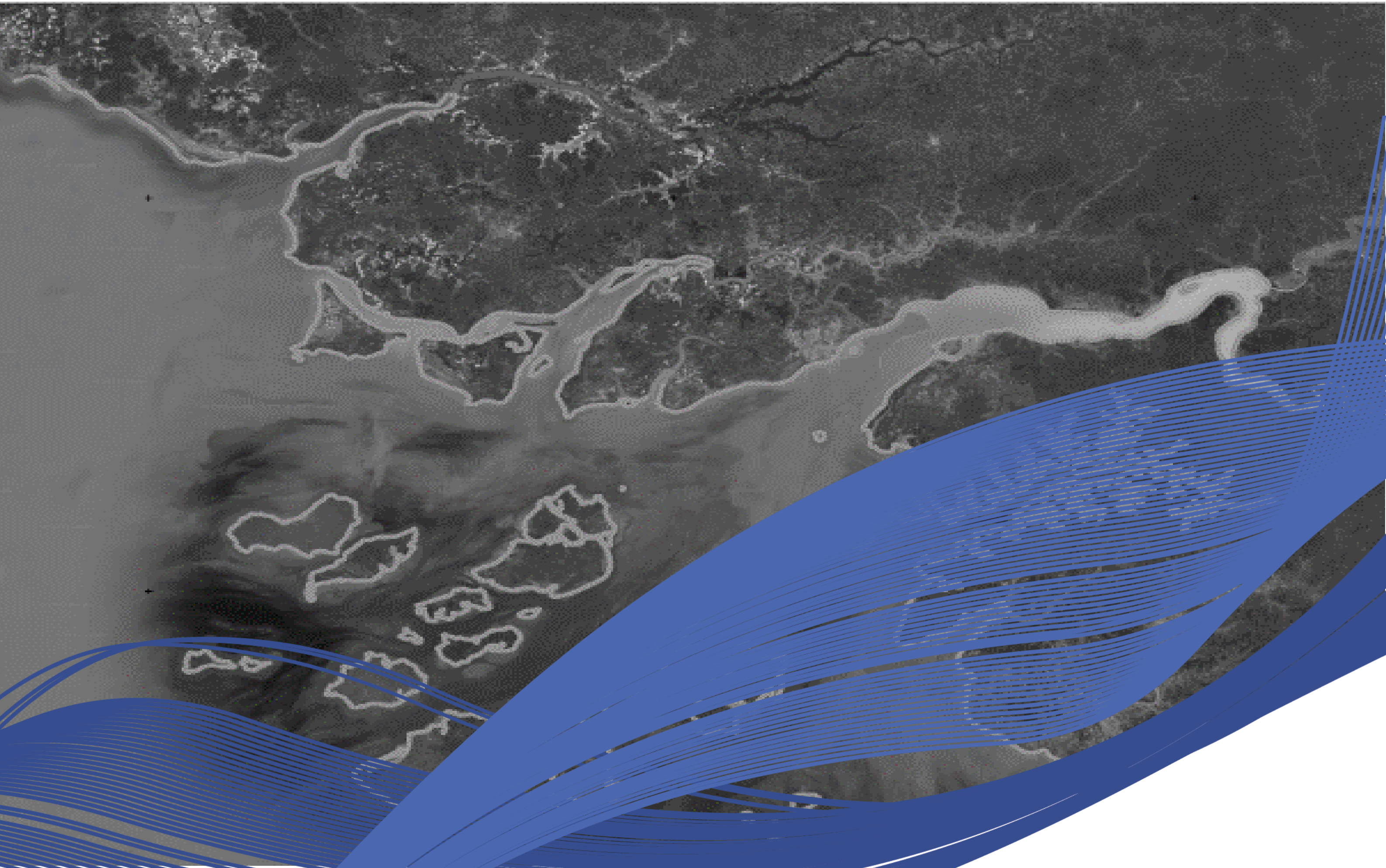

“Vulnerability of Guinea-Bissau's Coastal Zone to the Effects of the Climate Change ”

Final Project Report

2023

elittoral gesplan SIZTEMA INGENIERIA

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Justification

On December 28, 2022, contract UNDP-GNB-00006 was signed between the consortium led by the company elittoral wand the representative of the United Nations Development Programme (UNDP) in Guinea-Bissau. Alongside elittoral, the consortium is composed by the companies Gesplan and Sistemas Ingeniería. The overall objective of the contract is to map the vulnerability of the coast of Guinea-Bissau to rising sea levels and the global effects of climate change. Specifically, the delivery of the following products is agreed:

1. Cartographic report on the vulnerability of the coastal zone of Guinea-Bissau to the effects of climate change.
2. Technical and methodological proposal of strategies to mitigate the effects of climate change in the 10 (ten) areas of study proposed.
3. Cartographic report on vulnerability mitigation in the coastal zone of Guinea-Bissau, based on the recommendations of the consulting consortium.
4. Socioeconomic report of the cost of implementing the mitigating measures proposed by the consulting team.
5. Final Project Report.

This document corresponds to point 5 "Final Project Report".

After the revision of this document, changes were suggested and added to it. In this way, the Consortium team considers it valid to highlight one of the modifications so as not to generate doubts during the reading of this document. Therefore, the area of interest of the project, previously called "Bruce-Bubaque", was changed to "Bubaque Island", in order to encompass both regions of the villages of Bubaque and Bruce in the coastal vulnerability study, along with all other parts of the island that are covered by the adaptation and mitigation measures proposed for the area of interest of the project.

Acronyms and abbreviations

To simplify and helping the understanding of this report, it is recommended to read this section that contains the definitions of the acronyms and abbreviations that were most used throughout the work.

PPP	Preliminary phase of the project
CPU	Coastal protection unit
IPCC	Intergovernmental Panel for Climate Change
RCP	IPCC Representative Concentration Route
SSP	IPCC's Shared Socio-Economic Route
Pto	Observation point
SWH	Sea wave height
Hs	Significant Wave Height
Tp	Wave Period
WNW	West-Northwest
SW	Southwest
SSW	South-Southwest
NE	Northeast
NNE	North-northeast
WW	West
NN	North
NNW	North-Northwest
MSL	Mean Sea Level
SLR	Sea level rise
GEBCO	General Bathymetry Chart of the Oceans
CVI	Coastal Vulnerability Index
EI	Exposure Index
SI	Sensitivity Index
VI	Vulnerability Index, corresponds to the final CVI that was obtained after the theoretical implementation of the adaptation and mitigation works
AMM	Adaptation and Mitigation Measures
WACA	West Africa Coastal Areas
DEM	Digital Elevation Model

Overview

This document corresponds to the fifth (5th) deliverable of a total of five reports that are part of the deliverables for the project on the *Mapping of Coastal Vulnerability in Ten Zones of Interest in Guinea-Bissau*.

The main objective of the project's final report is to synthesize and integrate the results obtained in the four previous deliverables, offering a unified and cohesive view of the proposed strategies to mitigate coastal vulnerability in the ten areas of interest of the project.

In addition, this final report aims to consolidate the detailed information in the Cartographic and Socio-Economic reports, providing a comprehensive understanding of the challenges faced by the coastal zone of Guinea-Bissau as a result of climate change. This includes the clear identification of vulnerable areas, projections of future impacts, and the costs associated with implementing the mitigating and adaptative measures.

Furthermore, significant emphasis is given on the integration of the proposed strategies into the vulnerability and mitigation reports. Thus, the final report highlights how these strategies were developed considering the unique characteristics of each pilot zone and area of interest, aiming at an adapted and efficient response to the specific challenges of each region.

An analysis of the costs associated with the implementation of mitigating measures is also presented, going beyond the financial aspects to include the expected social and economic benefits. The goal is to provide a comprehensive view of the positive impacts which result from allocating resources to coastal protection and community resilience.

Throughout this document, all this information will be presented in a summarized manner according to the respective deliverable. Each of the four deliverables are divided into subsections in which the context and main objectives are first explained, then the methodology used is detailed, and finally the main results obtained. The list of deliverables documents that have been previously composed is shown in Table 1.

Table 1. List of deliverable documents that are part of the project.

	Deliverables
1	Cartographic report on the vulnerability of the coastal zone of Guinea-Bissau to the effects of climate change
2	Climate Change Mitigation Strategies for the Proposed Pilot Zones in Ten Study Areas
3	Cartographic Report on Vulnerability Mitigation in the Coastal Zone of Guinea-Bissau
4	Comprehensive Evaluation of Proposed Adaptation and Mitigation Measures Implementation

Conclusively, this final report should not only serve as an informative document, but also as a tool for mobilization. It represents a call to action, emphasizing the urgency of implementing the proposed strategies.

Cartographic Report on the Vulnerability of the Coastal Zone of Guinea-Bissau to the Effects of Climate Change

This section describes the context in which the document was developed, the methodology applied, and the main results obtained for Deliverable 1, entitled "Cartographic Report on the Vulnerability of the Coastal Zone of Guinea-Bissau to the Effects of Climate Change".

1. Framework

The objective of this first deliverable was to map the coastal vulnerability to sea level rise along the areas of interest of the project. Three scenarios were considered to map the coastal vulnerability: current (2023), near future (2050) and far future (2100). It is worth noting that since the beginning of the development of this study, limitations have been identified regarding information's availability and data access. Data such as bathymetry in Guinean coastal and deltaic zones, presented low level of detail, as well as topographic information of coastal areas, meteorological information had short historical records, and the available oceanographic data with historical records did not encompass the areas of interest of this project.

To achieve the proposed objective, the first task consisted of choosing from a long list of villages located along the coastal and rural area of Guinea-Bissau the intervention areas of the project which could potentially be the areas of interest for this study's development. This site selection process was carried out during the preliminary project phase (PPP), when villages ("localities") were studied, visited (mostly) and their selection validated. Due to the extension of the coastal zone and the fact that it is home to about 80% of the country's population, the coastal zona was divided into three areas of interest, in order to ensure the most benefits from the project's intervention.

- Zone 1: "Bolama-Bijagos Archipelago", with all its features, including a complex of coastal marine protected areas and the spatial management arrangements that this entails;
- Zone 2: "Varela-Cacheu", an area strongly affected by erosion and induced by climate. It includes natural and artificial resources vulnerable to climate change (agricultural land, docks, bridges, roads, tourist infrastructure, mangroves, marshes, etc.);

- Zone 3: "The South" and "Mansoa-Buba-Cufada" actually includes two zones that have been combined into one zone to manage project activities. It includes areas of great importance for coastal agriculture (rice, cashews) as well as protected areas.

Subsequently, the consortium's geoprocessing team reanalyzed the project's intervention zones and proposed some adjustments, so that the study areas comprised the natural ecosystem and urban developments. Thus, a second zoning was proposed, resulting in Figure 1

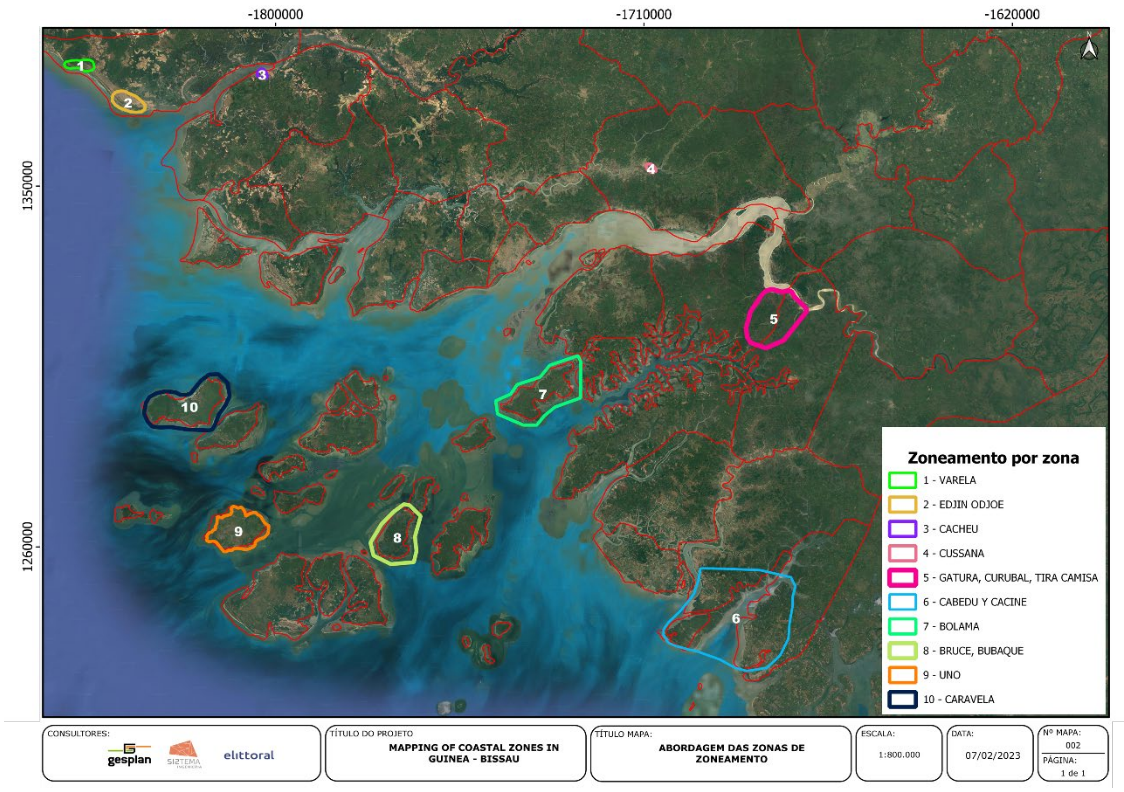


Figure 1.Zoning proposed by the consortium. Source: Consortium.

For the second task, the oceanographic variables were characterized through reanalysis and future projections for Guinea-Bissau coastal zone. To carry out the modelling study of sea level rise scenarios, the selected parameters were significant wave height (Hs), sea surface elevation, air temperature (at 2 m above sea level), precipitation and wind intensity. For each variable, observation points located in Guinea-Bissau territory were extracted and the respective average regimes were studied.

For the third task, the coastal vulnerability study was developed for each area of interest applying a widely known methodology, the Costal Vulnerability Index (CVI). The CVI consists on an approach for vulnerability classification, which varies in a range of 1 to 5, with lower values representing less vulnerability and higher values a greater vulnerability. This index which is calculated from the normalization of the values given to a series of variables and forcings to assess the impact that sea level rise causes in a region.

For the fourth and final task, the possible impacts derived from the rise in the mean sea level were discussed and the vulnerabilities of each location were identified. Furthermore, the consequences of the SLR in the areas of interest were presented for the three modeled scenarios, 2023, 2050 and 2100; and in a second moment, the present or future problems related to the SLR for each zone were detailed.

2. Methodology

To put in context, the Republic of Guinea-Bissau coastline exceeds 300 km in extension and has a width of 250 km. It is an area whose tidal effects can be felt more than 100 km towards the interior of the continent, because of its high tidal range, of great rivers' flows and rivers' branches which cut the landscape, and because of coastal areas' low elevation. Figure 2 represents the study area's topobathymetric chart acquired from GEBCO and processed by the Consortium.

Following to the second task, the oceanographic variables were characterized through numerical modelling with reanalysis and future projections data for Guinea-Bissau coastal zone. The variables selected to carry out the modelling study of the SLR scenarios and to characterize the maritime climate in the region were **significant wave height (Hs), sea surface elevation**, **air temperature (at 2 m above sea level), precipitation and wind intensity**. For each variable, information points located in the Guinea-Bissau area and surroundings were extracted from the database, and the respective average regimes were characterized to create three realistic scenarios (projections): historical/current (2023), near future (2050) and distant future (2100), to be incorporated into numerical models to simulate coastal flood vulnerability in each of the 10 areas of interest.

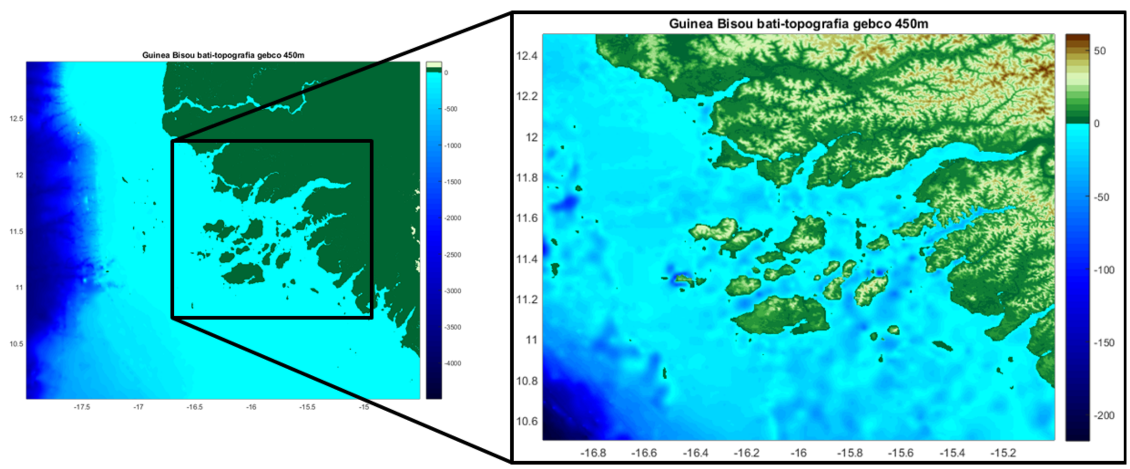


Figure 2. Localization of the study area. Source: elittoral.

For the flood model implementation, the entry data were: the result of the effects of SLR in the three simulated scenarios, the topobathymetry and the maritime climate variables. MIKE 21 Flow Mode (FM) was the model employed for the SLR simulation. It is developed by the Danish Hydraulic

Institute - *DHI,* and it simulates free surface flows in 2D. The numerical scheme used in MIKE21 FM uses a FV (finite volume method) of cell-centered spatial discretization. The spatial domain is discretized using an unstructured triangular mesh to solve equations in shallow water, providing flexibility when making shoreline contour adjustments.

For the simulations of the present study, an unstructured mesh with variable resolution was employed as shown in Figure 3, i.e., with higher spatial resolution in the areas of interest. The coastline was scanned for modeling from territorial orthophoto and the bathymetry used was obtained from the GEBCO portal, which contains an average resolution of 450m per-pixel.

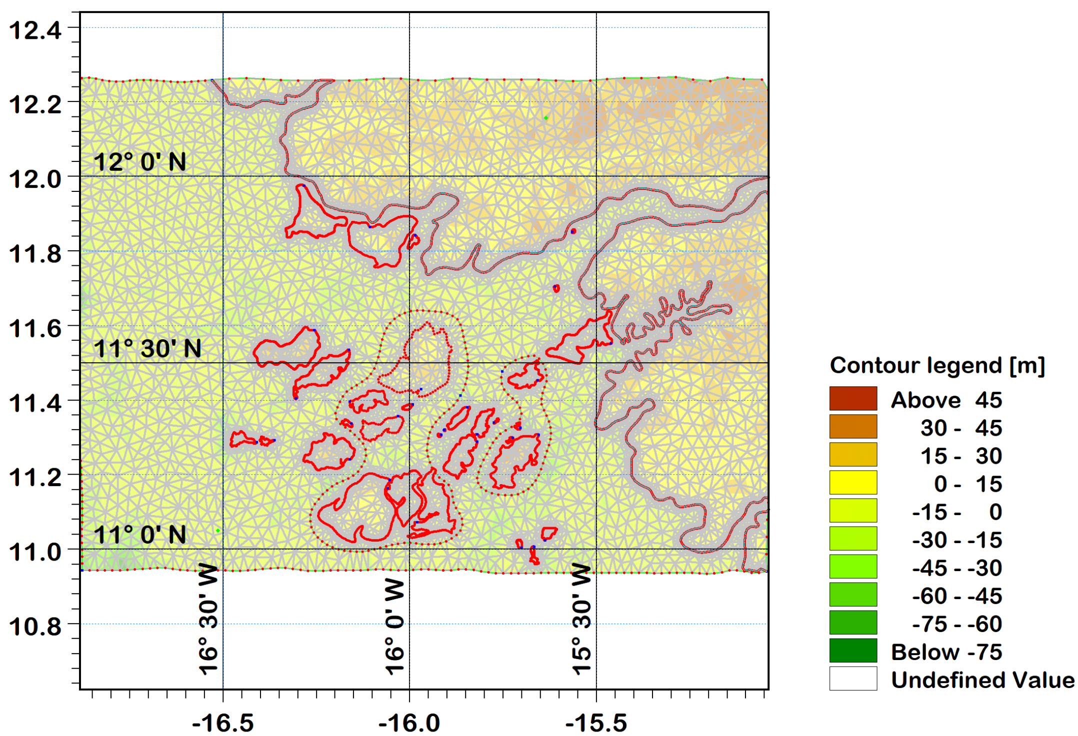


Figure 3. Unstructured mesh in a domain of interest with variable spatial resolution. Source: elittoral.

The numerical modeling results represent the main product to assess the level of vulnerability of the coast of Guinea-Bissau, being able to identify through a cartographic process, the most vulnerable areas to sea level rise caused by climate change. In 2023, the simulation include only the sea surface elevation increase generated by waves; but for the 2050 and 2100 scenarios, it also incorporates the sea level rise data offered by the IPCC for the SSP 4.5 and SSP 8.5 models.

In order to map the coastal vulnerability of the study sites, after validating the input and output data of the model, three reference criteria were determined for the construction of vulnerability scales and identification of the most susceptible areas to sea level rise:

1. Level of maximum increase in the sea surface elevation until 2023 related to the effect of the wave regime, produced under the effects of storm surges processes.
2. Maximum sea level rise by 2050, linked to the IPCC's proposed sea level rise for WACA region.
3. Maximum sea level rise by 2100, associated with the sea level rise proposed by the IPCC for WACA region.

The above criteria allowed the definition of four categories for the vulnerability scale (Figure 4). This classification helps on identifying the most vulnerable areas, as well as monitoring their temporal evolution for the three studied periods.

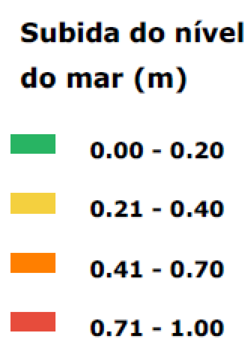


Figure 4. Sea level rise scales. The green value represents the lowest mean sea level rise, while the red value represents the highest value. Source: elittoral.

Finally, the CVI was applied. This index assesses the impact that the sea level rise will have on each of the ten (10) locations of interest. In other words, the CVI acts as a numerical approach based on the potential impact of coastal hazards and SLR, or other issues, for categorising sections of the coast. This index was obtained as a result of the Exposure Index (EI) and the Sensitivity Index (SI) which were calculated based on the CVI model of the InVEST model, designed by the Natural Capital Project.

The CVI can be calculated as the root raised to the number of sorted parameters and divided by the total number of parameters using the following equation:

$$CVI = \left(\sqrt[nEI]{EI}\right)$$

For all indicators used, 13 in total, the lowest value attributed was one (1) and the highest value of exposure and vulnerability was five (5). The indicators selected for this study are shown in Table 2.

Table 2. Variables included for the calculation of the CVI for the project's areas of interest. To check the classification given to each of the variables, see Deliverable 1, section 10.

	Variable	Definition
Coastal variables	*Landform*	Geomorphology of the terrain may present greater or lesser resilience to sea level rise
	Elevation	Height above the ground can condition the vulnerability of localities
	Bathymetry	The slope of the coast and its depth make the coastline more or less vulnerable
	Mean Wave Height	The height of the wave that breaks off the coast can make localities more or less vulnerable
	Mean Tidal Range	Tide level can favour combined storm events and flood larger areas of coastline
	Air *Temperature*	It allows you to determine the impact that the increase in temperature will have for each of the study periods
	Precipitation	Determine the possibility of more or less rain in the study area
	Wind Speed	Determines how the higher the velocity present in the localities, the higher the height of the waves present
Socio-economic variables	*Population Over 65*	Indicates how the age of the population determines the ability to adapt and respond to exposure in each locality
	Education Level	It indicates the effect that the level of education has on the population when applying the proposed mitigation measures
	Population Density	It represents the number of people who will potentially be exposed in each of the locations
Coastal Forcings	*Sea Level Rise*	This criterion governs the level of vulnerability, so the annual increase in mm determines exposure. In the present study, only the current impact is presented
	Storm Surge	This criterion determines the impact that the height of the incident waves associated with an extreme event may increase to the extent of people exposed

It is important to emphasize that **this coastal vulnerability study was developed for the current scenario (2023)**, since in order to understand that this index requires updated data, therefore, to determine vulnerability in other scenarios, such as the near future (2050) and the distant future (2100), reliable statistical data must be available, to calculate and represent the behaviour of each of the variables in the future studied, and that was not the case regarding data availability for this project.

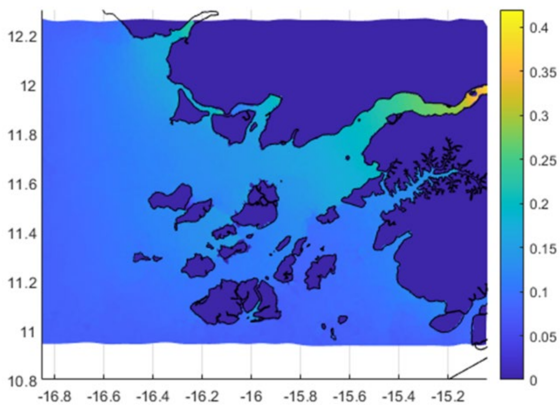
For this deliverable, the following **SLR and coastal vulnerability maps were prepared**:

- Three global maps that include the entire coast of Guinea-Bissau, one for each of the study periods (2023, 2050 and 2100)
- Ten regional maps, one for each of the locations, for the 2023 period.
- Ten regional maps, one for each of the localities, for the period 2050.
- Ten regional maps, one for each of the localities, for the period 2100.
- Ten regional CVI maps, one for each of the locations, for the 2023 period.

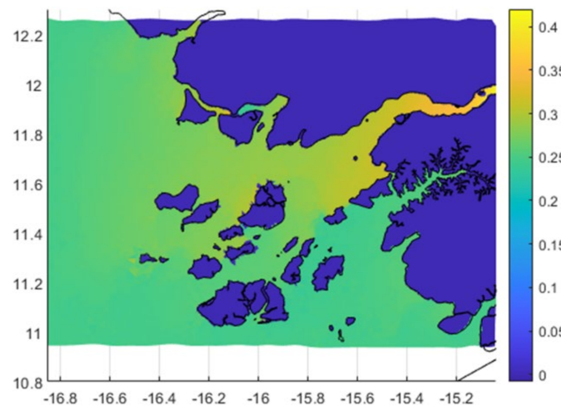
Those maps were attached to the respective deliverable document.

3. Results

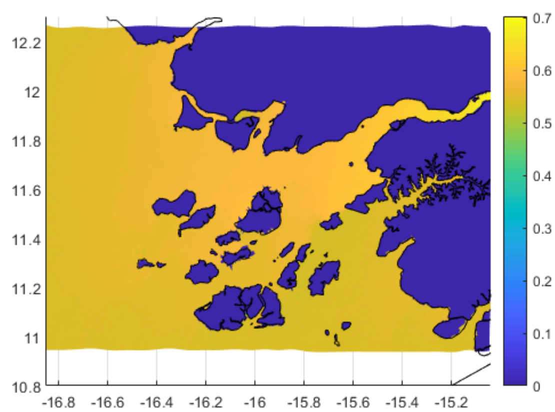
The main results are presented for the sea level rise model and for the coastal vulnerability study. The numerical modelling result for the sea surface elevation obtained as the main consequence of the rise in the sea level, accordingly to the proposed scenarios, the coastal flooding in the whole coastal region and in a specific point in the areas of interest of the project. Figure 5 shows the **result for sea surface elevation modelling for the coastal zone of Guinea-Bissau** for the three scenarios. Even if it is an increase of less than 1 m, because of the low-lying coastal lands, the slightest increase will cause damage to the nation and the activities developed.



Surface Elevation for the Historical Period (2023).



Surface Elevation for the Near Future (2050).



Surface Elevation to the Far Future (2100).

Figure 5. Results for the local sea level obtained from the output of the flood model for the coastal region of Guinea-Bissau. Source: elittoral.

The combination of all the coastal forcings, the geomorphological and the climatic conditions of Guinea-Bissau coast show that although there is an increase in the SLR of the historical accumulated of between 10 mm and 12 mm per year, this trend is changing drastically. In the near future, it could reach values up to 0.4 m. And, if this trend continues, sea level rise could reach up to 0.7 m by the year 2100.

The results on the state of coastal vulnerability (Figure 6) in which the project locations are currently located identified nine out of ten areas most vulnerable to the effects of climate change. The coastal vulnerability index for the islands of Bolama (CVI=3.21) and Uno (CVI=3.19) and for the coast of Varela (CV=3.19) were classified as high vulnerability sites. The other localities are classified as having a moderate level of coastal vulnerability: Caravela (CVI=2.94), Ilha de Bubaque (CVI=2.82), Cacheu (CVI=2.94), Cabedu (CVI=2.91) and Edjin Odjoe (CVI=2.82) and Gã-ture, Tébe and Lagoa de Cufada (CVI=2.55).

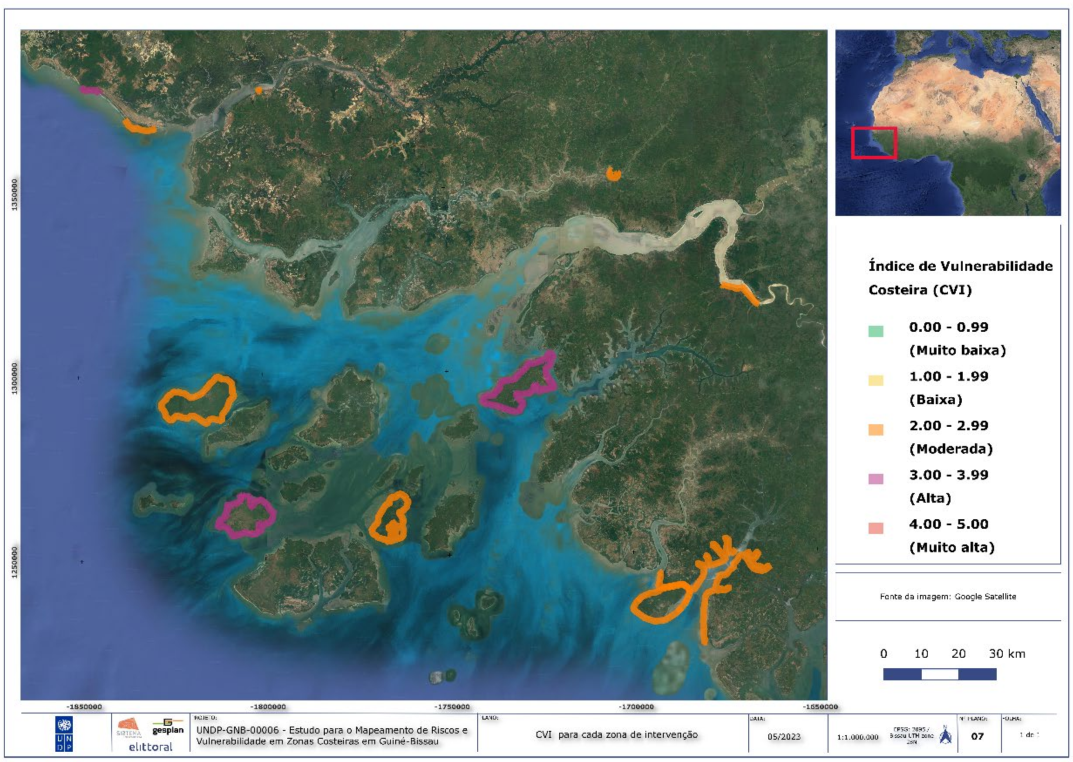


Figure 6. Mapping of coastal vulnerability for the ten locations of interest of the project. Source: Consortium.

Among the **consequences of the rise in the average sea level**, one of the most drastic is related to rice crops. The main national subsistence is based on the rice crops in bolanhas, so the success of its cultivation is extremely relevant not only for the country's economy, but for its population. The aggravation of coastal erosion and saline intrusion can alter the cycle of a crop so dependent on water and the effects of the climate change are already affecting such relevant activity to the economy and livelihood of the local population.

Due to the presence of the mangrove, which in addition to being a fertile ecosystem rich in biodiversity, acts as a coastal protection structure by promoting soil fixation, preventing erosion, and maintaining the stability of the coastline, it favours the development of rice crops in salty balls on the back side of the mangroves, in a cultivation style called bolanhas. However, with intense deforestation this natural protection is not enough for protecting the rice crops from the saline intrusion or erosion, and it is necessary to resort to the construction of earthen dikes, which in turn are threatened by the intensification of coastal erosion and increased wind and wave regimes.

Thus, in the different coastal regions of the country, water management structures have been created for the crop fields, but despite this, the rice agriculture still faces challenges, since mangrove rice is cultivated through the construction of dikes along the tidal channels with 1.5 to 2 m in height. Therefore, if measures are not taken to contain the advance of the sea towards the continent, permanent changes in the territory will affect this sector.

In addition, the expected effects to a greater or lesser extent of the SLR depend on:

- Extent of coastal vegetation cover, whether from the emersed beach, slopes or mangrove forest;
- The width of the sandy beaches, and whether they are permanent beaches or not;
- The presence and condition of coastal or port protection infrastructures;
- The presence of commercial, tourist or residential establishments.

To understand the problems and the reality experienced by the coastal communities surveyed for the project, a field trip was carried out, which served so that the specialists could analyse and photographically record the current situation to propose specific and appropriate improvements for each area aiming to reducing coastal vulnerability.

The region of interest in **Varela** is a beach environment with low elevation of the terrain, around 4 m, with an adjacent bathymetry less than 3 m deep and with a tidal range between 3 and 4 m, makes this area more vulnerable to transgression of the coastline and to coastal erosion. In addition, the area presents rice cultivated in bolanhas, which are threatened by saline intrusion, the advance of sea level and the lack of maintenance of the land dikes.

In **Edjin Odjoe – Catão**, the region has similar characteristics of the anterior region, except that it has an adjacent bathymetry deeper than the previous zone, with approximately 20 m depth. Furthermore, the same problems are faced in the area.

For **Cacheu**, the locality is inserted on a fluvial environment, marked by the presence of cultivated fields, coastal structures, and population settlements. The vulnerability of this area is mainly linked to the fact that there are urban/port structures and settlements by the river banks, and an adjacent bathymetry less than 3 m deep. However, it is a site with a tidal range between 2 and 3 m that has an average elevation of more than 10 m, which contributes to reducing the risks of impact of coastal processes. The main problems affecting Cacheu are the deterioration of coastal structures and tourist establishments and the lack of garbage management, which eventually ends up in the river.

In **Cussanja and Mansoa**, the reality is quite different from the others, being the only one located completely in the interior of the country. This is an area that is mainly dedicated to agriculture, and has problems related to water management, already presenting periods of drought, which affect the agriculture.

Gã-ture, Tébe and Lagoas de Cufada is a region marked by the presence of cultivated fields, coastal structures and population settlements. It is a fluvial and lacustrine zone, with an adjacent bathymetry about 40 m deep, with a tidal amplitude between 2 and 3 m, with an average elevation of the terrain greater than 4 m. In addition, Lagoas de Cufada area are an integral part of the RAMSAR Convention, and therefore have a high natural value for the region. The main problems faced by this locality are the formation of alluvial plains from the sedimentation promoted by the fixation of the roots of shrubby plants on the shores of the lagoons, loss of effectiveness of the dikes due to lack of maintenance and, consequently, the flooding of the cultivation areas in rainy seasons, drought in dry seasons and loss of vegetation in sloping marginal areas.

For **Cabedu and Cacine**, a flat estuarine environment, with an average elevation of approximately 4 meters and an adjacent bathymetry of less than 3 m in depth, which presents artificial structures, is a site with a tidal amplitude between 1 and 2 m and dense vegetation cover. The main problems in the area are the deterioration of coastal structures and saline intrusion on the crop fields.

For the insular region of **Bolama**, a very flat area, with a tidal amplitude of 3-4 m, adjacent bathymetry of approximately 5 m in depth, it has the presence of population settlements and coastal structures that have been under deterioration for a long time. The main problems faced by Bolama are the advance of the sea towards the land, wearing down basic coastal structures that are important for the movement and connection of the island to other parts of the continent and the coastal flooding of areas with low elevation.

Similar to the region of Bolama**, Bubaque Island** is quite flat, with a tidal range of 3-4 m in amplitude, adjacent bathymetry of approximately 10 m in depth. Similar problems to Bolama are also found in this locality.

Uno Island is also a flat territory, with a tidal range of 3-4 m in amplitude, adjacent bathymetry of approximately 3 m in depth, and faces problems of coastal erosion, loss of vegetation cover, and loss of beach area.

Finally, **Caravela**, an island marked by the population settlement of nomadic communities established on the coast of the island, faces problems with the amount of garbage and material found left on the ground. It is a very flat region, with a tidal range of 3-4 m in amplitude, with adjacent bathymetry of approximately 10 m in depth. The main problems faced by Caravela are the advance of the sea towards the land, and the coastal flooding of areas with low elevation.

Climate Change Mitigation Strategies for the Proposed Pilot Zones in Ten Study Areas

This section describes the context in which this document was developed, the methodology applied, and the main results obtained for Deliverable 2, entitled "Climate Change Mitigation Strategies".

1. Framework

The goal of the second deliverable is to identify the most vulnerable elements in the territory to the rise in mean sea level by zone and propose mitigation and adaptation strategies to address their risks.

To achieve the proposed objectives, the first task involved conducting a general diagnosis of coastal infrastructure, taking into account the topography, geology, water resources, bathymetry of the area, types of vegetation cover and their condition, and road conditions.

In a second phase, a zone-specific diagnosis of the existing infrastructure was carried out. The photographic records obtained during the field mission were crucial for illustrating the reality faced by each locality. These records were obtained through drone flights and traditional photography which is found in the Deliverable 2.

The third task involved a detailed description of adaptation and mitigation strategies (AMM) to the effects of sea-level rise. AMM were categorized into two groups: nature-based solutions and hard solutions.

Finally, AMM that best suited the problems and realities of each zone were proposed. The project's scope covers an area of aproximately 1,340 km^2 of coast, thus, due to administrative and logistics tasks, and in order to develop a suitable and specific work, the pilot zone of each one of the areas of interest presents a reduced dimension, counting in total with a 0.61% of the project's area of interest. The integral dimension of each target area and pilot zone are exhibited in Table 3. In this sense, the pilot zones were established to focus efforts and propose specific measures for regions that are more vulnerable, within each of the ten project target locations, and then the AMM could be integrally extrapolated target areas.

Table 3. Comparison between the project's study area dimension and suggested pilot zones dimension.

Region of interest	Integral Area (km2)	Pilot-zone extension (km2)
Varela	16.08	0.09
Edjin Odjoe-Catão	33.87	1.57
Cacheu	5.39	0.18
Cussanja and Mansoa	3.03	0.38
Gã-ture, Tébe and Lagoas de Cufada	134.34	5.65
Cabedu and Cacine	618.54	0.16
Bolama Island	147.34	0.04
Bubaque Island	93.39	0.03
Uno Island	121.77	0.04
Caravela Island	163.01	0.01
Total	**1,336.76**	**8.15**

2. Methodology

For the zone-specific infrastructure diagnosis, the main infrastructural problems affecting the intervention areas were detailed.

In the Varela sector, characterized by beaches, estuaries, and cliffs, there is a lack of coastal protection infrastructure at various levels. This region is dominated by limestone, thus presents little resistance to waves impact and currents, exacerbated by sea-level rise, which results in advanced coastal erosion with significant sediment loss.

Additionally, there is a lack of access infrastructure, with the area lacking well-structured roads for people and vehicles to access the beach and for coastal protection works to prevent the retreat of the coastline. Moreover, anchoring and fishing activities structures are scarce.

For Edjin Odjoe - Catão, an environment similar to Varela, with a watercourse running through the intervention zone and the nearby Catão River, agricultural activity is predominant. There is a need for land dikes and hydraulic infraestrures construction. As well as a necessity for improvement in road infrastructure to meet the demands of the area and promote agropastoral activities.

In Cacheu, an area located along a river, there are urban area with diverse housing and buildings of tourist interest, cultivation fields and port facilities. In geological terms, the terrain consists of marly limestone and small areas of mud and sand. The region has a good barrier agianst erosion due to the presence of mangroves, however, is prone to flooding during rainy season due to the increased river level. Lack of a strategically planned drainage system, of maintenance of port infrastructure, of apropriate waste management, of tourist resources supervision, of smaller docks to meet the fishing demand, of circulation routes for people and vehicles, and of beach access were the identified issues.

For the Cussanja and Mansoa sector, which is characterized by mud and sand soil, sections with limestone and possibly clayey soil are present as well. Despite being close to the urban area of Mansoa, the zone lacks many types of infraestructures, such as hydraulic works for water transport and drainage for crops and animals, bridges for people and vehicle crossing, well-maintained access roads, and maintenance of earthen dikes.

The infrastructural diagnosis for Gã-ture, Tébe, and Lagoas de Cufada, another study area located along a river, identified cultivation fields without coastal infrastructure, sourrounded by small population clusters, a river beach area composed of sand. The ongoing deforestation process of mangroves for opening up cultivation fields or other activities along the riverbank has been causing flooding of the bolanhas and eroding caused by waves and currents resulting on problems in the low-lying areas. Another problem existent in the region is the lack of access infraestructures, the sedimentation and alluvial plains formation due to the floating vegetation constantly present in the Lagoas de Cufada, decreasing its navegability. Furthermore, wooden docks in the Lagoas de Cufada region are in need for rehabilitation as they area collapsing.

Cabedu and Cacine is geologically characterized by beaches and sands with small percentage of limestone soil and cut by tributaries of Cacine River. Reguarding the fishing and port infrastructures, there is a dock area, however without access ramp to the fishermen and a small port with damaged structures. The problems identified on the region were deterioration of coastal structures, saline intrusion in crops, poor road conditions, lack of maintenance of earthen dikes, and a need for bridges and accessibility structures.

For Bolama Island, which is predominantly composed of mud and sand, and limestone rock dominate the area, being more sucesptible to erosion. There are still a dense mangrove forest coverage providing coastal protection, however it requires restoration in some parts. The region faces water scarcity despite having several watercourses, due to an inadequate water supply system form the groundwater. The island presents few port and coastal protection infrastructures, such as seawalls, which are in poor condition, requiring rehabilitation to indeed protect the villages, allow passengers boarding and products’ commercialization.

Also, ancient drainage infrastructures from the colonial period, built by the Portuguese, were identified which revealed obsolete trenches along the streets that could be rehabilitated and repurposed. In specific cases, improvised earth trenches were found along the streets for rain water drainage. However, in areas of the city where no trenches exist, rainwater runoff causing soil erosion, creating channels where city waste accumulates.

The diagnosis of Bubaque Island identified predominantly limestone geological formations, with sandy regions on the shores and the presence of laterites on the coast. The island contains several watercourses bordered by abundant vegetation. It features abandoned and deteriorating urban structures from the colonial period, including trenches that assist in surface water drainage and protection of slopes on hillsides in an advanced state of erosion. Additionally, the Bruce and Bubaque areas have hotels and restaurants that have been affected by erosion caused by the advance of seawater.

Due to the disorderly, inadequate, and/or obsolete nature of coastal protection constructions, they are no longer able to provide the necessary protection. Other existing coastal port structures are already deteriorated due to the advancing sea, with noticeable degradation in pier and stair structures, as well as collapsing walls.

Uno Island is geologically characterized by limestone structures, sandy beaches, mangroves forest, and laterites on the coast. The island has few watercourses, and likewise the other islands, the road conditions area poor and require pavement.

Lastly, Caravela Island presents a limestone predominant soil, with sandy beach regions along the shores, mudflats areas with mangroves, and various points with coastal laterites. Similar to Uno Island, Caravela has few watercourses. The exploration of resources, particularly marine resources, is mainly carried out by a non-native and non-national community that has settled in an area adjacent to the sea, where they have a pontoon and area that lacks infraestructures used by fishermen to dock their fishing boats. In terms of basic urban infrastructure, it is nonexistent, with residential constructions made of tin and local woods. Additionally, there is poor waste management, eventually leading to environmental pollution, as the island lacks solid and liquid waste sanitation. Furthermore, the coastal area lacks port infrastructure, such as cargo unloading and passengers facilities, as well as paved roads, similar to the other islands.

An exhaustive compilation of the most used strategies for adaptation and mitigation to climate change and sea-level rise issues was conducted and is described in the "Proposed Mitigation and Adaptation Strategies" section of Deliverable 2. Table 4 provides informative scores for the considered measures.

Table 4. List of the most frequently used sea level rise adaptation and mitigation strategies in coastal environments.

Nature-based solutions	Hard Engeneering Measures
Development of an Integrated Management Strategy for Coastal Areas	Construction/rehabilitation of reinforced concrete walls
Establish protected areas for conservation	Construction/rehabilitation of earthen dikes
Strengthen and improve the management and conservation of protected areas	Construction of cladding/rockfill structures;
Promoting and preserving green and blue infrastructure	Spike/jetty construction
Beach regeneration	Breakwater construction

Restoration of submerged beach vegetation	Construction of houses of Caneiras type
Coastal Forest Restoration	Hydraulic works construction
	Construction/rehabilitation of port structures

The main problems in each location of interest were previously identified in Deliverable 1, therefore, the methodology of this document to achieve the proposed objectives was restricted to identifying the AMM by study zone that the Consortium considered pertinent to act on the aforementioned complications.

3. Results

The main results are presented for the proposed MAMs (Mitigation and Adaptation Measures) for the pilot zones in each study area. These measures were designed to reduce coastal vulnerability and address the main consequences of flooding and climate change anticipated for the Guinean coast according to the proposed scenarios.

Varela pilot zone was divided into three areas of operation - beach, crop fields, and fishing village - the following AMM were proposed:

In the crop area, where rice bolanhas dominate:

I. Rehabilitation of earthen dikes or construction of new dikes around the rice fields to prevent seawater intrusion.
II. Construction of earth channels to allow water circulation within the fields.
III. Restoration of vegetation cover along the coastline to strengthen the mangrove forest and beach vegetation.

In the beach areas:

IV. Construction of concrete walls for protection and stabilization of the coastal slope.
V. Restoration of vegetation cover.

In the fishing village:

VI. Construction of anchoring docks and concrete ramps.
VII. Demolition of shacks and construction of Caneiras houses.
VIII. Artificial nourishment of the beach to provide greater width to the emerged beach.
IX. Construction of access roads to the village area.

For the **Edjin Odjoe-Catão pilot zone**, the following AMM were proposed:

I. Construction and maintenance of agricultural dikes to prevent saline water intrusion into agricultural fields.

II. Restoration and reinforcement of coastal forest cover in areas with deficient vegetation.

III. Construction of water supply channels for crop fields where water does not reach adequately.

IV. Construction of a road connecting the village and agricultural fields.

For the **Cacheu pilot zone**, characterized by a significant population settlement, the proposed AMM include:

I. Construction of new walls with sufficient height to protect infrastructure against tidal waves, reinforced with mangrove or tarrafes restoration in front of the walls.

II. Protection and restoration of existing historical heritage (fort).

III. Rehabilitation of the pier and construction of a concrete ramp.

IV. Beach restoration.

V. Construction of a pedestrian walkway along the coastal perimeter, with access to infrastructure along the shorelines through stairs and access ramps.

For the **Cussanja and Mansoa pilot zone**, the proposed AMM include:

I. Construction of conduits for water crossing where bridges exist.

II. Construction of roads for better access.

III. Dredging and widening of the river channel.

IV. Construction of earth dikes to allow more abundant water in the fields.

For the **Gã-ture, Tébe, and Lagoas de Cufada**, three sectors were proposed. For **Gã-ture pilot zone**, the recommended AMM include:

I. Use of geotextile containers for protection and stabilization of the river coastal margin.

II. Construction and rehabilitation of earth dikes.

III. Restoration and reinforcement of vegetation along the riverbanks.

For the **Lagoas de Cufada pilot zone**, the proposed AMM include:

IV. Rehabilitation of a set of wooden bridges/walkways/pier distributed throughout the area for river crossing, currently unused due to high deterioration.

V. Intentional and mechanical clearing of vegetation to promote water and boat circulation and prevent silting.

For **Tebé pilot zone**, the proposed AMM include:

VI. Construction of earthen dikes.

VII. Construction of trenches drains for water circulation

For the **Cabedu and Cacine**, both with population settlements, the proposed AMM **for Cabedu pilot zone** include:

I. Construction of boat anchoring docks and transportation for people.

II. Construction of access road to the village.

III. Construction of a bridge.

IV. Rehabilitation of earthen dikes.

For the **Cacine pilot zone**, the proposed MAMs include:

V. Rehabilitation and construction of coastal protection walls around the inhabited area to offer security and protection to infrastructure.

VI. Rehabilitation of the existing pier.

VII. Construction of a concrete ramp.

VIII. Construction of wooden docking area for boats.

IX. Construction of access road to the village.

For the **Bolama Island pilot zone**, located in the village of Bolama, the proposed AMM include:

I. Construction and rehabilitation of existing walls along the coast with sufficient height to prevent flooding in inhabited areas.

II. Demolition of the existing pier and construction of a new pier, along with a concrete ramp.

III. Creation of drainage channels and correction of rainwater drainage lines through the construction of reinforced concrete tranches and drains.

IV. Restoration of coastal vegetation forest.

For the **Bubaque Island pilot zone**, the proposed AMM include:

I. Construction of reinforced concrete walls at the base of the slope, with foundations on firm soil and approximately 1.50 m deep.

II. Construction of a concrete walkway along the entire coastline for people's circulation, including stairs for access to these platforms and beach areas.

III. Construction of drainage channels for rainwater, channeled to the sea through appropriate channels.

IV. Rehabilitation of the port, which is already in a high degree of deterioration and needs maintenance.

V. Restoration and reinforcement of vegetation cover on coastal margins to assist in protection against coastal hazards.

For the **Uno Island pilot zone**, as no visit could be carried out, the AMM were suggested based on local population issues identified during intereactions with local population:

I. Rehabilitation of all degraded coastal structures, including protection walls and port facilities.

II. Restoration of coastal green cover by planting mangrove or tarrafes.

For the **Caravela Island pilot zone**, the proposed AMM include:

I. Creation of an urbanization plan for the area.

II. Demolition of all existing shacks and construction of new social houses with better conditions for people engaged mainly in fishing activities.

III. Creation of plans for waste collection and treatment, defining locations where waste should be placed and then removed by competent authorities.

IV. Construction of a road , made of concrete pavement, providing better mobility and access to the coast, construction of a wooden pier, and construction of a concrete ramp.

V. Restoration of green covers along the margins to protect the coasts against erosion caused by the advance of the sea.

In addition to all the information described above, technical sheets were developed where the characteristics of each zone, existing issues, and the aforementioned AMM for each pilot zone are detailed in the document attached to Deliverable 2.

Cartographic Report on Vulnerability Mitigation in the Coastal Zone of Guinea-Bissau

This section describes the context in which the document was developed, the methodology applied and the main results obtained for Deliverable 3, entitled "Cartographic Report on Vulnerability Mitigation in the Coastal Zone of Guinea-Bissau".

1. Framework

The objectives of Deliverable 3 were correlating coastal problems associated with the sea-level rise to the main proposed measures by area of interest aiming on mitigating significant and further damages to infrastructure and the population, and to calculate the spatial and temporal scales in which each measure would be most effective in addressing the problems. This deliverable also aimed to outline the cartograph the new coastal vulnerability index (final VI) and the result of the flood level modeling after the theoretical implementation of the proposed AMM.

To achieve these objectives, the first task was to compile and provide a detailed description of all the coastal problems associated with climate change affecting the project's study regions.

Next, the document presented a description of the positive effects and a list of factors influencing the temporal scale to achieve benefits after the implementation of each proposed AMM in Deliverable 2.

In a third task, information about the regions' characteristics, coastal problems faced, pilot zones, and suggested AMM for reducing vulnerability were summarized by zone of interest.

For the CVI reduction mapping, the Rapid Vulnerability Assessment methodology was employed. This methodology evaluates the sensitivity, adaptability, and exposure of the area of interest through matrices developed for each problem, considering a desired temporal and spatial scale of protection. The results of these matrices were then interpreted, and tables were developed to display the temporal and spatial scale for generating the greatest benefit for the implementation of each respective protective measure.

Finally, through numerical modeling of the SLR an evaluation of the proposed coastal engineering works was conducted after the theoretical integration of the AMM in the the coastal zone digital elevation model (DEM) of Guinea-Bissau.

2. Methodology

The coastal problems identified in association with sea-level rise include coastal erosion, lack of management of stormwater, deforestation of coastal forests, damage to rice field dikes, lack of basic sanitation, absence of paved roads, coastal flooding, saline intrusion, and loss of agricultural fields. For more detailed information about each adversity, it is recommended to refer to the "Coastal Problems Related to Climate Change" section in Deliverable 3.

The adaptation and mitigation mesaures (AMM) for the identified problems are presented in Table 5. These measures were detailed by zone in the "Mitigation and Adaptation Strategies" section in Deliverable 3.

Table 5. Nature-based and hard engeneering measures for the adaptation and mitigation of problems related to sea level rise in Guinea-Bissau.

	Proposed adaptation and mitigation measures
Number	**Nature-based solutions**
1.1	Elaboration of a GIAL strategy
1.2	Establishment/Reinforcement and improvement in the management and conservation of protected areas
1.3	Promoting and preserving green and blue infrastructure
1.4	Beach regeneration
1.5	Restoration of the vegetation of the emersed beach
1.6	Ecological restoration of coastal forest
1.7	Recovery and improvement of cultivation areas and rice paddies
	Hard engeneering measures
2.1	Construction of earthen dikes in rice paddy areas
2.2	Installation of hydraulic system in agricultural fields
2.3	Geotextile Sandbag Liners
2.4	Construction work for reinforced concrete walls
2.6	Paved roads construction work
2.7	Restoration and/or construction of port infrastructures
2.8	Dredging of herbs and sediments

For the assessment of coastal vulnerability reduction, the key point was to determine the most effective combination of nature-based and hard measures that could alleviate vulnerabilities in these regions. This objective is achieved through the application of the Rapid Vulnerability Assessment methodology, adapted by the Commission for Environmental Cooperation and EcoAdapt. For each AMM, five time periods ranging from short-term (1-2 years) to long-term (50-

100 years) and five spatial scales, covering small (0-1 km) to large areas (16-30 km), are considered. This fragmentation recognizes that the effect of a measure on a problem may vary based on its temporal period and spatial context. For example, the consequences of constructing a seawall to combat coastal erosion would be different within two years versus fifty years after its implementation, as well as when protecting an area of 2 km versus one of 30 km.

With these variables integrated into a matrix (Figure 7), the final task involves determining the value of vulnerability reduction and selecting the most suitable temporal and spatial scale. This approach assesses vulnerability as the product of Risk multiplied by Adaptive Capacity, employing a scale of 1-5. To ensure alignment with the context of this study, the scale is normalized to a range of 0 - 1.8 using a simple three-to-one rule. The risk components – sensitivity and exposure – and adaptive capacity are clearly differentiated.

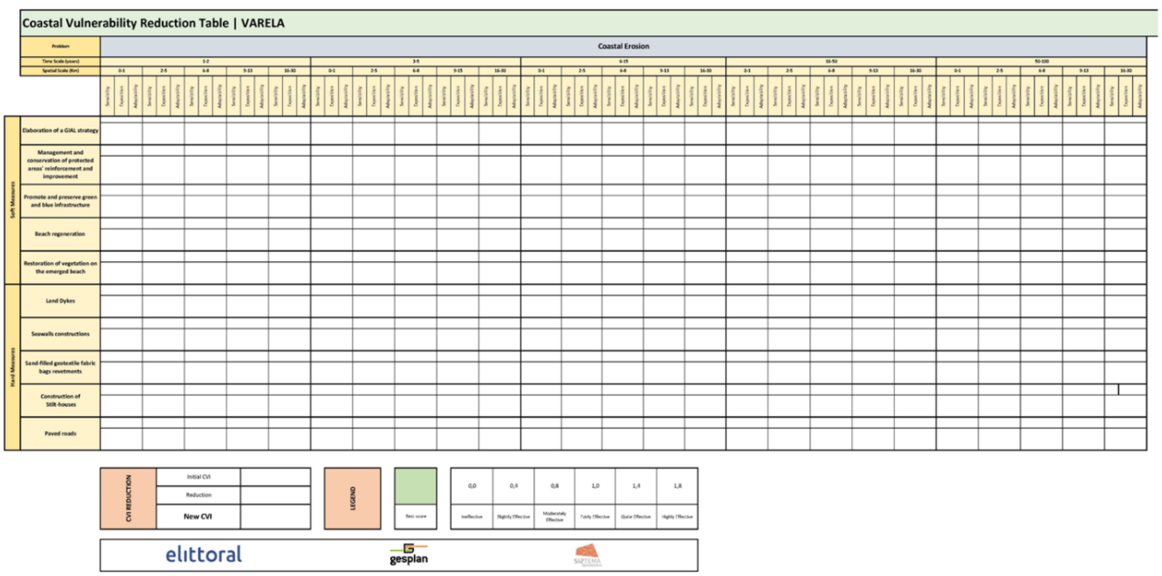


Figure 7. Assessment matrix for the reduction of coastal vulnerability to a specific problem, according to the temporal and spatial scale of the implementation of nature-based and hard-built solutions. The values of the original CVI (initial CVI), the reductionof the CVI (reduction) by the application of the measures and the final VI (New CVI), as well as the classification scale of the efficiency of the measures are located below the matrix

The numerical simulation of coastal flooding identified the most vulnerable points to sea level rise, identified on the coasts and banks of the rivers of Guinea-Bissau and which pilot areas would potentially benefit from the construction of one or more Mitigation and Adaptation measures. Ultimately, this methodology assessed whether the implementation of these new measures will help prevent potentially catastrophic flooding in the future.

This type of analysis, called flood potential filter, evaluates the proposed work in three domains and three different scenarios, historical (with a rise of 0.25 m), near future (with a rise of 0.40 m) and distant future (with a rise of 0.65 m) (Figure 8).

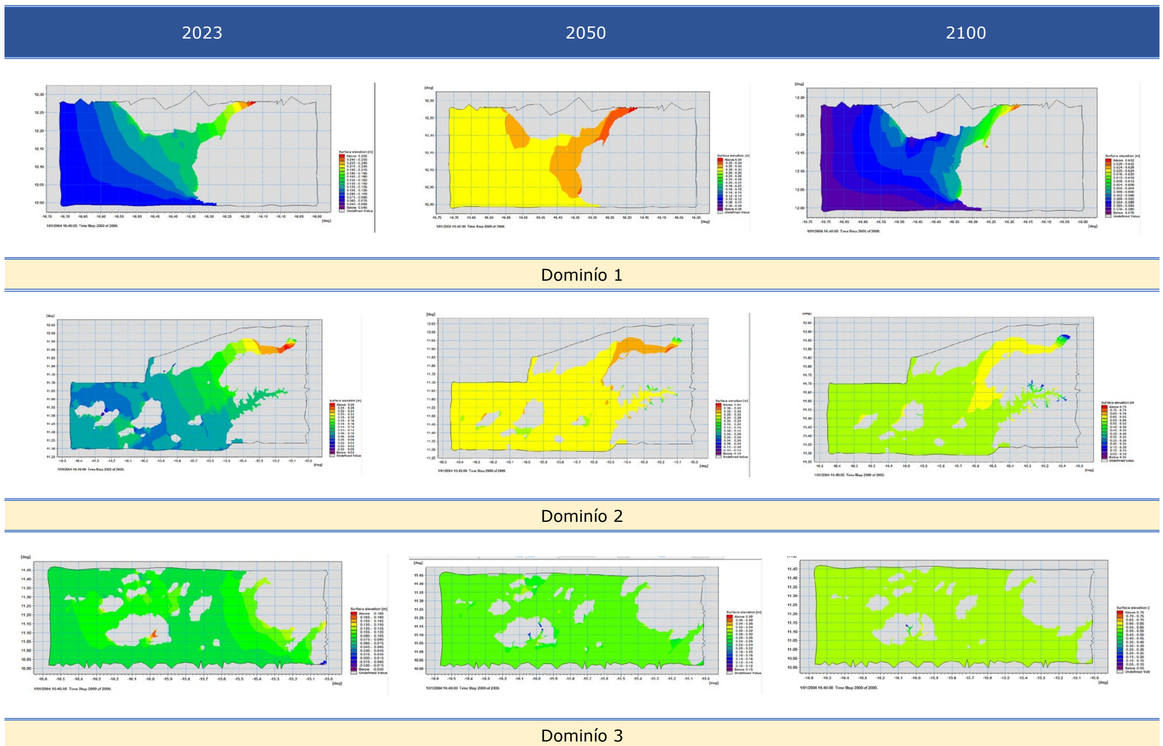


Figure 8. Model domain regions and modeled sea level rise scenarios. Source: elittoral.

The impact assessment of the proposed coastal works was conducted using the modified DEM to represent future conditions with the implemented protection structures. The methodology involved comparing simulations of sea elevation surface for the SLR projections with and without the protection works to identify changes in coastal flooding, erosion, and other alterations in the coastal environment. Finally, the results were analyzed to determine the effectiveness of the protection works in reducing the impacts of SLR.

This methodology provides a robust framework for modeling sea-level rise and assessing the impact of coastal works in Guinea-Bissau, enabling informed decision-making regarding coastal protection and adaptation to climate change in the region.

3. Results

Through the implementation of these coastal protection measures, Guinea-Bissau could enhance its resilience to natural threats such as coastal erosion and flooding. This not only safeguards the natural resources essential for the livelihoods of local communities but also provides a safer and more stable environment for a sustainable economic development of the country. Thus, the reduction of coastal vulnerability represents a crucial step towards ensuring a safer and more thriving future for the country and its coastal populations.

Therefore, it is expected that the integration of the proposed AMM in each pilot zone within each of the ten project areas will help reduce coastal vulnerability. The result of the reduction in the original Coastal Vulnerability Index (CVI) after the theoretical implementation of the measures can be observed in Table 6. Furthermore, the spatial plans for the implementation of the mentioned AMM for each pilot zone are detailed in the document attached to Deliverable 3.

Table 6. Original CVI values, CVI reduction by the application of adaptation and mitigation measures and final VI for each area of interest of the project. The color scale that is applied to the table refers to the degree of vulnerability that the zone is subjected to (0 – 5). Green – very low, yellow – low, orange – moderate, purple- high, and red – very high

Locality	Zone	CVI (1-5) original	RCVI (0 - 1,8)	Final VI (1-5)
Varela	Cacheu	**3,19**	**1,30**	**1,89**
Edjin Odjoe - Catão	Cacheu	**2,82**	**1,31**	**1,51**
Cacheu	Cacheu	**2,94**	**1,22**	**1,72**
Cussanja and Mansoa	Oio	**2,59**	**1,24**	**1,35**
Gã-ture, Tebe Lagoa de Cufada	Quinara	**2,55**	**1,21**	**1,34**
Cabedu and Cacine	Tombali	**2,91**	**1,26**	**1,65**
Bolama Island	Quinara	**3,21**	**1,32**	**1,89**
Bubaque Island	Bolama	**2,82**	**1,43**	**1,39**
Uno Island	Bolama	**3,19**	**1,47**	**1,72**
Caravela Island	Bolama	**2,94**	**1,31**	**1,63**

The current coastal vulnerability index (CVI) and the projected final index for after the implementation of the AMM (Final VI) are shown in Figure 9.

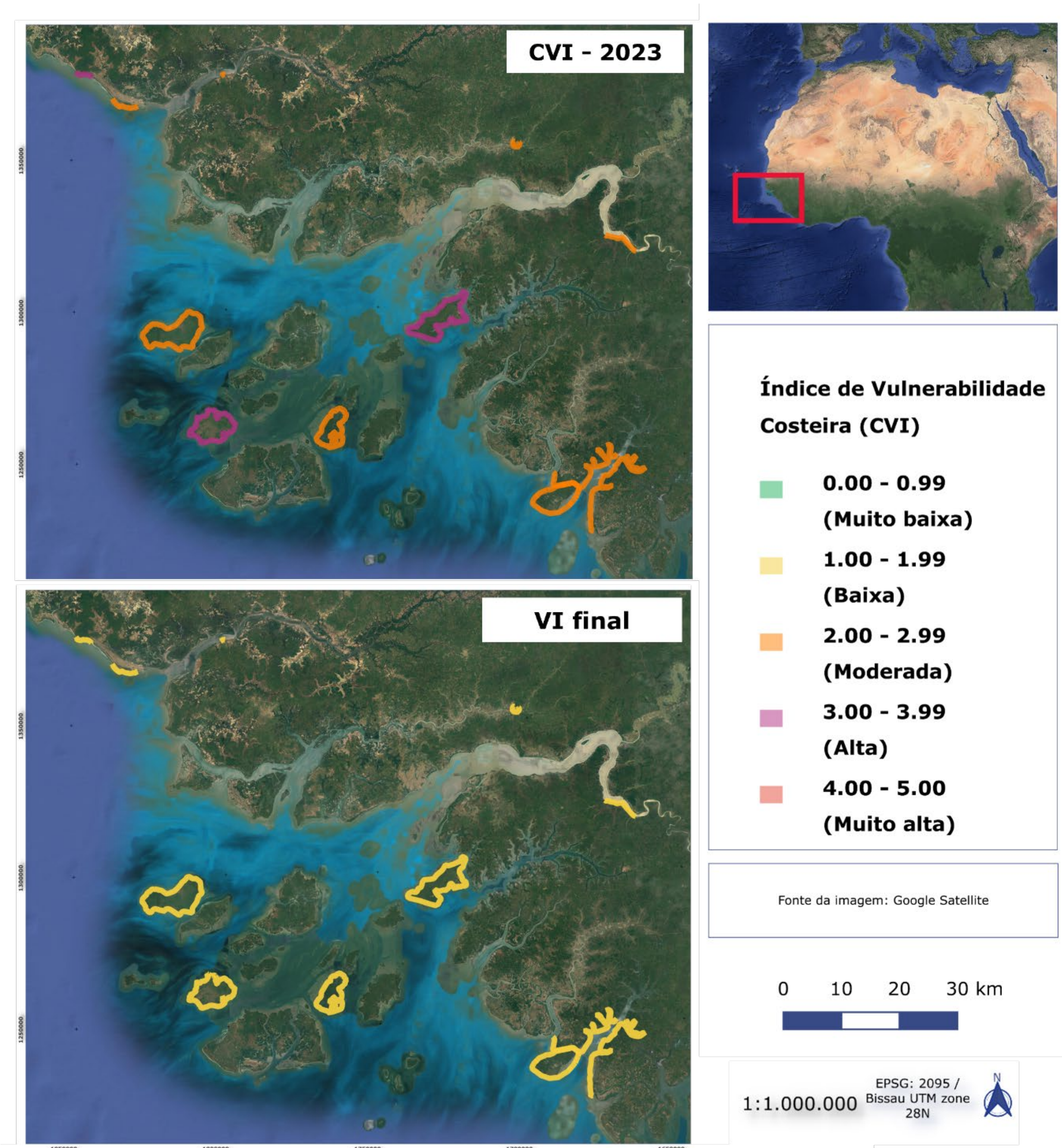


Figure 9. Comparison of the original CVI (above) and final VI (below) after the implementation of the proposed works for mitigation and adaptation of Coastal Vulnerability for the ten zones of the project. Source: elittoral.

For details regarding the temporal and spatial scale where the greatest benefits of the AMM are expected, please refer to the "Coastal Vulnerability Reduction – Zone Discussion" section of Deliverable 3.

The results for the flood simulation are presented for only six areas of interest of the project due as only the coastal areas were considered for the SLR numerical modelling. The assessment outcome for historical, near-future, and distant-future scenarios for the implemented measures in the **pilot zones of Varela and Cacheu** is illustrated in Figure 10. According to the investigation, the applied measures for both pilot zones can contribute to preventing floods in the near and distant future.

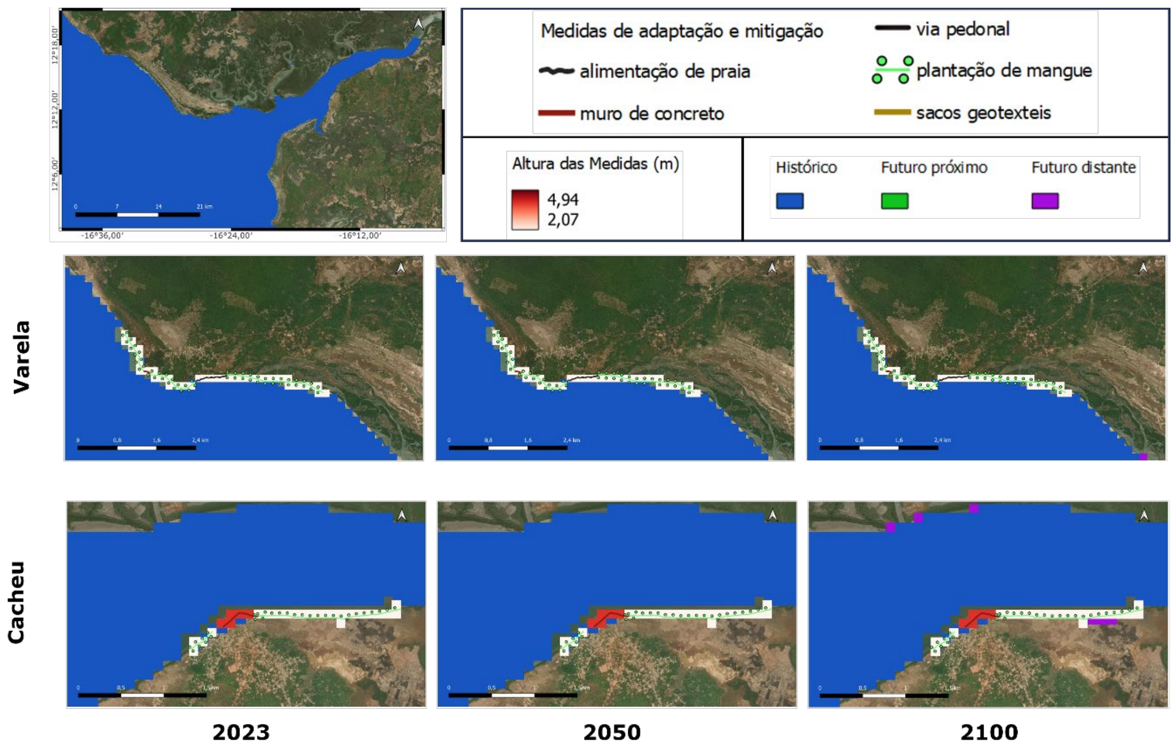


Figure 10. Evaluation of the protection of the proposed measures for the pilot areas of domain 1 for the three simulated scenarios. Source: elittoral.

The assessment results for historical, near-future, and distant-future scenarios for the implemented measures in the **pilot zones of Bolama and Gã-ture, Tébe, and Lagoa de Cufada** are depicted in Figure 11. It is observed that for the Gã-ture pilot zone, the implementation of protective measures contributes to preventing floods in all three scenarios. On the other hand, Bolama appears more susceptible to sea-level rise in the distant-future scenario.

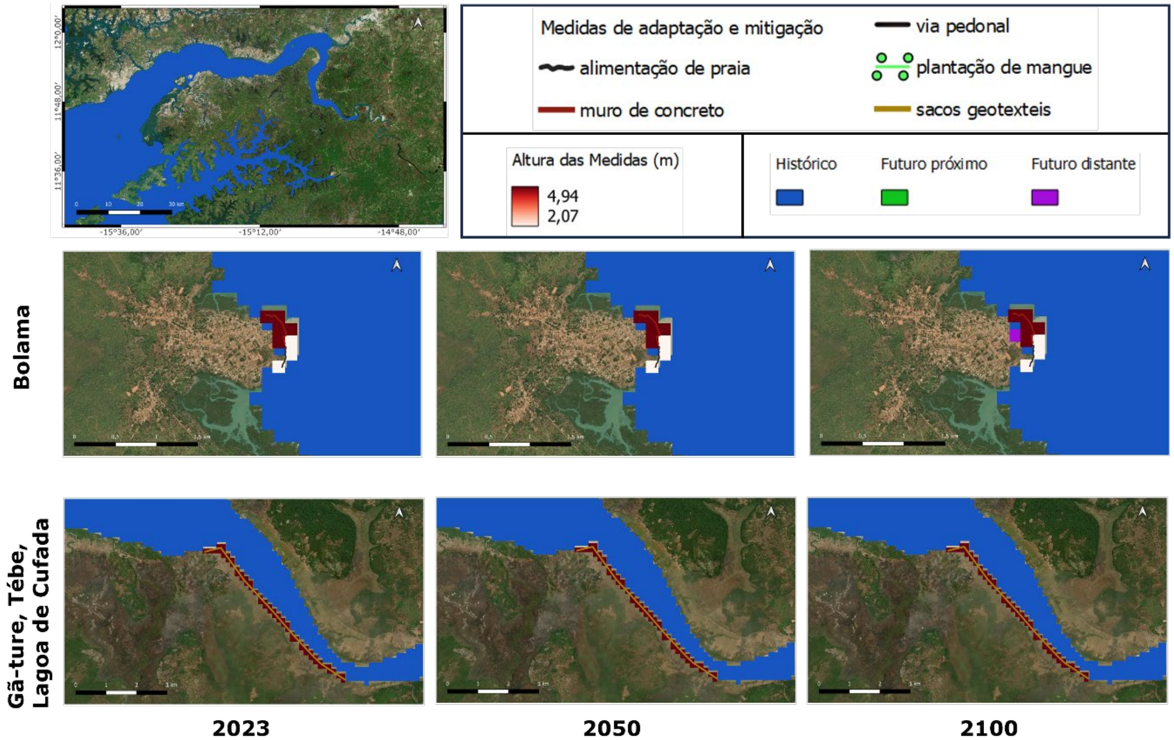


Figure 11. Evaluation of the protection of the proposed measures for the pilot areas of domain 2 for the three simulated scenarios. Source: elittoral.

The assessment results for historical, near-future, and distant-future scenarios for the implemented measures in the **pilot zones of the Bubaque Island and Cabedu and Cacine** are presented in Figure 12. The protective measures in both pilot zones efficiently contribute to preventing floods in all three scenarios.

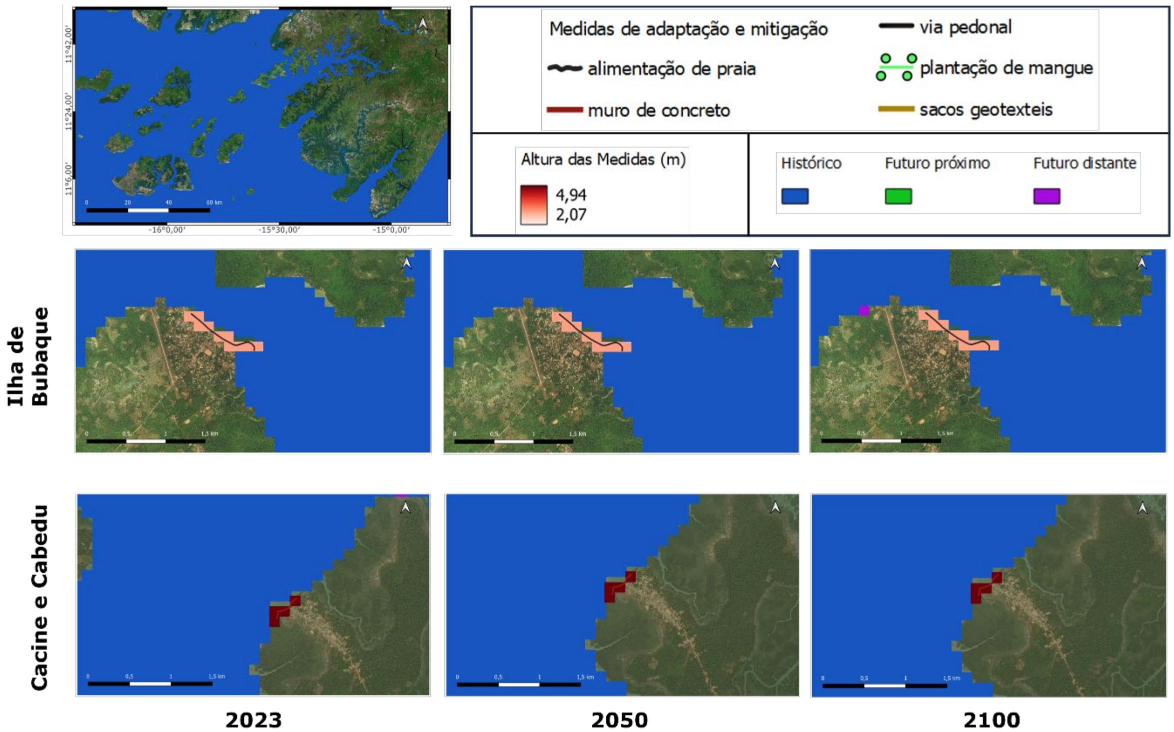


Figure 12. Assessment of the protection of the proposed measures for the pilot areas of domain 3 for the three simulated scenarios. Source: elittoral.

Some areas located behind the protective measures showed a signs of flooding. The explanation for this event is tied to the binary classification used in the model, with 0 indicating dry and 1 indicating wet surface, applied to the topobathymetric data. This classification recognizes pixels that contain water but does not necessarily mean that these pixels located behind the protective measures will experience future flooding. This phenomenon is due to the fact that these areas are very low, essentially at sea level, or sometimes below sea level.

Comprehensive Evaluation of Proposed Adaptation and Mitigation Measures Implementation

This section describes the context in which this document was developed, the methodology applied, and the main results obtained for Deliverable 4, entitled "Comprehensive evaluation of the implementation of the proposed adaptation and mitigation measures".

1. Framework

The objectives of the fourth deliverable were to detail the necessary works for the entire extent of the ten regions of interest and to calculate the budget required for implementing adaptation and mitigation measures for the climate change and sea-level rise protection in each of the ten areas covered by this project.

the starting point for this Deliverable 4 was Table 5, which helped understanding the complexity of coastal vulnerability reduction (RCVI) in each study area.

The economic valuation of implementing the AMM for the pilot zones and the each project's whole regions of interest was considered. For this purpose, the prices for for each action and the cost at different levels of protection extension were detailed. Additionally, maps were presented to cartograph the implementation of AMM for nature-based and/or hard infrastructure works throughout the areas of interest.

2. Methodology

For the budget calculations, unit prices were gathered for each proposed measure in the pilot zones of the study locations. For the cost evaluation per extension/area of the implementation of the AMM in the locations of this project, a carthography of these solutions, whether nature-based or hard engeneering, that should be applied was conducted. In this context, the following aspects were considered for the budget calculation:

- The cost per working day for non-measurable measures, such as GIAL strategy development.
- The cost for 100-meter width terrain coverage from the coastline inland for mangrove and beach areas and vegetation restoration.
- The cost for, at least double the current width, for beach regeneration with the supply of allochthonous sand, enabling adaptation to sea-level rise and conserving the ecosystem.
- The cost of recovery and/or construction of concrete walls, stairs, docks, etc., where necessary for coastal and port infrastructure,.
- The cost of recovery and/or construction of hydraulic works and earthwashing fields for the best functioning of bolanhas (rice fields).
- The cost of Caneiras houses construction for the replacement of shacks,.
- The cost of paved roads construction for access between cultivation fields/port and village or access bridges, for the improvement of transportation routes.

The final result of this economic report per zone was displayed in Deliverable 4 in two tables identifying the total cost per measure — i.e., the calculation of the unit value of implementing the measure multiplied by its respective dimension — for the pilot zones and for the entire area. Additionally, the costs of implementing 100%, 75%, 50%, 25%, or 10% of the AMM for the project's areas of interest can be identified in a third table.

3. Results

The main results by regions of the socioeconomic report are described as follows.

For the **Varela** region, the primary investment to be made is in the pilot zone, but other interventions were proposed for the area, as seen in Figure 13. The budget estimated to cover all expenses for the implementation of AMM is shown in Table 7. In the case of aiming to protect the total or a percentage of the cultivation and beach zones, Table 8 displays the respective value according to the extent of protection desired.

Table 7. Total cost of adaptation and mitigation measures for Varela region.

Proposed works for the area of interest - Varela					
Zone	**Typology**	**Extension(m)**	**Area (m2)**	**Unit cost**	**Total Cost**
Varela	**Proposed works - pilot area**				$ 7.686.155,00
	Restoration of the vegetation of the emersed beach		115129	$ 12,00 (m2)	$ 1.381.548,00
		Estimated working days		**Cost per day**	**Total cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for the Varela area					**$ 9.131.490,50**

Figure 13. Plan of adaptation and mitigation measures for Varela region. Source: Consortium.

Table 8. Cost per percentage of implementation of adaptation and mitigation measures for Varela region.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Beach regeneration	$696.735,00	$522.551,25	$348.367,50	$174.183,75	$69.673,50
Restoration of the vegetation of the emersed beach	$4.598.520,00	$3.448.890,00	$2.299.260,00	$1.149.630,00	$459.852,00
Pier construction work	$53.000,00	$39.750,00	$26.500,00	$13.250,00	$5.300,00
Concrete wall construction work	$594.600,00	$445.950,00	$297.300,00	$148.650,00	$59.460,00
Protective construction with geotextile bags	$1.408.500,00	$1.056.375,00	$704.250,00	$352.125,00	$140.850,00
Construction of hydraulic works in the bolanhas	$98.600,00	$73.950,00	$49.300,00	$24.650,00	$9.860,00
Construction of Canerias type houses	$201.200,00	$150.900,00	$100.600,00	$50.300,00	$20.120,00
Paved road construction work	$35.000,00	$26.250,00	$17.500,00	$8.750,00	$3.500,00

For the **Edjin Odjoe-Catão** region, the primary investment to be made is in the pilot zone, but other interventions were proposed for the area, as seen in Figure 14. The budget estimated to cover all expenses for the implementation of AMM is shown in Table 9. In the case of aiming to protect the integrality or a percentage of the cultivation and beach zones, Table 10 displays the respective value according to the extent of protection desired.

Table 9. Total cost of adaptation and mitigation measures for Edjin Odjoe-Catão region.

Obras propostas para a zona de interesse – Edjin Odjoe - Catão					
Zone	**Tipology**	**Extension(m)**	**Area (m2)**	**Unit cost**	**Total Cost**
Edjin Odjoe-Catão	**Proposed works - pilot area**				$ 668.792.000,00
	Restoration of the vegetation of the emersed beach		585241	$ 12,00 (m2)	$ 7.022.892,00
	Mangrove restoration		1016555	$ 12,00 (m2)	$ 12.198.660,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Edjin Odjoe - Catão					**$688.077.339,50**

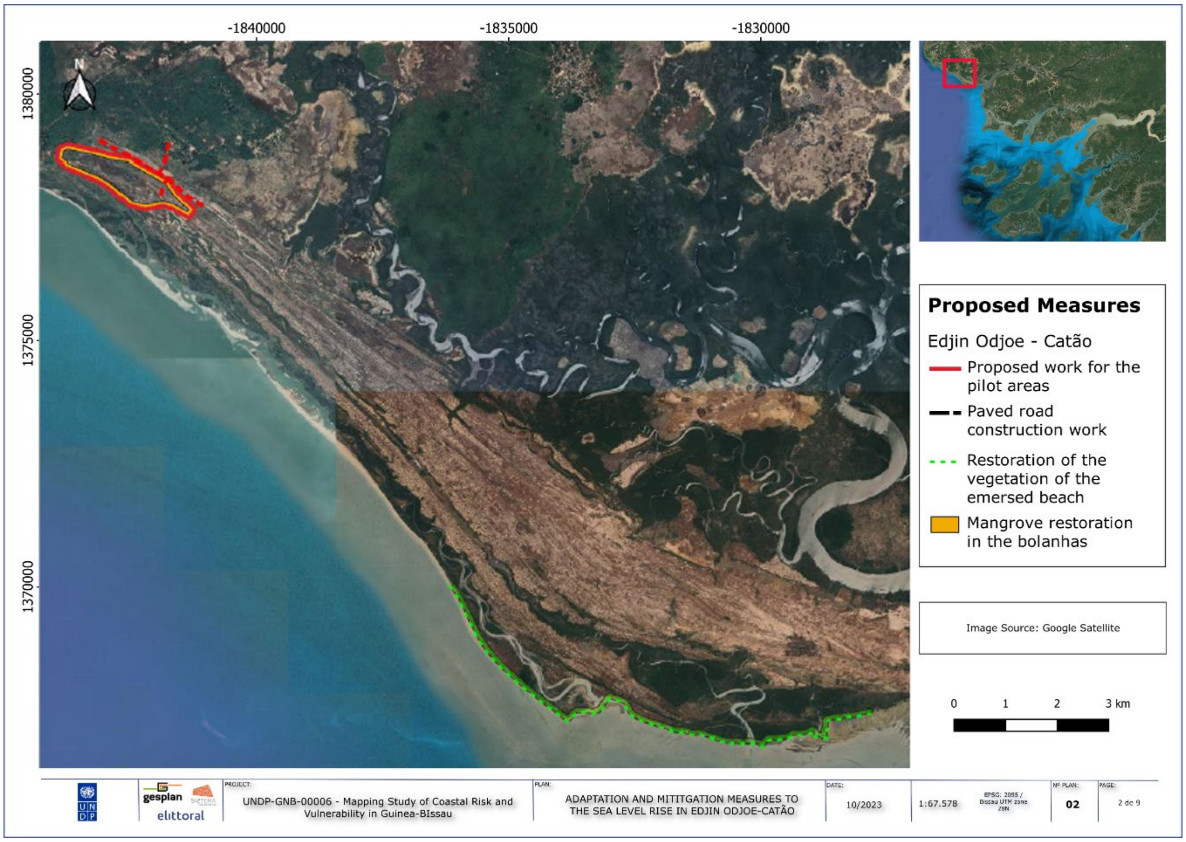


Figure 14. Plan of adaptation and mitigation measures for the region of Edjin Odjoe - Catão. Source: Consortium.

Table 10. Cost per percentage of implementation of adaptation and mitigation measures for Edjin Odjoe - Catão region.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Mangrove forest restoration	$ 7.022.892,00	$ 5.267.169,00	$ 3.511.446,00	$ 1.755.723,00	$ 702.289,20
Restoration of the vegetation of the emersed beach	$ 12.198.660,00	$ 9.148.995,00	$ 6.099.330,00	$ 3.049.665,00	$ 1.219.866,00
Construction of hydraulic works in the bolanhas	$ 2.192.000,00	$ 1.644.000,00	$ 1.096.000,00	$ 548.000,00	$ 219.200,00
Paved road construction work	$ 666.600,00	$ 499.950,00	$ 333.300,00	$ 166.650,00	$ 66.660,00

For the **Cacheu** region, the primary investment to be made is in the pilot zone (Figure 15). The budget estimated to cover all expenses for the implementation of AMM is shown in Table 11. In the case of aiming to protect the entirety or a percentage of the zone, Table 12 displays the respective value according to the extent of protection desired.

Table 11. Total cost of adaptation and mitigation measures for Cacheu region.

Proposed works for the area of interest – Cacheu					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Cacheu	**Obras propostas - zona piloto**				$ 18.467.008,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Cacheu					**$18.509.533,00**

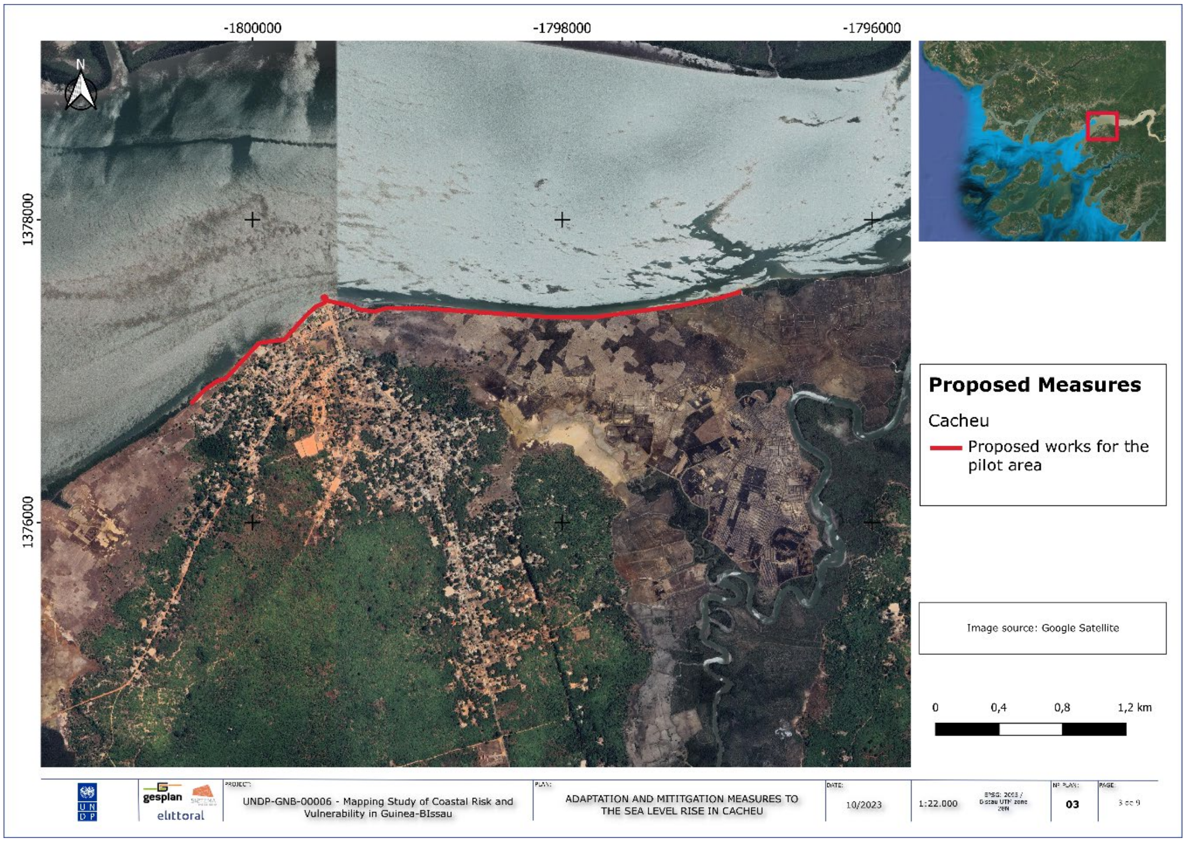


Figure 15. Plan of adaptation and mitigation measures for Cacheu region. Source: Consortium.

Table 12. Cost per percentage of implementation of adaptation and mitigation measures for Cacheu region.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Mangrove forest regeneration	$3.736.008,00	$2.802.006,00	$1.868.004,00	$934.002,00	$373.600,80
Pier construction work	$302.000,00	$226.500,00	$151.000,00	$75.500,00	$30.200,00
Concrete wall construction work	$1.395.000,00	$1.046.250,00	$697.500,00	$348.750,00	$139.500,00
Rehabilitation of port structure	$194.000,00	$145.500,00	$97.000,00	$48.500,00	$19.400,00
Protection with geotextile bags	$4.590.000,00	$3.442.500,00	$2.295.000,00	$1.147.500,00	$459.000,00
Construction of hydraulic works in the bolanhas	$8.250.000,00	$6.187.500,00	$4.125.000,00	$2.062.500,00	$825.000,00

For the **Cussanja and Mansoa** region, the primary investment to be made is in the pilot zone (Figure 16). The budget estimated to cover all expenses for the implementation of MAM is shown in Table 13. In the case of aiming to protect total or a percentage of the zone, Table 14 displays the respective value according to the extent of protection desired.

Table 13. Total cost of adaptation and mitigation measures for Cussanja and Mansoa study region.

Proposed works for the area of interest – Cussanja and Mansoa					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Cussanja e Mansoa	**Proposed works - pilot area**				$ 9.724.180,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Cussanja and Mansoa area					**$9.766.705,00**

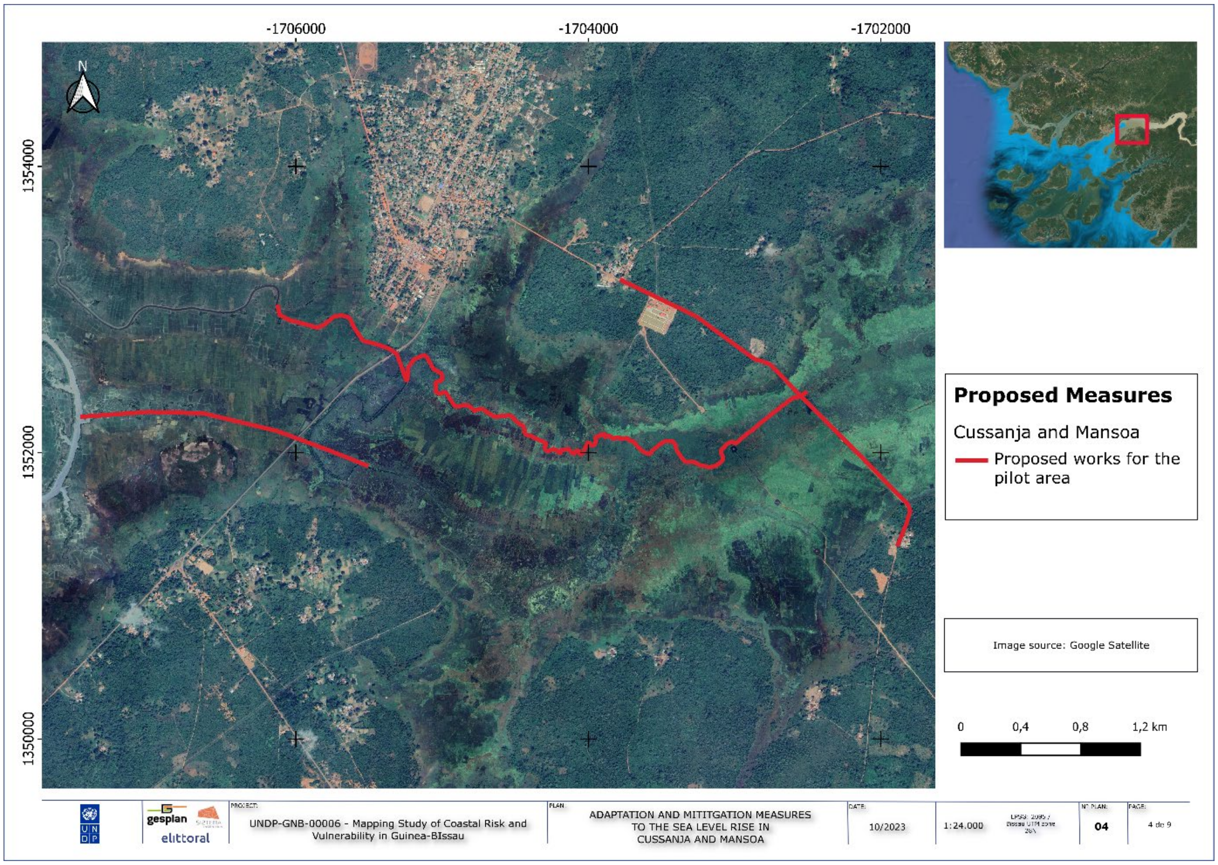


Figure 16. Plan of adaptation and mitigation measures for the region of Cussanja and Mansoa. Source: Consortium.

Table 14. Cost per percentage of implementation of adaptation and mitigation measures for the Cussanja and Mansoa region.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Mangrove forest regeneration	$5.817.180,00	$4.362.885,00	$2.908.590,00	$1.454.295,00	$581.718,00
Paved road construction work	$2.350.000,00	$1.762.500,00	$1.175.000,00	$587.500,00	$235.000,00
Construction of hydraulic works in the bolanhas	$27.000,00	$20.250,00	$13.500,00	$6.750,00	$2.700,00
Widening of the riverbed and desilting	$1.530.000,00	$1.147.500,00	$765.000,00	$382.500,00	$153.000,00

For the **Gã-ture, Tébe, and Lagoa de Cufada** region, the main investment to be made is in the pilot zone, although other parts will also benefit (Figure 17). The budget estimated to cover all expenses for the implementation of AMM is shown in Table 15. In the case of aiming to protect the integrality or a percentage of the zone, Table 16 displays the respective value according to the extent of protection desired.

Table 15. Total cost of adaptation and mitigation measures for the entire study region of Gã-ture, Tébe and Lagoa de Cufada.

Proposed works for the area of interest – Gã-ture, Tébe and Lagoa de Cufada					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Gã-ture, Tébe and Lagoa de Cufada	**Proposed works - pilot area**				$343.565.230,00
	Mangrove forest restoration		820596	$ 12,00 (m2)	$9.847.152,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for the Gã-ture, Tébe and Lagoa de Cufada area					**$353.454.907,00**

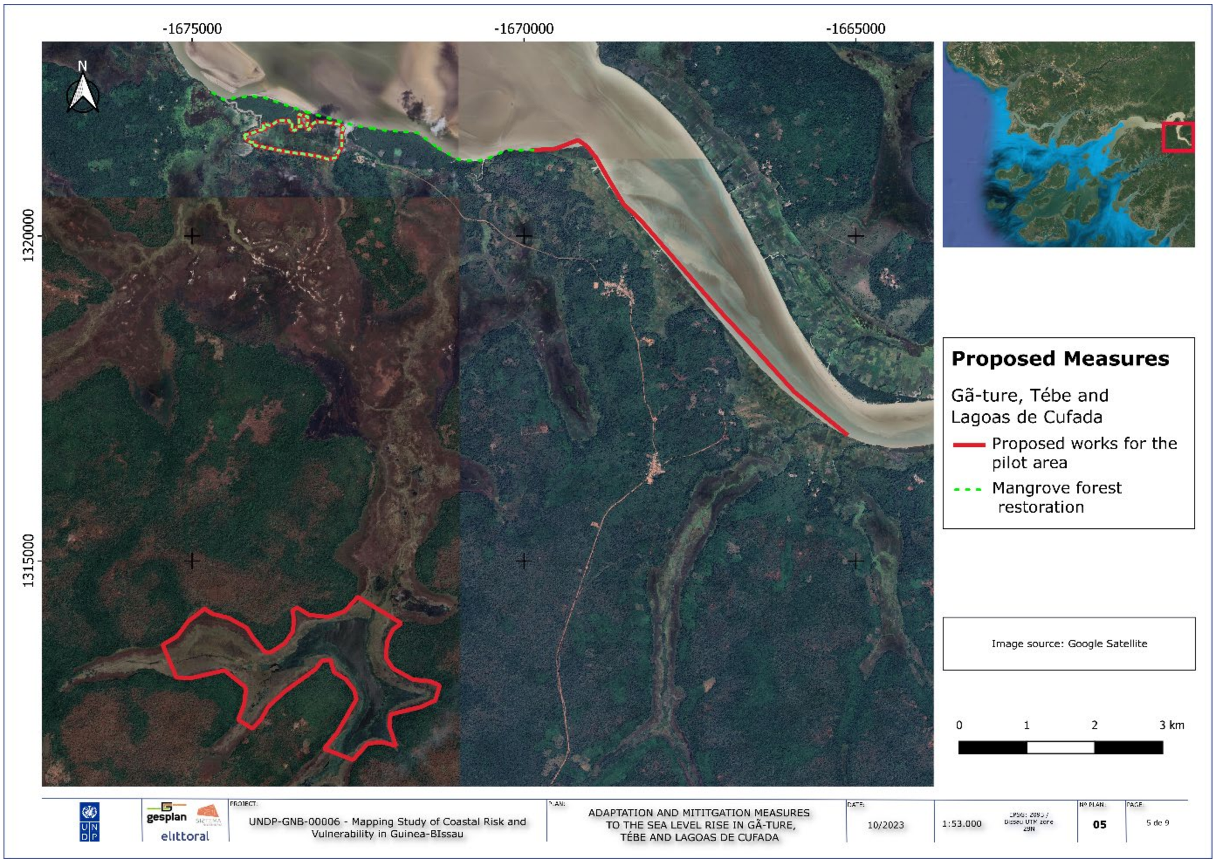


Figure 17. Plan of adaptation and mitigation measures for the region of Gã-ture, Tébe and Lagoa de Cufada. Source: Consortium.

Table 16. Cost per percentage of implementation of adaptation and mitigation measures for the region of Gã-ture, Tébe and Lagoa de Cufada.

Custo por extensão de proteção					
	100%	**75%**	**50%**	**25%**	**10%**
Mangrove forest regeneration	$9.847.152,00	$7.385.364,00	$4.923.576,00	$2.461.788,00	$984.715,20
Construction of earthen dikes	$2.747.750,00	$2.060.812,50	$1.373.875,00	$686.937,50	$274.775,00
Protection with geotextile bags	$13.272.000,00	$9.954.000,00	$6.636.000,00	$3.318.000,00	$1.327.200,00
Construction of hydraulic works in the bolanhas	$900.000,00	$675.000,00	$450.000,00	$225.000,00	$90.000,00
Dredging of river herbs	$326.592.480,00	$244.944.360,00	$163.296.240,00	$81.648.120,00	$32.659.248,00

For the **Cabedu and Cacine** region, the investment to be made in its pilot zone is shown in Figure 18. The budget estimated to cover all expenses for the implementation of AMM is presented in Table 17. In the case of wanting to protect the entirety or a percentage of the area, Table 18 displays the respective value according to the desired extent of protection.

Table 17. Total cost of adaptation and mitigation measures for the entire study region of Cabedu and Cacine.

Proposed works for the area of interest – Cabedu and Cacine					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit cost**	**Total Cost**
Cabedu and Cacine	**Proposed works - pilot area**				$32.121.100,00
	Restauração da floresta de mangal		14064404	$12,00 (m2)	$168.772.846,96
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
Total cost for adaptation and mitigation measures for Strengthening protected areas for conservation Cabedu and Cacine area					**$200.957.734,46**

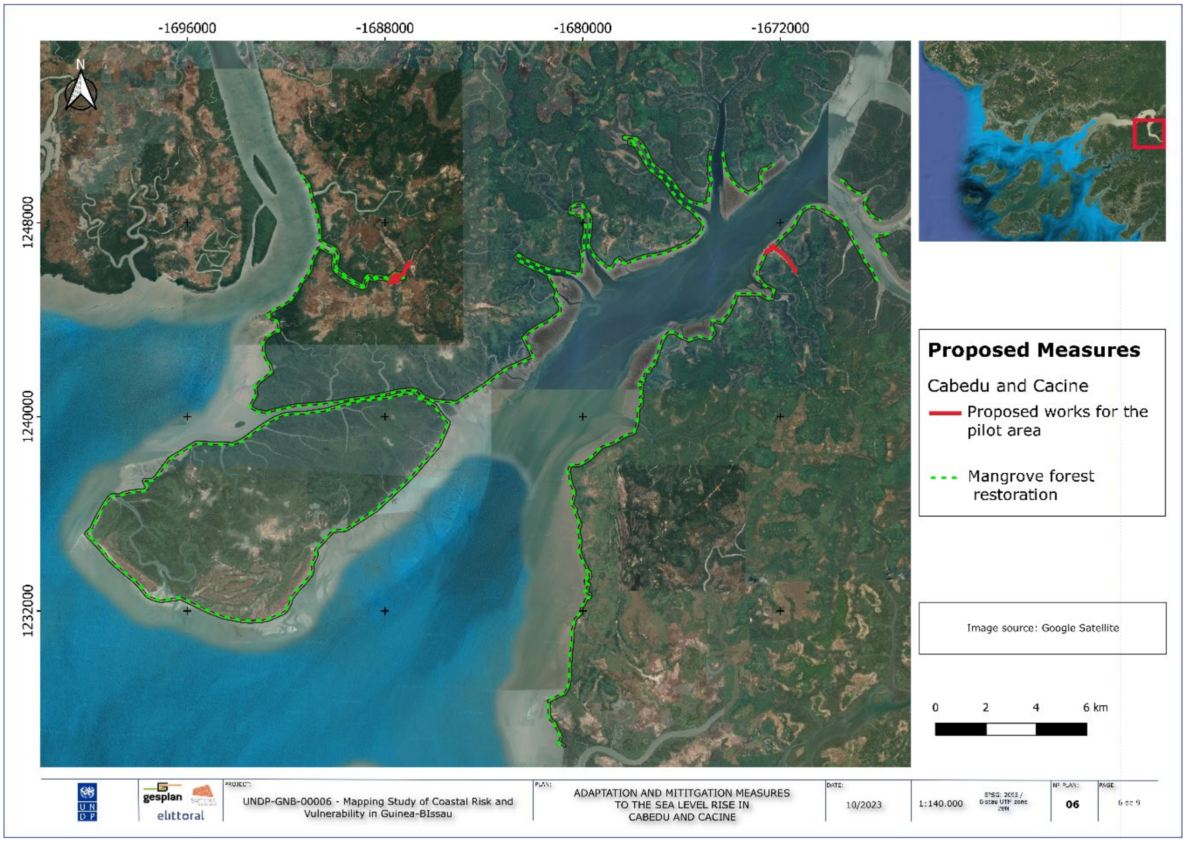


Figure 18. Plan of adaptation and mitigation measures for Cabedu and Cacine region. Source: Consortium.

Table 18. Cost per percentage of implementation of adaptation and mitigation measures for the region of Cabedu and Cacine.

	Cost per protection extension				
	100%	**75%**	**50%**	**25%**	**10%**
Mangrove forest restoration	$169.426.846,96	$127.070.135,22	$84.713.423,48	$42.356.711,74	$16.942.684,70
Paved road construction work	$1.008.500,00	$756.375,00	$504.250,00	$252.125,00	$100.850,00
Construction of hydraulic works in the bolanhas	$440.500,00	$330.375,00	$220.250,00	$110.125,00	$44.050,00
Bridge construction	$140.000,00	$105.000,00	$70.000,00	$35.000,00	$14.000,00
Rehabilitation of port structures	$168.000,00	$126.000,00	$84.000,00	$42.000,00	$16.800,00
Construction work for new port structures	$397.000,00	$297.750,00	$198.500,00	$99.250,00	$39.700,00
Concrete wall construction work	$981.000,00	$735.750,00	$490.500,00	$245.250,00	$98.100,00

For the **Bolama Island** region, the investment to be made for the pilot zone is shown in Figure 19. The budget estimated to cover all expenses for the implementation of AMM is presented in Table 19. In the case of wanting to protect the entirety or a percentage of the area Table 20 displays the respective value according to the desired extent of protection.

Table 19.Total cost of adaptation and mitigation measures for Bolama study region.

Proposed works for the area of interest - Bolama Island					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Bolama Island	**Recovery of port infrastructure (pier construction - Bolama de Baixo)**		100	$ 600,00 (m2)	$ 60.000,00
	Beach regeneration - Praia da Gamoreira		6603	$ 45,00 (m2)	$ 297.135,00
	Beach regeneration - Praia de Bolama de Baixo		2355		$ 105.975,00
	Beach regeneration - Praia de Bolama de Baixo 1 (middle)		2491		$ 112.095,00
	Beach regeneration - Praia de Bolama de Baixo (tip)		4716		$ 212.220,00
	Mangrove forest restoration		8069926	$ 12,00 (m2)	$ 96.839.112,00
	Proposed works - pilot area				$ 6.084.076,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Bolama Island area					**$103.774.400,50**

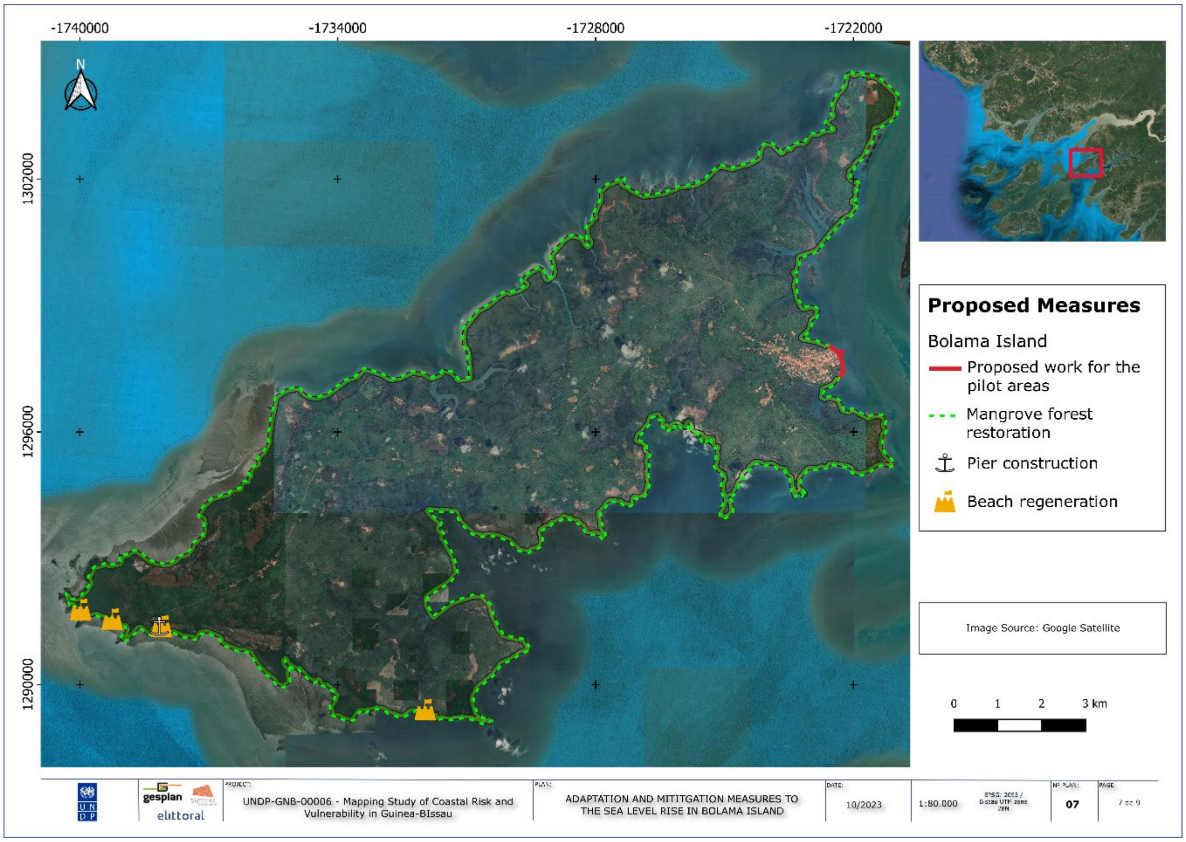


Figure 19. Plan of adaptation and mitigation measures for Bolama Island region. Source: Consortium.

Table 20. Cost per percentage of implementation of adaptation and mitigation measures for Bolama region.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Beach regeneration	$ 727.425,00	$ 545.568,75	$ 363.712,50	$ 181.856,25	$ 72.742,50
Regeneração da floresta de mangal	$ 96.839.112,00	$ 72.629.334,00	$ 48.419.556,00	$ 24.209.778,00	$ 9.683.911,20
Port infrastructure rehabilitation	$713.000,00	$534.750,00	$356.500,00	$178.250,00	$71.300,00
Concrete wall construction work	$988.200.000,00	$741.150.000,00	$494.100.000,00	$247.050.000,00	$98.820.000,00
Construction work for hydraulic works	$3.850.000,00	$2.887.500,00	$1.925.000,00	$962.500,00	$385.000,00
Pier construction work	$660.000,00	$495.000,00	$330.000,00	$165.000,00	$66.000,00

For the region of **Bubaque Island**, the investment to be made for the pilot zone is shown in Figure 20. The budget estimated to cover all expenses for the implementation of AMM is presented in Table 20. In the case of wanting to protect the entirety or a percentage of the area, Table 21 displays the respective value according to the desired extent of protection.

Table 21. Total cost of adaptation and mitigation measures for Bubaque Island region.

Proposed works for the area of interest – Bubaque Island					
Zone	**Typology**	**Extension(m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Bubaque Island	**Proposed works - pilot area**				$4.312.670,00
	Dakota Eco Retreat Pier Construction			$120.000,00 (un)	$120.000,00
	Construction of eastern Bubaque Pier				$120.000,00
	Construction of northwestern Bubaque Pier				$120.000,00
	Construction of northern Bubaque Pier				$120.000,00
	Construction of southern Pier Bubaque				$120.000,00
	Construction work for a concrete wall in the north of Bubaque	525		$1.100,00 (m)	$577.500,00
	Construction work for east concrete wall in Bubaque	758			$833.800,00
	Construção de muro de betão noroeste Bubaque	584			$642.400,00
	Dakota Eco Retreat concrete wall construction work	484			$532.400,00
	Concrete wall construction work at Bruce Beach	233			$256.300,00
	Concrete wall construction work Wefa Hotel	263			$289.300,00
	Regeneration of northwest beach Bubaque		4455	$45,00 (m2)	$200.475,00
	Regeneration of wild east beach Bubaque		4061		$182.745,00
	Hidden beach regeneration		5190		$233.550,00
	Etikorete beach regeneration		4959		$223.155,00
	Bruce Beach Regeneration / Punta Canapá		130912		$5.891.040,00
	South Wild Beach 1 Regeneration		9292		$418.140,00
	South Wild Beach 2 Regeneration		19152		
	Mangrove restoration		4267755	$12,00 (m2)	$51.213.055,80
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Bubaque island area					**$67.332.158,30**

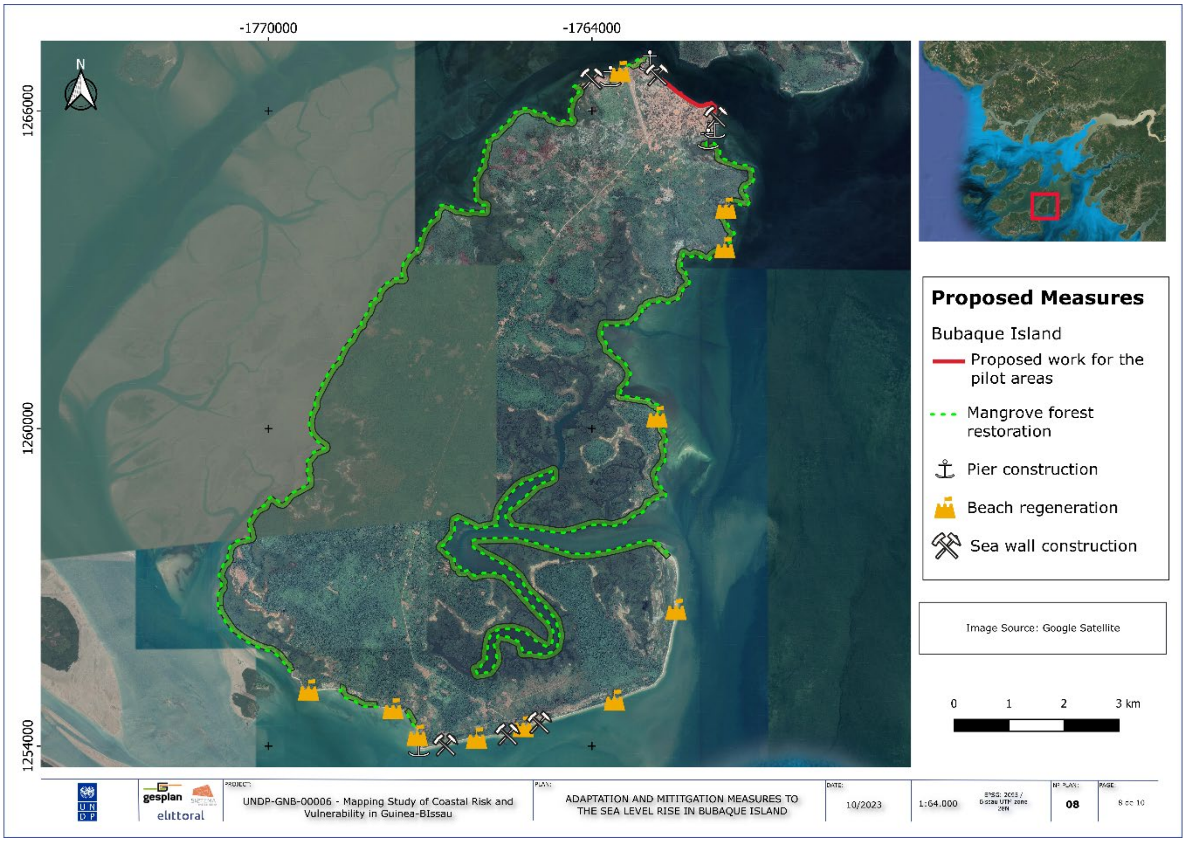


Figure 20. Plan of adaptation and mitigation measures for island of Bubaque. Source: Consortium.

Table 22. Cost per percentage of implementation of adaptation and mitigation measures for Bubaque Island.

Cost per protection extension					
	100%	**75%**	**50%**	**25%**	**10%**
Beach regeneration	$8.010.945,00	$6.008.208,75	$4.005.472,50	$2.002.736,25	$801.094,50
Mangrove forest restoration	$51.213.055,80	$38.409.791,85	$25.606.527,90	$12.803.263,95	$5.121.305,58
Pier construction work	$600.000,00	$450.000,00	$300.000,00	$150.000,00	$60.000,00
Concrete wall construction work	$3.131.700,00	$2.348.775,00	$1.565.850,00	$782.925,00	$313.170,00

For the region of **Uno Island**, the investment to be made for its pilot zone is shown in Figure 21. The budget estimated to cover all expenses for the implementation of AMM is presented in Table 22. In the case of wanting to protect the entirety or a percentage of the area, Table 23 displays the respective value according to the desired extent of protection.

Table 23. Total cost of adaptation and mitigation measures for Uno Island study region.

Proposed works for the area of interest – Uno Island					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Uno Island	**Beach regeneration**		394460	$45,00 (m2)	$17.750.700,00
	Pier construction work			$53.000,00 (un)	$53.000,00
	Concrete wall construction work	357		$1.800,00 (m)	$642.600,00
	Restoration of the vegetation of the emersed beach		4669000	$12,00 (m2)	$56.028.000,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for Uno Island					**$74.538.087,50**

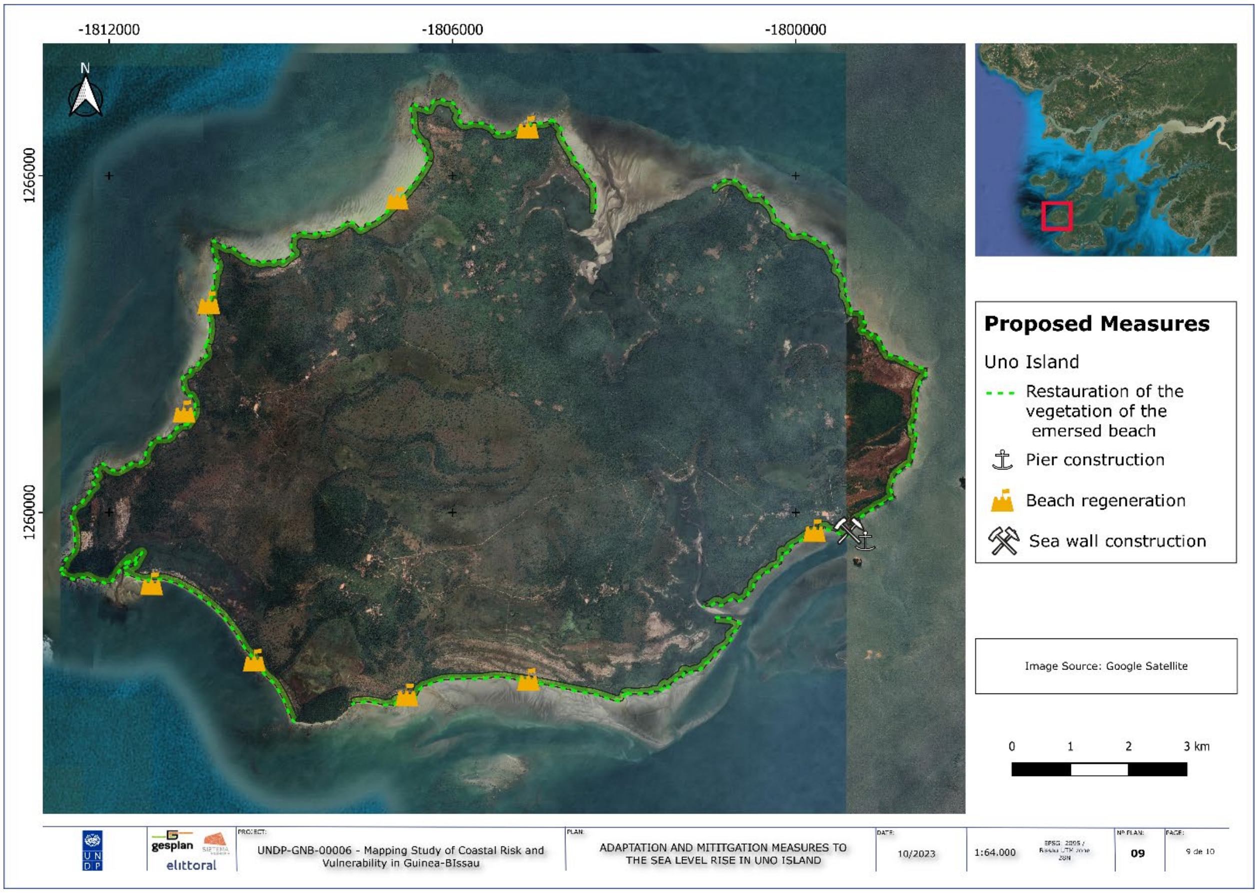


Figure 21. Plan of adaptation and mitigation measures for Uno region. Source: Consortium.

Table 24. Cost per percentage of implementation of adaptation and mitigation measures for Uno region.

	Cost per protection extension				
	100%	**75%**	**50%**	**25%**	**10%**
Restoration of the vegetation of the emersed beach	$56.028.000,00	$42.021.000,00	$28.014.000,00	$14.007.000,00	$5.602.800,00
Beach regeneration	$17.750.700,00	$13.313.025,00	$8.875.350,00	$4.437.675,00	$1.775.070,00
Construção de muro de betão	$642.600,00	$481.950,00	$321.300,00	$160.650,00	$64.260,00
Pier construction work	$53.000,00	$39.750,00	$26.500,00	$13.250,00	$5.300,00

For the region of **Caravela Island**, the investment to be made for the pilor zone is shown in Figure 22. The budget estimated to cover all expenses for the implementation of AMM is presented in Table 24. In the case of wanting to protect the entirety or a percentage of the area, Table 25 displays the respective value according to the desired extent of protection.

Table 25. Total cost of adaptation and mitigation measures for Caravela Island study region.

Proposed works for the area of interest - Caravela Island					
Zone	**Typology**	**Extension (m)**	**Area (m2)**	**Unit Cost**	**Total Cost**
Caravela Island	**Proposed works - pilot area**				$4.231.000,00
	Construction of Caneira type houses	100		$20.000,00 (un)	$2.000.000,00
	Removing shacks	vg		$30.000,00	$30.000,00
	Beach regeneration		207755	$45,00 (m2)	$9.348.975,00
	Pier construction work			$53.000,00	$53.000,00
	Restoration of the vegetation of the emersed beach		3419634	$12,00 (m2)	$41.035.608,00
		Estimated working days		**Cost per day**	**Total Cost**
	Elaboration of a GIAL strategy	45		$ 472,50	$ 21.262,50
	Strengthening protected areas for conservation				$ 21.262,50
	Promotion and preservation of green and blue infrastructure				$ 21.262,50
Total cost for adaptation and mitigation measures for the Caravela area					**$56.762.370,50**

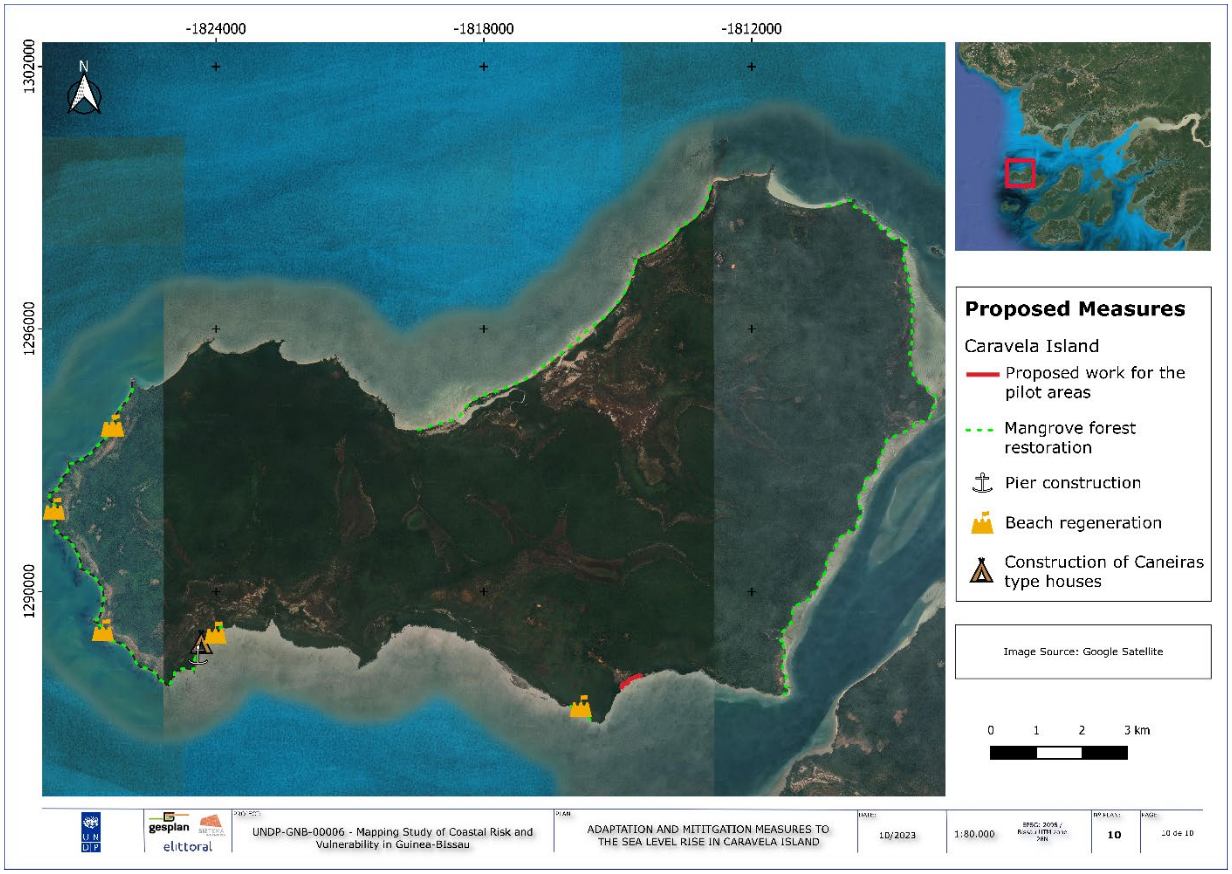


Figure 22. Plan of adaptation and mitigation measures for Caravela Island region. Source: Consortium.

Table 26. Cost per percentage of implementation of adaptation and mitigation measures for Caravela Island.

	Cost per protection extension				
	100%	**75%**	**50%**	**25%**	**10%**
Vegetation restoration From the emersed beach	$41.035.608,00	$30.776.706,00	$20.517.804,00	$10.258.902,00	$4.103.560,80
Beach regeneration	$9.348.975,00	$7.011.731,25	$4.674.487,50	$2.337.243,75	$934.897,50
Paved Road construction work	$1.050.000,00	$787.500,00	$525.000,00	$262.500,00	$105.000,00
Port Infrastructure construction work	$98.000,00	$73.500,00	$49.000,00	$24.500,00	$9.800,00
Pier construction work	$53.000,00	$39.750,00	$26.500,00	$13.250,00	$5.300,00
Construction of Caneiras type houses	$2.030.000,00	$1.522.500,00	$1.015.000,00	$507.500,00	$203.000,00

Final Considerations

With the conclusion of this project, the consortium wishes to extend its appreciation to UNDP for entrusting and providing the opportunity to conduct the cartographic study focused on identifying and managing coastal risks and vulnerabilities in Guinea-Bissau.

In parallel, the consortium acknowledges the high level of professionalism and dedication demonstrated by the Coastal Protection Unit, led by the Principal Investigator, Mrs. Mary Seck, throughout the execution of each task, thereby ensuring the successful realization of the project.

In conclusion, the consortium expresses gratitude to all national collaborators for their contributions with theis knowledge and experience exchanged with the consortium. The collaborative efforts, in conjunction with insights from local communities and experts, have been essential for accomplishing the project's specified objectives.

This initiative has enabled Elittoral, Gesplan, and Sistemas — the consortium's constituent entities — to acquire an in-depth understanding of Guinea-Bissau's coastal, insular, and riverine regions. The consortium has gained profound insights into the potential of the national natural capital, directly experiencing the geographical richness and resilience of the local population during the field mission conducted in May/23. The field visit, coupled with a thorough review of bibliography and secondary sources, has provided the foundational information necessary to identify coastal vulnerability, key challenges, and their underlying causes.

Leveraging this comprehensive understanding, the consortium harnessed the collective expertise of its technical team, deploying state-of-the-art numerical models and advanced aerial imaging technology. This approach was crucial in determining the Coastal Vulnerability Index for each of the ten (10) study areas, establishing a pivotal criterion for generating the project's baseline cartography.

With the updated diagnosis, the consortium's technical team adapted diverse methodologies employed in the region (WACA) and globally. This adaptation led to the proposal of a comprehensive suite of measures designed to adapt and mitigate the impacts of climate change on Guinea-Bissau's coast. These measures encompass the development of planning instruments and public policies for effective land use planning, nature-based solutions, and the integration of hard engineering structures.

Subsequent to defining the mitigation and adaptation measures, the consortium executed a pilot intervention plan, strategically selecting pilot zones within the study areas. The plan outlined the comprehensive utilization of suitable measures, validated by local teams, with the overarching aim of significantly mitigating coastal vulnerability within these designated study areas. This pilot initiative served as a valuable opportunity to extrapolate the efficacy of the proposed measures to the completeness of the areas of interest coastline.

Upon identifying potential measures for implementation in the areas of interest, an economic assessment was meticulously conducted. This assessment helped the preliminary identification of two fundamental concepts crucial for governmental decision-making and practical execution:

1. The estimated cost per linear meter or unit of measure for implementation at present value.
2. The conceptual value associated with the decision of not implementing specific actions.

Both pieces of information enable an informed and strategic management of the cost implications associated with governmental decisions.

To streamline the implementation of the proposed measures, the consortium developed a methodology that effectively gauges the impact of each measure in each area, specifically focusing on vulnerability reduction. The methodology further allows for the precise identification of the impact, especially in scenarios where practical decisions necessitate the phased implementation of the proposed plan across various zones.

It is imperative to note that the final implementation of this study mandates the updating of the topographic and bathymetric base to ensure the precision and accuracy of each proposed measurement. Finally, given the inherent challenges associated with safeguarding Guinea-Bissau's coastline, the consortium underscores its unwavering commitment to collaborate closely with UNDP and the Government of Guinea-Bissau. This collaborative effort aims to undertake the requisite tasks necessary to effectively reduce the elevated level of vulnerability elucidated in this comprehensive document.