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Assessing Coastal Erosion and Climate Change Adaptation Measures: A Novel Participatory Approach

Carlos Coelho [1,*], Márcia Lima [1,2], Filipe M. Alves [3], Peter Roebeling [4], Joaquim Pais-Barbosa [1,5] and Marco Marto [6]

1 RISCO & Department of Civil Engineering, University of Aveiro, 3810-193 Aveiro, Portugal; marcia.lima@ua.pt (M.L.); joaquim.paisbarbosa@ua.pt (J.P.-B.)
2 Porto University Center (CUP), Lusofona University, 4000-098 Porto, Portugal
3 Climate Change Impacts, Adaptation and Modelling (CCIAM), Centre for Ecology, Evolution and Environmental Changes (CE3C), Faculdade de Ciências da Universidade de Lisboa, 1749-016 Lisboa, Portugal; fmalves@ciencias.ulisboa.pt
4 CESAM & Department of Environment and Planning (DAO), University of Aveiro, 3810-193 Aveiro, Portugal; peter.roebeling@ua.pt
5 CESAM and Department of Physic, University of Aveiro, Campus Universitário de Santiago, 3810-193 Aveiro, Portugal
6 GOVCOPP & Department of Social, Political and Territorial Sciences, University of Aveiro, 3810-193 Aveiro, Portugal; marcovmarto@ua.pt
* Correspondence: ccoelho@ua.pt

Abstract: This work aims to provide a more complete characterization of coastal erosion mitigation and climate change adaptation measures by presenting a participatory approach that integrates medium- to long-term perspectives, considering simultaneously social, environmental, economic and engineering dimensions to help decision makers implement sustainable climate change adaptation (CCA) strategies. The work lists, explains and characterizes existing climate change mitigation and adaptation measures as well as their costs and positive and negative social, environmental and economic impacts, in three distinct databases. These databases are discussed, complemented and validated in participatory moments with local stakeholders of the Ovar Municipality, Portugal, which represents the case study to support the proposed methodology. Although Ovar is a pilot case, the integrated framework for resilient CCA has a global application with respect to methodologies and concepts. The proposed approach is useful to help coastal management entities to engage in more efficient, effective and beneficial planned action to mitigate coastal erosion and adapt to future climate change effects. The open-source databases and the participatory approach facilitate decision makers and coastal communities to navigate the complexity of solutions and build consensus around collective actions for coastal areas.

Keywords: decision support; social impacts; environmental impacts; economic impacts; planning and management; costs and benefits; coastal measures database

Citation: Coelho, C.; Lima, M.; Alves, F.M.; Roebeling, P.; Pais-Barbosa, J.; Marto, M. Assessing Coastal Erosion and Climate Change Adaptation Measures: A Novel Participatory Approach. *Environments* **2023**, *10*, 110. https://doi.org/10.3390/environments10070110

Academic Editor: Jason K. Levy

Received: 31 May 2023
Revised: 20 June 2023
Accepted: 22 June 2023
Published: 26 June 2023

1. Introduction

Over 75% of the world's shorelines face coastal erosion problems [1–3] and due to climate change (CC) [4–6], it is expected that coastal erosion will have an even greater impact [7–9], especially in urbanized regions that may partly or entirely disappear [10]. Despite coastal erosion impacts being confined to coastal areas, these areas host over 40% of the world population, as well as a wide variety of coastal ecosystems that provide a wide range of services [11,12]. Due to the social, environmental and economic importance of coastal areas and their growing erosion problems, together with climate change (CC) phenomena, an increase in investments destined for coastal interventions may be anticipated [13].

Strategies to mitigate losses of territory are mainly reactive and tend to not include local stakeholders in the decision-making process [14]. Coastal erosion and climate change adaptation (CCA) tend to be locked-in technical solutions. Traditionally, coastal erosion and coastal flooding problems and responses were assessed using engineering approaches that have evolved little and may be falling short in various ways [15] without considering associated cost and benefit analysis (CBA). Although some erosion impacts can be mitigated through coastal protection works, such measures [16] may represent negative second-order impacts on coastal environments and socio-economic systems. Thus, long-term action plans for the implementation of sustainable planning and management of coastal zones, with a detailed assessment of social, environmental and economic impacts, costs and benefits are still scarce. The complexity of the climate change problem and the uncertainty about the timing, severity, magnitude and type of impacts make planning for climate change a challenge [17].

The Intergovernmental Panel on Climate Change [18] states that adaptation measures should reduce CC vulnerability and risk, seek opportunities, build the capacity of social-environmental systems to cope with climate impacts and mobilize that capacity by implementing decisions and actions [17]. To deal with complexity and uncertainty, the development of CCA action plans requires well-developed methodologies and tools, including participatory approaches, to provide efficient and effective means of supporting decision making [19–22] as well as increase the resilience of social-ecological systems [23].

According to Larsen and Gunnarsson-Östling [19] and Berkhout et al. [20], implementation plans to reduce CC impacts need to manage diverse interests and expectations in decision-making processes. To ensure an effective long-term CCA process, local action plans for implementing coastal erosion and flooding adaptation strategies should be, as much as possible, participatory [24,25]. Participation can lead to more coherent, credible, fair and locally contextualized strategies to adapt to CC [26]. Scenario-based stakeholder engagement is a useful tool to facilitate coastal management planning that takes into account the complexities and challenges of climate change and could be used in conjunction with existing approaches, such as the shoreline management planning process [17]. However, long-term action plans for the implementation of CCA, with detailed assessments of social, environmental and economic impacts, costs and benefits, are still scarce.

Thus, the goal of the present work is to promote an approach that integrates short-, medium- and long-term (SML-term) perspectives, considering the social, environmental, economic and engineering dimensions of adaptation to help decision makers design action plans for implementing sustainable future-proof CCA strategies (i.e., suites of adaptation measures across time and space). The expected outcome is to reduce the vulnerability of coastal territories and increase the resilience of local communities to coastal erosion in a climate change context. The main outputs are an open-source database (three levels) of analyzed adaptation measures, costs, effectiveness and benefits as well as a set of potential adaptation strategies that can be used along the world coastlines. The three-level database gathering mitigation and adaptation measures, its impacts and direct costs are Database #1—Mitigation and Adaptation Measures; Database #2—Impacts of Mitigation and Adaptation Measures; and Database #3—Direct Costs of Mitigation and Adaptation Measures. Considering the information of the databases, the participatory moments allowed us to define adaptation pathways and tipping points for future coastal erosion mitigation and climate change adaptation.

The work is organized as follows. Section 2 presents a brief literature review of coastal management approaches. In Section 3, the methodology is presented, which includes the databases, the case study, the participatory approach, the evaluation of the land use and ecosystem services and, finally, the definition of the adaptation pathway and tipping points. In Section 4, results related to the previously referred issues are explored. Finally, in Section 5, a discussion on the results is provided, and, finally, in Section 6, the main conclusions are provided.

2. State of the Art

The classification of coastal management strategies was initially established by Dronkers et al. [27], who identified three broad categories: retreat, accommodation and protection. In 2002, the European Parliament and Council outlined the general principles and options for an Integrated Coastal Management Strategy for Europe (Recommendation 2002/413/CE). However, due to insufficient contributions from each member state, the European Council urged all EU countries in 2005 to establish their own Integrated Coastal Zone Management Strategies (ICZMS) by presenting national efforts and setting ground rules [28].

Multiple approaches have been proposed to enable densely populated coastal areas to adapt to sea-level rise (SLR), erosion and coastal flooding [29]. A summarized overview of existing strategies can be found in Table 1.

Table 1. Coastal erosion and climate change mitigation and adaptation strategies.

References	Strategy
[3,29–39]	**Protection**—involving all defense techniques (hard and/or soft protection) used to preserve vulnerable areas, such as population centers, economic activities and natural resources.
[3,29,30,32–35,38,40–43]	**Accommodation**—considering all strategies necessary to increase the society's resilience to coastal erosion, including land use change, emergency planning and hazard insurance; persisting in occupying sensitive areas but accepting a greater degree of flooding by changing land use, construction methods and improving preparedness.
[3,29,30,32,34,35,44]	**Planned/Managed Retreat/Relocation**—limiting the effects of a potentially dangerous event, landward resettling of risky population centers and economic activities.
[3,29,34,35,45,46]	**Use of Ecosystems/Ecosystem-based adaptation**—influencing processes related to coastal erosion and marine flooding (e.g., sediment capture and energy attenuation) by means of the creation and restoration of coastal ecosystems, such as wetlands (e.g., mangroves), biogenic reef structures (e.g., corals, oysters and mussels), seagrass beds and dune vegetation.
[3,34,35]	**Doing nothing/sacrificing areas**—unplanned retreat in loss by erosion.

While the vision behind protection, accommodation and planned/managed retreat/relocation varies, the differences lie more in terminology than in implementation. This variation in terminology raises questions about how adaptation responses are classified. For example, the classification of wetland restoration differs among authors, with some considering it an accommodation response and others categorizing it as ecosystem-based adaptation [47,48].

Coastal defense strategies are both expensive and temporary, as they involve the construction of hard and/or soft techniques and seaward side defenses to maintain the existing defense line and preserve the shoreline position [49,50]. In the 1970s, beach nourishment emerged as a groundbreaking alternative for coastal protection [51], and it has become the preferred method in many countries [52–56]. Considering accommodation, it is crucial to incorporate a range of technological, architectural and urban planning measures that can adapt to changing climatic conditions. On the other hand, planned/managed retreat/relocation has been identified as the most effective approach to protect people and assets from coastal risks, but its implementation is often complex and contentious, both politically and socially, as demonstrated by Haasnoot et al. [44] and Barnett and O'Neill [57]. Finally, ecosystem-based adaptation approaches have gained traction, showcasing how ecosystems can mitigate wave power, reduce erosion and enhance overall coastal protection [29].

Coastal erosion management practices worldwide show limited success or even failure. Different national approaches to coastal protection exist in Europe, emphasizing the need for socio-economic planning and practical alternatives [49]. Shoreline management plans in England and Wales have sparked public debates [58]. Specific programs in the USA, such as the National Flood Insurance Program and Coastal Area Management Act, have failed

due to legal flaws and inadequate projections of sea-level rise and erosion [59]. Kuwait requires sustainable solutions and Integrated Coastal Zone Management policies [60]. The coastal defense strategy in Buenos Aires resulted in unintended imbalances and severe beach damage [61]. Combining hard and soft solutions yields optimal results along the Colombian Caribbean coast [62]. Erosion strategies in Senegal and Benin, Africa, are often individual and uncoordinated and exacerbate coastal erosion [63].

Rangel-Buitrago et al. [59] emphasize the necessity of robust management action for addressing the challenges posed by coastal erosion. This action should encompass a range of techniques, knowledge, equipment, institutional instruments and the active involvement of stakeholders. Its primary objective is to minimize or, ideally, eliminate the impacts associated with coastal erosion. However, it is important to note that current decisions regarding coastal erosion management are significantly influenced by economic factors, which present two conflicting aspects:

- Action–reaction basis [62];
- Cost–benefit analysis approach [64].

Existing strategies for coastal erosion and flooding adaptation primarily focus on implementing local-scale adaptation measures. However, the actual costs, impacts and benefits of these measures are determined by the suite of adaptation measures adopted at the landscape scale [33,65–68]. It is crucial that adaptation measures not only address current challenges but also reduce vulnerability and risk associated with climate change [69–71]. Additionally, these measures should aim to identify opportunities and enhance the capacity of social and environmental systems to withstand climate impacts, which can be achieved through the implementation of informed decisions and actions [17].

To effectively address the complexity and uncertainty involved, action plans need to incorporate well-developed methodologies and tools, including participatory approaches. These approaches can provide efficient and effective means of supporting decision-making processes [21,72]. By involving relevant stakeholders and considering diverse perspectives, participatory approaches ensure that the actions taken are inclusive, informed and representative of the local context. The significance of involving citizens and the community in decision-making processes regarding coastal management has been acknowledged by both the scientific community and policymakers [73–75]. The increasing consensus on terms such as "stakeholder knowledge" and "bottom-up approach" in risk management studies [76] highlights this recognition [77–79]. Public participation not only benefits citizens themselves but also enhances the overall decision-making process by building trust, preventing conflicts, improving acceptance and even securing funding [80,81].

The social-environmental system (SES) framework focuses specifically on how systems adapt in a changing physical and social environment [82]. Resilience is the ability of a system to maintain its characteristics when facing external changes [83]. The SES may be flexible enough to rearrange itself around a potential array of alternate states and continue to function until it reaches a threshold point, and change becomes more radical [84]. CC is surrounded by uncertainties, and, therefore, adaptation should entail a portfolio of response options [22]. In addition to traditional scenario analysis tools, in which the impact of different climate scenarios and possible responses is assessed [85], the adaptation pathways approach [86] starts with the possible extension over time of feasible options under CC.

Subsequently, this approach aids in studying if and how current portfolios of responses can be diversified through adaptation measures. Under current coastal development practices and climate change conditions, smart, innovative and strong coastal erosion management plans are needed [35].

3. Methodology

This work develops a new framework to support the design and implementation of CCA strategies, guided by an understanding of adaptation as a long-term incremental and transformational process that may radically change social and environmental systems. The

framework combines economic appraisal methods with engineering models and integrates the adaptation pathways and tipping points method [85–87]. Through its systemic and interdisciplinary approach, this work develops a methodological framework to compare the (social, environmental and economic) costs and benefits of different coastal adaptation strategies over the short, medium and long term (SML term). Economic appraisal tools and application of the adaptation pathways method are embedded in a social-environmental system (SES) analysis (i.e., considering local cultures, governance structures, institutional, political and organizational factors and the biophysical, geographical and morphological aspects) [82,83] and follow a participatory approach [24] while working with a case study pilot.

The work involves stakeholders, who assess different options, create meaningful debates over important assumptions and point in the right direction regarding more quantitative valuation of impacts [88]. The results allowed the participatory co-design of SML-term adaptation pathways and tipping points [24,86]. This paper presents a new framework to contribute to the core aspects mentioned previously, considering the following steps:

- Identification of different coastal erosion mitigation and climate change adaptation measures and their respective characterization;
- Identification of the positive and negative impacts, associated with the social, environmental and economic dimensions of implementing the measures;
- Identification of descriptor parameters that allow qualifying/quantifying the respective positive and negative impacts;
- Identification of direct and indirect economic costs of implementing the measures;
- Integration of stakeholders in participatory moments, for the discussion of the databases, allowing the adjustment and complementation of the created databases;
- Discussion on a proposal of the adaptation pathways and tipping points for the future of the Ovar Municipality coastal zone.

In short, this methodology allowed us to achieve a sustainable littoral, based on the Ovar case study, located in Portugal, that can be replicated worldwide.

3.1. Databases

One main objective of this work was the identification and characterization of mitigation and adaptation strategies for coastal erosion and the effects of climate change, culminating in the development of a mitigation and adaptation measures manual, applicable across all sedimentary coastal zones. Presently, the manual has 3 different databases:

- Database #1—Mitigation and Adaptation Measures;
- Database #2—Impacts of Mitigation and Adaptation Measures;
- Database #3—Direct Costs of Mitigation and Adaptation Measures.

It is important to mention that this manual constitutes a base that is intended to be of general use but is subject to reassessment and improvement regarding its contents. In this way, the work involved local populations through workshops, to develop a participatory approach, benefiting from the contributions of different stakeholders and experts on the topic of coastal erosion.

3.1.1. Database #1

A logical division of measures is to consider their impact on the causes or consequences of the key problem, coastal erosion due to a widespread sediment deficit. In this context, the interventions at the level of causes are all measures that aim to act directly on the sediment balance of the coastal system, either by reducing the deficit, by adding sediments or by intervening in sediment flows and distribution. On the other hand, actions at the level of consequences are all measures that aim to reduce the impacts caused by coastal erosion, either on natural or human systems. This document, therefore, analyzes separately those strategies to mitigate coastal erosion that focus on reducing the cause of the problem (the

sediment deficit) and those that aim at adaptation (to reduce the impacts and consequences of coastal erosion). This classification of mitigation and adaptation measures was defined in the INCCA project (Integrated Climate Change Adaptation for Resilient Communities), following the division presented in the following groups:

- Group A, acting on the causes (with 29 measures);
- Group B, acting on the consequences (with 24 measures).

Within these two main groups, measures were sub-grouped according to the scope of their function (e.g., reduction in sediment deficit in the coastal system; regularization of sediment fluxes in the coastal system; artificial supply of sediment to the coastal system; protection with coastal structures; accommodation; relocation and/or removal). Section 4 describes the measures of groups A and B and their respective sub-groups.

3.1.2. Database #2

The characterization of impacts is described in Database #2, which aims to describe the impact and its metric characterization with values (or value ranges). The list is divided into positive and negative impacts that characterize each one of the measures, at a social, environmental and economic level, into a total of 160 impacts (25 positive social, 34 negative social, 24 positive environmental, 27 negative environmental, 22 positive economic, 28 negative economic).

3.1.3. Database #3

Database #3 aims to present all the information collected regarding direct costs that characterize the coastal erosion and climate change mitigation and adaptation measures identified in Database #1, namely, implementation costs, maintenance costs and operation costs.

3.2. Ovar Case Study

The participatory approach, as well as the design of the adaptation pathways and tipping points, was co-developed and applied in the pilot case study for Ovar, in Central Portugal (Figure 1). The case study region is a critical shoreline retreat zone, presenting high erosion rates and sediment deficit, several coastal defense structures, different levels of land use and questions related to tourism, fishing and the environment. In fact, this coastal zone is referred to as one of the most affected by erosion problems, being protected by coastal defense structures throughout a large extension of the coast, in its three urban areas (Esmoriz, Cortegaça and Furadouro). The region faces serious social-environmental challenges, related to the diversity of coastal engineering defense structures (groins and longitudinal revetment works, dune reinforcements, small artificial nourishments, walking paths and fences), economic activities (fishing, hotel and camping, surf schools and summer music festivals) and environmental values (proximity to the Aveiro and Esmoriz lagoon, forests and a sealed landfill in Maceda; the latter is highly threatened by coastal erosion, leading to concerning ecological consequences), as well as social aspects, including the effects of adaptation in more vulnerable communities (e.g., relocation of the Esmoriz fishing community) [89].

The sediment deficit along the Ovar coastline is a complex problem and will continue to be in the near future, so situations of overtopping and shoreline retreat tend to be more and more frequent. The urbanized coastal areas (Esmoriz, Cortegaça and Furadouro) have reduced the size of the beaches, presenting coastal works that protect but also artificialize the coastline. The beaches that are protected with works no longer feed sediment to the beaches further south, so the phenomenon of erosion spreads to the south with more intensity [90]. Coelho et al. [90] suggested that to face the erosion problem, the degree of the artificialization of the coastline depends on the level of protection intended for the future. Maintaining all existing construction and fixing the position of the coastline, carrying out a planned withdrawal, maintaining only certain infrastructures, creating artificial beaches by nourishing sand in limited areas of the coast, etc., are options that must be clearly

defined by the authorities. In certain places, namely the beaches of Esmoriz, Cortegaça and Furadouro, artificial nourishments combined with the existing groins are being discussed in order to maintain recreational use on artificial beaches. This solution must consider ways of financing the costs of maintaining the beach (frequent nourishment of sand and rehabilitation of coastal defense works).

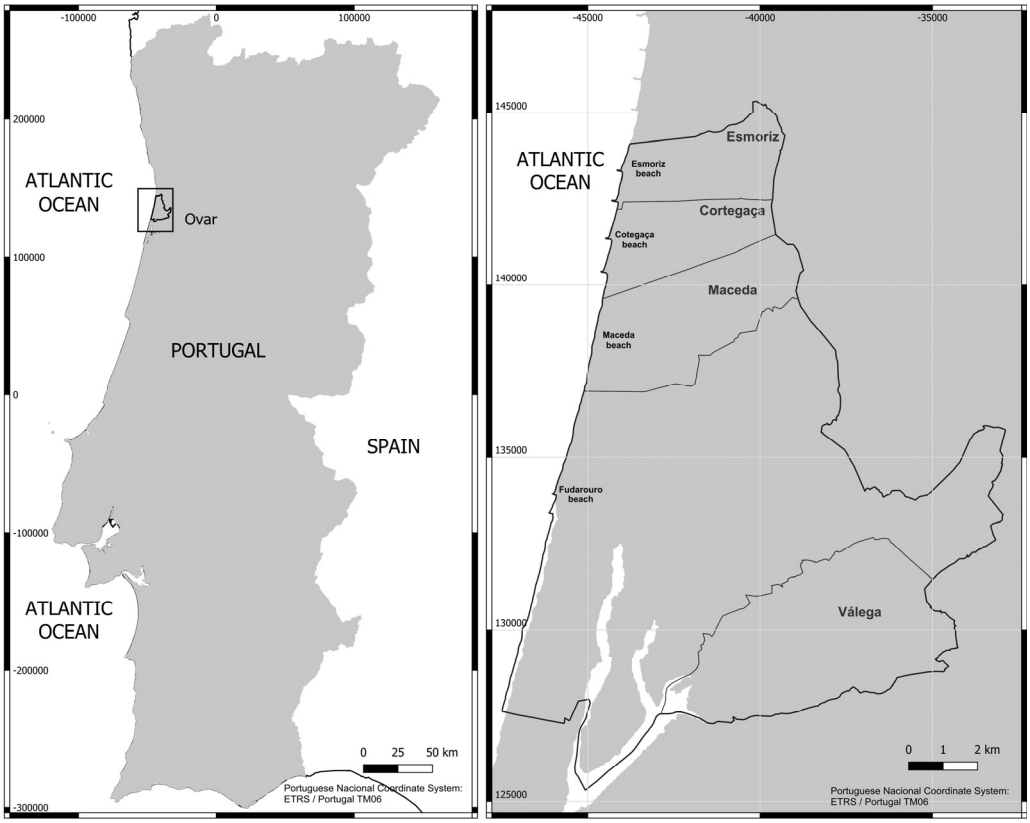

Figure 1. Location of the Ovar Municipality case study area.

It is necessary to carry out projections, including the identification and assessment of the costs and benefits of different hypotheses to evaluate the relationship between gains that result from the interventions and the economic loss of their implementation, operation and maintenance. It is considered that only this (complex) analysis makes it possible to technically support the political options to be adopted [90]. The mitigation and adaptation scenarios considered the different options of identified measures (Database #1), highlighting those that were considered more adequate. For the chosen scenarios, all the costs and benefits were evaluated and compared, and adaptation pathways were co-designed with local stakeholders in participatory workshops. The pilot case should provide the local municipality with a dynamic action plan for implementing CCA measures, illustrated by adaptation pathways, which highlight not only the different costs, benefits and (negative and positive) secondary effects of measures but also the date of each policy or measure according to changes in external conditions (e.g., sea-level rise). The participatory framework that supports the making of the plan also sets the stage for social learning and a more inclusive governance experience.

3.3. Participatory Approach

Databases were validated, complemented, criticized and tweaked by the stakeholders throughout the participatory process (e.g., interviews, stakeholder analysis, scenario workshops) in order to develop and test the framework. This methodology is replicable and applied to any other coast, in Portugal or elsewhere.

The participatory action–research approach in the INCCA project was operationalized through the realization of participatory workshops throughout its development. The results of the 1st workshop (held in November/December 2020) were essential for the definition of the mitigation and adaptation strategies of this work, while the 2nd and 3rd workshops benefitted from the databases that were used in the Ovar Municipality case study region.

The 1st participatory workshop, called "Strategies, costs and benefits", aimed at involving local communities and stakeholders in the definition of strategies to reduce coastal erosion and adapt to climate change, in order to get answers to questions such as the following:

- How should we act? At the level of the causes and/or consequences of coastal erosion?
- Which type of intervention should we choose?
- What are the economic, social and/or environmental impacts of each type of strategy?
- What are the costs and benefits inherent to each type of solution?

In view of the pandemic situation Portugal was going through in late 2020, two virtual collaborative work sessions were held (27 November and 4 December 2020). A third session was then defined (14 May 2021), with the main goal of validating the impacts and metrics of MMA and economic analysis [91].

The 2nd participatory workshop, called "Scenarios for the territory" was held in Ovar (27 October 2021). In this workshop, the stakeholders shared their visions for the future, given climate change scenarios, discussed them and converged toward a common consented future vision for the evolution of the coastline. Databases #1 and #2 were used to inform and support the debates about what measures can be taken now and what can be expected from their effects in the medium and long term over space and time. The stakeholders were asked to think about the question "Does the territory have to adapt to us, or do we have to adapt ourselves to the territory?".

Finally, in the 3rd participatory workshop, "Adaptation pathways and tipping points", held in Cortegaça (5 April 2022), the future actions were discussed with the stakeholders, given projection details for the period 2020–2100, considering costs and benefits data and the specific characteristics of the coastal stretch along Esmoriz-Cortegaça, Cortegaça-Maceda and Maceda Furadouro-Torrão to Lameiro. Working in smaller groups per stretch of coast, the stakeholders developed an integrated roadmap of actions to be undertaken for the period 2020–2100.

The participatory workshops were held with a group of approximately 30 people (team facilitator and stakeholders), having in common the desire to discuss the problem of coastal erosion and climate change in the Ovar Municipality. The stakeholders were representing the different actors with responsibility for management, decision making and coastal use in the Municipality of Ovar (including the Ovar City Council, Portuguese Environment Agency, local Parish Councils, Polis do Litoral da Ria de Aveiro, Voluntary Fire Brigades, local associations and researchers).

3.4. Land Use and Ecosystem Service Values

To determine the socio-economic benefits, a methodology based on the value of ecosystem services (VSE) was applied, using meta-analytic value function transfer (following Magalhães-Filho et al. [92]). To determine the VSE, meta-analytic value functions consider local variables such as agricultural and forest areas, density population and GDP (income).

As the objective was to determine the value of the socio-economic benefits of the territory in the coastal region of Ovar, between the years 2020 and 2100, secondary data obtained from the Intergovernmental Panel on Climate Change (IPCC) were considered, through the "SSP public database", which created a series of future scenarios, called Shared Socio-Economic Pathways (SSPs). Among these future scenarios, it was decided to adopt scenarios SSP3 "Regional rivalry" and SSP5 "Development driven by fossil fuels", due to their more pessimistic character, from the environmental point of view.

3.5. Adaptation Pathway and Tipping Points

The realization of participatory moments in the Municipality of Ovar ended in the application of the participatory methodology SWAP—Scenario Workshop and Adaptation Pathways [93], applied to the topic of adaptation to coastal erosion and climate change. The SWAP methodology is divided into two parts: the scenario workshops and the adaptation pathways. This methodology was previously implemented in Aveiro, within the scope of the project European BASE—Bottom-Up Climate Adaptation Strategies Towards a Sustainable Europe (https://base-adaptation.eu/, accessed on 30 May 2023), where, in the case study of Ílhavo (https://baseadaptation.eu/coast-%C3%ADlhavo-and-vagos-%C3%ADlhavo-portugal.html, accessed on 30 May 2023), the stakeholders were involved in the co-construction of an action plan through scenario workshops and performed cost–benefit analyses across the adaptation pathways.

In the scenario workshops component, all the previous information about the study area was gathered through the work and investigations already carried out up to the moment and the modeling and future projections, creating a set of scenarios for different time intervals that are described by Scenario Narratives. In the adaptation pathways component, the aim was to gather the information obtained in the SWAP and build a set of pathways that can be adopted through the mitigation and adaptation measures and the defined time intervals (2030, 2050 and 2100), which reflect actions that can be taken to respond to coastal erosion and climate change.

4. Results

One of the main objectives of the present work is to define strategies for mitigation and adaptation to coastal erosion and the effects of climate change, translated into the development of a Manual of Mitigation and Adaptation Measures, applicable across all sedimentary coastal zones. Presently the manual has 53 measures, characterized into three databases (Figure 2):

- Database #1—Mitigation and Adaptation Measures (53 individual sheets);
- Database #2—Impacts of Mitigation and Adaptation Measures (160 individual sheets);
- Database #3—Direct Costs of Mitigation and Adaptation Measures (53 individual sheets).

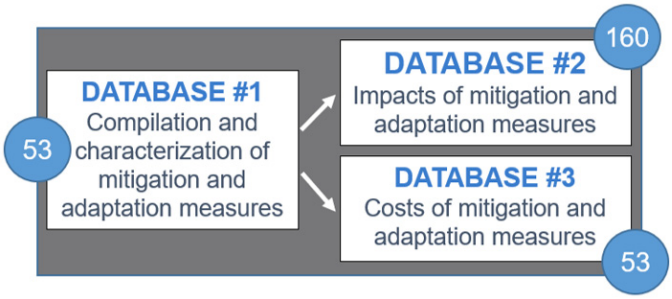

Figure 2. Databases of the Manual of Mitigation and Adaptation Measures.

These databases constitute a base that is intended to be of general use but is subject to continuous assessment and improvement regarding its contents. In this way, future involvement of local populations through workshops and other participatory approaches will benefit manual updates with the contributions of different experts and stakeholders involved in the coastal erosion processes.

4.1. Database #1: Mitigation and Adaptation Measures

As defined in Section 3 and building on the results and data collected in the first participatory workshop, 53 mitigation and adaptation measures for coastal erosion were identified and characterized (Table 2), available online (http://incca.web.ua.pt/, in Portuguese, accessed on 30 May 2023).

Table 2. List of coastal erosion mitigation and climate change adaptation measures.

A. ACTION ON THE CAUSES OF COASTAL EROSION			
1. Reduction of the sediment deficit in the coastal system: Set of measures aimed at combating the deficit of sediments reaching the coastal system, via rivers, or removed directly from the coastal zone.	1. Re-naturalizing or conditioning the uses of the soil (hydrographic basin): Subset of measures that can allow a greater amount of sediment that results from water erosion of watershed soils to effectively reach the coast.	1. Decrease of the artificialized or lined area on the slopes of the catchment area	A111
		2. Reduction of obstacles that condition soil erosion by water	A112
	2. Reduction or removal of works across watercourses: Subset of measures that suggest the reduction or removal of sediment deposition at weirs and dams.	1. Elimination or partial removal of weirs and dams	A121
		2. Reduction or removal of sediment deposition on dams	A122
	3. Longitudinal works (on banks): Subset of measures that suggest less protection of riverbanks (revetments and walls) to allow greater flow of sediments in rivers so that they can reach the coast.	1. Reducing the impact of riverbank protection	A131
	4. Channels—bypasses: Subset of measures that suggest an increase in the net flow rate flowing into natural waterways, also inducing greater solid transport.	1. Increase of liquid and solid flow by reduction of diversions	A141
		2. Increase of liquid and solid flow by reduction of irrigation/supply channels	A142
	5. Sand extraction: Subset of measures that aim to reduce the volumes of sand extraction in order to keep the sand in the river and coastal system.	1. Limitation and control of volumes of sand used in construction	A151
		2. Replacement of sediments in the river or coastal system resulting from de-sanding actions	A152
	6. Non-replenishment port dredging: Subset of measures that suggest that port dredging results in the replenishment of the sand in the coastal system.	1. Prohibition of port dredging without replenishment	A161
	7. Beach users: Subset of measures aimed at controlling the outflow of sand from the coastal system through the beach users for leisure or sport.	1. Control of beach sanding by beach users	A171
2. Regulating the flow of sediments in the coastal system: A set of measures designed to balance the flow of sediments in the coastal system, allowing it to be regularized.	1. Mobilization of sands within the coastal system: Subset of measures aimed at transferring sands in the harbor system to the most eroded areas, on the seabed or at moving them along the beach profile.	1. Fixed sand transposition in port areas	A211
		2. Mobile sand transposition in harbor areas	A212
		3. Sand ripping	A213
	2. Dune system preservation: Subset of measures designed to balance and maintain sediments in dune systems (fences, control of beach access, planting of vegetation).	1. Limitation of trampling through beach access walkways	A221
		2. Retention of sand carried by the wind through dune regenerators	A222
		3. Planting of vegetation for dune stabilization	A223
	3. Management of groins: Subset of measures designed to manage groins in order to keep sediments in the coastal system in a more effective way.	1. Abandonment and/or removal of the spur to restore sediment dynamics	A231
		2. Resizing the groin geometry	A232
	4. Navigation channel dredging: Subset of measures that suggest deposition in areas of greater potential erosion, on the foreshore.	1. Mandatory deposition of sediments below the navigation channel	A241
3. Artificial feeding of sediments into the coastal system: Set of measures aimed at artificial feeding in order to mitigate coastal erosion.	1. Nourishment of the littoral drift: Subset of measures focusing on the artificial nourishment of the littoral drift.	1. Feeding the coastal drift through sediments from offshore	A311
		2. Feeding the coastal drift through sediments from onshore deposits	A312
		3. Feeding the coastal drift through sediments coming from dredging in the estuary/river	A313
	2. Beach nourishment: Subset of measures focusing on artificial beach nourishment.	1. Beach nourishment by sediments from offshore	A321
		2. Beach nourishment through sediments from onshore deposits	A322
		3. Beach nourishment by sediments from dredging in the estuary/river	A323
	3. Dune cordon reinforcement: Subset of measures focused on the artificial feeding of the dune cordon.	1. Dune cordon reinforcement through offshore sediments	A331
		2. Reinforcement of the dune cordon through sediments originating from onshore deposits	A332
		3. Reinforcement of the dune cord through sediments coming from dredging in the estuary/river	A333

Table 2. *Cont.*

B. ACTION ON THE CONSEQUENCES OF EROSION			
1. Protection with coastal structures: Set of measures aimed at protecting infrastructures and assets from coastal erosion, as well as from damage caused by the advancing sea.	1. Groins: subset of measures that promote the retention of sediments in the area to be protected, creating a more robust beach.	1. Protection with linear groins (perpendicular or oblique)	B111
		2. Protection with non-linear groins (Y, T, L)	B112
	2. Adhering longitudinal works: Subset of measures that aim to protect the heritage near the coast by fixing the position of the shoreline and dissipating wave energy.	1. Protection with longitudinally adherent works on simple slope	B121
		2. Protection with longitudinal earthworks with intermediate landing(s)	B122
		3. Protection with longitudinal earthworks with raised crest	B123
		4. Protection with longitudinal earthworks with geocylinders or other geosynthetic materials	B124
	3. Retaining walls: Subset of measures aimed at protecting the slopes, land and property next to the coast.	1. Protection with vertical structures for embankment containment	B131
	4. Detached breakwaters: Subset of measures that aim to dissipate wave energy further away from the coast, also promoting sediment accumulation in the sheltered area.	1. Protection with detached sunken pillars	B141
		2. Protection with detached submerged breakwaters	B142
		3. Protection with submerged detached breakwaters, in geosynthetic materials	B143
		4. Protection with submerged detached breakwaters, as artificial reefs (blocks or sunken ships)	B144
2. Accommodation: Set of measures aimed at accommodating the coast to coastal erosion mechanisms.	1. Building/urbanization adaptation: Subset of measures that aim at the adaptation of buildings near the coast, to adjust to possible sea onslaughts.	1. Accommodation of the built environment to the natural dynamics of the site (empty ground floors or temporary buildings)	B211
		2. Rearrangement of urban fronts, creating infrastructures adjusted to the new reality	B212
		3. Zoning and management of coastal areas according to the mapping of risk levels	B213
	2. Warning systems: Subset of measures that aim to warn the population of possible damage caused by sea assaults and storms.	1. Warning system management	B221
	3. Education, awareness raising and monitoring: Subset of measures that aim to educate and raise awareness among the population of the consequences of coastal erosion.	1. Educating and raising awareness of the population of the problem and its solutions	B231
		2. Promotion of knowledge through monitoring and studies	B232
	4. Participatory governance: Subset of measures aimed at involving stakeholders in coastal management.	1. Participatory involvement of stakeholders in coastal management through articulated and coherent governance	B241
	5. Financial instruments and incentives: Subset of measures aiming at the mitigation and financial compensation of the risks of loss and damage caused by coastal erosion.	1. Insurance management according to risk levels	B251
		2. Identifying and raising complementary sources of funding	B252
		3. Municipal fiscal instruments	B253
3. Relocation and/or removal: Set of measures that provide for relocation and/or removal as a way of mitigating the risk of coastal erosion.	1. Building relocation through demolition and construction	B311	
		2. Relocation of mobile or semi-mobile buildings	B312
	2. Building demolition: Subset of measures that aim at the demolition of buildings in order to avoid losses or damage caused by coastal erosion.	1. Demolition of the built environment	B321

For each measure of Database #1, an individual sheet was developed, based on available bibliographic information and stakeholders' opinions. An example of an individual sheet, corresponding to the A222 measure, can be seen in Figure 3.

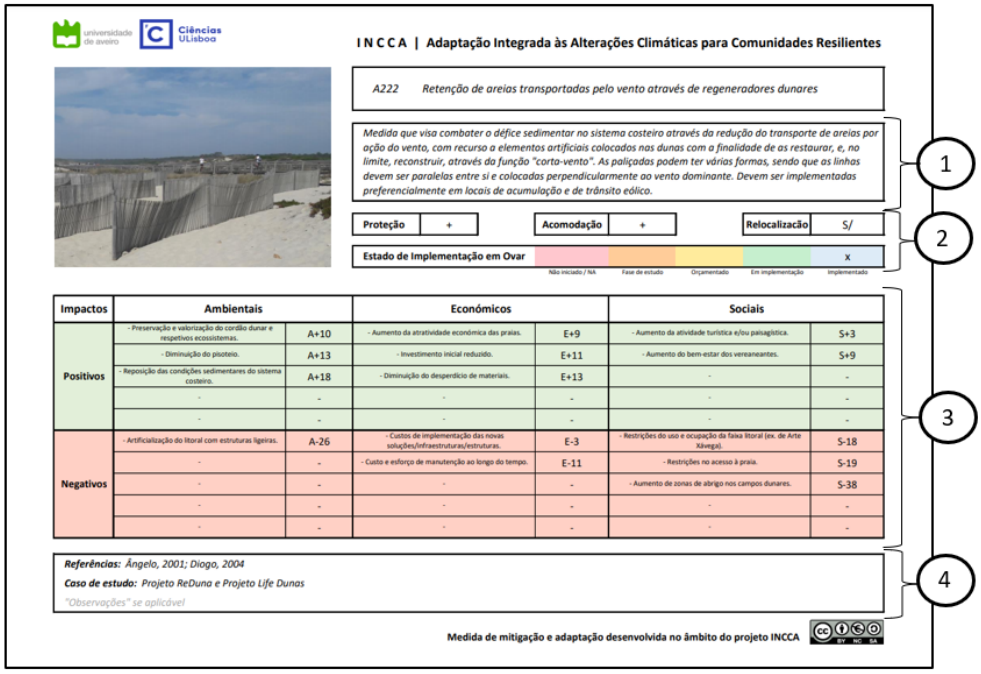

Figure 3. Individual sheets of Database #1 (example of A222 measure). Note: the text in the image is intentionally left illegible, as the database is only available in Portuguese at this stage. See http://incca.web.ua.pt/ (accessed on 30 May 2023).

The information provided on each sheet is similar so that they can be easily accessed and compared with each other. Each sheet has an identifying code according to Table 2. Each sheet provides a brief description of the measure and an illustrative figure is presented (1). Moreover, its action level is classified into three distinct components: protection, accommodation and relocation (scaled in 7 levels: - - -: - -; -; without; +; ++; +++) (2). The general data on each sheet ends with the identification of the measure's implementation status in the Municipality of Ovar, the INCCA project's case study. In the central area of each sheet, there is the identification of the impacts (positive and negative) that characterize the measure, at social, environmental and economic levels (3). The characterization of the impacts gives rise to Database #2 (Section 4.2). The sheet ends with complementary information, namely the identification of applicable case studies, bibliographic references and/or notes and observations (4).

4.2. Database #2: Impacts of Mitigation and Adaptation Measures

The list with the characterization of impacts is carried out in Database #2. Each impact is characterized based on descriptors, with their metric characterization (with values or ranges of values) whenever possible. This list is divided into positive and negative impacts that characterize the measure, at a social, environmental and economic level, which represent 6 different lists and a total of 160 impacts (25 positive and 34 negative social impacts, 24 positive and 27 negative environmental impacts, 22 positive and 28 negative economic impacts). Figure 4 presents an example list of impacts (in this case, positive environment impacts with 24 different impacts) with the following information: identification of all identified impacts (1); identification of measures (from Database #1) characterized by each of these impacts (2); and access to the respective individual impact sheets (example in Figure 5). Each individual impact sheet presents information about descriptors, with their metric characterization and respective bibliographic source.

ID	IMPACTO (1)	MEDIDAS DE MTIGAÇÃO E ADAPTAÇÃO (ID) (2)	FICHA INDIVIDUAL
A+1	- Renaturalização das margens dos rios.	1 5	Link pdf
A+2	- Aumento do transporte de sedimentos para o sistema costeiro.	2 5 6 7	Link pdf
A+3	- Renaturalização do fluxo fluvial com benefícios para o ecossistema fluvial e marinho.	3 4	Link pdf
A+5	- Aumento da melhoria da qualidade da água nos rios.	6 7	Link pdf
A+6	- Aumento da melhoria dos habitats para as espécies.	7 36 37 38 39 52	Link pdf
A+7	- Evitar a retirada de organismos dos ecossistemas.	8	Link pdf
A+8	- Manutenção dos sedimentos no sistema fluvial e costeiro.	9	Link pdf
A+9	- Mitigação da erosão costeira a sotamar das zonas portuárias.	10 12 54 19	Link pdf
A+10	- Preservação e valorização do cordão dunar e respetivos ecossistemas.	11 13 14 15 26 27 28 44	Link pdf
A+12	- Aumento da deposição de sedimentos da deriva litoral na zona baixa da praia.	55	Link pdf
A+13	- Diminuição do pisoteio.	13 14 44	Link pdf
A+14	- Desenvolvimento de espécies e de ecossistemas.	1 5 15 29 30 36 37 38 39 52	Link pdf
A+15	- Regeneração de ecótonos.	1 5	Link pdf
A+16	- Reposição do trânsito sedimentar natural.	3 4 9 12 54 16	Link pdf
A+17	- Promoção de um litoral menos artificializado.	20 21 22 23 24 25 26 27 28 40 41 49 50 52	Link pdf
A+18	- Reposição das condições sedimentares do sistema costeiro.	14 20 21 22 23 24 25 26 27 28	Link pdf
A+19	- Acumulação de sedimentos na zona a barlamar da estrutura.	29 30	Link pdf
A+20	- Mitigação da erosão costeira na zona de implementação da estrutura.	31 32 33 34	Link pdf
A+21	- Proteção dos terraplenos.	35	Link pdf
A+22	- Prevenção de galgamentos.	26 31 32 33 36 37 38 39	Link pdf
A+23	- Acumulação de sedimentos na zona abrigada pela estrutura.	36 37 38 39	Link pdf
A+24	- Melhoria do enquadramento paisagístico do edificado.	40 41	Link pdf
A+25	- Aumento do uso de materiais mais sustentáveis e naturais na construção.	40	Link pdf
A+26	- Diminuição da contaminação oceânica em eventos extremos.	40	Link pdf

Figure 4. List of impacts presented on Database #2 (example of positive environmental impacts). Note: the text in the image is intentionally left illegible, as the database is only available in Portuguese at this stage. See http://incca.web.ua.pt/ (accessed on 30 May 2023).

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I N C C A | Adaptação Integrada às Alterações Climáticas para Comunidades Resilientes

IMPACTO AMBIENTAL POSITIVO (A+)

A+1 - Renaturalização das margens dos rios.

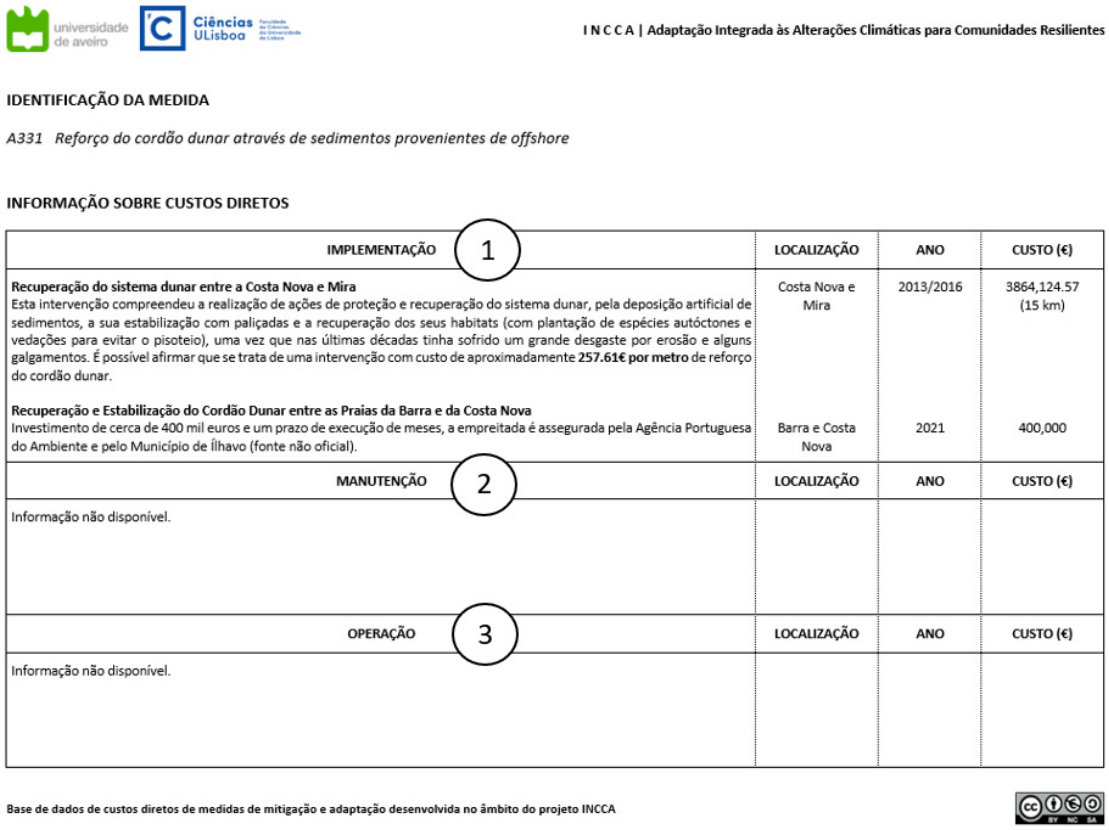
DESCRIÇÃO	FONTE	MÉTRICA	INTERVALO DE VALORES
1. Valoração dos serviços dos ecossistemas regenerados. Nota: Culturas temporárias de sequeiro e regadio (Roebeling *et al.*, 2014); Agricultura com espaços naturais e seminaturais (Roebeling *et al.*, 2014); Praias, dunas e areais costeiros (Costanza *et al.*, 2014); Florestas de espécies invasoras (Costanza *et al.*, 2014); Zonas húmidas (Costanza *et al.*, 2014); Matos (De Groot *et al.*, 2012); Pastagens espontâneas (De Groot *et al.*, 2012); Massas de água de transição e costeiras (De Groot *et al.*, 2012).	Partidario and Gomes (2013)	€/ha/ano	- 602 602 20,345 2207 136,390 1117 1117 345
Outras referências para quantificação e valoração dos serviços de ecossistemas. documento de suporte, documento de suporte1	Newton, A. et al (2018); Raymond, C. M. *et al.* (2017)		
2. Capacidade de retenção de CO_2. Nota: documento de suporte; dados relativos a 2018.		ton/ha/ano ou Mg/ha/ano	4.5 - 40.7
3. Caso de estudo no Reino Unido, taxa de retenção média de CO_2 de habitats costeiros nas dunas. documento de suporte	Beaumont, N. J., *et al.*, (2014)	g/m²/ano	59.5 ± 25.8

Base de dados de impactos de medidas de mitigação e adaptação desenvolvida no âmbito do projeto INCCA

Figure 5. Individual sheets of Database #2 (example of A+1 impact – renaturalize river banks). Note: the text in the image is intentionally left illegible, as the database is only available in Portuguese at this stage. See http://incca.web.ua.pt/ (accessed on 30 May 2023).

4.3. Database #3: Costs of Mitigation and Adaptation Measures

Database #3 gathers all the information collected regarding direct costs, which characterize each mitigation and adaptation measure identified in Database #1. Figure 6 shows an example of an individual cost sheet, which has information about implementation costs (1), maintenance costs (2) and operational costs (3). The same information is provided in the remaining 52 individual cost sheets of Database #3, whenever information is available.



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I N C C A | Adaptação Integrada às Alterações Climáticas para Comunidades Resilientes

IDENTIFICAÇÃO DA MEDIDA

A331 Reforço do cordão dunar através de sedimentos provenientes de offshore

INFORMAÇÃO SOBRE CUSTOS DIRETOS

IMPLEMENTAÇÃO 1	LOCALIZAÇÃO	ANO	CUSTO (€)
Recuperação do sistema dunar entre a Costa Nova e Mira Esta intervenção compreendeu a realização de ações de proteção e recuperação do sistema dunar, pela deposição artificial de sedimentos, a sua estabilização com paliçadas e a recuperação dos seus habitats (com plantação de espécies autóctones e vedações para evitar o pisoteio), uma vez que nas últimas décadas tinha sofrido um grande desgaste por erosão e alguns galgamentos. É possível afirmar que se trata de uma intervenção com custo de aproximadamente **257.61€ por metro** de reforço do cordão dunar.	Costa Nova e Mira	2013/2016	3864,124.57 (15 km)
Recuperação e Estabilização do Cordão Dunar entre as Praias da Barra e da Costa Nova Investimento de cerca de 400 mil euros e um prazo de execução de meses, a empreitada é assegurada pela Agência Portuguesa do Ambiente e pelo Município de Ílhavo (fonte não oficial).	Barra e Costa Nova	2021	400,000
MANUTENÇÃO 2	**LOCALIZAÇÃO**	**ANO**	**CUSTO (€)**
Informação não disponível.			
OPERAÇÃO 3	**LOCALIZAÇÃO**	**ANO**	**CUSTO (€)**
Informação não disponível.			

Base de dados de custos diretos de medidas de mitigação e adaptação desenvolvida no âmbito do projeto INCCA

Figure 6. Example of individual cost sheet (one of 53). Note: the text in the image is intentionally left illegible, as the database is only available in Portuguese at this stage. See http://incca.web.ua.pt/ (accessed on 30 May 2023).

4.4. Adaptation Plan

The participatory approach allowed us to support the adaptation plan for the Ovar Municipality. The first participative moment aimed at presenting to the stakeholders the meta-measures for mitigation and adaptation to coastal erosion in sandy systems, listed by the INCCA project research team, and proceeded with their selection and prioritization, focusing on a strategy for the Ovar Municipality. The first result of the workshop was the selection of the TOP 10 measures indispensable and unavoidable in a future strategy for the Municipality of Ovar.

The second participative moment was a deeper analysis of the measures already selected and prioritized in the first moment (the final set of nine measures was grouped into three sets of measures), with concrete criteria and comparable metrics:

1. Artificial beach nourishment (meta-measure A32);
2. Preservation of dune systems (meta-measure A22);
3. Strengthening of the dune systems (meta-measure A33);
4. Nourishing the littoral drift (meta-measure A31);
5. Detached breakwaters (meta-measure A14);
6. Accommodation of the built-up area (meta-measure B21);
7. Education, awareness raising and monitoring (meta-measure B23);
8. Participatory governance (meta-measure B24);
9. Financial instruments (meta-measure B25).

These measures were worked out at the level of a multi-criteria analysis. The defined criteria (effectiveness; cost/investment; urgency; environmental impact; acceptance of the local population; temporality of the measure; and level of certainty and confidence) led to the identification of TOP 3 measures, for which a participatory cost–benefit analysis was carried out. The three measures analyzed were as follows:

1. Preservation of dune systems (meta-measure A22);
2. Accommodation of urbanized buildings (meta-measure B21);
3. Detached breakwaters (meta-measure A14).

The sharing and debate that the INCCA project promoted and facilitated with this first workshop, besides allowing the prioritization of the proposed meta-measures and the cost–benefit analysis of the three measures defined as priority, were spaces of meeting and convergence, where different voices were considered, reinforcing the importance of the participatory component in the decision-making processes. The ideas shared by the stakeholders revealed that it is possible to reach a common vision for the coast of the Municipality of Ovar. To achieve the objectives of adapting to coastal erosion, the stakeholders accessed the developed manual and highlighted measures such as coastal protection works, artificial nourishments, the relocation of people and goods and the reinforcement of dune systems—in particular the following:

1. Avoiding the loss of urban territory through the use of artificial nourishments, as opposed to the expansion of rocky engineering works (groins and revetments);
2. Relocation of communities (housing and activities) that are currently in danger and whose scenarios show that they will remain so in the coming years;
3. Maintaining coastal defense works and evaluating the possible construction of a detached breakwater in the Furadouro area. Combining engineering works with artificial nourishments in key areas—Esmoriz, Cortegaça and Furadouro;
4. Naturalization of areas left free by the relocation of communities (e.g., Cortegaça camping area).

In fact, during the second workshop, considering the coastal protection works, the stakeholders acknowledged the importance of protecting people and properties. They indicated the importance of maintaining the existing engineering works on the coast of Ovar and investing in their maintenance. Some stakeholders went further, by addressing the issue of building new works, such as Y- and T-shaped groins or detached breakwaters. All stakeholders were unanimous regarding the need for artificial sand nourishments on Ovar's beaches. Some consider the nourishments as a valuable complement to engineering works, while others referred to it as an individual measure of mitigation and adaptation to coastal erosion.

The participants in the second workshop also had a common idea that the areas that remained without major human interventions should be left that way, in order to evolve and retreat naturally. This retreat must be accompanied by monitoring so that critical areas, such as the Maceda landfill, are not affected. Some stakeholders suggested that areas that are now artificial, but where there is already a plan to vacate them, must be naturalized so that they can become more resilient areas and buffer zones against coastal erosion. The stakeholders also converged on the need to relocate populations that live in critical areas of the coast of Ovar, namely the fishermen's neighborhood of Esmoriz and the camping site of Cortegaça. This measure does not involve consensus when talking about Furadouro's urban waterfront.

During the third workshop, three working groups were defined to discuss the measures for each coastal stretch of the Municipality of Ovar, over an 80-year period (2020–2100). Among the measures suggested by the different groups, there are some that, due to their broader or systemic character, make them applicable to the entire Ovar region rather than just specific locations. This is the case for the participatory involvement of stakeholders in coastal management through articulated and coherent governance, as well as measures to educate and raise awareness of the population regarding the problem of coastal erosion and its possible solutions. In addition, the immediate and continuous application of fiscal instruments was suggested as a way of discouraging the construction and use of housing in the flood risk zone in all urban areas of the region. This measure aims to prepare the localities for the relocation of these buildings to start between the years 2050 and 2080, progressing until it is completed.

In the specific case of Esmoriz, it was decided that the beach area should not be given over to the advancing sea. Thus, the measure of the artificial nourishment of the beach is envisaged to start around 2030, when it is expected that the turning point of loss of 10% of the beach area will be reached, and continue indefinitely in order to maintain the beach.

The final plan for Cortegaça suggests abandoning the southward groin, leading to its gradual disappearance, while monitoring the coastline. If the coastline undergoes significant changes as a result of abandoning the groin, it can be recovered. The artificial nourishment of the beach is also foreseen in this locality, with an immediate and continuous character. The abandonment of the longitudinal rocky revetment along the campsite was also projected, emphasizing that this measure should only be carried out after investigating the impact of removing the groin located on the southern limit of Cortegaça, in order to control possible negative effects on shoreline evolution. Additionally, it was suggested to develop a study to investigate the interest in building T/L-shaped groins at the site.

In Maceda, the decision to remove the groin located to the north was unanimous, and this measure should be applied immediately and be effective until 2050. At this point, if the turning point of 25 m of shoreline retreat is reached, it will be necessary to artificially nourish the beach in order not to exceed this value.

Finally, in Furadouro, it was decided that it would be necessary to immediately build a T-shaped groin or two L-shaped groins, based on the results of a comparative study of the alternatives, in order to protect the urban front. If it turns out that these measures are not sufficient to prevent overtopping (damaging the urban front), it can resort to reinforcing the longitudinal revetment works by raising its crest level. Regarding Furadouro's beaches, it was decided that a loss of more than 50% of its area would be unacceptable, and it was then necessary to proceed with artificial sand nourishments, occasionally, in order to maintain the available sandy area.

The main conclusion of the participatory approach in the design of the adaptation plan is the common vision shared by the different stakeholders and the definition of a path on how to achieve these agreed objectives. The final path represents a combination of different measures for coastal management in the Municipality of Ovar. It is a path that considers both the territorial factor (integrated vision for the entire coast of the municipality) and the temporal factor (short-, medium- and long-term vision). It considers rocky fixed intervention measures (i.e., hard engineering works) and studies of potential future interventions and adaptation measures (e.g., education, raising public awareness or tax policies).

5. Discussion

Faced with the uncertainty, volatility, complexity and ambiguity of our collective future, whether from the perspective of the climate, the economy or socio-political (dis)balances, it becomes increasingly urgent and important to design and develop adequate management models for the territory. Based on the existing literature, as well as the experience within this case study, participatory, dynamic, iterative, flexible and transparent governance models are the best long-term solution for coastal management. Existing case studies, mostly in Europe, strengthen these findings and the conviction that these new governance models should replace traditional top-down, centralized approaches to coastal management. These new processes that promote engagement and collaboration across stakeholders in the different phases—dream, plan, implement, evaluate—are key to bringing knew knowledge, technologies, investment and perspectives for the future of coastlines and are already replacing traditional models. They bring new technologies, new knowledge and, above all, new processes that promote the involvement of all stakeholders in the different phases to think, reflect, plan, implement and evaluate the strategies and measures that are needed to mitigate and adapt coastal zones to future conditions [94].

Currently, several approaches are used to assess coastal erosion and climate change adaptation measures. Gallina et al. [95] conducted a study to analyze the potential consequences of climate change on coastal erosion (e.g., impacts on beaches, wetlands and protected areas) by applying a regional risk assessment (RRA) methodology to the North

Adriatic (NA) coast of Italy. The work presents how spatial risk mapping can be used to establish relative priorities for intervention, to identify hot-spot areas and to provide a basis for the definition of coastal adaptation and management strategies. Baills et al. [96] conducted a review of the literature to select 51 measures, analyzing each criterion independently and, also, using a multi-criteria analysis. The findings of the study highlight the existence of numerous short- and medium-term adaptation possibilities, spanning the periods of 2030–2050 and 2080–2100.

Within the presented work, efforts were made to give voice to the different stakeholders and to involve them in the selection, prioritization and evaluation of measures, in a conscious and iterative effort to calibrate and adapt models and scientific information to the needs of technicians, policymakers and populations. In this interactive process, the final measures primarily fall into the category of protection (both hard and soft) (Section 2). However, it is important to note that other strategies were also identified and discussed during this participatory process. These additional strategies include accommodation and the utilization of ecosystems/ecosystem-based adaptation measures, such as dune restoration [95]. Considering this, a vision of the future for the Ovar coastline was developed, being representative of the different actors with responsibility for or direct interest in the territory. Those paths are dynamic, with turning points and moments of reflection. The path traced reflects today's vision, knowledge, values and aspirations, but these are not unalterable lines. For this reason, it is important not to be too attached to the defined path but, instead, focus more on the process itself. The path can change, especially if that is the will of and the direction that the different stakeholders involved want to give it, in a participatory, transparent and informed way.

A plan that is defined in a participatory way also needs participatory monitoring, implementation, evaluation and reflection. Uncertainties regarding the future, whether related to climate change, sea-level rise, changes in tourism patterns or socially and economically impactful events, require greater flexibility and ability to adapt by coastal communities. In this way, following up and monitoring the implementation of planned measures should ensure that the direction of coastal adaptation plans is aligned with the needs of communities, making them more sustainable and resilient.

The adaptation pathway that was developed during the participatory workshops serves as the basis for the ideation of a coastal erosion mitigation and adaptation plan for the coast of Ovar. The presented work served to explore and demonstrate the importance of innovation in coastal management for adapting to changing conditions. The recommendations for future use are as follows:

- Information: It is necessary to expand and make accessible the databases referring to the dates of overtopping/flooding events and the respective damage, as well as data referring to the implementation and maintenance of protection works. These historical and present data are crucial for the public, technical and scientific communities in the debate about the most viable adaptation plan for each location.
- Participation: The involvement of diverse groups of stakeholders in participatory and decision-making processes is fundamental for delineating future plans with the greatest acceptance and collective benefit. By integrating members of academia, local administration, institutions, civil protection entities, NGOs and interested citizens, it is possible to merge scientific and empirical knowledge, reconcile tradition with development, obtain a multidisciplinary vision of the system and reach equitable solutions.
- Intervention: The decision on the most relevant measures to be adopted must be considered, always bearing in mind the potential for complementary solutions. During the participatory moments, the stakeholders expressed their interest in protecting the urbanized areas and maintaining the socio-economic values of the beaches of Ovar through the combined application of artificial nourishments and the reconfiguration of existing coastal protection works.

- Projection: It is necessary to continue investing in local knowledge, namely regarding the social and economic potential of beaches and urban areas but also the value of coastal ecosystems in the region. Additionally, the costs of interventions must be defined in such a way as to allow cost–benefit analyses to be carried out with rigor and real representativeness.
- Monitoring: It is necessary to reinforce the idea of the need to continuously monitor the progress of the implementation and effectiveness of the measures adopted and consider all the effects that may affect their functioning. Observing coastal erosion patterns and the sea-level rise rates, the performance of both coastal protection structures and artificial nourishment interventions must be studied year by year, allowing adjusting and, if necessary, adopting different adaptation paths.

6. Conclusions

The main objective of this work was to promote an approach that integrates adaptation to climate change and the mitigation of coastal erosion from short-, medium- and long-term perspectives, considering the social, environmental, economic and engineering dimensions of adaptation—thereby adopting a strong participatory component, which aimed to involve local populations and stakeholders through workshops. The first phase of the work aimed to develop a manual of mitigation and adaptation measures for coastal erosion and climate change, accessible to the public and subject to updating over time. This concept was presented in this work and was supported by three participatory moments, which helped to prioritize and characterize the mitigation and adaptation measures and their respective multiple impacts and costs. Due to the positive feedback from the participants in the workshops, the public utility of these moments was reinforced. Public participation represents an important step toward a more transparent, balanced and rooted governance at the level of coastal management—a fundamental condition for the education and sensitization of local populations. The involvement and information of the population aim at a better acceptance of the foreseen measures and more efficient, effective and beneficial planned action, in the short and long term, for all. The list of measures for mitigation and adaptation to coastal erosion and climate change, as well as each of the 53 individual sheets developed within the project, is available online. The manual of mitigation and adaptation measures already built and constantly being updated can be consulted and commented on at http://incca.web.ua.pt/ (in Portuguese, accessed on 30 May 2023). These elements should reach the largest number of stakeholders, experts and individuals interested in coastal management, allowing them to comment and suggest changes and/or improvements in the elements developed, given the participatory character of this work.

The coast, its people and the socio-economic activities that take place represent dynamic, complex and highly iterative factors that require present, flexible, integrated and holistic management. More than plans, it matters above all to build a civic culture of participation and involvement in the decision-making processes and to cultivate the development of visions and shared paths for a collective future. This work represents an important step taken in this direction, as the combination of all the presented elements and the participatory process of how to get there is a unique and innovative approach in terms of coastal management.

Author Contributions: Conceptualization, C.C., M.L. and F.M.A.; methodology, C.C., M.L. and F.M.A.; validation, C.C., M.L. and F.M.A.; formal analysis, J.P.-B. and P.R.; investigation, M.M.; resources, C.C.; data curation, M.L. and M.M.; writing—original draft preparation, C.C., M.L., F.M.A., P.R., J.P.-B. and M.M.; writing—review and editing, C.C. and P.R.; supervision, C.C.; project administration, C.C. and M.L.; funding acquisition, C.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: All the INCCA project databases and related publications are available at http://incca.web.ua.pt/ (accessed on 30 May 2023).

Acknowledgments: This work was financially supported by the project "Integrated Coastal Climate Change Adaptation for Resilient Communities", INCCA—POCI-01-0145-FEDER-030842, funded by FEDER, through "Competividade e Internacionalização" in its FEDER/FNR component and by national funds (OE), through FCT/MCTES. It was also supported by the Foundation for Science and Technology (FCT)—Aveiro Research Centre for Risks and Sustainability in Construction (RISCO), Universidade de Aveiro, Portugal (FCT/UIDB/ECI/04450/2020). Finally, thanks are due for the financial support to CESAM by FCT/MCTES (UIDP/50017/2020+UIDB/50017/2020+LA/P/0094/2020), through national funds.

Conflicts of Interest: The authors declare no conflict of interest.

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