

NATURE-BASED SOLUTIONS FOR COASTAL ADAPTATION: A MODELLING STUDY IN THE SICILY COAST (ITALY)

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INTRODUCTION

Since the middle of the last century, coastal ecosystems have experienced an unprecedentedly rapid decline in biodiversity and ecologic value (Waltham et al. 2020). The combination of climate change and anthropic activities has led to a global scale degradation of these habitats in terms of spatial extent and ecosystem functionality (Toimil et al., 2020). This occurrence entails not only the depletion of the species richness these environments encompass, but also a reduction in the ecosystem services they provide. However, coastal vegetation is more efficient in storing carbon than forests up to one order of magnitude (Mossman et al., 2022), besides being an effective climate regulator and pollutant filterer. Moreover, effectiveness of seagrass in wave energy attenuation is largely proven in literature, same applies to coastal wetlands in laminating flood surges (Ondiviela et al. 2014; van Zelst et al., 2021).

In the light of the above, a lot of attention is given recently to Nature-based solutions (NbS) in coastal environments. These measures have the potential to serve as an effective means of fostering biodiversity conservation and concurrently mitigating the adverse consequences of climate change (Sanchez-Arcilla et al., 2022).

However, the long-term effectiveness of NbS under varying climatic scenarios and across diverse ecosystems warrants comprehensive investigation (Seddon et al., 2020). Extensive research efforts are still required to assess their feasibility, scalability, and adaptability, as well as their potential trade-offs and synergies with other climate adaptation and mitigation strategies. This knowledge is essential to inform evidence-based decision-making and optimize the integration of NbS into broader climate resilience and biodiversity conservation strategies.

In the present work, a study to investigate the performance of coastal NbS to mitigate climate change-driven flooding and erosion within a case study is carried out. An hydro-morphodynamic modelling chain is setup to assess the effectiveness of restoration actions to reduce coastal risk in present and future scenarios in a case study. The model is able to simulate dissipative effects of vegetation, and is employed to assess performance of a set of measures to reduce coastal flooding and erosion due to extreme wave events combined with sea level rise.

CASE STUDY

The modelling chain is applied to a pilot site, i.e. the Cuba-Longarini coastal wetland complex in the SE of Sicily, Italy (Figure 1). Cuba and Longarini are two coastal saline lagoons covering approximately 300 ha, in connection with the close beach environment. The lagoons experience significant water level variations during the year, being connected with the sea only during rain flood events and becoming completely dry during the summer. In the 1970s,

the town of Granelli was built over the dune beach strip, inducing a permanent hydraulic disconnection of the Cuba lagoon to the sea. The building of the town is probably at the origin of the progressive erosive process of the Granelli beach.

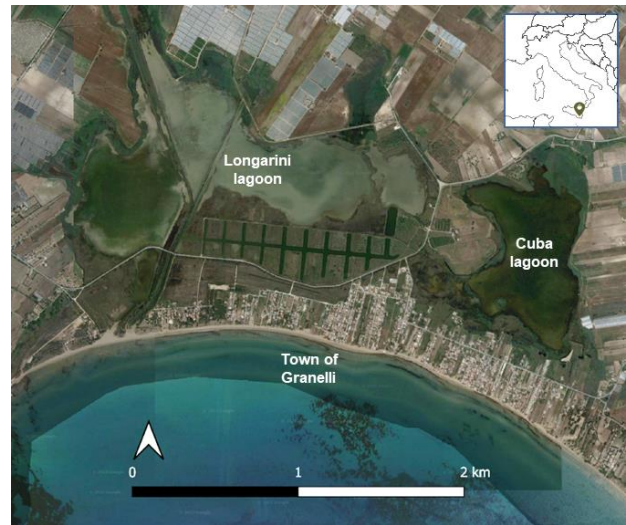


Figure 1 - The Cuba-Longarini coastal lagoon complex and the town of Granelli

METHODOLOGY

A modeling framework is developed to simulate the hydro-morphodynamic processes characterizing the case study area. The modeling framework comprises a wave motion propagation model (SWAN, Booji et al., 1996) coupled with a morphodynamic model (XBeach, Roelvink et al., 2009). Input hydrodynamic forcings include offshore wave data for current, RCP 4.5, and RCP 8.5 scenarios (IPCC AR5), as well as local sea-level rise (SLR) projections (IPCC AR6). A 1993-2021 year window has been chosen for analysis of present conditions, whereas two year windows for future projections 2056-2084 and 2071-2100. The model allows for the simulation of dissipative effects of vegetation. Vegetation characteristics were obtained from literature data (Garzon et al., 2019; Unguendoli et al., 2023), while the spatial distribution of vegetation is derived by intersecting the Carta Natura with the EUNIS classification (Chitry et al., 2020), associating a representative species to each habitat. The simulations were conducted to model: (i) the conditions in the absence of restoration actions, (ii) the influence of dune revegetation with *Ammophila arenaria*, and (iii) the contribution of a seagrass meadow revegetation with *Posidonia oceanica*.

RESULTS

Figure 2a shows the inundation map for a without-restoration for the RCP 8.5 scenario, year window 2056-2084, with significant wave height $H_s = 5.85$ m and SLR = 0.477 m. The image shows a dramatic increase of the surface occupied by the lagoon induced by sea level rise. Moreover, the urban area in between the beach and the lagoon is heavily flooded due to the sea storm. This heavy flood occur for all future scenarios, as shown in Figure 2b, which reports the flooded surface of the urban area in all the simulations. However, the results highlight that the implementation of the Nature-based measures significantly reduce the flooded surface, up to 59% for the seagrass replantation RCP 4.5 year window 2056-2084 case.

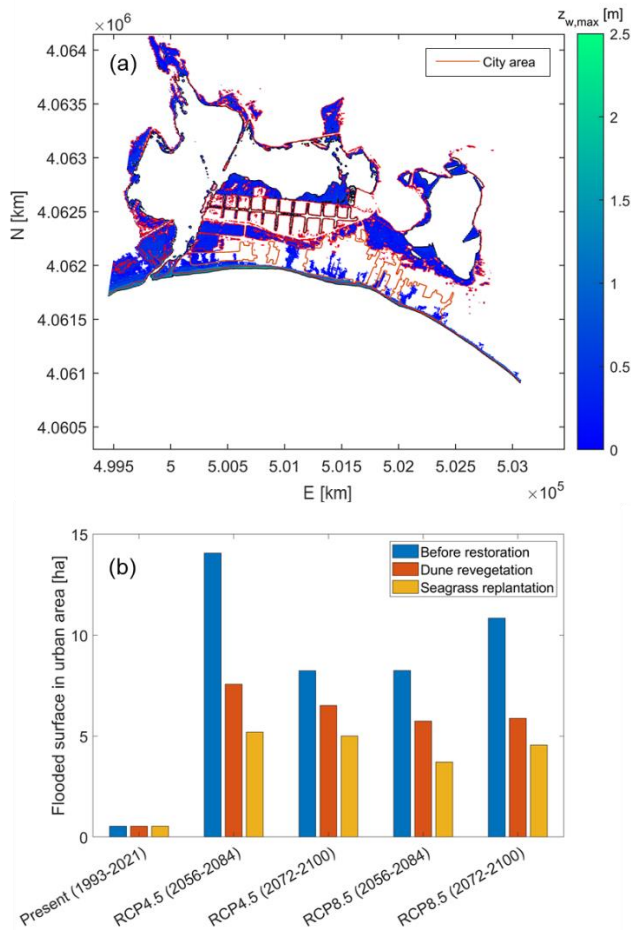


Figure 2 - Water level $z_{w,max}$ for a before restoration condition simulation, RCP8.5 scenario, $H_s = 5.85$ m ($T_r = 100$ years), year window 2056-2084 (a), flooded surface in urban area for all simulations (b).

ACKNOWLEDGEMENTS

This work was funded by the project REST-COAST - Large scale RESToration of COASTal ecosystems through rivers to sea connectivity (call: H2020-LC-GD-2020; Proposal no. 101037097) and PROMETEO, financed by the PRIN 2022 fund in the context of the PNRR.

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