Coastline Behavior Under Climate Change and Sea-Level Rise Scenarios: A Western Portuguese Littoral Case Study

4 authors:

Blanca Mendiguren
University of Malta

Carlos Coelho
University of Aveiro

Rita Pombo
MIT Portugal Program

Margarida Ferreira
University of Aveiro

Coastline behavior under climate change and sea-level rise scenarios: a western Portuguese littoral case study.

Blanca Mendiguren*, Carlos Coelho*, Rita Pombo*, Margarida Ferreira*
*RISCO and Department of Civil Engineering, University of Aveiro, 3810-193, Portugal.
blancamg@ua.pt, ccoelho@ua.pt, ritanovo@ua.pt, margarida.ferreira@ua.pt

Introduction

Coastal sandy areas are highly dynamic environments, where sediment transport driven predominantly by wave action define its morphology. More than 50% of the sandy coast of Portugal is under a significant recess of the coastline (Pranzini *et al.,* 2015), where low-lying sandy coasts are most vulnerable when it comes to storm surges and flood risks (Santos & Miranda, 2006; Alves *et al*., 2011). Additional risks can be expected from climate change and its undesirable consequences, such as a projected increase in frequency and magnitude of extreme events, demanding an ever-increasing need for adaptation actions (SROCC, 2019).

In an effort to overcome the effects of climate change, the United Nations Intergovernmental Panel on Climate Change (IPCC) defined a series of future scenarios based on greenhouse gas concentration trajectories, designated as RCP (Representative Concentration Pathway). The present work aims to highlight the influence of climate change on the western Portuguese coastline, studying its effects in the future wave characteristics and in the sea level rise (SLR). Regarding the effects of climate change in the wave characteristics, two wave series generated considering the future RCP intermediate scenario (RCP4.5) and the most adverse (RCP8.5) were studied. Under these different forcing scenarios, the shoreline evolution of three littoral stretches were analyzed, with a total length of 43 km, due to their vulnerability to persistent erosion processes: Barra-Vagueira (Aveiro); Claridade-Leirosa (Figueira da Foz) and; São João-Fonte da Telha (Caparica coast).

Methods

Coastline projections were simulated with the LTC, Long-Term Configuration, numerical model (Coelho, 2005). The model calibration relied on average shoreline rate-of-change, evaluated through shoreline position displacements between of 1958 and 2010 (Lira *et al.*, 2016) and, considering previously validated wave climate data produced in WAVEWATCH-III (WWIII) spectral model for a similar period as the forcing agent (Dodet *et al.,* 2010; GeoFCUL, 2021).

Marine wave climate can be forecasted (and hindcasted) through numerical models that solve equations describing the wind-waves generation processes (WMO, 1988). Therefore, 3 marine wave climate datasets (significant wave height, peak period, and wave direction) derived from numerical models were considered to characterize the study area, in a scenario based on past events and, two future scenarios considering the effects of climate change. In order to reproduce historical events, 20 years of spectral wave data derived from the WWIII hindcast model were simulated. The future scenarios, RCP4.5 and RCP8.5, characterized the future wave climate for the different greenhouse gas concentration evolution, corresponding to 20 years of records (2026 to 2045). The future scenarios wave climate data, were obtained from wave datasets downscaled with the WWIII model for a point location offshore of the Portuguese West coast (10ºW 40.50ºN) in the scope of MarRisk (2017) research project (Ferreira *et al.*, 2021; Vieira *et al*., 2021). In order to isolate the effect of SLR, each of the previous defined scenarios were then simulated with an increase in the sea water level of 0.0075m/year, value that represents an intermediate scenario of SLR forecasted for the Portuguese western coastline (Antunes, 2019). Considering the shoreline position along time, annual areas of erosion and accretion were measured for the six scenarios, in the three coastal stretches.

Results

The influence of SLR and wave climate showed a different behavior of the coastline along the Portuguese littoral. The coastal stretch between Barra and Vagueira is expected to undergo the greatest erosion among the study areas. It is projected for this stretch a land loss of about 50 ha under historical wave climate. An intermediate future scenario would represent a land loss of 30 ha and the effect of RCP8.5 wave climate resulted in a land loss of 38 ha. These results show different shoreline evolution responses to climate change scenarios, where future scenarios not necessarily increase coastal erosion and the intermediate emission scenario corresponds to the lowest erosion in the future. These results are related with the main wave direction future variations and will also have impact on wave propagation phenomena, when combining the SLR scenarios.

The coastal stretch between Claridade and Leirosa was divided into two subs-stretches, due to the presence of the jetties built on either side of the Mondego river. North to the Mondego river's mouth, accretion will prevail under the three wave climates, with greater rates due to climate change and, a slight decrease of these rates due to SLR. At South, it is expected a similar coastline behavior under RCP8.5 climate change scenario, with and without SLR, with a land loss of 24 ha after 20 years of simulation. A slightly larger area of erosion is projected to occur under historical wave climate, 27 ha, whereas the influence of SLR will increase the total eroded area to 30 ha in a time frame of 20 years. The highest values of erosion for this sector where observed under RCP4.5 climate change scenarios (45 ha), with a slightly lower land loss (43 ha) as a result of SLR, attributed to changes in the wave propagation for a higher sea water level.

At the Caparica coast, between São João and Fonte da Telha, it is expected a similar erosional behavior of the coastline under the three wave climates, expecting values of the order of 5 ha. The influence of SLR in Caparica coast appears to double the erosional rates, predicting, however keeping a similar behavior for the three wave climates.

Conclusions

The obtained results show the importance of defining future forcing scenarios in the projection of the shoreline position along time, representing significant differences in the areas that may be lost due to coastal erosion. Climate change scenarios may shift the position of the most vulnerable places, but will not necessary increase the global erosion rates.

Acknowledgements

This study was funded by the EEAGrants through the COAST4US project (Application of the COAST tool to the Portuguese littoral), promoted by R5m Marine Solutions, in partnership between R5e Consulting Engineers and University of Aveiro. This project is supported by the Agência Portuguesa do Ambiente, Programa Crescimento Azul and Direção-Geral de Política do Mar.

Bibliography

Alves, F. L., Silva, J. V., Pereira, C. A., & Sousa, L. P. (2011). Ten years assessment of ICZM principles applied at local scale: Ria de Aveiro case study. Journal of Coastal Research, 64, 1311–1315.

Antunes, C. (2019). Assessment of sea level rise at west coast of Portugal Mainland and its projection for the 21st century. Journal of Marine Science and Engineering, 7(3), 61.

Coelho, C. (2005). Riscos de Exposição de Frentes Urbanas para Diferentes Intervenções de Defesa Costeira. Tese de doutoramento, Universidade de Aveiro, 405p.

Dodet, G., Bertin, X., & Taborda, R. (2010). Wave climate variability in the North-East Atlantic Ocean over the last six decades. Ocean modelling, 31(3-4), 120-131.

Ferreira, M., Fernández-Fernández, S., Coelho, C., Silva, P.A. (2021); Caracterização de Tempestades e da Deriva Litoral no Litoral de Aveiro, em cenários de Alterações Climáticas. 15º Congresso da Água, 22 a 25 de março, #17.

GeoFCUL (2021). MICORE wave download, accessible at: http://disepla.fc.ul.pt/Micore/WaveDownload.html

Lira, C., Nobre Silva, A., Taborda, R., Freire de Andrade, C. (2016). Coastline Evolution of Portuguese Low-Lying Sandy Coast in the Last 50 Years: an Integrated Approach. Earth Syst. Sci. Data 8, pp. 265-278, doi: 10.5194/essd-8-265-2016.

MarRisk (2017). MarRisk: Costal Adaptation to Climate Change: Knowing the Risks and Increasing Resilience. Research Project (EP-INTERREG).

Pranzini, E., Wetzel, L. & Williams, A.T. Aspects of coastal erosion and protection in Europe. J Coast Conserv 19, 445–459 (2015). https://doi.org/10.1007/s11852-015-0399-3

Santos, F. D. & Miranda, P. (2006). Alterações climáticas em Portugal: Cenários, Impactos e Medidas de Adaptação - Projecto Siam II. Gradiva, Lisboa. ISBN 989-616-081-3.

SROCC (2019). IPCC SR Ocean and Cryosphere Sea Level Rise and Implications for Low Lying Islands, Coasts and Communities - Chapter 4, Final Draft, p. 31.

Vieira, B. F., Pinho, J. L., & Barros, J. A. (2021). Extreme wave value analysis under uncertainty of climate change scenarios off Iberian Peninsula coast. Ocean Engineering, 229, 109018.

WMO (1988). Guide to Wave Analysis and Forecasting. 2nd Edition. World Meteorological Organization, Genebra, Suíça, 168 p.