EXPLORING THE VIABILITY OF ACCOMMODATION SPACE-BASED COASTAL ADAPTATION IN DEVELOPED MEDITERRANEAN COASTS

José A. Jiménez, Universitat Politècnica de Catalunya· BarcelonaTech, jose.jimenez@upc.edu
Rut Romero-Martín, Universitat Politècnica de Catalunya· BarcelonaTech, rut.romero@upc.edu
Herminia I Valdemoro, Universitat Politècnica de Catalunya· BarcelonaTech, herminia.valdemoro@upc.edu

INTRODUCTION

At present, a substantial part of the Mediterranean sedimentary coastline is retreating (e.g. Luijendijk et al. 2018), a trend that could be intensified by climate change, thereby increasing the risk of beach disappearance (e.g. Vousdoukas et al. 2020). This potential loss of beaches is influenced by erosion rates and the presence of barriers in the hinterland, hindering the natural capacity for beach rebuilding in response to external forces. As a consequence, the Mediterranean coast currently features hotspots of extreme exposure to coastal hazards and recurring damage. This underscores the imperative to implement adaptation strategies, both in the short and long term. While in the short-term, the conventional approach has been to seek full protection, the escalating impact of these changes makes it increasingly advisable to adopt long-term transformative adaptation strategies.

Thus, harnessing the natural resilience of coastal ecosystems to adapt to external pressures is gaining prominence as a favored approach for enhancing climate resilience and thus support EU policy priorities. While research into the practicality and viability of many nature-based coastal protection methods in real-world conditions remains somewhat limited, certain approaches, like dunes and sand banks, are deemed crucial for future coastal defense. Nonetheless, their application in highly developed and urbanized areas such as the Mediterranean coastline, poses a significant challenge. This challenge is rooted in the availability of space for implementation without immediate (short-term) disruption, which can hinder their effectiveness as long-term adaptation measure.

In this context, this work presents a framework for assessing the necessary accommodation space to facilitate the natural rebuilding of beaches under an external forcing. It integrates predictions of the space requirement to cope with coastal hazards under both current and future climate change scenarios, within relevant time horizons for planning purposes. The ultimate practical goal is to categorize the territory based on space requirements, land characteristics, and the feasibility of generating the necessary space. This classification will also enable the identification of areas suitable for the implementation of adaptation measures that demand additional space, such as dunes, wetlands or managed retreat, differentiating between those where such measures can be easily applied and areas where they are only viable for short-term horizons.

The framework is applied in the Catalan coast (NW Mediterranean), covering approximately 500 km of coastline characterized by a rich diversity of geomorphic, environmental, socio-economic and oceanographic conditions, making it a representative example of developed Mediterranean coasts.

METHODS

The *accommodation space* is here calculated as the space landward of the shoreline required to accommodate the cumulative contribution of (ii) SLR-induced changes, *Xslr*; (ii) mid-term -decadal- shoreline changes, *Xmt*; (iii) storm-induced erosion, *Xsto*; and the (iv) active beach width, *Xact* (Figure 1). In addition to this, and to account for the uncertainty inherent to the calculation of each component, a *safety buffer* is calculated by summing the individual uncertainties (Figure 1). While the first one corresponds to the likely area of influence of considered processes controlling shoreline evolution, the safety buffer will represent a “worse-case scenario” limit.

Figure 1 - Components contributing to the total space required to accommodate to coastal retreat under a SLR-scenario

RESULTS

Figure 2 shows the magnitude of the spatially-averaged contributions to the accommodation space along the Catalan coast for three considered time horizons (2050, 2075 and 2100). While the storm reach and active beach components are time-independent, the mid-term and SLR-induced components increase as the projection timeframe lengthens. This causes their relative weight in the final accommodation space to increase progressively, with their final magnitude depending on the adaptation time horizon.

The component displaying the most significant spatial variability is *Xmt*, that is influenced by local beach evolution, with three sectors exhibiting retreats up to 50 m by 2100. It’s important to note that while the sector-averaged values provide an overall segment behavior representation, individual beaches within these segments may exhibit significant variability based on their local characteristics.

Long-term SLR-induced shoreline retreat, *Xslr*, is also time-dependent, with a non-linear increase after 2050, reflecting an acceleration in SLR changes according to the

AR6 SSP5-8.5 scenario. The spatial variability is mainly influenced by shoreface morphology, with milder shoreface slopes experiencing more significant retreat, resulting in a hotspot in the Ebro delta.

The magnitude of storm-induced contribution, *Xsto*, along the coast is predominantly driven by the wave power content in the study area, which exhibits higher-energy storms in the northern half of the coast. The final magnitude depends on the selected return period, *Tr*, for characterizing storm action, a decision guided by safety criteria set by coastal planners, which may vary along the coast depending on properties of the hinterland.

Lastly, the active beach width, *Xac*, exhibits the most spatially uniform pattern along the coast, with slightly larger values being found in the southern region where dissipative beaches are predominant. This leads to larger theoretical horizontal projections of wave runup.

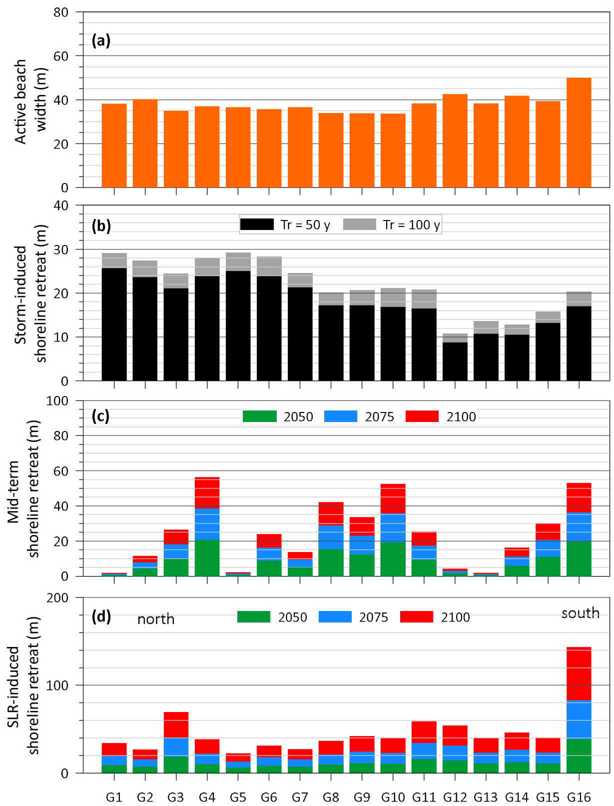

Figure 2 - Magnitude of components contributing to the accommodation space along the Catalan coast. X-axis represent coastal sectors with homogeneous wave conditions. (a) Active beach width; (b) storm-induced retreat associated to *Tr* of 50 years and 100 years; (c) medium-term shoreline evolution, and (d) SLR-induced shoreline retreat at different timeframes.

The projected total accommodation space required at the three considered time horizons after integrating all components is shown in Figure 3. As anticipated, this land requirement grows over time, with an average value of about 80 m in 2050, 100 m in 2075 and 130 m in 2100.

Alongside this temporal increase, there is a corresponding rise in spatial variability, characterized by the standard deviation of the projections, which expands from 14 m in 2050 to 26 m in 2075 and 40 m in 2100. The sectors with the largest projected accommodation space requirements are those where the time-varying components, Xac and Xslr, attain their peak values. It should be noted that, within each sector, the space required for local adaptation varies at the beach scale, in such a way that hotspot areas may require significantly larger spaces than the average.

The sector-averaged safety buffer accounting for potential uncertainties in the assessment of the accommodation space is shown in Figure 3. The temporal dynamics align with the patterns of its constituent components, while the observed spatial pattern mirrors the behavior of the *Xslr* component. This similarity underscores the significance of *Xslr* as the component with the highest associated uncertainty over the long-term.

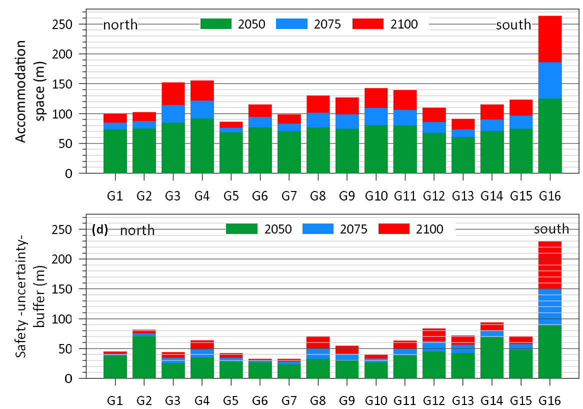

Figure3 - Sector averaged projections of the accommodation space (*top*), and the safety buffer due to associated uncertainties (*bottom*) along the Catalan coast for different timeframes.

Lastly, the accommodation and safety buffer assessments are extended across the entire coastline, classifying the area into three types of stretches based on the feasibility of implementing accommodation space-based coastal adaptation measures. This classification aids coastal planners in making informed decisions regarding future adaptation strategies.

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