

MONITORING A BEACH NOURISHMENT PROJECT IN BENIDORM (E SPAIN) USING REMOTE SENSING

Carlos Cabezas-Rabadán, CGAT, Dep. I. Cart., Universitat Politècnica de València; Univ. Bordeaux/CNRS, carcara4@upv.es
 Josep E. Pardo-Pascual, CGAT, Dep. Ing. Cartog., Universitat Politècnica de València, jepardo@cgf.upv.es
 Jesús Palomar-Vázquez, CGAT, Dep. Ing. Cartog., Universitat Politècnica de València, jpalomav@upvnet.upv.es
 Andrew Cooper, School Geogr. & Env. Sc., Ulster University; Discip. Geology, Univ. KwaZulu-Natal, jag.cooper@ulster.ac.uk

INTRODUCTION

Efficient coastal management requires decision-making actions based on accurate and up-to-date information on the state of beaches. Coastal engineering actions have the potential to modify the morphology of beaches in an attempt to contribute to their physical maintenance in the face of erosion problems. Nevertheless, in many cases, monitoring of beach nourishment effects is limited in time and space, and the resulting morphological consequences of these actions are not well known. The possibility to freely access the optical satellite imagery from the Landsat and Sentinel-2 constellations has opened up a new scenario for the efficient characterisation of coastal spaces and beach dynamism. Based on satellite imagery, different tools for identifying the shoreline positions (Satellite-Derived Shorelines, SDSs) and monitoring their changes over time have been proposed (see Vos et al., 2023). With this same goal, the shoreline extraction tool SHOREX (Sánchez-García et al., 2020) constitutes a solution encompassing all the necessary steps from data acquisition to the final shoreline definition. Sustained on remote sensing, this work presents a methodological approach for the continuous monitoring of the morphological effects of beach nourishment actions.

CASE OF STUDY

Benidorm is a famous tourist resort and a paramount example of the modification of the coastal territory to accommodate human interests, and a highly developed tourist industry mainly sustained on the recreational use offered by the beaches. Platja de Ponent is a 3100 m oval-shaped sandy beach delimited by rocky cliffs (Fig.1) facing the Mediterranean with SSE orientation. The coast presents an almost negligible astronomical tidal range (<20 cm) and small waves ($H_s = 0.7$ m; $T_p = 4.2$ s). With the aim to sustain a developing tourist industry in the municipality, an important beach nourishment was carried out in 1991 in Platja de Ponent. The eastern part of the beach received an artificial contribution of 710,847 m³ of sand from the dredging of the seabed (MOPT, 1991), which represents more than 500 m³ per linear meter, and was complemented by the construction of a breakwater in the easternmost limit of the beach (Aragónés et al., 2015).

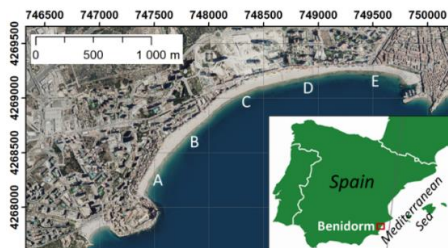


Figure 1 - Study site in Platja de Ponent Beach, Benidorm. Five zones (A-E) are distinguished for the analysis by sectors.

METHODOLOGY

This work proposes the employment of Landsat and Sentinel-2 imagery to define the series of SDSs using the tool SHOREX. After discarding the cloudy images, 521 shorelines were defined between 25/05/1984 and 30/01/2023 as the water/land intersection at the acquisition time of the satellite images (Fig. 2), with an estimated accuracy of about 3.5 m RMSE according to previous assessments in Mediterranean sandy beaches (Sánchez-García et al., 2020).

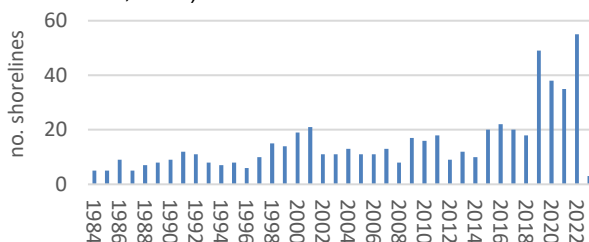


Figure 2 - Satellite images employed in the analysis: L5 (1984-2011), L7 (2011-2013), L8 (2013-2022), L9 (2022-23) and Sentinel-2 (2015-2023).

At the same time, the inner limit of the beach was defined by photointerpretation of aerial orthophotography, and the distance to each of the SDS was measured in order to define the beach width at each date. All the width measurements were organized within a spatial-temporal model (STM) as described by Cabezas-Rabadán et al. (2019) enabling a continuous characterisation of the beach width changes over time and space (Fig. 3).

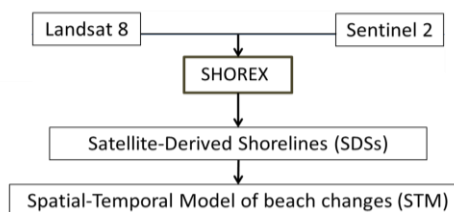


Figure 3 - Workflow of the methodological approach.

RESULTS

The analysis of the STM shows the abrupt widening of the beach between February and May 1991 (Fig. 4), when the average width increased from 37.6 m (22/02/91) to 80.8 m (13/05/91). The results show that in the 12 months after the peak widening associated with the engineering project, there was a certain setback, although the beach remained wider than before the action. The shoreline trend recorded before the nourishment (between 25/05/1985 and 22/02/91) was -0.41 m/year while subsequently (between 27/04/1991 and 30/01/2023) the trend was -0.13 m/year. Although the greatest widening of the beach took place in 1991 associated with the nourishment project, that was not

the period of maximum width along the series. Thus, in 2012 the width reached a peak of 75 m probably linked to changes in wave conditions. The analysis of the STM allows the derivation of spatial and temporal profile plots of the beach width changes. This enables the identification of the different responses to nourishment broken down into five zones (Fig. 5). The initial widening linked to the project was significant in the eastern part of the beach (zones D and E) while towards the west the widening was progressively smaller, being almost non-existent in zone A. It is striking to note that the eastern part (zones D, E) followed an erosive trend both before and after nourishment, while sectors A and B maintained a positive trend in both cases. These results show the progressive westward migration of the sediment, and this characteristic could be a key factor in designing policies that favour the future sustainability of all the beach segments.

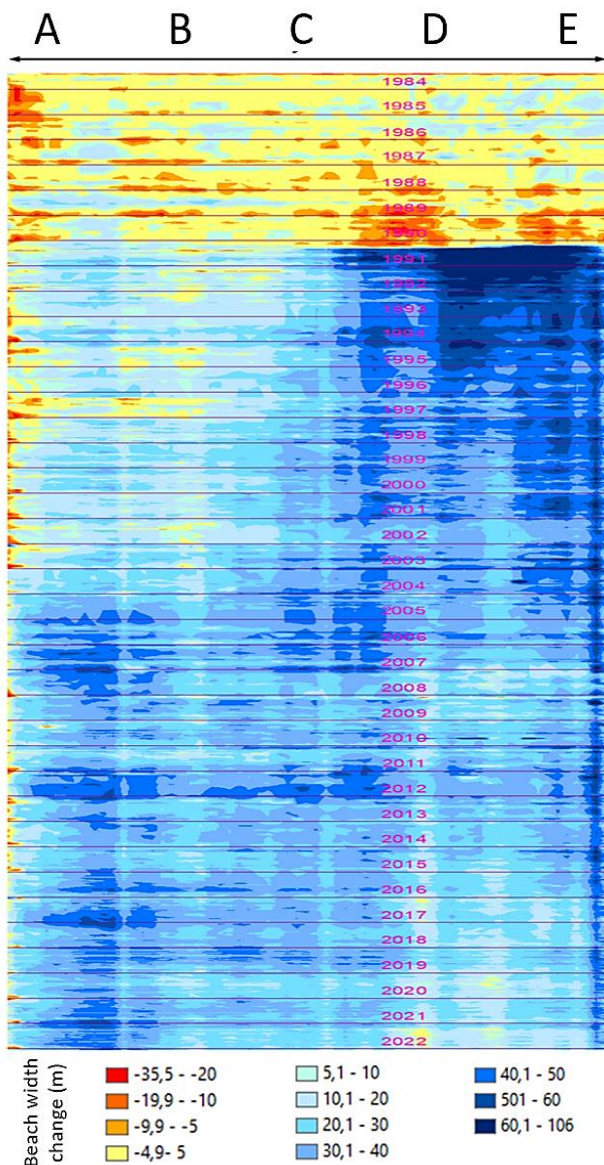


Figure 4 - Spatial-temporal model of the beach width changes (m) in Platja de Ponent Beach (May 1984 - January 2023). Zones A-E are identified in Fig. 1.

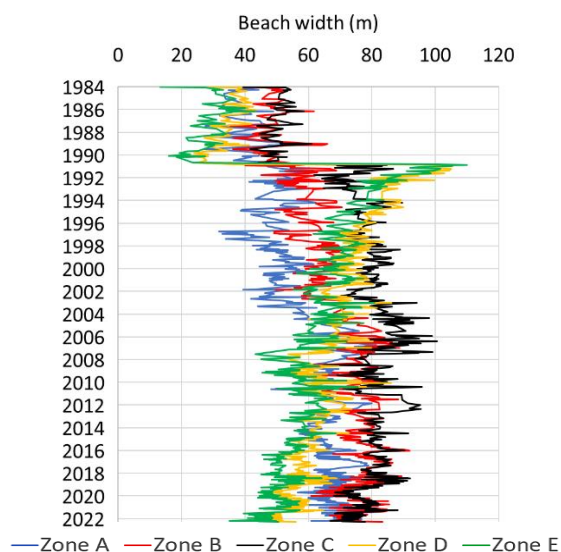


Figure 5 - Beach width evolution at zones A-E (see Fig. 1).

CONCLUSIONS

The continuous monitoring of the nourishment project at Benidorm is presented based on the systematic and massive study of the SDSs derived from all the Landsat and Sentinel 2 images available in the last four decades. The combination of the large shoreline dataset and methods for organising this information and deriving useful indicators such as the beach width may constitute a comprehensive approach to monitor civil engineering interventions, assess their effectiveness, and support decision-making.

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