Contribution of two-dimensional modelling in assessing marine submersion risks: A study of the Saidia-Cap de l'Eau and Al Hoceima Bay coastlines

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Abstract. The onset of climate change is exacerbating sea level rise and intensifying storms, leading to increased coastal degradation, notably in the form of coastal erosion. This represents a global phenomenon, and the coastlines of Al Hoceima Province and Saidia-Cap de l'Eau in the Mediterranean are no exceptions. The primary objectives of this study include the following: 1) to utilise Geographic Information Systems (ArcGIS) for simulating marine submersion phenomena along the Al Hoceima Bay and Saidia-Cap de l'Eau coastlines, 2) to employ two-dimensional modelling using Iber 2D software for a more nuanced understanding of marine submersion, and 3) to map the marine submersion risk in these areas. Our findings indicate that the areas most at risk from marine submersion are the low-lying sandy beaches in both study areas.

Keywords: climate change, marine submersion, coastline, 2D modelling, 2D Iber software

1 Introduction

In the context of global climate change and its consequential impacts on coastal regions, the accelerated rise in sea levels, combined with the heightened probability of extreme weather events and storm surges in the 21st century, is anticipated to amplify flood risks globally. The Mediterranean shores, particularly in areas of increasing urbanisation, are susceptible to this increasing threat. Marine submersion, the flooding of coastal zones due to severe meteorological and tidal conditions, predominantly impacts areas below the level of the highest tides. However, it can extend to higher altitudes if forceful waves and sea spray surpass protective barriers or the crests of barrier beaches. The marine submersion phenomenon is influenced by several factors: (1) the cyclical sea-level changes determined by tides, (2) the formation of swells from offshore winds, (3) the gradual erosion of dunes through wind or swell forces, and (4) the minimal elevation of the seafront.

The primary objective of this study is to conduct a comparative analysis of two-dimensional simulations using Iber 2D software, assessing the risk of marine submersion along two contrasting coastlines: the Saidia-Cap de l'Eau coast and Al Hoceima Bay.

2 Study area

The focus of this research encompasses two distinct coastal regions: the Saidia-Cap de l'Eau coastline and Al Hoceima Bay.

2.1 Coastal Saidia-Cap de l'Eau

The Saidia-Cap de l'Eau coastline, stretching over 20 km, represents a significant pole of attraction and investment of national interest. This northeastern coastline exhibits a distinctly contrasting Mediterranean climate, characterised by increasing aridity. It experiences an average annual rainfall of 320 mm and maintains an average annual temperature of 17 °C [1], [2], [3].

Fig. 1 illustrates the land-use map of the coastal Saidia-Cap de l'Eau, highlighting the major elements of the studied region and revealing the expansion of residential development, which has led to the degradation of the original forest ecosystem.

2.2 Al Hoceima Bay

The Al Hoceima coastline, known for its sandy and rocky shores, extends from the bay of Al Hoceima to the Nekor River. The area is part of the Bokkoya Massif within the inner domain of the Rif, occupying...
the central and northern segments of the Rif mountain range. Annual rainfall here averages around 350 mm, with the annual temperature remaining fairly consistent between 17.5 °C and 19.5 °C [4].

Following the characteristics of the Moroccan Mediterranean coastline, the tidal pattern at Al Hoceima is semi-diurnal with a relatively low amplitude [5]. The mean amplitude of spring and neap tides is noted to be 45 cm and 21 cm, respectively [5]. The average tidal level is approximately +0.40 m. However, accounting for variances induced by meteorological factors such as wind and pressure, sea levels can fluctuate between 0.00 hydro and +1.20 hydro [5]. Despite the modest amplitude of Mediterranean tides, which seldom exceed 2 m, their effects are often minimally perceptible due to the steepness of the shoreline. However, in the bays of the eastern zone, storms are fairly common, precipitating exceptional wave activity [1].

3 Materials and methods

The Iber 2D software represents a numerical model designed for simulating unsteady and turbulent free-surface flows and environmental processes, particularly in river hydraulics and marine flooding scenarios. Its application spans various fields, including fluvial hydrodynamics, flood zone evaluation, sediment transport, discharge computations, and wave dynamics in estuaries. The employment of Iber 2D software was pivotal for this study, especially in evaluating the risk of marine submersion.

Numerous studies have utilised this approach to map marine submersion risks [2], [5], [6], [7], [8], [9], [10]. The methodology adopted for developing the model is concisely depicted in Fig. 3.

4 Results and discussion

The ensuing section delineates the outcomes of the two-dimensional simulations conducted using Iber 2D software. These results are compared with prior research conducted in the two focal areas of this study, Saidia-Cap de l'Eau and Al Hoceima Bay [5], [11], [13], [14].

4.1 Marine submersion risks at the Saidia-Cap de l'Eau coastline

The primary factors influencing the risk of marine submersion along the Saidia-Cap de l'Eau coastline include the topography of the land and the intensity of meteorological storms, which can elevate marine water levels. Fig. 4 illustrates that beaches at lower altitudes
are most susceptible to marine submersion. Our findings confirm the research of Sbai and Lasgaa [13], which identified the Saidia-Cap de l’Eau coastline as particularly vulnerable to sea-level rise due to its topographical and socio-economic attributes.

Fig. 4. Vulnerability map to marine submersion in the Saidia-Cap de l’Eau coastline

4.2 Vulnerability assessment of Al Hoceima Bay to marine submersion

In Al Hoceima Bay, areas with a topography ranging between 0 and 10 m form a plain that is highly prone to marine submersion. Fig. 5 highlights the low-lying lands in red, indicating areas at the greatest risk of submersion. These findings from simulations with Iber 2D software are in agreement with the work of Khoukhi and Snoussi [11].

4.3 Confirmation of findings

Our findings indicate that areas at altitudes ranging from 0 to 10 m exhibit a heightened susceptibility to marine submersion. This observation aligns with the research of Khoukhi and Snoussi [5], who noted similar vulnerability patterns along the Ghiss-Nekkor Bay coastline. Furthermore, Niazi’s [14] studies on the Tétouan coastline support this, revealing that regions within this altitude range are likely to be impacted by marine submersion. These consistent findings across different studies lend credibility and validate the reliability of our results.

5 Conclusion

The outcomes of our field observations corroborate the simulations conducted using Iber 2D software. Notably, the areas most at risk from marine submersion are the low-lying sandy beaches in both study areas. Moreover, field investigations have uncovered extensive overexploitation of beach sands by construction firms. It has been noted that the zones most vulnerable to marine submersion in both study areas are those in close proximity to the coastline, where the pressure from human activities such as harbour infrastructure and tourist marinas is intensified. This anthropogenic exploitation renders these coastal areas more susceptible, heightening their risk of inundation during future storm events.

The risk posed by marine submersion constitutes an ongoing and serious threat, particularly in terms of the intensity of its impacts, the rapidity of its onset, and the extent of the affected areas.

The results obtained in this work must be supplemented by subsequent research following the socio-economic changes in the two areas studied.
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References


