RAPID ASSESSMENT OF COASTAL FLOODING VULNERABILITY OF HERITAGE SITES: OPTIMIZATION AND LIMITATIONS

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INTRODUCTION

The risks of losing cultural heritage whether natural values or historical artifacts enhanced the importance of assessing the vulnerability of these sites to climate change impacts. Coastal flooding and inundation vulnerability of these sites are being assessed at different scales, focusing on one site (Anzidei et al., 2020) to all sites of a continent (Vousdoukas et al., 2022). For regional to larger-scale assessments, the assessment methods tend to be desk-based using indicators and simpler flood mapping approaches. A rapid assessment approach is a practical choice considering the high number of sites and the variety of shoreline characteristics considered. While the information provided by the rapid assessments is valuable in prioritizing the heritage sites considering the limits of adaptation resources, desk-based vulnerability studies are argued to be conservative in determining the number of vulnerable sites due to simplification of the physical processes, coarser datasets, and weak consideration of the local characteristics of the heritage area (Rivera-Collazo 2020). In this study, the requirements and limitations of rapid assessment methods for coastal flooding are discussed considering the differences between natural and archeological coastal heritage sites exposed to impacts of sea level rise. The selected sites, methods, and datasets are considered within the ongoing project "Vulnerability of Coastal Cultural Heritage Areas to Sea Level Rise and Its Impacts" (No: 122M613) funded by The Scientific and Technological Research Council of Turkiye (TUBITAK).

METHODOLOGY

Rapid coastal flooding vulnerability assessment methods in the literature usually combine indicators with GIS-based flooding maps to determine a vulnerability index for comparative purposes (Vousdoukas et al., 2022). Indicators such as beach slope, distance to shore, or coastal vulnerability indices are used to simplify the physical process and integrate heritage site information such as material type or heritage value. Flood maps are generally constructed with a bathtub approach using extreme water levels including sea level rise combined with a Digital Elevation Model. These maps help to analyze the extent of exposure of the sites. The limitations of the bathtub model and DEM resolution compared to hydrodynamic models have been presented especially for urban areas in the literature (Williams and Luck-Vogel, 2020). On the other hand, large-scale assessments are limited by data availability and require resource optimization within the study's objectives.
The bathtub model, enhanced bathtub model (eBTM, Williams and Luck-Vogel, 2020), and hydrodynamic model (Delft-3D) are applied to selected coastal natural and archeological heritage sites of Turkiye with similar projected extreme water levels in 2100 under RCP8.5. The extreme water level scenarios are obtained from Large Scale Integrated Sea Level and Coastal Assessment Tool (LISCOAST, Vousdoukas et al., 2018). The enhanced bathtub model considers slopes, hydraulic connectivity, and roughness to represent the flood extent realistically. The elevation uncertainty introduced by resolution will be discussed using 10-30m resolution DEMs, high-resolution UAV-based Digital Surface Models (<1m), and 12m resolution DSMs. DSMs present all the surface assets in the elevation information, providing details related to hydraulic conductivity.
The flood area information will be used to understand the range of uncertainty introduced into the desk-based approach through flood mapping techniques. Additionally, the ranking of the selected sites based on flood maps will be compared to the results of the indicator-based fuzzy coastal vulnerability model (FCVAM, Ozyurt 2010) and heritage location used in the project. FCVAM assesses coastal flood vulnerability based on 7 indicators such as storm surge, sea level rise, slope, tide, nature-based protection, coastal protection structures, and shoreline urbanization considering the distance of the heritage area to the shoreline and the elevation. This approach does not use flood area or flood extent.

RESULTS

As an ongoing project, some of the preliminary results are presented here for selected natural and archeological sites located in the Aegean and Mediterranean coastline of Turkiye. Site A (Figure 1) is a coastal delta protected as a natural heritage site with an underdeveloped coastline. Site B (Figure 2) is a small pocket beach with low sea walls protecting the local settlements. Site C (Figure 3) is a coastal archeological heritage site behind a beach/dune system that is protected by a headland on the West, Initial flood maps of these sites are based on a bathtub approach using EU-DEM (25m resolution) provided through Copernicus Land Service under extreme water levels of 1.67m for 2100 under RCP8.5 (Vousdoukas et al., 2018).

Figure 1 - Coastal flood map of Site A and its borders (red)

Figure 2 – Coastal flood map of Site B and its borders (red)

Figure 3 - Coastal flood map of Site C with archeological remains

Based on these flood maps, 46% of Site A is exposed to coastal flooding while 21% of Site B and 7.8% of Site C is flooded. However, the limitations of the 25m resolution of DEM and the bathtub approach are apparent for Site B and Site C. The effect of the sea wall in Site B cannot be reflected through the DEM which results in a larger flood area although not the extent. For Site C, the local dunes dominate the DEM which decreases the actual extent of the flood zone. An enhanced bathtub model with hydraulic connectivity is expected to increase the accuracy for Site B, and higher resolution DEM and use of DSM will provide more realistic results for Site C. On the other hand, the flood map of Site A represents the flood exposure reasonably well. These differences among the sites highlight different possibilities of optimization based on heritage type, land use, and geomorphology. The level of added benefit of hydrodynamic models in flood mapping is ongoing work but will be presented.

On the other hand, Site A is assessed with higher vulnerability (4 out of a maximum score of 5) than Site B (3.7/5) by the FVCAM model without any information from a flood map. Still, FVCAM could consider the presence of the sea wall as part of the coastal protection structure within the model without flood modeling and reflect the information on the site's vulnerability. Although the information provided is different than flood maps, for rapid assessment with the aim of ranking and grouping many heritage sites, a model like FVCAM combined with the simpler flood mapping tools could be an optimized approach. The combination, optimization, and selection of methods can be driven by a small set of parameters that will be discussed through the results of this study. A field survey of one of the study sites is planned for the Winter of 2024 after a storm event to compare with model results to provide further guidance and validation on the selection of rapid vulnerability assessment methods for the heritage sites.

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