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Luis Garrote
George Tsakiris
Vassilios A. Tsihrintzis
Harris Vangelis
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A proposed framework for flood risk assessment in cultural heritage sites upon specific ultra-detailed stage-damage functions

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Introduction

River floods are possibly the natural phenomenon that has the greatest impact on the actual deterioration of cultural heritage. That is why the study of flood risk becomes essential in any attempt to manage cultural heritage (archaeological sites, historic buildings, art-works, etc.). In this context, this paper proposes a methodological framework for flood risk analysis in cultural heritage locations (BICs) in central Spain. The analysis is implemented in two phases: a first phase of estimating the level of qualitative risk at a regional scale; and a second phase of calculating the damages on patrimonial assets in a quantitative way, at a local scale. The first phase is based on a flood risk matrix for patrimonial assets, fed by spatial information from a GIS. The developed risk matrix outweighs previous proposals of this type (Ortiz et al. 2016; Arrighi et al. 2018), making it more versatile and useful.

For the second phase of analysis, several BICs (of different typology) with high susceptibility to flooding have been selected, for which ultra-detailed magnitude-damage functions have been developed. These functions have to adjust to the unique characteristics of the assets they represent, although they may be similar to functions developed for other types of buildings (i.e. Pistrika et al. 2014; Blanco-Vogt and Schanze 2014; Godfrey et al. 2015), and also present unique characteristics. Finally, the proposed methodological framework allows us to quantify the damages (tangible, both direct and indirect) associated with each scenario (return periods) considered, which cover ordinary and extraordinary events.

Materials and methods

Flood Risk – Cultural Heritage Matrix development: The development of a risk matrix for heritage buildings is an analytical methodology that has been used previously in the last decade (Ortiz et al. 2016; Arrighi et al. 2018). However, the complexity of the matrix developed in this work significantly exceeds that of previous matrices and it is based on 7 variables (three linked to the hazard factor and four linked to the vulnerability factor), from which six levels of potential risk are defined (qualitatively). The process of estimating the level of risk can be considered as an iterative process dependent on the T-year return period flood (Figure 1), and the spatial relationship between BICs and flood prone areas.

Development of ultra-detailed Stage-Damage Functions: For the development of magnitude-damage functions, the city of Zamora has been taken as a study area, and a detailed catalogue of cultural heritage was prepared. Economic losses have been considered both in the continent (buildings) and in the content (movable heritage, such as sculptural, pictorial or documentary assets). These patrimonial assets have been classified into different categories (Figure 2), depending mainly on the type of material used for their construction; considering their vulnerability and the effective potential damage depending on water depth, flow velocity and the time of permanence of the flood (flash floods vs. deluge floods).

Results and concluding remarks

A total of 11 BICs are affected by the 500-year return period flood, including the old town of Zamora, 8 churches, 1 convent and 1 museum. The numerical and cartographic results of this work are influenced by many of the limitations already pointed out by Pistrika et al. (2014) with respect to the deficiency in the quality of the information available regarding flood damage to buildings. This limits the quality of the

results obtained and increases their associated uncertainties.

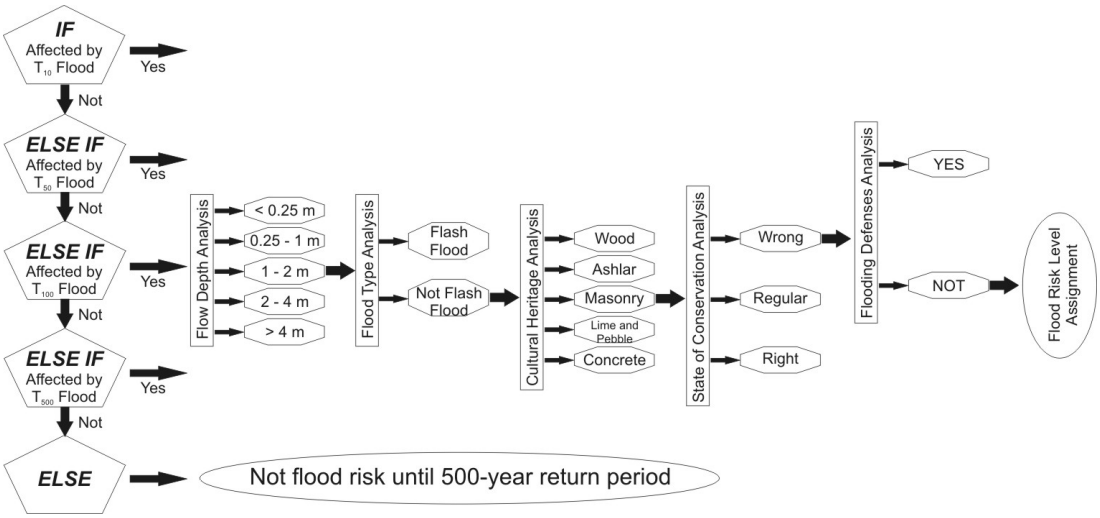

Figure 1. Flow chart for Flood Risk assessment in Cultural Heritage.

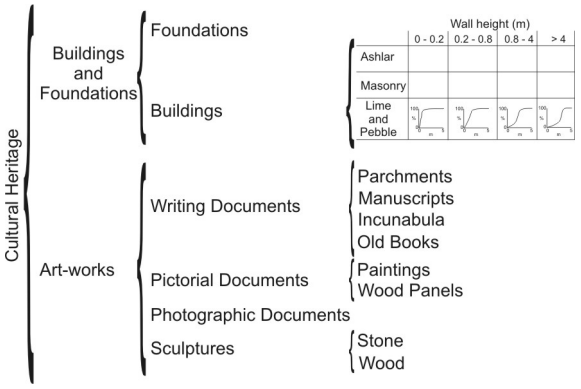

Figure 2. Diagram of the Cultural Heritage typologies.

In addition, in the case of sculptural and pictorial assets, evaluation of their exposure to floods is complicated (due to the possibility of being moved to safe areas). Despite these circumstances, the development of specific magnitude-damage functions for each heritage element has proved essential for a correct estimation of flood risk in cultural heritage, and as an aid to preventive conservation and rescue in emergencies.

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