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Assessing Building Vulnerability to Tsunami Hazard in Kamari, Santorini, Greece

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Introduction

Thera Island (Santorini) is an area susceptible to tsunamis, due to its geotectonic position within the broader geodynamic setting of Greece. Thera neighbours major fault zones in the South Aegean basin and constitutes the most active volcanic structure of the Hellenic Volcanic Arc. Seismicity and volcanic activity, in combination with submarine landslides triggered by them, are the main causes of tsunamis in the entire Aegean Sea. The subduction zone located south of Thera Island, is a major tsunamigenic area, since some of the largest known earthquakes have generated tsunamis. Characteristic events as those of 365 and 1303 AD, which were followed by two earthquakes of M8 or higher, greatly affected the coasts of the East Mediterranean Sea (Papazachos and Papazachou, 2003; Papadopoulos et al., 2014).

Aside from seismicity originated sea waves, tsunamis caused by submarine landslides, triggered mainly by earthquakes can also affect the Aegean Sea area, producing extensive run-ups, such as the 1956 AD event which impacted several islands of the Cyclades island complex (Dominey-Howes et al., 2000a). Moreover, volcanic activity has been linked to one of the largest tsunamis in the Mediterranean Sea, that initiated the decline of the Minoan Civilization in the Late Bronze Age (Cita and Aloisi, 2000; McCoy and Heiken, 2000). Likewise, a tsunami with run-ups exceeding 10 m, was produced by the collapse of the Columbo submarine volcano cone in 1650 AD, in the NE of Thera, affecting the Cyclades islands as well (Dominey-Howes et al., 2000b).

The aforementioned events have caused significant loss of life and construction damage in the past. There is a high likelihood for similar events to take place and affect the coasts of the Aegean Sea, once more, in the near future. Furthermore, the disaster risk is now significantly higher due to increased exposure of the buildings as a result of economic and touristic growth in Aegean Islands. In this regard, the purpose of the study is to assess building vulnerability to tsunami, in order to aid the coastal societies raising their resilient status.

Study Area

This study focuses on the eastern coast of Thera Island, as its geomorphology and human presence amplify the necessity of its vulnerability assessment. In terms of disaster management, the coastal settlement of Kamari poses the highest physical, social and economic relative exposure to natural hazards. According to the Hellenic Statistical Authority (2015), Kamari stands as the town with the highest population density (433 residents/ km^2) hosting 10% (1,344 residents) of the total island population. The number of buildings in Kamari amounted to 849. The majority is used as residential dwellings (55%), tourist facilities (21%) and commercial stores (15%). Furthermore, the presence of critical facilities including hospitals, schools and the airport increases the risk. With a coastline length of 2 km and maximum elevation of 50 m, the number of the vulnerable buildings to tsunami increases.

Methodology

In order to achieve the objective of this research, which is to quantify the buildings stock's vulnerability, a 'worst-case run-up scenario' was developed, based on scientific research that links tsunami run-up to earthquake magnitude, as presented in the literature (see Iida, 1963). Considering the history of tsunamis in the Aegean Sea (e.g. Maramai et al., 2014), a 10 m run-up tsunami – caused by a M8 earthquake – was assumed. To create the inundation and the run-up heights scenario in Thera, a 5 m resolution Digital Elevation Model, provided by National Cadastre & Mapping Agency S.A. (2016), was utilized.

The scale of the vulnerability assessment was set on the level of human settlement, which was selected based on the degree of relative exposure to the hazards. The calculations of the relative vulnerability of buildings in Kamari, were conducted via the application of the PTVA-3 analytic model (Dall'Osso et al., 2009) and the results were visualized using GIS software. The PTVA-3 model calculates each building's numerical index, referred to as the Relative Vulnerability Index (RVI) which ranges from 1 (Minor) to 5 (Very High). The model takes into account a weighted summation of two different components: the vulnerability of the carrying capacity of the building structure which is linked to the horizontal hydrodynamic force associated with water flow, and; the vulnerability of different building components due to their prolonged contact with water. The produced cartographic layers indicate the spatial distribution of the relative vulnerability of the buildings, in correlation with the inundation depth and their use. To apply the PTVA-3 model in Kamari, a field survey was conducted in order to catalogue the necessary attributes of the buildings for the application of the model.

Results

The results indicate that 423 out of 849 buildings are located within the inundation zone. The different RVI classes are distributed in a linear pattern according to the inundation depth. The buildings that have "Average" to "Very High" RVI scores are clustered in water depths that exceed 5 m. In contrast, buildings with “Minor” to “Moderate” RVI scores are clustered in the lower water depths of up to 4 m. In specific, 68 buildings –16% of the total of the inundated buildings – obtained a RVI score of “Minor”, 44 (10%) scored as “Moderate”, 96 (23%) scored “Average”, 140 (33%) scored “High”, and 75 (18%) scored as “Very High”. Figure 1c portrays the distribution of the building RVI scores within the inundation zone.

Finally, by correlating the main use of buildings with the RVI score, 50% of the dwellings are characterized by “High” and “Very High” scores, while the corresponding percentage for buildings occupying tourist facilities is 43%. However, the stores and food outlets are both characterized as having “Very High” scores – 76% and 83% respectively – which is explained by the substantial touristic growth of the coastal front. The abovementioned results reveal that after a tsunami event, the possibility of damage in economic and touristic facilities is high, leading to the loss of local comparative advantage of the settlement.

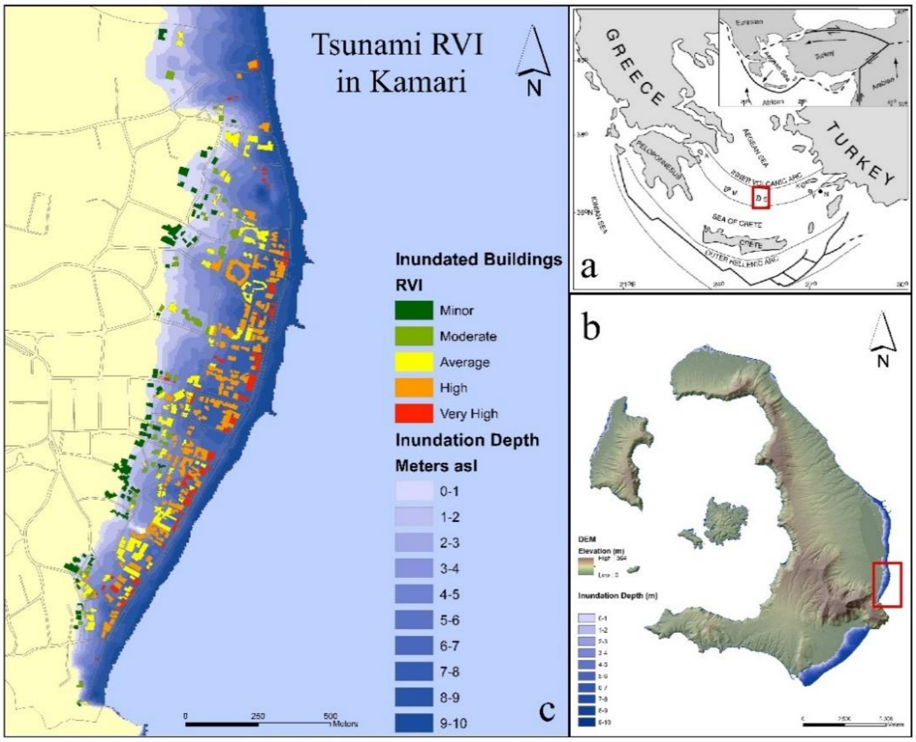

Figure 1. (a) The geodynamic framework of the Hellenic Arc (Dominey-Howes, 2004). (b) Map of the inundation zone according to the 10 m run-up scenario and the location of the study area. (c) Map of building RVI score distribution as a result of the application of the PTVA-3 model in Kamari.

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