NATURAL AND HUMAN INDUCED INDICATORS IN COASTAL VULNERABILITY AND RISK ASSESSMENT

G. Alexandrakis[1], S. Petrakis[1,2], G. Ghionis[1,2], N. Kampanis[1] and S.E. Poulos[2]

1. Institute of Applied and Computational Mathematics, Foundation for Research and Technology, Hellas, Nikolaou Plastira 100, Vassilika Vouton,70013 Heraklion, Crete, Greece

2. Department of Geography & Climatology, Faculty of Geology and Geoenvironment, University of Athens, Panepistimioupolis, Zografou, 15784, Greece

Introduction

The estimation of coastal vulnerability induced by climate change is usually based primarily on natural processes and less on socio-economic considerations, probably due to the difficulties in obtaining and ranking the data. The present investigation proposes a new methodology to examine the vulnerability to wave-induced erosion of a highly touristic area in the Island of Crete with the introduction of socio-economic indicators into a GIS-based coastal vulnerability index (CVI). This approach includes three sub-indices: coastal forcing, socio-economic, and coastal characteristics. All variables are ranked on a 1-5 scale, with 5 indicating higher vulnerability. The socio-economic sub-index includes the population of the study area, cultural heritage sites, transport networks, land use and economic activities. The coastal forcing sub-index includes the variables representing the marine processes, while the CVI includes the geological variables. The main difficulty for the estimation of the index lies in assessing the socio-economic indicators. The whole approach was tested and validated through field and computer studies, using as a case study the Elounda bay, NE Crete Isl., an area of high cultural and economic value, which combines monuments from ancient and medieval times with a large touristic development since the 1970s.

Study Area

Elounda bay is located at the NE part of Crete Island, covering an area of about 10 km^2. It is a semi-enclosed bay with an eastward-facing entrance on the north side. Its southern end consists of a tombolo formation, which connects the island of Crete with the Kolokitha peninsula. The area is surrounded by various sites of archaeological interest, such as ancient cities and facilities, dating from the Minoan era (27^{th} -15^{th} century B.C.) to the recent historical monuments of the early 20^{th} century. The most important is the Spinalonga fortress, located on a small island at the center of the gulf, which has recently been nominated as an UNESCO World Heritage site. Six coastal types have been identified in the area: Hard rocky coasts (HR) occupying 58.89 % of the total shoreline length, soft rocky coasts (SR) (2.34 %), beaches with length <1 km (B2) (12.23 %), beaches with length <100 m (B1) (2.75 %) and a very small percentage (0.39 %) of beaches with length more than 1 km (B3); the latter are very narrow, rarely exceeding 10 m in width. A significant percentage (23.41 %) of the shoreline hosts man-made structures (HM) (ports and fishing shelters, coastal walls and groynes). The broader area is exposed primarily to winds of northern directions (32.96 % annual frequency of occurrence) followed by western and southwestern winds (20.58% and 13.25%, respectively). Wave regime is dominated mainly by NE and E wind-waves with relatively low frequencies of occurrence (7.37% and 3.44% respectively), while severe storm conditions (H_s > 5 m) occur with an annual frequency not exceeding 1%.

The area hosts several hotels and other leisure facilities, while tourist development is still growing. In the surrounding areas, there are organized settlements and scattered farmhouses. The main agricultural activity in the area is the production of olive oil from the abundant olive trees, while there aren't any forests or significant industries. The local transport network consists of a paved coastal road and some dirt roads that serve agricultural activities. The main road is of major importance, as it is the only road connecting the coastal town of Elounda with the villages in the North, and it is supported by a coastal wall for most of its length.

Method

The CVI of Gornitz et al. (1993) was used, which includes six physical variables (geomorphology; coastal slope, relative sea-level rise rate; shoreline erosion/accretion rate; mean tidal range and mean wave height) ranked from 1 to 5. Additionally, a Socioeconomic Vulnerability Index (SocCVI) based on the work of McLaughlin et al. (2002) was used. This includes social indicators such as the presence of settlements, sites of cultural heritage, transport network, land use and economic activities in the coast. The variables of SocCVI are separated into three sub-indices: (i) a coastal characteristics (CC) sub-index, to determine the coast's resistance to erosion, (ii) a coastal forcing sub-index to quantify the forcing variables, and (iii) a socio-economic sub-index to identify the risky infrastructures. Each one has equal weight in the final index score. The variables were ranked on a 1-5 scale according to their perceived vulnerability and ArcGIS (ESRI) was used to calculate the index and map the results.

Results

Estimations using CVI show that, the majority (85.55%) of the coastline is characterized as low vulnerability areas, mainly rocky coasts, steep slopes, and man-made structures. A very small percentage (0.28 %) is classified as medium vulnerability areas. High and very high vulnerability areas correspond to 7.81 % and 5.84 % of the total coastline length respectively, being mainly beaches and soft rocky coasts that are located mostly at the northern part of the bay. Estimations using SocCVI present no areas with very low vulnerability, while 57.21 % of the coastline is characterized as low vulnerability, consisting mainly of rocky coasts. The 37.46% of the coastline is classified as of medium vulnerability, while the categories of high and very high vulnerability represent 5.09 % and 0.22 % of the coast, respectively. CVI classifies most of the coastline in the extreme categories, either high or low (predominantly) vulnerability, the latter due to the fact that most of the coastline is characterised as rocky coast and man-made structures. The medium vulnerability SocCVI values are due to the socioeconomic value that man-made structures and heritage sites have introduced in the index. Thus, in areas where there are no human activities, the ranking score is lower even if the area is more vulnerable in terms of environmental characteristics (e.g. south area of the Elounda bay). A ternary diagram (Fig. 1) shows the relative influence of each of the three sub-indices on the overall index score. The overall index via its sub-indices shows that the coastline presents only small differences between its sub-sections, while the sub-indices of coastal forcing and coastal characteristics seem to dominate the overall score. In hard rocky areas with no human activities (e.g. north side of bay and Kolokitha Isl.) the socio-economic index has the least influence.

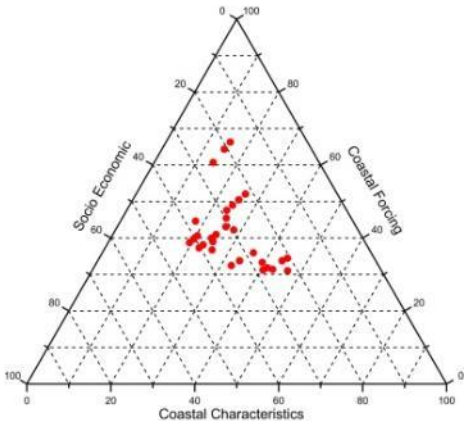

Figure 1: Ternary diagram showing the relative contributions of the three sub-indices of SocCVI

Conclusions

The indicators that are selected for the coastal vulnerability analysis can strongly influence the final outcome and the socio-economic elements of coastal vulnerability are a key issue in management practices and decisions. Therefore, the addition of socio-economic variables in coastal vulnerability indices is extremely important, even though the accurate quantification of most of them is a serious challenge. The addition of socio-economic variables in a coastal vulnerability index can provide a useful tool for making coastal management decisions more focused to the actual needs of the society.

Acknowledgments

This work has been supported by the Action «Supporting Postdoctoral Researchers» of the Operational Program "Education and Lifelong Learning" of the Ministry of Education and Lifelong Learning (co-financed by the European Social Fund and the Greek State) and by the Project “Effective management of erosion, protection and recasting of the coastline, of Plaka, E. Crete; Environmental effects of the coastal protection and restoration project” funded by the Region of Crete.

References

Gornitz, V. 1990. Vulnerability of the East Coast, USA to future sea level rise. Journal of Coastal Research, 1, (Special Issue No. 9), 201-237.

McLaughlin, S., McKenna, J., Cooper, J.A.G. 2002. Socio-economic data in coastal vulnerability indices: constraints and opportunities. Journal of Coastal Research, 1, (Special Issue No. 36), 487-497.