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1 Abstract

Climate change has significant repercussions on the natural environment, triggering changes in the natural processes that might have a severe socio-economic impact on the coastal zone; where a great number of human activities are concentrated. So far, the estimation of coastal vulnerability has been based, primarily, on the natural processes and, secondarily, on socio-economic variables, which would assist in the identification of vulnerable coastal sectors. The present investigation proposes a methodology to examine the vulnerability of a coastal areas. The methodology is based on the combination of socio-economic indicators and existing natural indicators, GIS-based, of the coastal vulnerability index (CVI) for sea level rise and related wave-induced erosion. This approach includes three sub-indices that contribute equally to the overall index. The sub-indices refer to coastal forcing indicators related to extreme natural events; (ii) socio-economic indicators, such as those of population, cultural heritage sites, transport networks, land use and protection measures; and, (iii) indicators of coastal characteristics that refer to both geological variables (i.e. coastal geomorphology, historical coastline changes, and regional coastal slope) and marine processes (i.e. relative sea level rise, mean significant wave height, and tidal range). All variables are ranked on a 1-5 scale with the rank 5 indicating the highest vulnerability. The socio-economic sub-index includes, as indicators, the population of the study area, cultural heritage sites, transport networks, land use and protection measures. The coastal forcing sub-index includes the frequency of extreme events, while the Coastal Vulnerability Index includes the geological variables (coastal geomorphology, historical coastline changes, and regional coastal slope) and the variables representing the marine processes (relative sea level rise, mean significant wave height, and tidal range).

2 INTRODUCTION

The expected accelerated sea level rise and the potential physical changes to the coastline can endanger coastal ecosystems, populations and infrastructure (McLean et al., 2001). The sensitivity of the coastal zone to sea level rise, combined with the social, economic, and ecological value (e.g., Costanza et al., 1997; Agardy et al., 2005), has led to the proposition of a significant number of vulnerability indices developed for specific coastal areas (Gornitz et al., 1993; Hoozemans et al. 1993; Leggett and Jones, 1996; O’Riain, 1996; Cambers, 1998; Thieler and Hammar-klose, 1999; Mimura, 2000; Vafiadis et al 2008, Alexandrakis and Poulos 2014, Alexandrakis et al 2015). The main objective of most of the existing indices is the classification of the coastline into areas with similar attributes or characteristics, while the majority uses multidisciplinary data related to natural processes. The need for the inclusion of socioeconomic variables has also been noted by Gornitz et al. (1993), stating that the omission of socio-economic variables from their coastal vulnerability index could potentially limit evaluation of vulnerable areas. Likewise, indices reviewed by Cooper and McLaughlin (1998), acknowledge a general need to include socio-economic variables in the classification procedure (McLaughlin et al., 2002). Nevertheless, the estimation of coastal vulnerability related to climate change is still based, primarily, on natural processes and to a lesser extent on socio-economic considerations. This has led to criticism to vulnerability studies and to separation of the physical from the socio-economic aspects in vulnerability studies (e.g., Blaikie et al. 1994; Gough et al. 1998; IPCC, 2001; Nicholls and Small, 2002). The exclusion of the socio-economic variables derives from the difficulty in obtaining and ranking the data. Besides, socio-economic data can change over time (e.g. building of new houses and roads etc.) and perceptions of threat and of appropriate response may also change with time (Carter, 1993). Also, the fact that socioeconomic indicators are time constrained makes their use more difficult (McLaughlin et al., 2002), while their ranking could be proved difficult, since it is not easy to assign an economic value to an attribute. The indicator-based approach proposed by Kaiser (2006) was accepted as one of the most appropriate for the use of intangible elements in ranking this kind of data. Despite these difficulties, the inclusion of socio-economic variables is of great importance, perhaps even essential, in the development of valid coastal vulnerability indices in order to mitigate hazards, and adapt to environmental and climate change (Birkmann, 2006; O'Brien et al., 2006). However, evaluation of the vulnerability involves diverse practical challenges, including political willingness, complexity of the problem, poor understanding of related issues and the importance of the results (Patt et al., 2009). Some coastal vulnerability studies have attempted more integrative assessment approach by combining both physical and socioeconomic

vulnerability to an overall vulnerability index system (Wu et al.2002; Cutter et al. 2003; Boruff et al. 2005; Preston et al. 2008).

The present investigation proposes a methodology to examine the vulnerability to wave-induced erosion and sea level rise, of a coastal areas with the introduction of socio-economic indicators into a GIS-based Socio-economic Coastal Vulnerability Index (SocCVI) and compares the results with those produced by the CVI of Thieler and Hammar-Klose (1999). 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 whole approach was tested and validated through field observations and numerical studies, using the various case studies

3 Case study

Larnaca district covers the central part of the southern shoreline on the island of Cyprus. Its share in the area of Cyprus under government control is 18%, share in the population 17% and it is occupying 23% of the coastline. From all the districts it is closest to the average of Cyprus regarding population density and change of the population – density of 122 inhabitants per sq Km being slightly lower than the whole Cyprus under government control, and the population change of 11.1% between 2001 and 2005 being the same as Cyprus as a whole. The town of Larnaca with 46,666 inhabitants represents 40% of the district and including the closest suburban municipalities of Aradippou and Livadia 62,997 inhabitants or 55% of the whole district. The town itself is third largest city in Cyprus after Nicosia and Limassol. Larnaca district is located in the central southern part of the island. It includes 94 Km of the Mediterranean coastline, mountain area of the Troodos Mountains covering much of the western part of the district and a small part of Mesaoria Plain in the north. It has patches of woodland in which eucalyptus, acacia, cypress, and lowland pine predominate. The terrain of the eastern and southern part is relatively flat whereas the western and northern part is mountainous. The area could be considered less mountainous than the Limassol and Paphos Districts. The highest elevation is 1,404m, on the border with Nicosia district.

Larnaca District as well as the rest of Cyprus have Mediterranean climate with warm and dry summers and mild winter. The summer season, which extends from May until September, is characterized by clear sunny sky and almost no rain. The winter season, starting in October up until March, is mainly windy with certain periods of heavy rains. Most of the rainfall occurs in winter with maximum in December (15 days with rain and 86.4 mm precipitation) and minimum in August (0.4 mm precipitation or practically no rain). The summer and winter monthly averages of air temperatures do not reach extreme values. In Larnaca minimum monthly average of air temperature is reached in February (11.7°C) and maximum in August (27.6°C). Agricultural areas, located mainly close to the coastline, produce barley, potatoes, fruits, vegetables, and nuts. Industry, located mainly in the town of Larnaca, produces milled flour, canned fruit and vegetables, beverages, wood and furniture, paper products and textiles. The coast in Larnaca District is mainly flat or slightly hilly. There is some sand and a rocky beach along the coast, surrounded mostly with the agricultural areas.

In the area there is an important natural monument– The Larnaca Salt lakes close to Larnaca International Airport. Along the Larnaca District there are five Natura 2000 Sites. The coastal strip belonging to the town of Larnaca is mainly under protection, and some remaining coastal areas are declared as tourist zones.

As Cyprus as a whole, Larnaca district is very rich in cultural heritage, especially from the ancient period. In district there are total 33 ancient monuments of first schedule (or first and second schedule) and 107 monuments of second schedule. From the tourist point of view the most important monuments of first schedule are the site and remains of the ancient town and necropolis of Kition and the Fort in Larnaca and the site and remains of a Neolithic settlement at Vouni in Choirokoitia (UNESCO World Heritage Site).

Cyprus is the third largest island in the Mediterranean, with a total coast length of 735 km. Around 110 km of the coastline (30%) under control of the Republic of Cyprus is subject to erosion. During the last three decades, the island experiences a very rapid touristic development, which is by 90% concentrated along the coasts (European Commission Report, 2009).

To prevent coastal erosion, it was decided in the late 70s to construct small-scale groynes and breakwaters of various types and sizes along the shoreline, initially on an experimental basis. These structures succeeded in protecting the coastal areas in front of them. However, they caused further erosion and shoreline retreat problems to neighbor areas (Shoukri et al., 2012).

Previous studies highlighted that many parts of the southern coastline of Cyprus Island are mainly exposed to adverse wave conditions and to sea level rise. In the 1970s to 1980s, there was a sharp increase in anthropogenic interventions in coastal areas. The construction of ports, fishery reserves or concrete jetties (e.g, Marina of Larnaka in 1969 and Marina in Zygi in 2012) were the main reasons for the serious changes seen along the coastline. In addition, the coastal quarries excavating material used in the building industry back in the 1960s and 1970s were still a major cause for the deterioration of the shoreline erosion. Furthermore, hotels and other touristic actions caused serious problems altering the area's hydrodynamics. The erosion phenomena of the coastal front seem to be a major issue presently, despite all actions and measures are taken for mitigation (Doukakis, 2014).

A number of breakwaters were constructed at various parts of Larnaca Bay and in Zygi Bay to protect the coastal front from deteriorating erosion, but in many occasions, the results were not desirable.

Two coastline zones located at the South East Region of Cyprus Island are selected as the study areas for the HERMES project. More precisely, this research is focused at the three coastal zones near Zygi village (5 km) and Oroklini and Ormideia shorelines (25 km), with a total shoreline length of 30 km.

Most of the rivers in Cyprus island originate from the Troodos region. The seasonal distribution of the run-off follows the seasonal distribution of precipitation, with a minimum in summer months and a peak value during the winter. As a result, the area is governed by the Eastern Mediterranean climate, which is characterized by warm, long-lasting summers and low-to-average annual rainfall. There are no rivers flowing

continuously along their entire coastline length. Most rivers flow for 3 to 4 months a year and are dwindling for the rest of the year. Only parts of some rivers upstream of the Troodos area have a continuous flow (the rivers Xeros, Diarizos, Kargotis Marathasas, Kouris and Germasogeia). Both study areas (Oroklini and Zygi) are located in the south-eastern region of the island. The area is affected less from the rivers' runoff and precipitation than the north-western region. There are some seasonal rivers flowing in these two basins, but during most of the year these rivers are dry. According to E-Hype model the river discharge in Oroklini Study area is 1-5 m³/s and in Zygi study area is 0-1 m³/s, with no rivers flowing in these two basins.

3.1 The Coastal Vulnerability Index

In science, an indicator is considered as an inherent characteristic that quantitatively estimates the condition of a system offering people a sense of the “bigger representation”. Gras et al. (1989) defined an indicator as “a variable which supplies information on other variables which are difficult to assess (...) and can be used as benchmark to make a decision”. Such definition implies that the indicator is an informative function, which supplies simplified information about a complex system (e.g., an environmental system), or an un-measurable criteria (e.g. biodiversity, sustainability, vulnerability). In the last decade, the development of indicators at the national, regional, local or field level, has become a commonly approach to meet the crucial need for assessment tools.

Environmental indicators are essential tools for tracking environmental progress, supporting policy evaluation and informing the public (OECD, 2004). Such indicators may (Dale & Beyeler, 2001): a) assess current conditions and establish environmental baselines, b) monitor trends in conditions relative to this baseline over time, c) diagnose causes of observed changes, d) forecast future changes in the environment, and e) identify appropriate actions for remediation or mitigation.

In terms of coastal systems, it appears that all systems are in hazard; therefore, risks should be exploited and quantified. The concept of coastal vulnerability is based on human value judgements concerning risk to various elements of the natural and human environment from a variety of sources (Green and McFadden, 2007). Therefore, vulnerability is considered as the extent of harm, which can be expected under certain conditions of exposure, susceptibility and resilience (Balica et al. 2009; Hufschmidt 2011; Scheuer et al. 2010; Willroth et al. 2010; Fuchs et al. 2011).

However, the concept of vulnerability is closely related to concepts such as **hazard, risk and resilience**. Hazards may be divided into technological hazards and into hazards associated with natural extreme events (like storm surges, tsunamis, etc.). Risk introduces a quantitative or qualitative estimate of probability of possible events and the likely impacts related to these events. Finally, resilience is the maximum possible disturbance that a system may receive to remain at the same state or to maintain its functions. Therefore, resilience is directly related to the capacity of the system to re-organize, renew and re-build itself, thus its adaptive capacity.

A vulnerability index therefore aims to simplify a number of complex and interacting parameters, represented by diverse data types, to a form that is more readily understood and therefore has greater utility as a management tool. In the coastal zone, and in view of the ICZM approach, several coastal vulnerability indicators have been developed. The simplest indicators to assess the physical vulnerability of the system, are a) the Coastal Vulnerability Index (CVI), initially proposed by Gornitz et al., (1991) and modified by Thieler (2000), and b) the Beach Vulnerability Index (BVI), introduced by Alexandrakis and Poulos (2014).

Other more complex indicators were gradually introduced to include the social dimension of the coastal system, as the Social Vulnerability Index (SVI) by Boruff et al., (2005), socio-economic indices as the Risk Matrix (Hughes and Brundrit, 1992) and the Sustainable Capacity Index by Yamada et al., (1995). McLaughlin and Cooper (2010) introduced a tripartite CVI comprised of three sub-indices: a) a coastal characteristics sub-index concerned with the resilience and susceptibility of the coast to erosion, b) a coastal forcing sub-index to characterize the forcing variables contributing to wave-induced erosion, and c) a socio-economic sub-index to assess the infrastructure potentially at risk. The three sub-indices can be merged to calculate the overall index, which is portrayed in the form of color-coded vulnerability maps.

Presently, **the CVI is the most commonly used vulnerability index to assess the impact of coastal erosion and climate change on the coastline.** It provides a simple numerical basis for ranking sections of coastline in terms of their potential for change. This information may later be used by coastal managers to identify regions where risks may be relatively high. The CVI results can be displayed on maps to highlight regions where the factors that contribute to shoreline changes may have the greatest potential to contribute to changes to shoreline retreat (Gutierrez et al., 2009).

The first methodological step deals with the identification of key variables and their respective significant driving processes affecting coastal vulnerability. In general, CVI formulation includes the 6 to 7 main variables that shape the physical environment of the studied area. The second step deals with the quantification of these variables. Quantification is based on the definition of semi-quantitative scores according to a 1-5 scale (Gornitz, 1990; Hammer-Klose and Thieler, 2001), where score 1 indicates a low contribution to coastal vulnerability of a specific key variable for the studied area or sub-areas, while 5 indicates a high contribution. Finally (third step), all key variables are integrated into a single index.

An index, based on physical variables such as coastal landforms, relief, geology, relative sea-level rise, shoreline displacement, tide range and wave height, has been widely used to assess the vulnerability of

coasts in the USA, Europe, Canada, Brazil, India and Argentina (Gornitz 1991; Shaw et al. 1998; Thieler and Hammar-Klose 1999; Pendleton et al. 2004; Doukakis 2005; Diez et al. 2007; Nageswara Rao et al. 2008).

The physical parameters used widely in CVI estimation are:

1. Geomorphology (G), is directly linked to the erosivity risk of the coastal area. Beaches having silt site geology exhibit a much higher erosivity risk than beaches made of boulders.
2. Historic Shoreline Change Rates (RSCR), expresses a measure of the past tendency of the shoreline to retreat or advance. Shores with accretion have overall low risk while those with erosion have subsequently higher risk. It is one of the more complex physical variables, as the rate and its trend may change significantly over time. The quantification of this parameter will be based on the analysis of historic satellite imagery, the use of a semisupervised algorithm to identify and digitize the shoreline position and the statistical package DSAS software applied on a Q-GIS environment.
3. Coastal Slope (CS), is directly linked to the susceptibility of a coast to inundation by flooding and to the rapidity of shoreline retreat.
4. Relative Sea Level Change Rate (RSL), expresses the tendency of an area to eustatic changes and other vertical land motions. This parameter may be assessed from the existing network of tidal gauge stations.
5. Mean Significant Wave Height (WH), expresses the main incident to the shoreline energy shaping and transforming the coastline through along-shore and cross-shore transport. This variable is an indicator of the amount of material that may be moved offshore and permanently removed from the coastal sediment cell.
6. Mean Tidal Range (TR), it is directly linked to the permanent and episodic inundation hazards. Thus, a large tidal range depicts that a significant spatial extend of the coast is impacted by waves. These areas are susceptible to episodic flooding events associated to storm surges, particularly if these coincide to high tides.

The above-described risk parameters are ranked on a linear scale from 1 to 5, representing the increased vulnerability due to coastal erosion and sea level rise. A score value of 1 represents the lowest risk, while a score value of 5 represents the highest risk.

Then, the squared root of the product of these scores divided by the number of the key parameters included in the analysis is used to compute the CVI in each pilot study area, as:

$$CVI = \sqrt{\frac{G \times RSCR \times CS \times RSL \times WH \times TR}{6}}$$

The key CVI parameters and their respective scores for the estimation of the CVI are shown in Table 1.

Table 1. Key parameters and their respective scores for CVI estimation along the pilot study sites of HERMES project.

Key Variables	1 Very Low	2 Low	3 Moderate	4 High	5 Very High
Geomorphology	Rocky, cliffed coasts	Medium Cliffs, indented coasts	Low cliffs, alluvian plains	Cobble beaches, estuary, lagoon	Barrier beaches, sand beaches, deltas
Historic Shoreline Change (m/yr)	> 2.0 m, accretion	1.1 to 2.0 m, accretion	-1.0 to +1.0	-1.0 to -2.0, erosion	> 2.0 m, erosion
Coastal Slope	>1/10	1/10 to 1/20	1/20 to 1/30	1/30 to 1/50	1/50 to 1/100
Relative Sea Level Change (mm/yr)	<1.0	1.0 to 2.0	2.0 to 5.0	5.0 to 7.0	>7.0
Mean Significant Wave Height (m)	< 0.5	0.5 to 3.0	3.0 to 6.0	6.0 to 8.0	> 8.0
Mean Tidal Range (m)	< 0.5	0.5 to 2.0	2.0 to 4.0	4.0 to 6.0	> 6.0

Based on CVI results, the studied coastal area may be classified as:

- Low Vulnerability Area: $CVI < 10.53$;
- Medium Vulnerability Area: $10.53 \leq CVI < 30.37$;
- High Vulnerability Area: $30.37 \leq CVI < 40.50$; and
- Very High Vulnerability Area: $40.50 \leq CVI$

3.2 The Socioeconomic Coastal Vulnerability Index

The calculation of the Socioeconomic Vulnerability Index was based on the work of McLaughlin et al. (2002). A set of physical and socio-economic variables were selected as indicators aiming to describe the characteristics related to the physical conditions, the coastal forcing, the economic growth and the social development.

The description of the Coastal Characteristics of a shoreline is based on the following parameters: a) the rate of relative sea level rise (RSL), b) the mean tidal range (TR), and c) the mean significant wave height (WH). Then, the Coastal Characteristics Sub-Index is produced as:

$$CC = \sqrt{\frac{RSL \times WH \times TR}{3}}$$

The description of the Coastal Forcing incident to the studied shoreline, the following parameters are considered: a) the geomorphology (G), b) the coastal slope (CS), and c) the shoreline erosion/accretion change rate (RSLR). Then, the Coastal Forcing sub-index is produced following the equation:

$$CF = \sqrt{\frac{G \times CS \times RSLR}{3}}$$

Finally, the Socio-economic sub-index includes the following parameters: a) the presence and size of Settlements (SET), b) sites of Cultural Heritage (CH), c) the presence/absence of Transport Network (TN), d) Land Use (LU), and e) Economic activities (E). From these variables, transport network and cultural heritage are easily to be obtained, while settlements, land use and economic activities are considered as time-dependent, they are time limited and they must be reassessed after a certain period.

$$SE = \sqrt{\frac{SET \times CH \times TN \times LU \times E}{5}}$$

All variables were ranked on a 1-5 scale, according to their perceived vulnerability (with 5 being the most vulnerable and 1 the least vulnerable). Then, the sub-indices CC, CF and SE were normalized between 0 and 100 following:

$$NV = \frac{(Sub - indexvalue - \min \ sub - indexvalue)}{(\max \ Sub - indexvalue - \min \ sub - indexvalue)}$$

Finally, all normalized values were inserted into the following relationship to derive the total social CVI as:

$$SocCVI = \frac{CC + CF + SE}{3}$$

The conceptual framework of the Socio-economic CVI is illustrated in Figure 1.



Figure 1. The conceptual framework of the Socio-economic CVI, based on three sub-indices: a) Coastal Characteristics, b) Coastal Forcing, c) Socio-economic index (after McLaughlin and Cooper, 2010).

The Settlement parameter (SET) is considered as a parameter to assess the population exposed to coastal erosion and climate change impacts. Settlement data are time dependent, since the size of the settlements

can change with time and need to be re-evaluated periodically. The settlement size is ranked on a 1-5 basis, with the assumption that, larger settlements are affected more by erosion; therefore, they are directly correlated with increasing vulnerability.

The vulnerability of cultural heritage (CH) sites (i.e. area with historical monuments) in the coastal zone is assessed through the second parameter included in the estimation of the SocCVI. Obviously, the ranking method of this variable is subjective. To address this problem, the ranking of the sites in the present study was made in terms of relative importance. Hence, sites of global interest are considered as most vulnerable, while less important sites are assigned a lower vulnerability value.

Transport Networks (TN) incorporate the risk coastal infrastructures are exposed in areas when coastal erosion and sea level rise due to climate change are considered. Transport networks present limited changes in time. Herein, the TN variable is ranked based on the size of the roads, with larger roads to be considered as more vulnerable.

Land Use (LU) type is very significant in determining vulnerability as increased protection measures for a vulnerable area will be considered only if it has sufficient economic, cultural or environmental value to justify protection. Ranking of Land Use variables, should consider the characteristics of the given area in terms of economic growth (Hughes and Brundrit, 1992).

Finally, the Economic activities parameter represents the financial value related to the land use type of the studied area. As most vulnerable are considered the coastal sectors that are used for tourism purposes, since tourism is the main factor that drives the economic growth in the coastal zone. All ranking are shown in table 2.

Table 2. Key parameters and their respective scores for CVI estimation along the pilot study sites of HERMES project.

Key Variables	1 Very Low	2 Low	3 Moderate	4 High	5 Very High
Settlements (SET)	Absent	Village	Small Town	Large Town	City
Cultural Heritage (CH)	Absent	Local	Regional	National	Global
Transport (TN)	Absent	Secondary	National Road	Ports	Highway
Land Use (LU)	Bare Rocks	Grasslands / Coastal Areas	Forest	Agricultural Areas	Urban / Industrial
Economic Activities (E)	Absent	Agricultural	Commercial	Industrial	Tourism

4 RESULTS

4.1 Larnaca

The variables controlling both CVI and SocCVI were determined and assessed on the basis of existing information, which are combined and interrelated spatially. The geomorphological variable has found to be Very Low vulnerable for the 12.53% of the coastline and Very High vulnerable for the 68.11%, with the remaining vulnerability ranks to refer to small percentages (8.94% Low, 10.3% Medium, 0.1% High) of the coastline. For the Shoreline Erosion variable the 12.53% of coastline is presented as Low vulnerable, while the 22.4% as Medium vulnerable. Very low, High and Very High ranks present percentages of 0%, 30.34%, and 34.69%, respectively.

The coastal slope was estimated by the distance between isobaths of 5m and the 5 m elevation contour line, while for its ranking the limits of the five classes in table 1 were utilized. Thus, the 74.04% of the coast presents very High vulnerable, the 23.67% (High vulnerability), the 2.27% Medium vulnerability) while there was no section of Low and Very Low Vulnerability.

Relative Sea Level Change and the Tidal variables are considered to have the same values in the whole area. Thus, according to Table 1, Relative Sea Level Change variable is ranked as Medium Vulnerability, while the Tidal range variable as Very High Vulnerability.

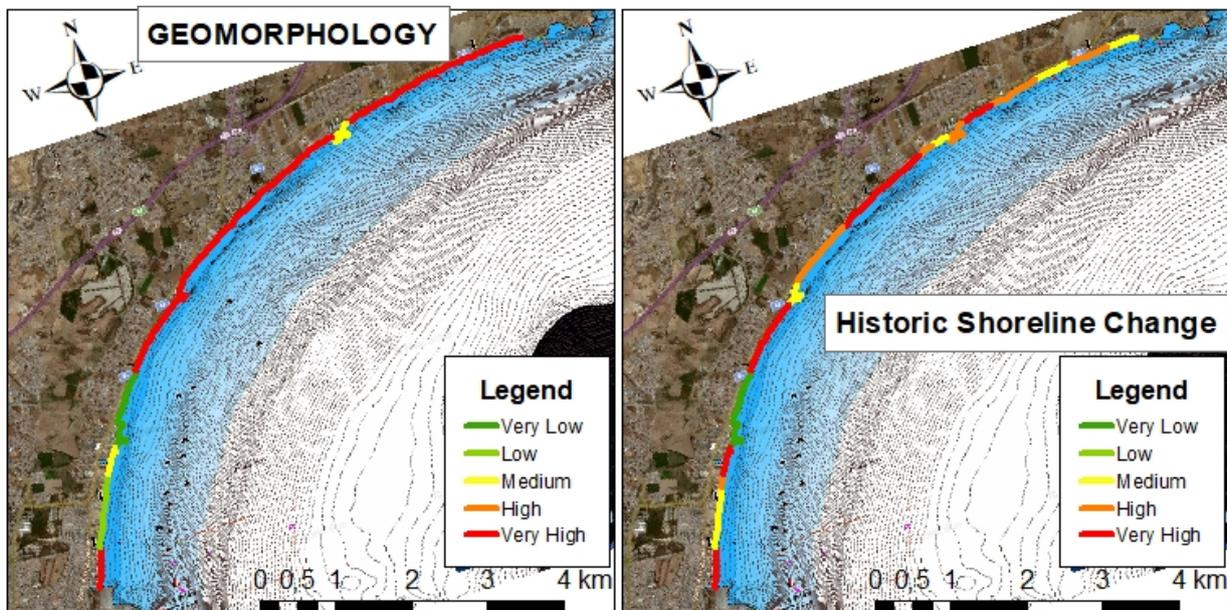
The majority of the coastline is ranked as medium Vulnerable (33.92%) and High Vulnerable (66.07%) with respect to Mean Wave Height variable.

For the Settlement variable, the majority of the coastline is ranked as Very Low (91.3%) since there are no settlements in these areas. The remaining 6.1% that corresponds to coastline in front of villages and tourist infrastructures is ranked as High and 2.6% that represents the coastal front of the town of Elounda Very High.

For the Cultural Heritage variable, 54.1% of the coastline is ranked as Very Low, 36.1% as Low, since there are cultural heritage sites of local importance in these areas, and 9.4% as Very High, representing the Spinalonga Island. Regarding the Transport Network variable, 56.4% of the coastline is ranked in the Low category, since it hosts secondary roads mainly dirt roads; 27.1% hosts roads of national importance and is ranked in the Medium Vulnerability category; in the 15% of the coastline there is no road network and it is ranked in the Very Low category, while 0.7% of coastline is ranked in the High and Very high categories, which represent ports and highways.

For the Land Use variable, the 56.4% of the coastline belongs to the Low category representing coastline in front of grasslands, and the 35.6% in the Very High category since it hosts urban structures. The remaining 9% being in front of bare rocks is ranked as Very Low vulnerable.

Finally, for the Economic Activities variable the majority of the coastline (59.3%) belongs to the Very Low category, as there are no economic activities in those areas, the 3.7% to Low category as it incorporates agricultural activities, the 17.9% having commercial activities to Medium category, the 17.2% to Very High category as it hosts tourism activities and only a very small percentage of the coastline (2%) to the High category as it hosts small scale industrial activities. All variable ranking is presented schematically in figure 2.



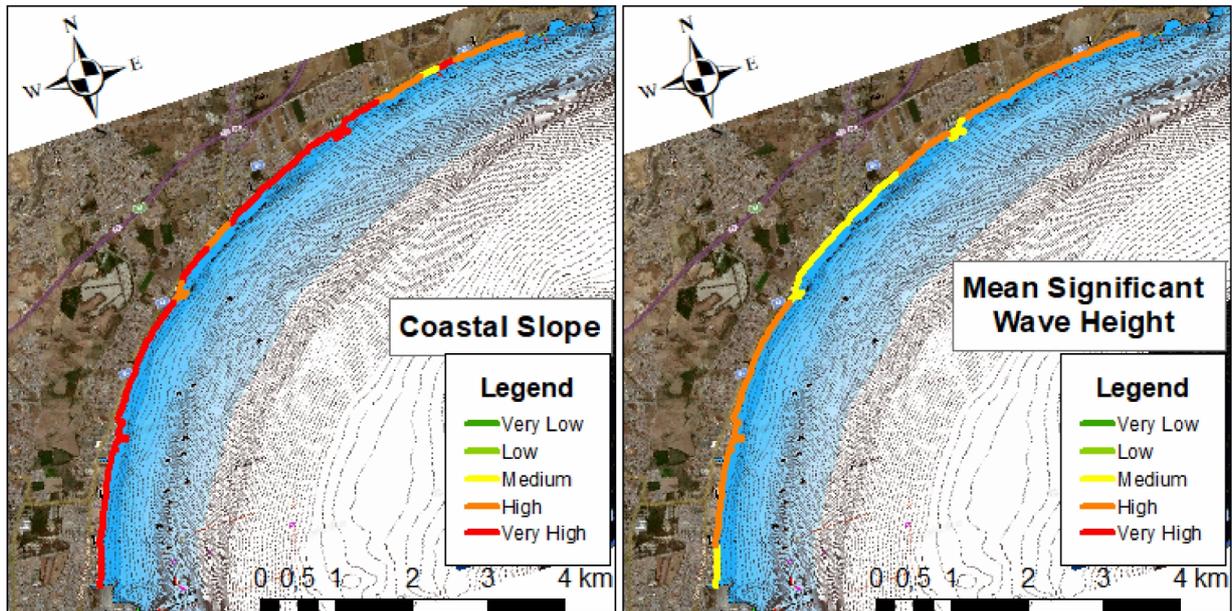


Figure 2: Schematic representations of the variable ranking for the CVI

4.1.1 Indices calculation

4.1.1.1 CVI

Estimations using CVI show that, the 39.93% of the coastline is characterized as High vulnerability areas. A very small percentage (0.2 %) is classified as low vulnerability areas. Very High vulnerability areas correspond to 17.06 %. Very low and medium vulnerability ranks represent the 12.53 and 30.26 % of the total coastline length respectively. The schematic presentation of the CVI classification is shown in figure 3.

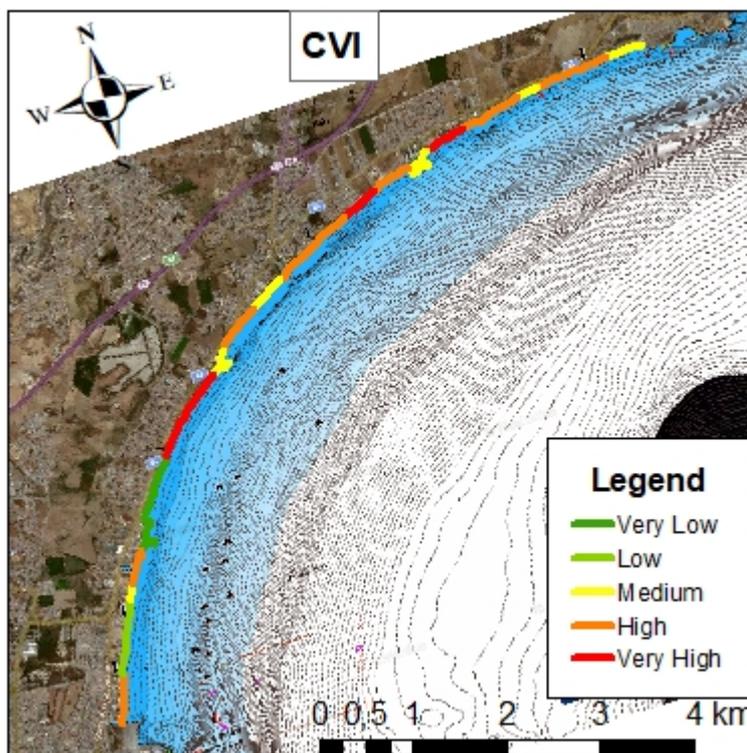


Figure 3. Vulnerability ranks for CVI

4.1.1.2 SocCVI

According to the results of the index SocCVI, there aren't any areas with Very Low, low and Very High vulnerability, while 87.46 % of the coastline is characterized as Medium Vulnerability coasts, and the 12.53% as High. They consist mainly of areas with low slopes and human constructions in the coastline, mainly touristic and industrial. The schematic presentation of the sub-indices are shown in figure 4 while the SocCVI classification is shown in Figure 5.

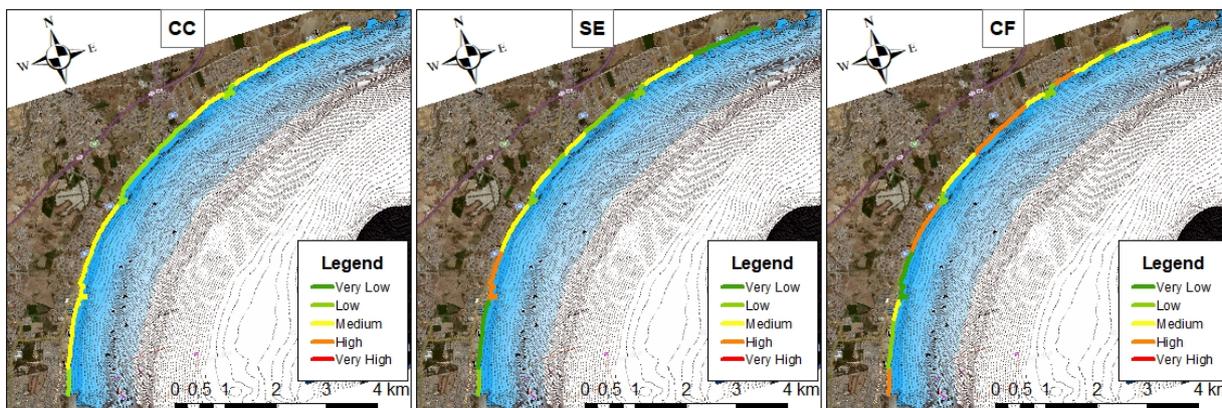


Figure 4: Vulnerability ranks for CC, CF and SE sun-indices.

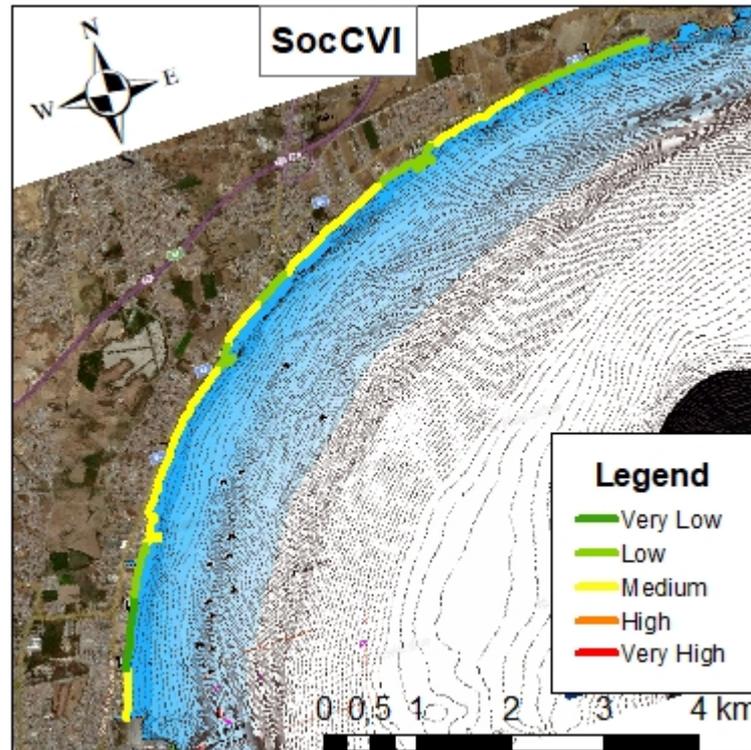


Figure 5: Vulnerability ranks for SocCVI.

5 Conclusions

The comparison of the results from the two indices shows that the CVI ranks most of the coastline to the category of high vulnerability with the remaining part to the extreme categories i.e., Very Low and Very High. It seems to be controlled mainly by the morphological variables. On the other hand, the SocCVI characterises the coastline mainly as of Medium vulnerability. This is explained by the addition to the natural variables, those expressing the socioeconomic value related to man-made structures and heritage sites. In areas where there are no human activities, the ranking is lower even if the area is more vulnerable in terms of its environmental setting.

In addition to the above, the relative influence of each of the three sub-indices of the SocCVI index is presented graphically in Figure 6. As it is shown the three sub-indices presents only small differences between the sub-sections of the coastline. Moreover, the sub-indices of coastal characteristics (CC) seem to dominate the overall SocCVI score.

In terms of validation, the three sub-indices of the newly formed SocCVI index were tested against site assessment validation studies and found that behave similarly ell. However, a problem noted during the breakdown of the overall SocCVI index scores into their component sub-indices was the low values of the socio-economic sub-index in its contribution to the overall index score in some sites. In contrast, in the areas near the tourism and industrial activities, the Socio-Economic sub-index had a significant contribution to the overall index score. This is explained by the fact that the rest of the coastline is partially developed in socio-economic terms, and the index is in fact reflecting reality.

The indicators that are selected for the coastal vulnerability analysis can strongly influence its final justification. The addition of socio-economic variables in coastal vulnerability indices based initially only on natural processes is of high importance, even though the accurate quantification of most of them remains a serious challenge. The input of socio-economic variables in a coastal vulnerability assessment studies could be proved a useful tool for making coastal management decisions more focused to the actual needs of the society.

6 References

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