ESTIMATION OF THE CLIMATIC CHANGE IMPACT TO BEACH TOURISM USING JOINED VULNERABILITY ANALYSIS AND ECONOMETRIC MODELING

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Abstract

The majority of the touristic activities, especially in the Mediterranean countries, are concentrated around coastal areas, making coastal erosion, among others, a significant threat to coastal economies that depend heavily on revenue from tourism. In this paper a methodology for the estimation of the economic impact of beach erosion to tourism, is been described. Input about the conceptualization, design and implementation of the method is provided. The method focuses on the identification of the vulnerability of the coast to sea level rise and associated erosion, in terms of expected land loss and economic activity in two scales. The economic value of the beach is estimated through a hedonic pricing econometric model, relating Beach Value with environmental social and economic attributes, which relationships can be better understood when distributed and analysed along the geographical space. As case study area Crete Island was selected, while for the small scale the high vulnerable beach of the city of Rethymnon, one of the most popular tourist destinations in Crete Isl, is presented. In the small scale vulnerability analysis, the sectors of the beach which are most vulnerable were identified, while the average revenue losses was found to be in the order of 18€/m^2/day.

Introduction

One of the consequences of the global climatic change is the loss of coastal land, an area where many human activities are concentrated, due to a potential sea-level rise and the associated erosion. On a global scale, sea level rise has been predicted to be in between 38 and 68cm for the year 2100 [1]. Sea-level rise over the next century is expected to contribute significantly to physical changes along shorelines, enhancing coastal erosion particularly on low-gradient coastal zones [2]. Coastal erosion results in three types of risks: (i) loss of land with economic value; (ii) destruction of natural coastal defences (e.g. dune system); and (iii) undermining of artificial coastal defences, potentially leading to flood risk. Across the Mediterranean, coastal erosion has been a longstanding, large-scale issue, especially to resort beaches [3]. More than 40% of beaches in France, Italy and Spain have been found to be eroding in the EU project Eurosion [4]. According to the Atlas of Italian Beaches [5], 27% of the Italian beaches are retreating. In Greece, generalized coastal retreat has already affected tourist beaches [6]. As most of the tourist activities in Greece are located on coastal areas, sea level rise poses a significant threat to tourist beaches and the associated revenues from the tourism industry. Regarding policy-making, beach erosion has been a concern for coastal managers for decades. However, beach management has received scant attention in studies relating beach erosion and property values [7]. In this context, the justification of erosion control cost in relation of avoiding revenue losses from business activities in resort beaches needs to examined. Also, it needs to be determined if policy interventions for stabilizing shorelines can be sustainable in the long run. And finally, to what extent can policy interventions be capitalized into tourism revenues. Answers to these questions require reliable estimates of economic and environmental factors put along the geographical space. These issues, the *ClimaTourism* database, which is been developing within the *ClimaTourism* project, aims to cover. This is addressed, firstly, by estimating the economic impact of beach erosion in the revenues from business activities in resort beaches. Secondly, by developing a managerial tool, though a join environmental and economics approach, so as to mitigate the negative economic impact of beach erosion and suggest cost-benefit scenarios for planning alternative protection measures. This paper presents the conceptual model and the structure of the *ClimaTourism* database and also an example of the application in a mass tourism destination as the island of Crete and the city of Rethymnon.

Study Area

The study area is the Crete Isl. which is the largest Greek island and the fifth largest in the Mediterranean, with a population of approximately 603,000 inhabitants. Its coastline totals 1300 km, 15% of which consists of sandy beaches [6]. In the last decades, Crete has become one of the most developed tourism destinations in the

Mediterranean basin, attracting almost 2.8 million tourists annually [8], making the tourism industry of the island plays a leading parameter to its economic growth during the last decades [9]. Moreover, it has consistently acted as the interface for strong inter-sectorial connections with further multiplying growth effects. It has been estimated that approximately 40% of the local population is, directly or indirectly, involved in the tourism industry [10].

The tourism development in Crete started in the late 1960s when tourists were attracted to Greek destinations mostly for their natural and cultural attractions and local capital took advantage of state subsidizations for building large hotels[11]. By 1981 the number of hotel beds had almost tripled in the island. Moreover, the "mass tourism" development paradigm followed in Crete led to sharp environmental stress, due to unequal seasonal and geographical distribution of activity, with 85% of tourist arrivals taking place from May to September on the north coasts of Crete [12]. Today Crete holds a share of 25% of total foreign guest nights in Greece [8]. For the smaller scale, the town of Rethymnon is selected. It is situated at the northern coast of Crete and is the third town of the island, with about 40.000 habitants. The Prefecture of Rethymnon extends to the southern coast and has about 73.000 habitants. Rethymnon is built on a cape which looms about 700 m into the Cretan Sea. The northern border of the town is the Cretan Sea with a sandy beach which provides a large number of hotel units of all categories as well as tourist facilities of all kind. In total, it has more than 200 accommodation establishments. It is of 7,5 km length and its width varies from 20 to 110 m (Figure 1). It has a West - East direction and receives waves induced predominately by the Northwestern, Northeastern and North origin winds. Northwestern winds are the most frequent, with an annual frequency of occurrence of 25.5%. Northern winds have an annual frequency of occurrence of 14.4% while the respective frequency of Northeastern winds is 3.0% [13].

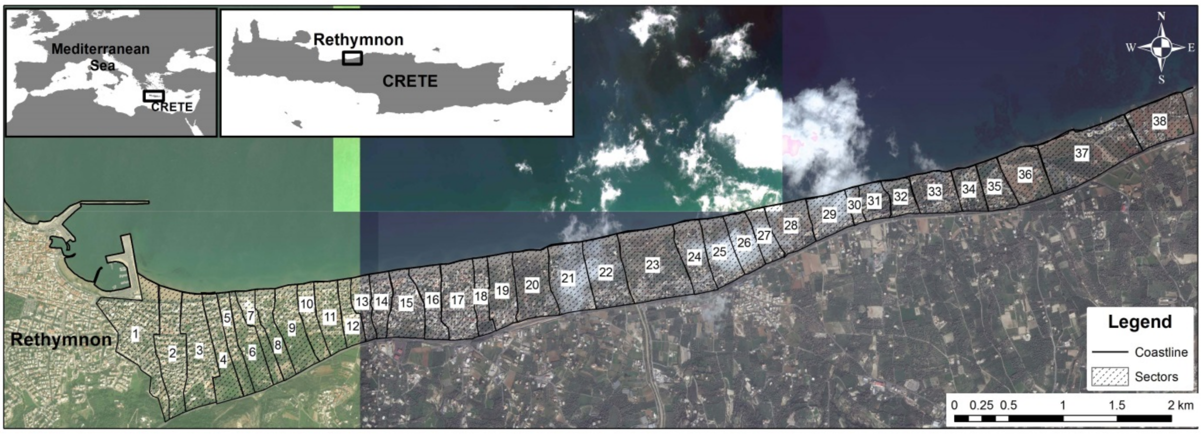

Figure 1: The location of Rethymnon case study area

Methodology

The analysis is based on multidisciplinary approach, combing environmental and economic data. This is implemented in a GIS database, the *ClimaTourism* database, through the estimation of the vulnerability of the coast in two scales and an econometric analysis. The database is organised in four levels in which the analysis is been implemented while in a fifth level the dissemination of the results to end users is been addressed. There are three types of data that are involved in the database: (a) Raw data, derived from maps and remote sensing products; field observations; laboratory analyses and social and economic features. (b) Analytical data, which are produced by analysing the previous categories and (c) thematic data, which, are created by interpreting the various types of data. Raw data are used as input, while analytical and thematic data are produced within the database. The first level concerns the gathering of raw data, which include data from existing datasets and bibliographical sources, data from field measurements and data from monitoring in already studied areas. In the second level the organization of the data is been made. The data are organized based on which scale will be used. The data that are involved in the first two levels are presented in table 1. In level 3, new thematic data can be generated for further utilization. The larger scale data refer to the estimations of the vulnerability in a regional level, with the use of the Coastal Vulnerability Index (CVI) method. CVI is a relatively simple and functional method, developed to estimate the vulnerability to erosion of any coastal zone in relation to a future sea-level rise using six variables, which are ranked in five categories of vulnerability from very low to very high. The calculated CVI values are ranked into five categories, in consistency to variable ranking, to highlight the different levels of vulnerability [14] [15] [16]. For this application, the geographical coverage of the large scale dataset covers the area of the Cretan shoreline and the area offshore which is included in the coordinates (Upper left 35.43N 24.69E, Low Right 34.91N 26.31E). In this scale data about elevation, geomorphology, sea level trends, shoreline displacement, tide ranges, and wave heights are used.

Table 1: Data and method of calculation

VARIABLES			METHOD	SCALE
ENVIRONMENTAL	Coastal geomorphology	GEO	Field measurements / Satellite images	Large
	Shoreline erosion/accretion rate (m)	RATE	Field measurements / Satellite images	Large
	Coastal slope (%)	CS	Field measurements / Satellite images	Large
	Relative sea-level change (mm)	RSLC	Tide gauges / Bibliographical	Large
	Mean significant wave height (m)	Ho	Field measurements / Bibliographical	Large
	Tidal range (m)	T	Tide gauges / Bibliographical	Large
	Profile length (m)	W	Field measurements	Small
	Beach slope (degrees)	β	Field measurements	Small
	Profile length subaerial (m)	W_s	Field measurements	Small
	Maximum profile elevation (m)	B	Field measurements	Small
	Wave breaking height (m)	H_b	Numerical modeling	Small
	Wave braking angle (degrees)	α_b	Numerical modeling	Small
	Significant wave height (m)	H_o	Numerical modeling	Small
	Wave length (m)	L_o	Numerical modeling	Small
	Wave period	T_o	Numerical modeling	Small
	Wave run up (m)	R	Estimate by equation [17]	Small
	Sea level rise (m)	S	Bibliographical [1]	Small
	Closure depth (m)	h_c	Estimate by equation [18]	Small
	Wind speed (m/sec)	U*	Bibliographical [13]	Small
	River sediment flux (m^3/year)	E	Estimate by equation [19]	Small
	Fall velocity (m/sec)	w_s	Estimate by equation [20]	Small
	Grain size (subaqueous) (mm)	D_{50S}	Field measurements [21]	Small
	Grain size (subaerial) (mm)	D_{50L}	Field measurements [21]	Small
ECONOMIC	Land value (€)	BV	Public records	Small
	Coastal Business Activities	B	Field measurements / Satellite images	Small
	Beach Area (m^2)	BA	Satellite images	Small
	Area used of touristic propose (€)	TA	Field measurements / Satellite images	Small
	Hotel beds	HB	Web sources	Small
	Number of Hotels	H	Field measurements / Web sources	Small
	Hotel room price*	E	Web sources	Small
	Number of sun umbrellas	U	Field measurements / Satellite images	Small

Subsequently, a smaller scale focuses on highly vulnerable beaches with high touristic and economic value. For this purpose, the Beach Vulnerability Index (BVI) [22] is used, in order to identify the key factors that result to beach erosion and produce the small scale data. It is a numerical approach of the parameters governing the sediment budget of beach zone and its evolution. It includes the natural processes of long-shore and cross shore sediment transport, the riverine inputs, the relative sea level change, the wave run-up and the aeolian sediment transport, also takes into account individual extreme events (e.g. storms), which often contribute considerably to the erosion of a particular beach. It characterizes those sections of a beach which are more liable to erosion. Shoreline retreat has been estimated for time periods of 10, 20, and 30 years for the corresponding sea level rise of 0.038m, 0.076m and 0.116m, (A1B scenario of IPCC [1]) with the use of Dean [23] formula:

$$R_S = (S + 0.068 H_b) \frac{W_b}{d_b + B}$$

where: B: berm height, H_b: breaking height, S: relative sea level rise, W_b: profile length and d_b: breaking depth.

The small scale data set covers the areas of the beach zones. Those data are derived by the numerical estimate of the processes that control beach evolution. The estimation of those processes depends on the calculation of other important variables, such as granulometry, wave characteristics and the geomorphology of beach zone (e.g. beach slope) and analytical data that are derived from those variables (e.g. wave run up).

The economic value of beach width, which is capitalized in income from tourism business in vulnerable beaches, is estimated with the "hedonic pricing method" [24]. It is the most common method used to estimate the value of environmental amenities that are reflected in property values. More specifically, Beach Value (BV) is a function of:

$$BV=f\,(A, CB, TA, BW, BA, U, L)$$

Where, A: accommodation facilities (number of hotels H, number of hotel beds HB, room price P); CB: coastal business (number of enterprises that use the beach); TA: tourist area (beach area used for touristic activities); BW: beach width; BA: beach area; U: beach attendance; L: section length.

The applications of the database are implemented in level 4 and refer to risk assessment analysis and cost benefit analysis for protection measures. In the fifth level the dissemination of the results to the end users is implemented by transforming the above information in user friendly form, like technical reports. The *ClimaTourism* database flow chart and the conceptual model are illustrated in figure 2.

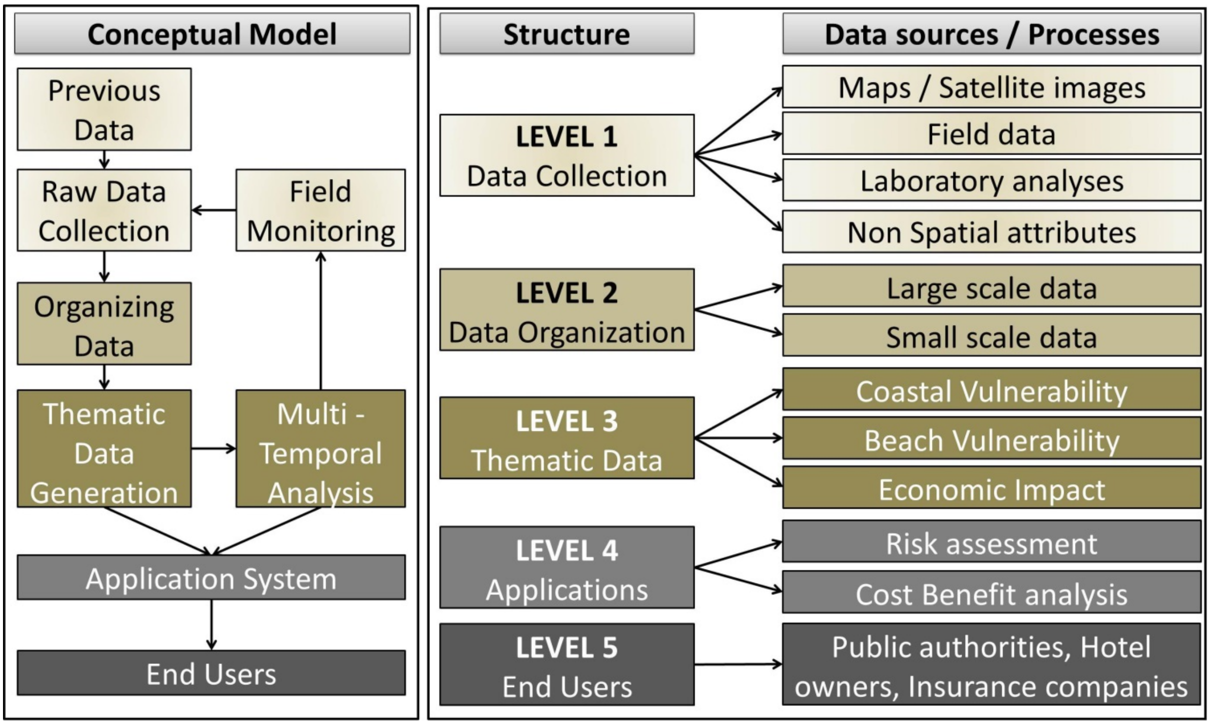

Figure 2: The conceptual model, structure, data and processes of the *ClimaTourism* database.

Results

In this section, the results of the analysis within the *ClimaTourism* database are presented. The presentation follows the order in which the thematic data are produced by downscaling, considering first the vulnerability of the whole coastline in a regional scale, then the vulnerability of high vulnerable areas in a smaller scale. When the vulnerability in small scale is been defined, coastline retreat rates are estimated. Then the econometric analysis of the area is been made, in order to estimate the current and future value of the beach and finally to estimate the expected revenue losses.

1. **Large scale vulnerability**

The calculation of the Coastal Vulnerability Index for the Cretan coast, in the case of sea level-rise, is presented schematically in figure 3. The 38.34% of Cretan coast is categorised as very low vulnerability, while in as low vulnerability is characterised the 19.49%. In the medium vulnerability category is the 14.27%. In High and very High vulnerability category is the 11.21% and the 16.69% of the Cretan coastline.

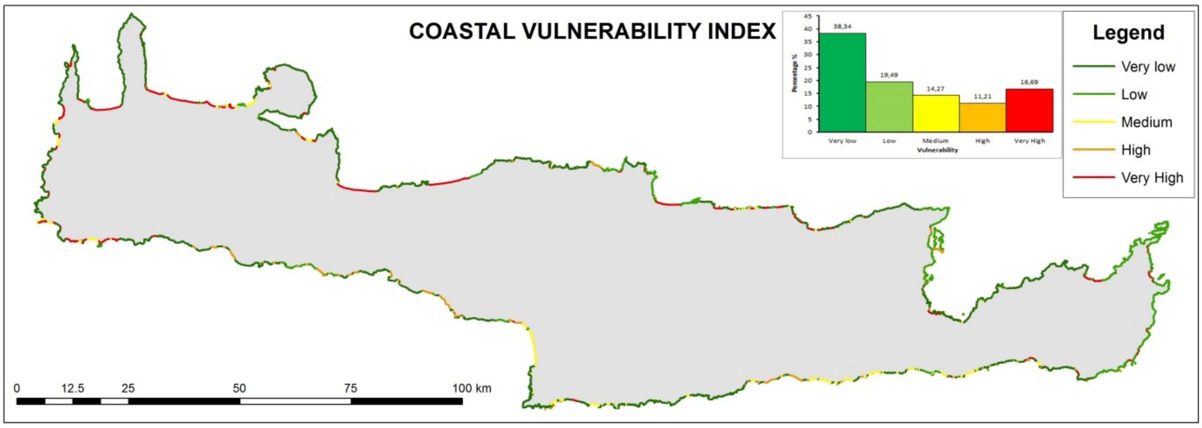

Figure 3: Map showing the vulnerability of the Cretan coastline and the location of Rethymnon beach.

The relation of the erosion vulnerability to the geomorphological categories of the Cretan coastline shows that the small beaches with length less than 200m (B1) present more than 50% very high vulnerability, a 43.52 high vulnerability and a very small percentage (6.01) of medium vulnerability. Similar results were found for beaches with length from 200-1000m (B2). Beaches with length more than 1km (B3), present a 75.26% of vulnerability while there is a 9.34% that are categorized to the very low vulnerability category. Man-made coastlines (HM) are in the low and very low category with the majority to by in the low vulnerability category. Hard rock coastlines (HR) are also categorised as very low and low, with the majority to be at the very low category. Muddy coasts (M) are in the low and medium vulnerability categories, while soft rock (SR) coastlines are in the low, medium and high vulnerability categories. This shows that areas of the coastline that have high value for tourism present the higher vulnerability values. All values and categorisation are shown in figure 4.

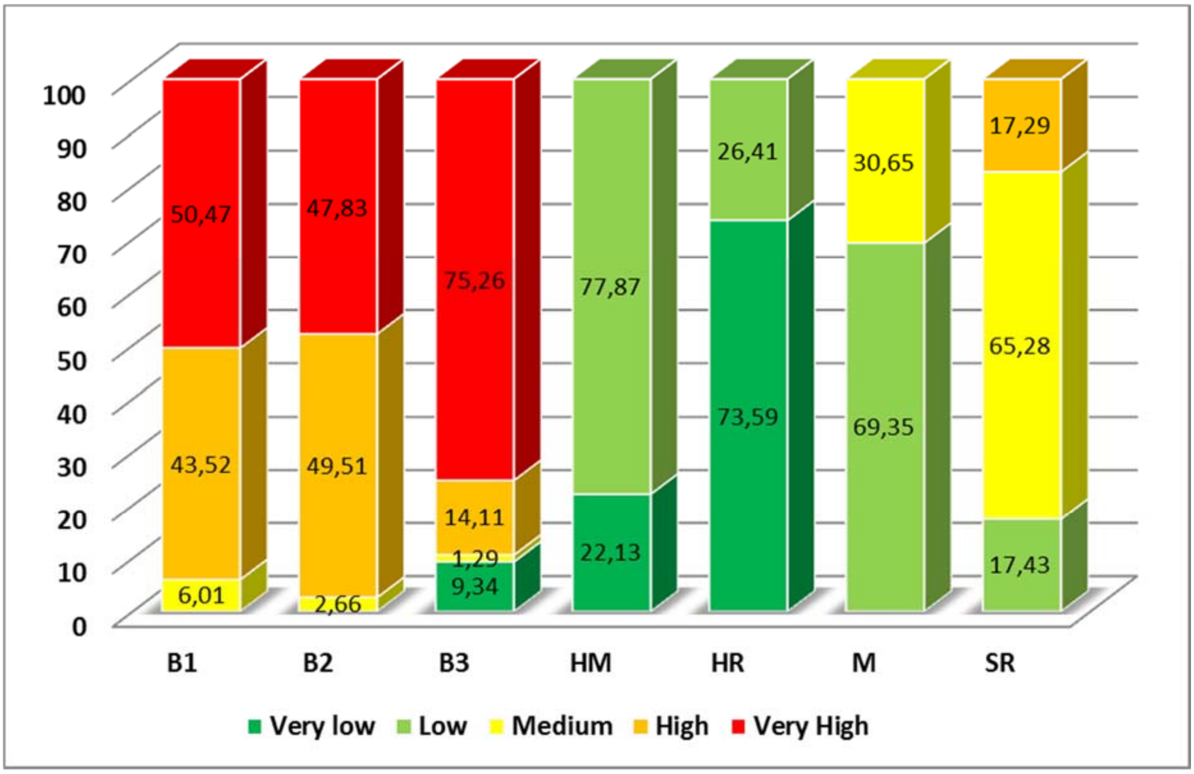

Figure 4: Vulnerability percentages by coastline type of the Cretan coastline.

2. Small scale vulnerability

The vulnerability to erosion was estimated with the use of the BVI method and the estimated values for each section of the beach zone are presented in figure 5. The overall BVI values range from 39.4 (section 22) to 74.5 (section 4). High values are presented on the west and east parts of the beach while lower values are presented on the central parts.

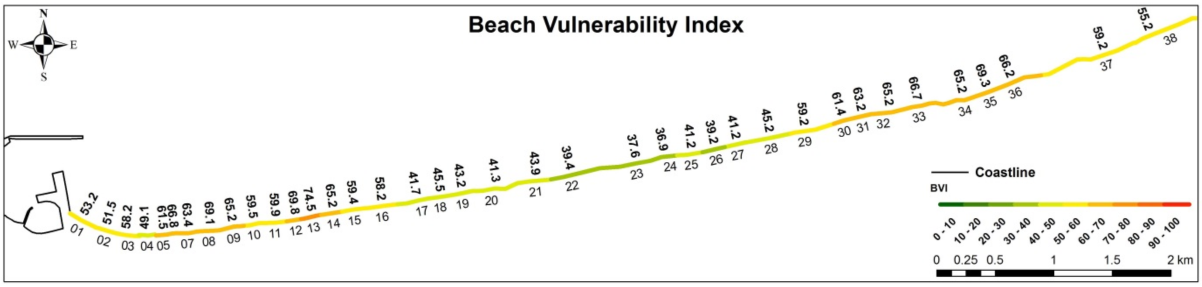

Figure 5: Beach vulnerability values in each section of Rethymnon Beach.

3. Shoreline retreat

The estimated values of shoreline retreat for time periods of 10, 20 and 30 years in the each section of beach under investigation are given in figure 3. The estimations suggest that in sections 4, 5, 6, 7, 8, 9, 10, 34 and 37, the beach is expected to be totally eroded in the next 10 years, while in section 38 in the next 20 years and in sectors 11 and 12 in the next 30 years. The other sections exhibit a linear decrease in beach width. Among these sections, section 15 exhibits the largest shoreline retreat, which is expected to have approximately 6% of the current beach width, after 30 years. Section 30 exhibits the smallest retreat, where, after 30 years, the beach width is estimated to be the 76% of the current. Changes in beach width are presented in figure 6.

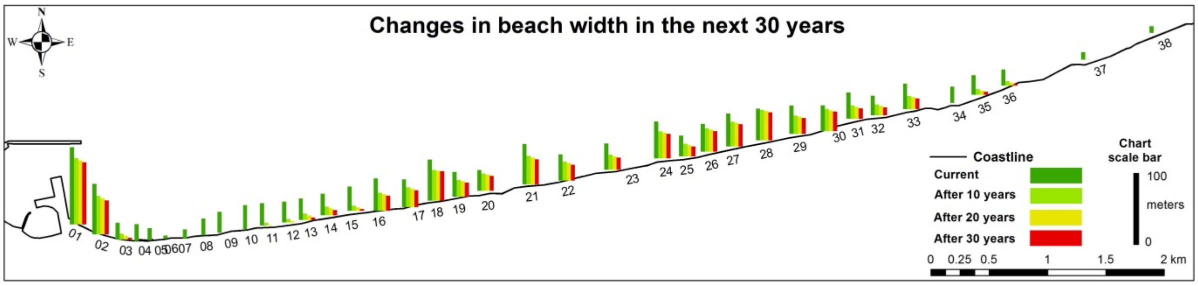

Figure 6: Changes in beach width for a 30 year period

4. Econometric results

Hedonic pricing models were estimated to relate beach value and beach width and it's estimated in small scale. Baseline values were estimated under eight specifications. First, the baseline values were estimated using ordinary least squares (OLS), for a semi-log and a double-log specification, treating beach width as exogenous. For the two-stage least squares (2SLS) estimations the beach area was used as an instrumental variable for beach width. The endogenity tests in the semi-log specification showed that the hypothesis that Beach width (BW) can be treated as exogenous has a 5% significance while in the other specifications the significance level is at 1%. Based on the statistical significance of the variables across the various model sets, the following specification is been used:

$$\begin{aligned} ln(\mathrm{BV}) = \; & 0.99786 \cdot ln(\mathrm{BW}) + 1.77230 \cdot ln(\mathrm{E}) + 0.12299 \cdot \mathrm{H} + 0.71371 \cdot ln(\mathrm{HB}) + 0.00013 \cdot \mathrm{TA} + \\ & 0.46389 \cdot ln(\mathrm{L}) - 0.08732 \cdot ln(\mathrm{U}) - 0.01956 \cdot \mathrm{CB} - 7.87814 \end{aligned}$$

This model uses the logarithmic expression for the depended variable of beach value (BV) and the explanatory variables of Beach Width (BW), Room price (E), Number of hotel rooms (HB), sector length (L) and beach attendance (U). The variables of Coastal business (CB); Number of hotels (H) and Tourist area (TA) are presented as non-logarithmic. The coefficients of the Coastal Business (CB) and beach attendance (U) are negative but their level of significance is 10%. All modelling results are presented in Table 2.

Table 2: Econometric specifications

Dependent Variable: *ln*BV Included observations: 38		
Variable	**OLS**	**2SLS**
C	-7.87814*** (1.1656)	-8.58302*** (1.1731)
CB	-0.0196* (0.0133)	-0.01667* (0.0133)
***ln*BW**	0.99785*** (0.10043	1.29796*** (0.1151)
***ln*E**	1.77297*** (0.2661)	1.68165*** (0.2665)
H	0.12299*** (0.0427)	0.08760*** (0.0432)
***ln*HB**	0.71371*** (0.1057)	0.78901*** (0.1066)
TA	0.00014* (0.0001)	0.00007* (0.0001)
***ln*L**	0.46389*** (0.1496)	0.42327*** (0.1497)
***ln*U**	-0.08732* (0.1017)	-0.07932* (0.1017)
R^2	0.963	0.953
F-stat	109.534***	95.82***
J-stat		28.47***
Robust standard errors in parentheses. *** $p<0.01$: Statistical significance at 1% ** $p<0.05$: Statistical significance at 5% * $p<0.10$: Statistical significance at 10%		

5. Current value of the beach and future state

The current value of the beach was estimated in euros per square meter per day, taking into account the attributes of the sectors as they are represented in equation 3. The estimations consider a 150 days season, which, for the case study area, represents the high tourist season. The highest value per square meter of the beach is presented in sector 31 (81€/m^2). In this section two five star hotels are located, with 670 rooms and average room price 180€. The lowest value per square meter (0.3€) is presented in section 30, where two small rent rooms establishments are located, with 37 rooms and average price 50€. In the sections where large hotels are located (2, 9, 21, 14-16, 24-28), the value of the beach is increasing. The average value of the beach per square meter, considering all sections, is estimated at 18.5 €/m^2/day. In section 1 the value of the beach is estimated at 15.7€/m^2/day (figure 7). This is very close to the average value of the whole beach. This is due to the variety of hotel categories and room prices.

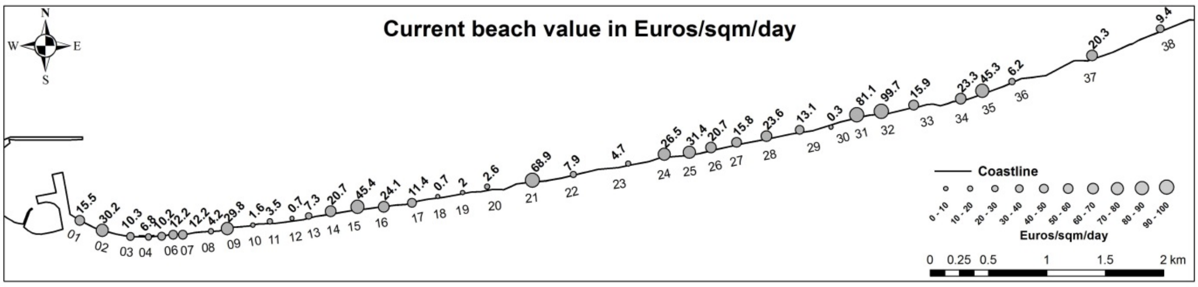

Figure 7: Current beach value in €/sqm/day.

The results from the hedonic pricing models suggest that the value of the beach exhibits variations similar to the respective of beach width implying that the retreat of the shoreline decreases the value of the beach.

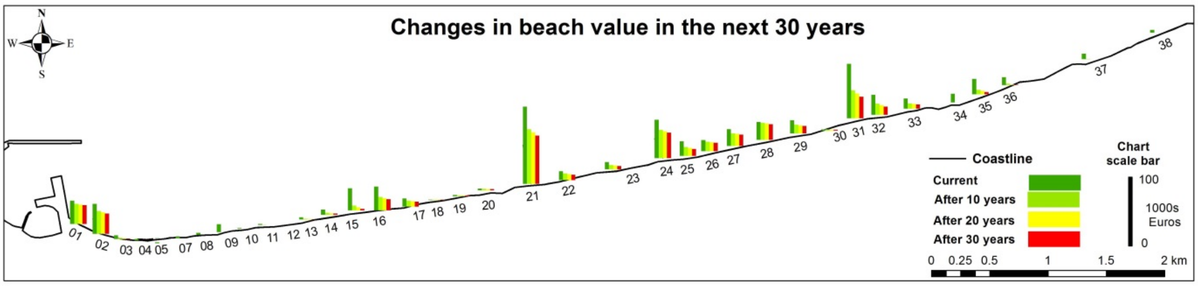

Figure 8: Beach value changes in the next 30 years

By compering the result for the vulnerability analysis and the beach value of each sector it can be seen that for the first ten years high value sectors present vulnerability vaules higher than 40% (e.g. 1,2, 21,31). Sectors 1 and 2 present the large number of coastal bussines and some hotels. In sectors 21 and 31 host 4 large hotels and very small number of coastal business.

Estimations for the economic loss in Rethymnon beach were performed for time periods of 10, 20 and 30 years in each beach section and are presented in Figure 5. The estimations take into consideration the land loss in each section and the calculated value per m^2 for the beach area per section (figure 7). The decreasing beach width will result to losses in revenues from tourism. Based on the beach value per m^2 in each section and the respected shore line retreat, it is estimated that in the next 10 years, the coastal erosion will result to revenue losses (RL) estimated at $60.8x10^3$ €/m^2 per year (section 31). Note also that there are beach sections that are not expected to provide any revenues, since the coastal area will be totally eroded. As beach width deceases, for the next 30 years, in section 31 revenue losses are estimated at $64.6x10^3$ €/m^2 per year. In section 31 the estimated revenue losses are larger than any other section's, although the shoreline retreat in this section is not the largest one (figure 9).

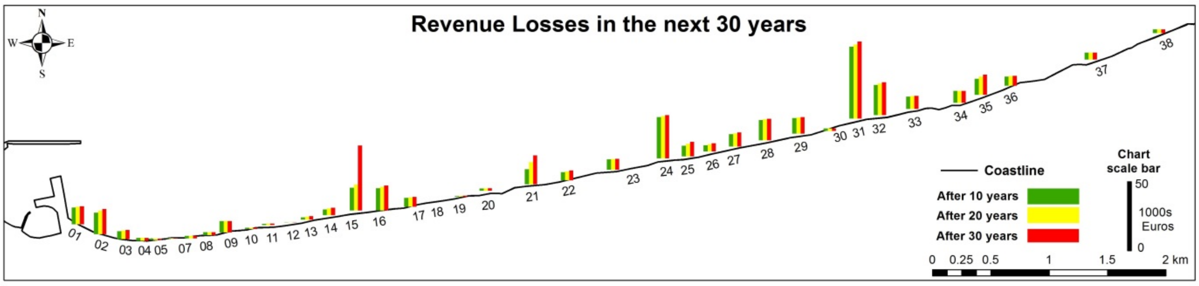

Figure 9: Revenue Losses (RL) in each beach sector for the next 30 years

Discussion

This methodological approach of the *ClimaTourism* database constitutes an improvement compared to other linear data models that have been used in the past for estimating the vulnerability of the coast and its implications[25]. By downscaling the area is analysed in detail and based on a series of scientific criteria, proving an organized and coherent data structure that reduces effectively the complexity to the minimum required. Moreover, it achieves all the above in a way that is compatible with the specific in both environmental and socioeconomic aspects. A restriction of the method is that the coast is presented as linear segments. However, this is common to all linear data reference models of the coast, including dynamic segmentation [26], with most vulnerability analyses to use the same approach in coastal segmentation [27]. The data structure that has been used provides that the complete analysis is been within the database and the results can be supplied to the end users easily but also to researchers and policy makers, without reducing the level of detail of the information contained in it. This is established by the fact that the coastline segmentation is been made in two scales that can be defined by the used based on the needs of the research. Due to this, the information contained in the database can be used at local scales and the large scale can be associated with global datasets. Since the database can be made public in a web-GIS form, the database can be easily accessible to wide range end users without the need of specialized software and hardware.

Conclusions

The *ClimaTourism* methodology has led to the generation of a coastal database for the purpose of vulnerability assessment. The structure and contents of the database address the needs of coastal management in tourist areas, in the fields of erosion mitigation measures. However, it can be used in a wider range of applications like investment risk and insurance cost estimations. The *ClimaTourism* database has a significant difference to other datasets, which are primarily based on estimation in one scale and using only an environmental or socioeconomic approach. Such a multi-disciplinary database by its reliability and user-friendly interface can satisfy a wide range of information needs not only to coastal researchers but also to other end users. Moreover, the ability to provide a reliable estimate of the marginal value of beach width, gives a necessary initial step for the accurate benefit–cost analysis of erosion mitigation measures and to provide information for a sustainable future tourism investments in the coastal zone, by considering all natural and socioeconomic processes.

List of symbols

A: Accommodation facilities

a_b: Wave braking angle

B: Maximum profile elevation

BA: Beach area

BV: Land value

BW: Beach Width

CB: Coastal business

CS: Coastal slope

D_{50L}: Grain size (subaerial)

D_{50S}: Grain size (subaqueous)

d_b: Breaking depth

E: River sediment flux

GEO: Coastal geomorphology

H: Number of hotels

HB: Number of hotel rooms

H_b: Wave breaking height

h_c: Closure depth

H_o: Mean significant wave height

L: Section length

L_o: Wave length

P: Room price

R: Wave run up

RATE: Shoreline erosion/accretion rate

S: Relative sea-level change

T: Tidal range

TA: Tourist area

T_o: Wave period

U*: Wind speed

U: Beach attendance

W: Profile length

w_s: Fall velocity

Ws: Profile length subaerial

β: Beach slope

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