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Linking Sea Level Rise Damage and Vulnerability Assessment: The Case of Greece

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1. Introduction

Throughout the course of modern history, coasts have been a substantial means of human development and an ever-growing number of people still continue to colonize the coasts worldwide. Coasts comprise dynamic and complex socio-ecological systems, encompassing a variety of biotic and abiotic elements. Their complexity and dynamics are reflected in the multiplicity of their forms. Their dynamic nature is responsible for their high productivity, leading both to periodic changes and gradual mutation. The marine ecosystems, by storing carbon dioxide and by releasing oxygen to the atmosphere through the living processes of the phytoplankton population, play a significant role in regulating climate. The coastal areas help create and preserve microclimates. The existence of coastal forests and wetlands ensures minimization of floods, erosion and other natural disasters, and offers valuable regulating and supporting ecosystem services. The importance of coastal resources for the prosperity of coastal areas can be specified through the ecosystem services and goods, which support the human life (Daily, 1997; Turner et al., 2001; Beaumont, 2007; Kontogianni et al., 2010a). The categorization of coastal services and goods is presented in Table 1.

However, the ensuing anthropogenic activities of industrialization and economic growth have brought the coastal areas under intense pressure. Climatic change accentuates these pressures while it makes mean sea level rise (SLR) one of the most predictable and alarming impacts globally (Church et al., 2001; Nicholls, 2007). To make things worse, SLR is known to be rather inelastic against the reduction of greenhouse gas emissions (OECD, 2006), a phenomenon known as "commitment to SLR". That is, even if drastic reduction policies globally succeed in stabilizing the climate, SLR and the accompanying phenomena of coastal erosion and storm surges will continue to occur for centuries (Meehl et al., 2005; Wigley, 2005), causing possible tipping points for some systems (Tipping Points Report, 2009).

This chapter examines the impacts of SLR on the Greek coastal zone and appraises their economic dimension. Researchers engaged in studies like this face two important issues. The first is the quantification of the economic impacts (damages) caused by the losses of coastal areas due to SLR. The second is the *ex ante* estimation of welfare gains from reducing SLR risks, since this estimation constitutes an important input for decision-making regarding

policy and technical measures (mitigation and adaptation measures). Cost-benefit analysis is used as a tool for prioritization among different policy goals. Therefore, methodologically, it must succeed in associating economic estimates with measurable physical indicators, so that researchers are well aware of exactly what is being appraised (Kontogianni et al., 2010a; Sonderquist et al., 2008). Changes in physical indicators mostly refer to non-tradeable environmental goods (magnitudes) (e.g. human health, biodiversity conservation, quality of ecosystems etc). Due to the difficulty in appraising their economic value, they are usually not taken into consideration in decision making, thereby they constitute an external cost. A multidisciplinary approach, in order to be integrated and successful, has to deal with the co-evolutionary aspects of both natural and socio-economic system, known together as the 'socio-ecological' system (Folke et al., 2002).

Supportive services	Regulating services
1 Biogeochemical cycling	1 Atmospheric regulation
2 Primary production	2 Local climate regulation
3 Food web dynamics	3 Sediment retention
4 Diversity	4 Biological regulation
5 Habitat	5 Pollution control
6 Resilience	6 Eutrophication mitigation
Provisioning services	Cultural services
1 Food	1 Recreation
2 Inedible resources	2 Aesthetic values
3 Genetic resources	3 Science and education
4 Chemical resources	4 Cultural heritage
5 Ornamental resources	5 Inspiration
6 Energy resources	6 The legacy of nature
7 Space and waterways	

Table 1. Categorization of services and goods in the coastal environment (Source: Adapted from Garpe, 2008 & MEA, 2005).

As pointed out in the latest national report submitted to the UNFCCC regarding climate change (Hellenic Republic, 2006), no coordinated effort to assess the long-term impacts of SLR and to design appropriate adaptation policies has been as yet conducted in Greece. To our knowledge and to date, only two studies have calculated the monetary losses of SLR for the Greek coastal zone. Dalianis et al. (1997) calculated the total cost of impacts caused by SLR (1-m) in Greece by 2100. The total cost was estimated at €3.4 billion. The authors cite IPCC's first Assessment Report as the source of their monetary estimates. The research program PESETA estimated the future impacts on coastal areas from SLR for 22 European countries including Greece (Richards & Nicholls, 2009; Vafeidis et al., 2008). The analysis was performed with a combination of the integrated model DIVA (Dynamic and Interactive Vulnerability Assessment Tool) and the scenarios A2 and B2 of the IPCC. The calculation of damages in the Greek coastal zone was restricted to land loss due to erosion and flooding and the ensuing human migration.

Few similar attempts have been performed to date in European scale. Sanchez-Arcilla et al. (2008) examined the implications of climatic change on the Ebro delta coast (Spain). Their research focused on the effects of climatic changes in wave return periods, inundation of

low-lying areas and saltwater intrusion, yet without implementing the monetary evaluation of the triggered impacts or the calculation of the necessary investment cost of adaptation policies. Pruszak and Zawadzka (2008) estimated total economic and social costs of land loss and flood risk in Polish coastal zone considering two scenarios of SLR (30 cm and 100 cm in 100 years). Kont et al. (2008) studied the impacts of SLR (1 m in 2100) on the coastal zone of Estonia without the implementation of adaptation measures. The coastal zone was studied either in the case of inundation by SLR or in the case of storm surges and the impacts were quantified in both physical and monetary terms. Sterr (2008) assessed the vulnerability (in economic terms) for five coastal states in Germany in the case of 1 m SLR and estimated the required costs for protection. Aunan and Romstad (2008) studied the potential damages from SLR to roads, bridges and port infrastructure in Norway based on possible restoration costs. Karacat and Nicholls (2008) performed a preliminary assessment of the potential costs due to SLR (1 m) in Turkey and the required investment costs for prevention. Devoy (2008) examined the physical components of coastal vulnerability to SLR in Ireland and presented available estimates for the capital value loss and the protection/adaptation costs assuming a scenario of SLR equal to 1 m until 2100.

This chapter is structured as follows: in section 2 we provide a description of the Greek coastal zone and its vulnerability. In section 3 we lay out our research hypotheses, methodology and sources of data. In section 4 we estimate the financial impacts (damages) of both long-term and short-term SLR. At last, in section 5, we summarize and conclude the chapter.

2. Ecosystem service and vulnerability assessment of the Greek coastal zone

According to the ATEAM (2004), Mediterranean is considered the most vulnerable coastal part of Europe with multiple potential impacts and low generic adaptive capacity.

Knowledge of the vulnerability and ability to adapt to climate change is valuable for adopting suitable policies for both natural and social systems.

Vulnerability holds several definitions. One of those refers to the degree to which an ecosystem service is sensitive to global change, plus the degree to which the sector that relies on this service is unable to adapt to the changes (Metzger et al., 2004).

Vulnerability is also assessed by the ATEAM (2004) as the likelihood of a specific human-environment system to experience harm due to exposure to perturbations, accounting for the process of adaptation. According to the ATEAM, high potential impact and low adaptive capacity constitutes a high degree of vulnerability for the system. Adaptive capacity according to Brooks (2003) has no direct implications to current vulnerability and can only diminish future vulnerability. IPCC (2007) defines adaptive capacity as the ability of a human-environment system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences.

According to IPCC, vulnerability is a function of the sensitivity of a system to changes in climate (the degree to which a system will respond to a given change in climate, including beneficial and harmful effects), adaptive capacity (the degree to which adjustments in practices, processes, or structures can moderate or offset the potential for damage or take advantage of opportunities created by a given change in climate), and the degree of exposure of the system to climatic hazards (IPCC, 2001).

Adger et al. (2004) adopt another approach by separating biophysical from social vulnerability. Vulnerability, according to Brooks et al. (2005), depends critically on context, and the factors that make a system vulnerable to a hazard will depend on the nature of the system and the type of hazard in question. Resilience is used to define two specific system attributes: The amount of disturbance a system can absorb and still remain within the same state or domain of attraction; the degree to which the system is capable of self-organization. (Klein et al., 2004). Handmer (1996) defines vulnerability generally as susceptibility to injury which may be seen as inversely related to resilience: the more resilient one system, the less vulnerable.

A typical case study of the `vulnerability` issue, described in the preceding paragraphs, is the Greek coastal zone. An assessment of coastal ecosystem goods and services in Greece and their physical geographic vulnerability are discussed below. We refer to the social vulnerability and relevant risk perceptions in section 4.3.

The Greek coastal zone has a total length of approximately 16,200 km, being one of the longest coastal zones among European countries. Almost half of the coastal zone belongs to the continental Greece while the remaining half to the 3,000 islands (or 9,800 if islets are included). The importance of the main categories of coastal goods and services (Table 1) provided by the coastal Greek area is described below (YPEXODE 2006, Zanou 2003).

About 33% of the Greek population inhabits coastal areas located at 1-2 km distance from the coast. If we consider coastal population as those inhabiting areas up to 50 km from the coast, then the percentage of Greek coastal population reaches 85% of the total. Twelve out of the thirteen Prefectures of the Greek territory are registered as coastal areas, while the largest urban centres are located in the coastal zone. About 80% of industrial activities, 90% of tourism and recreational activities, 35% of agriculture (usually of high productivity), fisheries and aquaculture, as well as an important part of infrastructures (ports, airports, roads, electricity and telecommunications network etc) are located in the coastal zone. The added value created in the coastal zone includes:

- The operation of 20 ports from which more than one million tonnes of goods are transported annually
- The total fishery production of 96,000 tonnes
- The total fishery sector fleet of 19,000 ships (constituting 20% of the total fleet of the 25 EU member-states)
- The total aquaculture production, 258,000 € worth (representing 10% of the total production of the 25 EU member-states)
- The majority of hotel beds in the tourist sector. During the tourist period, the population in some of the Greek islands increases 2 to 10-fold due to domestic and foreign tourists.

The fishery and aquaculture sectors are important due to their contribution to the Greek GDP, but mostly due to their role in fostering and preserving social and cultural cohesion of the coastal areas. The fishery sector in 1999 had 40,000 employees, with a total production of 231,000 tn, while the number of directly employed in aquacultures is 4,800 and the number of indirectly employed exceeds 7,500 employees.

The coastal zone consists of variable habitats, which contribute to the conservation of biogenetic reserves. Indicatively, over 6,000 different flora species, 670 vertebrate species and 436 avifauna species are found in coastal zones.

Over the last 20 years (1990-2010), there has been an increase in construction of summer residences at the Greek coastal areas (YPEXODE, 2006). The overall urbanized coastal zone area is estimated to be 1,315 km², accounting for 1.31% of the total Greek coastal zone. In

Greece, construction of summer residence occurs too close to the coast (Figure 1), increasing social vulnerability in the case of SLR. Construction near the coast happens due to the fact that tides in the Mediterranean do not exceed 40 cm. So, vulnerability rises due to the increased exposure of coastal constructions and the growing number of people colonizing the Mediterranean coasts.

Fig. 1. Storm surge in Molyvos coast, Lesvos island, Greece, December 2009 (photo T. Karabas).

All the aforementioned coastal resources contribute to the development of cultural services, such as leisure, aesthetics, and ability to perform scientific and educational activities, conservation of cultural heritage and cultural capital, also through arts, philosophy and inspirational sources. The coastal ecosystem services regulate, support and supply, in both natural and cultural terms, the Greek social capital through generations at a scale that exceeds the local and can be historically projected to a European and global level.

All the above ecosystem services provided by the Greek coastal zone lead to the conclusion that such an important natural resource should be worthy of respect and protection. The threats to the Greek coastal and marine environment stem mostly from anthropogenic driving forces (e.g. overexploitation of natural resources, urbanization, pollution, eutrophication, and invasive species). A major problem of the Greek coastal zone is the high rate of coastline erosion: over 20% of the total coastline is threatened making Greece the 4th most vulnerable country, among the 22 coastal EU member states, in terms of coastal erosion (EUROSION, 2004). Major causes for the increased erosion are the particularly strong winds and the storm surges in the Aegean Sea, the anthropogenic interventions (e.g. dams which reduce sediment input, Poulos et al., 2002) as well as the geomorphologic substrate of the coastline: the 2,400 km (15% of the total shoreline) correspond to non consolidated sediment deposits, while 960 km (6% of the total shoreline) correspond to coastal deltaic areas (Papanikolaou et al., 2010). Erosion is expected to increase in the immediate future due to (a) the foreseen rise of the mean sea level, (b) the intensification of extreme wave phenomena

and (c) the further reduction of the river sediment inflows due to changes in rainfall and construction of river management works (Emanuel, 2005; IPCC, 2007; Velegrakis, 2010).

A reliable assessment of the potential risk associated with SLR should take into account not only the trends and rates of eustatic SLR, but consider also such local factors as tectonics, sediment supply and compaction, and storm surges (Poulos & Collins, 2002; Vött, 2007). Especially the role of tectonism is important in tectonically active zones because it can counterbalance the relative SLR. Typical examples constitute the coastal zone of northern Peloponnese with an uplift rate ranging between 0.3 and 1.5 mm/year, Crete with an uplift rate between 0.7 and 4 mm/year and Rhodes between 1.2 and 1.9 mm/year. Thus, a supposed average value of 4.3 mm/year SLR would be reduced to 3.5 mm/year due to the counteraction of a mean tectonic uplift of about 0.8 mm/year (Papanikolaou et al., 2010). The expected sea level rise could also be locally offset by the increased fluvial sediment input and deposition in deltaic plains and resultant advance of the shoreline (Poulos et al., 2002). On the contrary, reduced fluvial sediment input in deltaic plains would reinforce sea inundation due to sea level rise. An important factor in the vulnerability of coastal areas to SLR is the coastal morphology (i.e. slope and lithological composition) because it is related directly to the rate of erosion. The latter can range from very high (several m/year) in the case of low-lying land to low (approximately mm/year) in the case of hard coastal limestone formations (e.g. cliffs).
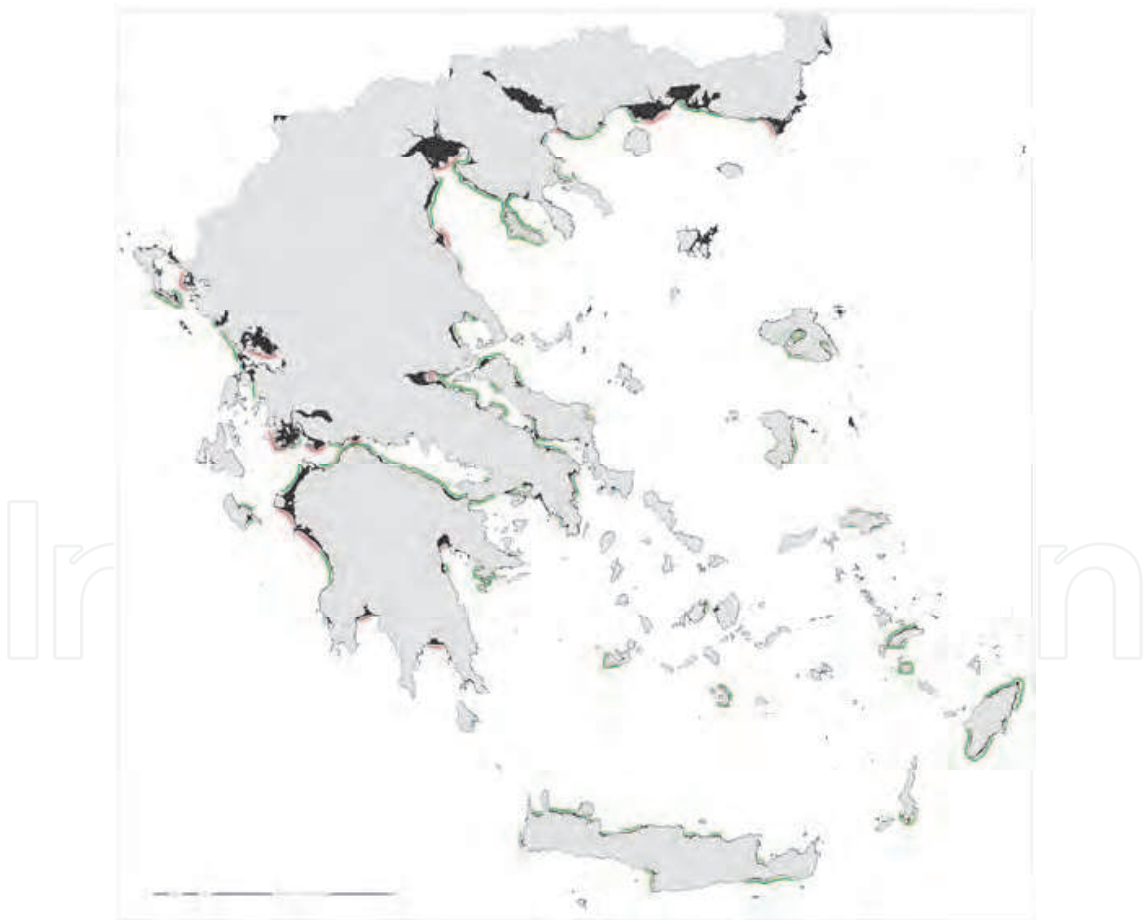

Fig. 2. Coastal areas in Greece with medium (green colour) and high (red colour) vulnerability. Black colour indicates areas with altitudes below 20 m, usually of loose sedimentary deposits. (Source: Papanikolaou et al., 2010)

In Figure 2, coastal areas are subdivided into: (a) those classified as of medium vulnerability to SLR (green colour) consisting of non consolidated sediment deposits in areas with low altitude, (b) those classified as of high vulnerability to SLR including deltaic deposits in low altitude (red colour). High risk areas are deltaic areas such as Evinos in Messolonghi, Kalama in Igoumenitsa, Acheloos, Mornos at the Corinthian Gulf, Pineios, Alfeios, Aliakmonas and Axios at the Thermaic Gulf, the area of North Aegean near Platamona, Amphipolis, Strymon, Nestos (to Abdyra), the Ebros, and the deltaic areas in Malliakos, Amvrakikos, Messiniakos and Argolikos Gulfs. Black colour indicates areas with altitudes below 20 m, usually of loose sedimentary deposits. The other zones designated as coastal areas of a low vulnerability are mainly rocky and high altitude coastal regions.

Assessing the severity of the rising sea level impacts on coastal areas includes uncertainties with regard to:

a. The intensity of sea level rise, which ranges between 0.2 and 2 meters. The evolution of the sea level rise is determined by the interaction between several natural (e.g. astronomical parameters) and anthropogenic (e.g. greenhouse gas) forces. The severity of each one of these will also determine the overall development of the climate cycle we are currently in, which seems to be at the peak of today's "warm" interglacial period.

b. The relationship between the tectonic elevation and the eustatic sea level rise which, for many areas of the Greek territory is quite significant, to the extent that it may counterbalance or locally exceed the sea level rise.

c. the sedimentation of clastic materials in coastal areas, which is determined by geological and climate conditions but also by anthropogenic interventions (e.g. dams, river sand mining), which for instance in the case of river deltas, may alter their vulnerability to the sea level rise.

The estimation of the length of these three types of coastal areas shows that from a total of 16,200 km, 960 km (6%) corresponds to deltaic areas of high vulnerability (red colour), 2,400 km (15%) to non consolidated sediments of medium vulnerability (green colour) and the remaining 12,810 km (79%) to rocky coastal areas of low vulnerability. Therefore, the total coastline length characterized by medium to high vulnerability to SLR is about 3,360 km representing 21% of the Greek shoreline (Papanikolaou et al., 2010).

Typical approximate values of flooded coastal areas and shoreline retreat (excluding the tectonics and geodynamics corrections) triggered by a possible SLR equal to 0.5 m and 1 m in high risk areas are presented in Table 2. This table illustrates the impacts of SLR as estimated in 27 Greek coastal zone case studies. Available case studies were surveyed through a literature review till September 2010. The coastal land retreat for a hypothetical increase of SLR equal to 0.5 m ranges from 15 m to 2,750 m, while the range for a hypothetical increase of 1 m ranges from 400 m to 6,500 m. Figure 3 maps the geographical distribution of the examined case studies.

The selected case studies used for the economic assessment of SLR impacts on Greek coastal zone are: C1: Skala Eressos Mytilene, C2: Gulf of Nafplio, C3: Lagoon Kotichiou, C4: Hersonissos Crete, C5: Aigio Achaias, C6: Lambi Kos, C7: Kardamaina Kos, C8: Tigaki Kos, C9: Afantou Rhodes, C10: Vartholomio Ileias, C11: Acheloos River Delta, C12: Plain of Thessaloniki, C13: Abdyra Xanthi, C14: Lake Alyki Limnos, C15: Saltmarsh Kitrous Pierias, C16: Porto Heli, C17: Ermioni, C18: Evinos River Delta, C19: Mornos River Delta, C20: Kalama River Delta, C21: Penaeus River Delta, C22: Thermaic Gulf (includes Axios River Delta, Aliakmonas River Delta, Loudias-Aliakmonas Deltaic plain), C23: Kiparissiakos Gulf (includes Alfeios River Delta - northern part and Alfeios River Delta - southern part), C24: South Euboean Gulf.

Coastal area	SLR (m)	Inundated area (10^3 m²)	Length/Area of shoreline	Source
Skala Eressos Mytilene	0.3	28	2.5 km	Doukakis, 2008
Gulf of Nafplio	0.5	4,200	25 km	Doukakis, 2005a
	1	8,700		
Lagoon Kotichiou	0.5	720	27.6 km	Doukakis, 2003
	1	1,760		
Hersonissos Crete	0.5	4,700	20 km	Doukakis, 2004
	1	5,200		
Aigio Achaias	0.5	1,070	6.8 km	Doukakis, 2005b
	1	1,800		
Lambi Kos	0.5	35	0.25 km	Papadopoulou & Doukakis, 2003
	1	52		
Kardamaina Kos	0.5	19	0.615 km	
	1	33		
Tigaki Kos	0.5	161	2.7 km	
	1	322		
Afantou Rhodes	0.5	375	3 km	
	1	439		
Vartholomio Ileias	0.5	190	2.65 km	
	1	300		
Acheloos River Delta	1	72	5.8 km	Doukakis, 2007
Plain of Thessaloniki	1	37,100	41.2 km	Kanelakis & Doukakis, 2004; Doukakis, 2007
Abdyra Macedonia	1	716	7 km	Doukakis, 2007
Lake Alyki Limnos	1	2,041	4.3 km	Pliakos & Doukakis, 2004; Doukakis, 2007
Saltmarsh Kitrous Pierias	0.5	9,450	-	Stergiou & Doukakis, 2003
	1	11,800		
Porto Heli	0.5	36	38.93 km	Seni & Karibalis, 2007
	1	161		

Ermioni	0.5	19	19.903 km	
	1	278		
Evinos River Delta	0.5	12,500	92 km2	Karibalis & Gaki-Papanastasiou, 2008
	1	21,300		
Mornos River Delta	0.5	2,580	28 km2	
	1	3,710		
Kalama River Delta	0.5	7,020	78 km2	
	1	10,060		
Penaeus River Delta	0.5	6,530	69 km2	
	1	14,780		
Alfeios River Delta (northern part)	0.5	224	110 km2	Poulos et al., 2009
	1	683		
Alfeios River Delta (southern part)	0.5	35		
	1	344		
Axios River Delta	0.5	10,825	390 km2	
	1	28,482		
Aliakmonas River Delta	0.5	4,875	120 km2	
	1	8,950		
Loudias-Aliakmonas Deltaic plain	0.5	8,900		
	1	25,575		
South Euboean Gulf	0.5	7,890	18.5 km	Roussos & Karibalis, 2009
	1	12,620		

Table 2. Shoreline retreat and inundated area for potential SLR of 0.5-m and 1-m.

Apart from long-term SLR, other climate phenomena capable of causing coastal erosion , are the foreseen increase of storminess / frequency of storm surges (IPCC, 2007).

Storm surges and SLR are distinct phenomena. However, climate change may increase the risk of storm surges by changing two drivers: cyclone 's frequencies/intensities and the mean sea-level rise (McInnes et al., 2000; Emanuel, 2005). The interannual and decadal variability in time of extremes is caused by mean sea level changes (Marcos et al., 2009).Changes in mean sea level and changes in the meteorological strength of storm surges (enhanced by climate change) may cause extreme wave phenomena and, accordingly, serious damage on coastal areas. This happens because strong winds affect larger water masses which unleash more energy to storm surges, while the height of the waves increases relatively to the mean sea level rise; as a result the waves further penetrate coastal areas and have significant impacts on coastline morphology. The strong coastal waves caused by the stormy winds cause erosion, while the normal, low-mid energy waves cause sediment deposition (Komar, 1998). The impacts of storm surges include:

• Flooding of coastal areas.
• Destruction of coastal infrastructure
• Coastal erosion.
• Intrusion of salt water in coastal habitats, lagoons, rivers e.t.c.

Fig. 3. Map of Greece displaying the 27 case studies (Google Earth).

3. Methodology and research hypotheses

In the present paper, we approach the assessment of economic impacts of SLR with respect to two different aspects: long-term (2100) and short-term (annual) damages. The long-term losses follow the gradual SLR as specified by the IPCC scenarios for 0.5-m and 1-m elevation. The short-term financial appraisal of losses is based on the increased frequency and intensity of storm surges, a consequence of climate change taking place in parallel to long-term SLR. The inclusion of such short-term losses in the estimation of SLR impacts follows IPCC and other experts' opinion (IIPCC CZMS, 1992; Hoozemans et al., 1993; McInnes et al., 2000; Emanuel, 2005; Velegrakis, 2010).

Referring to the long-term impacts, losses of the following land uses are quantified and evaluated:

- Housing
- Tourist
- Agriculture
- Wetlands
- Forestry

Selection was based on data availability from 27 case studies of the Greek coastal area (Table 2). Based on these studies, the total loss of land for the five uses under investigation and for 0.5-m and 1-m elevation is assessed. Then, for housing, tourist and agricultural uses, a market pricing approach is drawn on in order to estimate unit and total financial losses. For wetlands and forestry we rely on the widely used application of value transfer (Navrud & Ready, 2007). Loss of public infrastructure (airports, ports) and industrial zones were not taken into consideration. More specifically:

Housing and tourist uses

The cost assessment of these impacts - both in the 27 case studies as well as the wider coastline area - was achieved by multiplying the total area lost in each case by the mean market value of property in the specific area. Two problems were faced here: the sparse data regarding land uses in the case studies, and the wide variation of prices for land property. So the value of 1,200 €/m² was selected as the mean estimated market value of property, which better reflects the mean land price for housing and tourist purposes. This is equivalent to a similar figure (1300 €/year) a rough estimation by Velegrakis at al. (2008), representing the mean income from tourist activities per meter of Greek beach.

Agriculture

Assessment of the cost of loss of farmland was achieved by multiplying the lost area with the "specific basic value" (SBV) of the farmland for each location investigated. SBV represents the value of a square meter of non-irrigated farmland of yearly crop cultivations, as determined by the Ministry of Economics for property tax purposes. SBV applies only in areas facing roads or located up to 800 meters from the sea.

Wetlands

To estimate the cost of wetland losses, the total area of wetlands expected to be lost due to SLR is multiplied by their unit value. The unit value for wetlands (4.8 million €/km²) was 'transferred' from Darwin and Tol (2001), a well-known study regarding appraisal of SLR impacts. Table 3 depicts the social values for certain Greek wetlands.

Wetland	Value
Kerkini lake (conservation of terrestrial wetland)	21.3 €/household per year
Kalloni wetland (coastal wetland)	184-300 €/household
Heimaditida lake (conservation of terrestrial wetland)	115.3-144.1 €/household
Heimaditida & Zazari lakes (conservation of terrestrial wetlands)	134.8-226.4 €/household per year
Zakynthos National Marine Park (conservation of a marine park)	0.9-4.3 €/visitor
Plomari & Vatera beaches-Lesvos island (conservation of pocket beaches)	15 €/visitor per year
Karla lake (restoration of wetland)	27.4 € per trimonth for 3 years/household

Table 3. Social values for Greek wetlands.

Forests

The cost for loss of forests was based on the unit value of Greek forests (89.25 €/ha) as estimated in the study of Kazana and Kazaklis (2005).

The estimated value of the five coastal uses indicates the (future) financial loss due to SLR. A cost index is then calculated based on the estimated cost of impacts due to loss of housing, tourist, wetlands, forestry and agriculture land uses, as well as on the total length and area of the coastline examined in each case study. This index estimates the financial cost of SLR per km or km² of coastline, based on data available in each case. All unit values used were adjusted across locations and time on the basis of the Purchasing Power Parity Index (PPPI) and Consumer Price Index (CPI) (Pattanayak et al., 2002).

From a socioeconomic point of view, the accompanying phenomenon of intensified storm surges (what we call here the short-term impacts of SLR) is equally interesting as the long-term impacts (over a horizon of 90 years) accelerated SLR. To our knowledge, financial impact studies regarding storm surges in Greece do not exist. Financial calculations of the impacts of past storm surges from regional authorities are limited and incomplete. To fill this data gap, a stated preference survey was designed and implemented in order to elicit social welfare losses from short term SLR (Kontogianni, 2011). Our short-term estimation of SLR impacts is based on findings of this survey.

To properly appraise the coastal system and its total economic value, the totality of ecosystem services and goods described in Table 1 has to be evaluated (Skourtos et al., 2005). Our results indicate a partial value of the coastal zone, taking into consideration the five aforementioned uses. Consequently, our appraisal constitutes a lower threshold of the future losses due to SLR. At a second level, and in order to highlight the 'true' but unknown total economic value of SLR damages, the equally important aesthetic values of these areas are also estimated on the basis of values transferred from Brenner et al. (2010).

Finally, the present value of losses was estimated by discounting total amounts with interest rates of 1% and 3%. The selection of a suitable (social) discount interest rate is a vital parameter for similar long-term estimations. Economic theory and practice are not in a position to provide a definite answer on the choice of discounting rates, since in essence the issue of discount interest rate is a moral issue related to perceptions of intergenerational justice. For example, in OECD countries, the proposed discount interest rates for long-term investments range between 3 - 12% (OECD, 2007). The European Union recommends a 4% interest rate for mid- and long-term investments but also accepts implementation of lower interest rates in the case of extended timelines, such as climate change (European Commission, 2005).

4. Costing the damages of sea level rise

This section presents our results on the base of the proposed methodological approach for the evaluation of the financial loss due to the long-term impacts of SLR as well as the monetary estimates of the short-term impacts of SLR caused by storm surges. Aesthetic values are also estimated and added up to approach the total coastal value.

4.1 Financial impacts of long-term sea level rise

The loss of coastal land according to scenarios for a sea level rise of 0.5 m and 1 m, as specified in the case studies under examination, is presented in Table 2. The financial value of land loss in the case studies is then calculated as the area to be flooded times the

respective unit value for each specific land use. As a next step, cost coefficients are calculated for a SLR of 0.5 m and 1 m for housing, tourist and agricultural land uses, plus wetlands and forests. The cost coefficients are the quotient of the financial value of land loss in a specific location divided by the length/area of the coastline at this location. As a result, these coefficients comprise quantified indications of the overall financial loss expressed per km/km² of coastline for the five land uses examined. The values that were finally selected in terms of mean values for cost coefficients, the length and the area of the coastline per land use, are presented in Table 4.

Land use	Average cost coefficients		Length/Area of Greek shoreline
	SLR 0,5 m	SLR 1 m	
Housing & Touristic	144,891 10^3 €/km	262,851 10^3 €/km	2,400 km
Wetlands	138 10^3 €/km2	247 10^3 €/km2	1,000 km2
Forests	0.04 10^3 €/km2	0.13 10^3 €/km2	4,000 km2
Agriculture	222 10^3 €/km2	514 10^3 €/km2	35,511.5 km2

Table 4. Values for the average cost coefficients, the length and the area of the coastline per land use.

The estimated financial loss from the case studies is then extrapolated to the Greek territory. The total financial loss of SLR for the Greek coastal zone in 2100 is presented per land use in Table 5.

Land use	Total financial loss 2100 (10^3 €)	
	SLR 0.5 m	SLR 1 m
Housing & Touristic	347,738,400	630,842,400
Wetlands	138,000	247,000
Forests	160	520
Agriculture	7,883,553	18,252,911
Total	355,760,113	649,342,831

Table 5. Total financial loss of SLR in 2100 per land use.

The estimates of financial loss in 2100 were converted to present values using discount rates of 1% and 3%. The results are presented in Tables 6 and 7 respectively.

Land use	Total financial loss 2010 (10^3 €)	
	SLR 0.5 m	SLR 1 m
Housing & Touristic	142,013,297	257,630,475
Wetlands	56,358	100,873
Forests	65	212
Agriculture	3,219,574	7,454,328
Total	145,289,294	265,185,888

Table 6. Present value of total financial loss of SLR per land use for discount rate 1% (not including aesthetic/recreational/ storm surge damages).

Land use	Total financial loss 2010 (10^3 €)	
	SLR 0.5 m	SLR 1 m
Housing & Touristic	24,316,576	44,113,412
Wetlands	9,650	17,272
Forests	11	36
Agriculture	551,279	1,276,386
Total	24,877,517	45,407,106

Table 7. Present value of total financial loss per land use for discount rate 3% (not including aesthetic/recreational/ storm surge damages).

The aggregated results are presented in Table 8 under three discounting assumptions: 0%, 1% and 3%.

	SLR 0.5m	SLR 1m
NPV (0%)	355,760,113	649,342,831
NPV (1%)	145,289,294	265,185,888
NPV (3%)	24,877,517	45,407,106

Table 8. Total long-term financial loss of SLR in Greek coastal zone under different discount rates (10^3 €) (not including aesthetic/recreational/ storm surge damages).

At this point we need to remind the reader that the estimated loss in Tables 4, 5 and 6, are in their majority expressions of use values, with the possible exception of wetland areas, the transferred value of which might include, in part, non-use values. But non-use value components (e.g. cultural and spiritual) comprise a non-negligible part of the total economic value of coastal ecosystems in Mediterranean countries (Langford et al, 2001, Remoundou et al 2009).

To support the aforementioned position, and aiming at providing an approximate expression of the potential loss of these values, we also quantify the aesthetic/recreational and cultural/spiritual values of the Greek coastal zone. The estimation is based on transferring the corresponding values from Brenner et al. (2010) study, where the aesthetic/recreational and cultural/spiritual value of sandy and wetland areas of Katalonia, Spain, were estimated. A discussion could be raised at this point on whether adding up those values in the previous sum consists a double counting in our estimated loss due to SLR. This position could be founded on the fact that we already used market price values for housing, so one could suppose that the market had already integrated those values (at least the aesthetic/recreational) into housing prices. Ledoux et al state that 'the socio-cultural and historical contexts in which environmental assets exist provide for alternative dimensions of environmental value which may not be captured by the market paradigm'.

To minimize the possibility of overestimating our economic assessments, we abide to a strategy of using conservative estimates of financial losses while trying to avoid double counting. On the other hand, as long as we do not control for induced market adjustments, future damage estimates may be grossly overestimated. For example, the housing/tourist value of the coastal land represents a significant parameter in our damage estimates. Assuming risks regarding accelerated SLR and increasing incidents of extreme weather effects come gradually to the fore, a well functioning market for coastal land will probably internalize and discount future hazards. As a consequence, land values in coastal areas

should gradually depreciate solely as a consequence of costal risk anticipation. Therefore, future damages would also be diminished (Karageorgis et al, 2006).

Regarding the estimation of aesthetic/recreational and cultural/spiritual loss, the cost coefficients which were adopted in the current analysis are presented in Table 9.

Land use	Value	Average cost coefficients		Length/Area of Greek shoreline
		SLR 0,5 m	SLR 1 m	
Housing & Touristic	aesthetic/recreational	352 10^3 €/km	639 10^3 €/km	2,400 km
	cultural/spiritual	0.6 10^3 €/km	1.0 10^3 €/km	
Wetlands	aesthetic/recreational	0.1 10^3 €/km2	0.3 10^3 €/km2	1,000 km2
	cultural/spiritual	1 10^3 €/km2	1.8 10^3 €/km2	

Table 9. Values for the average value coefficients, the length and the area of the coastline per land use.

The estimated aesthetic/recreational and cultural/spiritual loss from the case studies is then projected to the whole Greek territory. The total loss of SLR for the Greek coastal zone in 2100 is presented per land use and value type in Table 10.

Land use	Value	Total loss 2100 (10^3 €)	
		SLR 0.5 m	SLR 1 m
Housing & Touristic	aesthetic/recreational	844,800	1,533,600
	cultural/spiritual	1,440	2,400
Wetlands	aesthetic/recreational	100	300
	cultural/spiritual	1,000	1,800
Total		847,340	1,538,100

Table 10. Total aesthetic/recreational and cultural/spiritual value loss of SLR in 2100 per land use.

The above estimates in 2100 were converted to present values using discount rates of 1% and 3%. The results are presented in Tables 11 and 12 respectively.

Land use	Value	Total loss 2010 (10^3 €)	
		SLR 0.5 m	SLR 1 m
Housing & Touristic	aesthetic/recreational	345,009	626,309
	cultural/spiritual	588	980
Wetlands	aesthetic/recreational	41	123
	cultural/spiritual	408	735
Total		346,046	628,146

Table 11. Present value of aesthetic/recreational and cultural/spiritual value loss of SLR per land use for discount rate 1%.

Land use	Value	Total loss 2010 (10^3 €)	
		SLR 0.5 m	SLR 1 m
Housing & Touristic	aesthetic/recreational	59,075	107,241
	cultural/spiritual	101	168
Wetlands	aesthetic/recreational	7	21
	cultural/spiritual	70	126
Total		59,253	107,556

Table 12. Present value of aesthetic/recreational and cultural/spiritual value loss per land use for discount rate 3%.

The aggregated results are presented in Table 13 under three discounting assumptions: 0%, 1% and 3%.

	SLR 0.5m	SLR 1m
NPV (0%)	847,340	1,538,100
NPV (1%)	346,046	628,146
NPV (3%)	59,253	107,556

Table 13. Total aesthetic/recreational and cultural/spiritual value loss of SLR in Greek coastal zone under different discount rates (10^3 €).

4.2 Welfare losses due to storm surges: The short-term impacts

Storm surges are the short-term aspect of the SLR phenomenon, with significant annual impacts on coastal areas. Knowledge of sea level extremes is important for coastal planning purposes (Marcos et al., 2009; Krestenitis et al., 2010). We consider it necessary to include these impacts in our study, due to their economic aspects and their potential yearly repetitiveness, which may induce an increase in coastal vulnerability. But since economic data on short term damages are limited and do not allow for extrapolation of loss to the total Greek coastal zone, an additional stated preference survey was conducted in order to elicit the social cost of storm surges (Kontogianni, 2011).The social cost of storm surges is defined as the maximum Wilingness to Pay to avoid the loss. As Ledoux et al. (2001) describe it 'in environmental economics, an individual preference-based value system operates in which the damages from environmental loss are measured by social opportunity cost . The assumption is that environmental goods and services are of instrumental value and some individual is willing to pay for the satisfaction of a preference. It is taken as axiomatic that individuals almost always make choices, subject to an income budget constraint, which benefit themselves or enhance their welfare. The social value of environmental resource committed to some use is then defined as the aggregation of private values'.

In Kontogianni 2011 an open ended contingent valuation survey was designed where participants were asked their willingness to pay to fund the construction of storm surge protection works in their area. The mean willingness to pay of the respondents was statistically estimated at 200.7 € per household (standard deviation = 286 €).

According to the "Report of Greece on Coastal Zone Management" (YPEXODE, 2006), coastal populations represent 85% of the total population (10,934,097 inhabitants), that is 9,293,982 inhabitants. Assuming an average of 3 persons per household, the total number amounts to 3,674,381 Greek households, out of which 3,097,994 are located in coastal areas. Using the mean value of 200.7 € per household, and extrapolating this to the Greek coastal

population, the total value for protection from short term SLR for Greek households amounts to 621,767,426 €.

4.3 Social perceptions for climate change, SLR and storm surges

Reducing vulnerability is a goal for preventative adaptation. Recent literature regarding vulnerability and adaptation, accentuates the need to take measures and plan policies on two levels: 1. Technological, 2. Institutional and behavioral. Assessment of vulnerability and risks (used as input for decision making), must also be implemented on two levels: objective and subjective (Fischhof, 1995; Slovic, 1979; Douglas, 1982; Adams, 1995; Kasperson, 1988; Kontogianni et al., 2008). By subjective assessment of risks, we mean the social perceptions of risk which are not necessarily identical to the objective assessment. For a more thorough understanding of the social perceptions of risk due to climate change in Greece, two research projects were designed and implemented, in Lesvos in 2010 and in Crete on January 2011. Their findings are comparable and demonstrate the dynamics in the respondents' perceptions, compared to a similar research conducted for the first time in Greece in South Evoia, in 2003-2004 (Kontogianni 2011). Among others, the following areas were investigated: whether respondents were aware of the climate change , whether they were aware of the causes and which they believe these causes are, their level of trust in institutions, how important they assess that the various climate change impacts are, whether they are prepared to cope with them as well as if they are willing to incur costs in order to protect themselves (from the impacts). The research in Evoia, a coastal region close to Athens, performed in 2003, shows that 87.4% out of 183 respondents regards that in a global level, climate change constitutes a very important problem, while only 2.4% believes it is of no importance. For their personal welfare, climate change represents an important risk factor (79.7%), while only 7.3% regard it irrelevant to their lives. Concerning impacts on biodiversity, 59.2% of the respondents express serious concerns, while 13.8% does not worry about it.

During July-August 2010 in Lesvos island, 312 respondents were asked about climate change. The majority (97.1%) is aware of the climate change, and 58.8% of them believe that it is directly influencing their lives. Out of the 312 respondents 27.3% believe that climate change impacts will be visible and destructive within the next 20 years, while 12.9% within the next 100 years. Only 3 out of 312 people refused the existence of climate change impacts. The survey participants (islanders) were asked to rank and assess the severity of certain impacts. Results are given in Table 14. It is quite conceivable that 91.9% rank impacts on coasts important to extremely important.

Impacts on	Of no importance	Not so important	Important	Very important	Extremely important
Water resources	0,6%	1%	13,5%	33,9%	51%
Ecosystems	1%	3,2%	20,3%	45,8%	29,7%
Food availability	0,6%	1,9%	19,5%	33,1%	44,8%
Coasts	1%	7,1%	**18,5%**	**35,7%**	**37,7%**
Health	0,6%	2,3%	9,1%	21,0%	67%

Table 14. Climate change impacts assesment by survey respondents (Lesvos island, Greece, summer 2010).

Similar results were obtained from the implementation of a similar study in Crete island (January 2011) on the perceptions of locals referring to weather extremes. A random sample of 100 people were personally interviewed. Half of the respondents (50%) is aware of the climate change, while 17.5% has no information on the subject. Regarding the time horizon of the climate change impacts 57.5% of them believe that it is directly influencing their lives. Out of 100 usable questionnaires, 17.5% believe that climate change impacts will be visible and destructive within the next 20 years, while 20% believes so within the next 100 years. Only 5% refused the existence of climate change impacts. As in the Lesvos survey, participants (islanders) were asked to rank and assess the severity of certain impacts. Results are given in Table 15. It is quite conceivable that the majority (97.5%) rank impacts on coasts important to extremely important.

Impacts on	Not so simportant	Important	Very important	Extremely important
Water resources	-	2,5%	17,5%	80%
Ecosystems	2,5%	5%	40%	52,5%
Food availability	2,5%	5%	27,5%	65%
Coasts	2,5%	**2,5%**	**37,5%**	**57,5%**
Health	7,5%	5%	35%	52,5%

Table 15. Climate change impacts assesment by survey respondents (Crete island, Greece, January 2011).

In both surveys water and food availability seem to be the highest social concerns as far specific impacts of climate change are concerned.

5. Conclusions

In this chapter we have used market and non-market values to estimate the SLR damages in Greek coastal zone. We have also combined this assessment with a preliminary socio-economic analysis of coastal vulnerability and risk perceptions. The proposed methodological approach focused on the assessment of two different categories of economic impacts: long term inundation effects of SLR and short-term extreme weather effects. In this assessment we have also incorporated a rough estimation of the losses due to cultural, recreational and other non-consumptive elements of value. In order to reaffirm the policy relevance of applying economic assessment methods in Integrated Coastal Zone Management, UNEP (1999) introduces the notion of 'resource consciousnesses' into its Regional Strategic Environmental Action Plan. It is asserted accordingly that 'raw cost information is insufficient to support investment decisions' what is needed is an investment plan where 'benefits [..] derived from the reduction or avoidance of pollution impacts on resources of social, economic and environmental value' are demonstrated. Moreover, in order for benefit estimates to be of relevance to prospective investors, their definition should include 'the conservation of resource for their existence (or non-use) value' [UNEP 1999, pp. 67-69].
Conservation (ie coastal protection measures) should be adopted if it can be demonstrated that net economic benefits are generated. So we need the total cost of SLR to compare it with the relevant conservation measures (benefit).

Tables 16 and 17 present the total SLR cost for discount rates of 1% and 3% correspondingly. Total cost here means the sum of long-term SLR, short-term SLR and non-use values (aesthetic/recreational and cultural/spiritual value loss). The total discounted SLR cost equals 2% of the Greek GDP (in 2010 prices).

Loss	Total loss 2010 (10^3 €)	
	SLR 0.5 m	SLR 1 m
Long-term SLR	145,289,294	265,185,888
Short-term SLR	621,767	621,767
Non-use values	346,046	628,146
Total	146,257,107	266,435,801

Table 16. Present value of total cost of SLR for discount rate 1%.

Loss	Total loss 2010 (10^3 €)	
	SLR 0.5 m	SLR 1 m
Long-term SLR	24,877,517	45,407,106
Short-term SLR	621,767	621,767
Non-use values	59,253	107,556
Total	25,558,537	46,136,429

Table 17. Present value of total cost of SLR for discount rate 3%.

Our study shows that there is an imperative need to study Greek coastal areas that are at high risk of flooding. This need is expanded to the detailed diagnosis/forecasting of the coastal zone's vulnerability also due to changes in the frequency/intensity of extreme weather phenomena (storm surges). From an institutional aspect, EU member states, according to Directive 2007/60/EC, must undertake a preliminary assessment of river basins flood risk (including coastal zone) by year 2011, aiming to identify areas where flooding is likely to occur. Moreover, by year 2013, member states must develop risk assessment maps for these areas, while by year 2015, member states must prepare flood risk management plans for these zones.

The principal determinant of a society's capacity to adapt to climate change is likely to be access to resources. Such access is determined by entitlements, which are often the product of external political factors. Therefore, poverty, inequality, isolation and marginalization can all undermine entitlements of individuals and groups (Adger et al., 2005). In Greece due to the imminent economic crisis the country is currently experiencing, poverty is a threatening factor; inequality is a social characteristic due to corruption; so entitlements of individuals and groups are under threat of undermining. A particularly coastal country facing SLR impacts finds itself within a vulnerable status. Is the country going to bounce back after the economic shock and prepare itself for adaptation to SLR? According to Tompkins et al. (2005) the basic preconditions for resilience are: ability to self-organize, ability to buffer disturbance and capacity for learning and adapting. Or as Handmer (1996) puts it: Stability is sought but change constantly redraws the playing field and demands redefinition of the rules.

6. Acknowledgment

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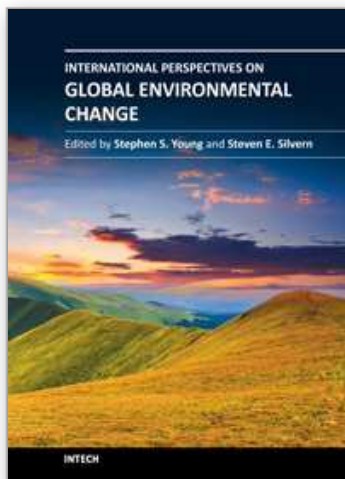
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