MULTIDISCIPLINARY VULNERABILITY ASSESSMENT FOR THE GREEK COASTAL AREAS DRIVEN BY THE GREENHOUSE EFFECT

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ABSTRACT
Over the last hundred years, global climate change has warmed by about 0.6° C and global temperatures are expected to rise from 1.5° to 5.5° C by the end of this century. It is believed that warming of this magnitude and speed has not occurred in the last ten thousand years. The purpose of this study is to examine the multidisciplinary vulnerability assessment methodology applicable to the Greek coastal areas, which is critical in the development of the mitigation strategy. The assessment process will help local mitigation planning organizations define the hazards threatening their jurisdictions, identify the vulnerability of the hazards and estimate how often such hazardous phenomena could occur.

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ΠΕΡΙΛΗΨΗ
Κατά τη διάρκεια των τελευταίων 100 χρόνων, η άνοδος της παγκόσµιας θερµοκρασίας ήταν περίπου 0.6° C, και αναµένεται δε να αυξηθεί από 1.5° έως 5.5° C μέχρι το τέλος του αιώνα. Πιστεύεται ότι τόση αύξηση στη θερμοκρασία είχε να παρατηρηθεί για περισσότερο από δέκα χιλιάδες χρόνια. Ο σκοπός της εργασίας είναι να εξετάσει μια πολυπλεξηδή μεθοδολογία εκτίμησης της εμβαλότητας των Ελληνικών παράκτιων ζωνών, κρίσιμη για την ανάπτυξη και τη μείωση των επιπτώσεων σ’ αυτές. Η διαδικασία αυτής της εκτίμησης μπορεί να βοηθήσει τους οργανισμούς σχεδιασμού να προσδιορίσουν τους κινδύνους που απειλούν, την εμβαλότητα των παράκτιων περιοχών και τη συχνότητα εμφάνισης των επικίνδυνων φαινομένων.
1. INTRODUCTION

It is well known today that sea level rise is one of the most important potential impacts of global climate change. Global average sea level has been rising over the last 100 years and global warming is expected to increase the annual rate of sea level rise by two to five times. An increase of this magnitude could inundate coastal areas, erode beaches and exacerbate coastal flooding. The costs associated with the protection of shorelines globally would be enormous. The threat of sea level rise spans a huge range of possible impacts from the relatively small and manageable to the catastrophic. One must include, in any calculation of the effects of sea level rise, a rapidly growing human population that relies heavily on coastal lands for food, recreation and natural resources. The majority of the world’s people live near sea level in large coastal cities or on coastal plains. Although more work needs to be done to quantify the number, a common estimate is that a 50 to 70 percent of humanity lives within the coastal zone. That means, that millions of people are presently live in the flood zone and are exposed to a storm surge in an average year and that the number will double if sea level rises 50 cm [1]. However, like picnickers on the beach ignoring the coming high tide, we all show little inclination to retreat from the edge. For this reason, we could refer to the trends of sea level rise and coastal population growth as a “collision course”. Responding to sea level rise by retreat, accommodation or protection we will impose a complex set of hard choices on society that will vary widely around the globe. Many issues including geography, technology, human resources, politics, cultural acceptance and economic considerations will dictate the choices made. It has become common knowledge that the poor are likely to be hit hardest by climate change, and the capacity to respond to climate change is lowest in developing countries and among the poorest people in those countries. It seems clear that the vulnerability to climate change is closely related to poverty, as the poor are least able to respond to climate stimuli.

The most serious physical impacts of climate change on coastal margins will be:
- Coastal erosion and shoreline change through sediment movement
- Coastal inundation causing landward displacement of estuaries, wetlands and marshes
- Increased vulnerability to coastal storm damage and episodic flooding
- Surface water, river water and ground water in lowlands becoming increasingly saltier from saltwater intrusion
- Increased difficulty draining coastal and river lowlands

The primary ecological impacts will stem from a rise in temperature, inundation and loss of habitat from increased sedimentation on intertidal areas and loss of intertidal areas where shoreline protection prevents the sea moving further inland.

The Intergovernmental Panel on Climate Change (IPCC) in its Second Assessment Report, defines vulnerability as “the extend to which climate change may damage or harm a system depending not only on a system’s sensitivity but also on its ability to adapt to new climate conditions” [1]. Consequently, vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capability. The topic of the environmental vulnerability is concerned with the risk of damage to the natural environment of a country. For the natural environment, the entities at risk include ecosystems, habitats, populations and communities of organisms, physical and biological processes, energy flows, diversity, genes, ecological resilience and ecological redundancy. Each of these entities may be affected by natural and anthropogenic hazards,
the risk of which may vary with time, place and human behavior. The complex natural vulnerability has required the development of vulnerability theory to provide a framework for logical development and measurement.

The vulnerability assessment is a critical step in the development of a local mitigation strategy. The assessment process helps local mitigation planning organizations define the hazards threatening their jurisdictions, how their communities are vulnerable to those hazards and how often such hazardous events could occur. This type of information can enable the government to better understand how it can develop programs to save lives, protect property and enhance future economic stability of its community. The vulnerability assessment enables local authorities to identify the hazard mitigation initiatives needed, to assign a priority for implementation of each initiative and to provide real basis justifying their implementation.

The methodology for the multidisciplinary vulnerability assessment followed in the present study is threefold:

1. Hazard identification
2. Vulnerability assessment and
3. Risk analysis

In simple words, one must first identify the hazards, assess their vulnerability and analyze their risks on the coastal environment.

2. HAZARD IDENTIFICATION

The vulnerability assessment process begins with the identification of all of the principal hazards threatening the coastal environment. Hazard identification information defines the natural, technological and societal hazards that threaten the coastal areas, as well as the areas or systems threatened by those hazards. Examples of the three above categories of hazards read:

1. Natural hazards: severe thunderstorm, drought, flood etc.
2. Technological hazards: hazardous material accident, water system failure, coastal oil spill etc.
3. Societal hazards: civil disturbances, economic crisis, terrorism etc.

Identifying and characterizing the hazards threatening the coastal areas will often require a significant amount of information. Public and private sector will already have a substantial amount of such information and data. Both information and data may either precisely define specific hazard areas, such as flood plain maps, or provide a more general insight to the geographical areas vulnerable to specific types of hazards, such as those locations of the country subject to severe winter weather. This information provides hazard identification information that is vital to successfully completing its vulnerability assessment process. In addition, the responsible board (e.g. the organization for preventing natural disaster impacts) may have other information regarding facilities using or storing hazardous materials or locations of repetitive flood damage, wildfire risk or other types of hazards. These data sets should be available in a geographical information system (GIS) format, making it easy to use them in conjunction with the incoming information.

When the hazards have been identified and their mode of impacting people and property characterized, the responsible organization can begin to define the actual vulnerabilities of the coastal
areas and communities. The mapping process begins with estimating the geographical area likely to be affected by the impacts that a specific hazard can cause. When the geographical boundaries of specific types of hazards and/or their impacting agents have been estimated or defined, they can be illustrated on maps, preferably using a GIS program. This will offer several advantages [2]:
A/ it will make the subsequent planning effort easier and more accurate, because different maps and databases can be readily compared and updated.
B/ existing databases can be used within a GIS environment to support the subsequent planning process.
C/ the use of a GIS environment will further provide the responsible organization with significantly more flexibility later in the process to analyze different options for mitigation initiatives.

The process to define the geographical areas that could be affected by a hazard should consider that disasters occurring in one geographical region could have direct impact in another due to the failure of a system to provide vital services or products to the community. Such system failures can occur as a result of all types of hazards and are often associated with damage to the “lifelines” or the linear components of the infrastructure important for sustaining normal community functioning. In identifying geographical areas vulnerable to the impacts of lifeline system failure, two factors must be considered:
1. Often, the vulnerable geographic area coincides with the service area of a particular lifeline system, such as the area served by a municipal water system or a specific electric power substation and
2. Lifeline systems often have specific components that are most vulnerable to failure during a disaster and, if damaged, have widespread consequences.
In considering system failure at such critical points, it is often possible to identify a specific geographical area that could be impacted, and to predict the safety, health and economic impact that could result within the area. Therefore, the responsible organization will also be interested in mapping the geographic areas vulnerable to the impacts of such a lifeline system failure.

When the areas vulnerable to the identified hazards have been delineated and mapped, the responsible organization is then positioned to identify the extent of the community’s potential vulnerability to each hazard. This is done by identifying the people, property, economic resources and valuable environmental features that are within the hazard areas, and then including this information on the hazard maps being prepared. Needless to state that the major objective of the identification of the vulnerability of its hazard will be to protect people from the health and safety impacts of disasters. Therefore, with the hazard areas for specific types of threats delineated, the population that may be threatened within those areas should also be defined. Important data must be readily available to the responsible organizations such as:
- Size of resident population
- Transient populations based on daily or seasonal changes (e.g. touristic population)
- Projected future populations and population density
- The population’s health, economic age and cultural characteristics.
Any or all of these characteristics of the population could be influential to the identification, prioritization and implementation of mitigation initiatives for the particular hazard zone.
3. VULNERABILITY ASSESSMENT

Vulnerability assessment is a systematic examination of building elements, facilities, population groups or components of the economy to identify features that are susceptible to damage from the effects of natural hazards. It is a function of the prevailing hazards and the characteristics and quantity of resources or population exposed to those effects. Vulnerability can be estimated for individual structures, for specific sectors or for geographic selected areas. The results of a vulnerability assessment can be used to prioritize mitigation activities and help inform disaster recovery, mitigation and response planning [3].

The vulnerability process is likely to be the origin of many of the mitigation initiatives to be included in the National Mitigation Strategy, or can otherwise demonstrate the need for their implementation. The number and type of mitigation initiatives developed from the findings of the vulnerability assessment could vary widely based on the approach taken by the responsible organization, the degree to which the process was focused and the actual vulnerabilities of the coastal community. Nevertheless, the process should identify the specific structural and non-structural mitigation initiatives that are needed to counteract the vulnerabilities identified.

The assessment of coastal vulnerability to climate-related impacts is a basic prerequisite for obtaining an understanding of the risks of climate change to the natural and socio-economic coastal system. At the global level, vulnerability assessment can serve to underline the overall significance of sea level rise for coastal communities and allows comparing the regional variations of sea level rise related risks. At this scale, vulnerability assessment demonstrates that anticipated impacts might exceed the coping ability of some coastal regions and nations. At the national and local level, vulnerability assessments are needed to identify the specifically vulnerable areas and sectors and reflect on the status of adaptation strategies designed to cope with adverse impacts such as flooding and erosion. It becomes clear that first order assessments carried out on a global level will not be sufficient to achieve all of the objectives. Instead, descriptions and analyses are needed to describe in greater detail the conditions that lead to site-specific exposures to risks of inundation, erosion or saltwater intrusion. Only on the basis of detailed and comprehensive information it will be possible for national and local policy makers to design the most appropriate response strategies, that is, to decide whether and which protection, accommodation or retreat options are most suitable for minimizing risks while optimizing future coastal resources use.

In spite of considerable interest in assessing coastal vulnerability to climate change, efforts are often damaged by the limited availability of data and resources for the assessment. Sometimes there has also been a mismatch between the available data, the level of effort and the sophistication of the models utilized in vulnerability assessments. In some cases, this has led to inappropriate expectations concerning the outcomes of the assessment studies. Analysis in the framework of a country like Greece should start with screening assessment, that is, a screening approach which focuses on one aspect of vulnerability, that of susceptibility. The results of the screening assessment can then be used to plan how the vulnerability assessment might be most effectively implemented. Next to vulnerability assessment, the planning assessment, involves analysis at an integrated level suitable for detailed coastal planning and would take place in the wider context of coastal management. Planning assessment asks more precise questions and, hence, the recommendations concerning possible adaptation measures would be precise.
Scenarios for vulnerability assessment reflect plausible future conditions of all environmental and socio-economic parameters of interest. Some parameters can be considered universally important, while others are more site-specific. Relevant parameters span the environmental or socio-economic and climate-induced or not climate-induced parameters. Coastal vulnerability assessments have focused primarily on scenarios of climate-induced changes in the environmental conditions of a study area. Nevertheless, scenarios of environmental and socio-economic developments not induced by climate change are increasingly being used in combination with climate scenarios. However, the fact that climate change will trigger socio-economic developments that in turn affect the manifestation of coastal impacts is as yet often ignored. These developments embrace autonomous and planned adaptation. The potential for adaptation and the dynamic effects of its implementation need to be considered as an integral part of vulnerability assessment, for example, by linking impact and adaptation scenarios.

It has to be stretched once more the vital importance of the acquisition of the basic data on a number of important parameters that characterize the study area. These data of the natural coastal system should include at least:

- Coastal topography
- Coastal geomorphology
- Relative sea level changes
- Dynamics and trends in sediment supplies
- Erosion and accretion patterns
- Meteorological and hydrological data
- Oceanographic data
- Ecosystem characteristics

Socio-economic data should include at least:

- Land use
- Cultural assets
- Economic assets
- Economic development
- Trends in resource use and
- Demographic development

Needless to state that it is vital to review critically any available material e.g. maps, aerial photographs, satellite images etc.) and previous studies that may have concluded results or contain background information relevant to vulnerability assessment.

4. RISK ANALYSIS

The final step in the vulnerability assessment process is to use the information gathered and analysis conducted to date as a basis to estimate the risk to which the coastal community is exposed to each hazard. A judgement regarding the risk of a specific type of event will be an important tool for the responsible organization to use later in prioritizing mitigation initiatives as they are developed from the vulnerability assessment results. Risk can be considered as a comparison of the consequences of an incident with the probability that such an incident could occur.
Two fundamental types of information are needed to conduct a risk analysis:

- the probability of occurrence of an event and
- the consequences of its impact.

Such data will be easier to obtain for some disaster types than others, and some assumptions by the responsible organization are very likely to be needed to complete the process.

The vulnerability assessment process described in the previous level can be expected to provide an excellent basis for predicting the consequences of a specific hazard event. This is because maps of the vulnerable coastal community characteristics located within each of the delineated hazard areas have been produced. The responsible organization will need to continue to develop information on the consequences of a specific type of hazard and if a reasonable prediction of the frequency of a hazard event can be developed then it can be compared to the information regarding the consequences of the event. The results of the comparison will allow the scientists of the responsible organization to reach a sound judgement on the relative risk represented by the range of events threatening the region studied. The magnitude of the risk of a hazard that is to be addressed by its initiative is an objective basis for their prioritization.

To develop a comprehensive risk analysis, we need the following type of information:

- Historical and/or predicted frequency of occurrence of the event, categorized by the magnitude or scale of the event
- The average or predictable human cost of the event
- The likely economic cost of the event and
- The potential costs of long-term changes in the characteristics of the coastal community.

Reference sources for this type of information may be readily available in some cases although in some other cases several assumptions or extrapolations may be used to develop any quantified basis for judgement of the risk of the coastal community represented by each type of hazard.

5. DISCUSSION

Today, there exists not any specific, clear and definite Greek policy to safeguard protection of the Greek coastal communities with regard to the impacts of hazards driven by climate changes. No policy is endorsed yet, but very often we witness damages of lives and property after a hit of a “never happened again” natural climatic phenomenon. The “do nothing” policy seems to be the current Greek state policy. But the scientific community must not remain silent behind the corner. Two precautionary principles must be endorsed before starting any other study:

1. We must state: where there are threats of serious or irreversible environmental damage, lack of full scientific certainty should not be used as a reason for postponing measures to prevent environmental degradation.
2. We must decide that: any new coastal development should be capable of being reasonably protected from 1 m sea level rise by the year 2100.

A very important idea to be considered, if a new protection policy will be emerged, is a general recommendation for an erosion setback distance. This is to be based upon 100 years of erosion at a site, allowing for local coastal processes and a sea level rise of 30 cm to the year 2050, taking into account
the storm erosion from a series of severe storms. For major coastal developments it is suggested that calculations are based upon 200 years of erosion.

It should be mentioned that sea level rise scenarios are constantly being re-assessed as new data come to light. There has been a downward revision for the predicted sea level rise. It now ranges with a best estimate of 50 cm and this is 25% lower than the best estimate of 1990 which was 66 cm. However, it should be noted that this represents a rate that is two to four times than that experienced during the last 100 years [1]. This reflects the extent of scientific uncertainty and should not be seen as a reason to abandon the precautionary principles stated above. Finally, it is an extremely important conclusion to find that the threat of coastal vulnerability from sea level rise is less important in some areas than the threat of human induced coastal hazards.

6. CONCLUDING REMARKS

As coastlines in Greece come under increasing pressure from tourism and other forms of economic development, there is an urgent need for the development of environmental acceptable solutions to present both the short and long term future effects of coastline problems. In Greece there is a paucity of information in relation to the parameters and hazards affecting the coastal communities. As a result there is a need of rapid data collection while providing the maximum amount of information with a high degree of accuracy. The central objective is to identify those coastal areas which can be considered as potentially vulnerable and protect them accordingly.

The multidisciplinary, multilevel vulnerability assessment methodology analyzed in the present work has sought to address how to conduct a hazard identification and vulnerability assessment process, as well as how to utilize the results in the development of Greece’s strategy. The vulnerability assessment process is:

- The most effective tool to identify the need for mitigation initiatives
- To define what the mitigation initiatives should be and
- To justify their implementation,

and along these lines, the present work has offered suggestions on an effective method to utilize.

To offer greater capabilities to the coastal communities to survive future disasters, the responsible organization must prove that the vulnerability assessment has been curried out in a way that:

1. It is comprehensive and feasible
2. All important coastal vulnerabilities have been identified
3. All appropriate initiatives to address those vulnerabilities have been proposed and
4. All priorities assigned to the implementation of those initiatives have been derived in an objective and equitable manner.

Data collection and information development are essential prerequisites for vulnerability assessment as well as for coastal adaptation. The more relevant, accurate and up-to-date the data and information are available, the more effective and targeted adaptation can be. Coastal adaptation requires data and information on coastal characteristics and dynamics, patterns of human behaviour,
as well as an understanding of the potential consequences of climate change. It is also essential that there is a general awareness amongst the public, coastal planners, governmental organizations and coastal managers of these consequences and of the possible need to act. It is doubtful if the Greek state today has the appropriate means, data and the expertise to address problems in every part of the coast in order to contact a vulnerability assessment analysis. As coastal disasters due to climate change escalate in an accelerated pace, it is of vital importance to start forming the responsible organization, creating the appropriate legislation, obtaining the existing data, gathering new accurate data and information, raising the awareness of the public, conducting a multistage, multidisciplinary, multilevel coastal vulnerability assessment, if we decide to protect lives and property. Otherwise, we will all be spectators of the same disastrous movie.

7. REFERENCES