Good practice

Risk Analysis
Modelling Coastal Floods Vulnerabilities
(Portugal)

The present work develops a decision support system using GIS, which employs the methodology of vulnerability classification according to sea energetic actions for the coastal lagoon area of Aveiro. The model provides concrete representation of the observed vulnerability phenomenon which is easy to understand and less susceptible to criticism. It is therefore a useful tool for coastal management.

Study Area

The study area is in the central coastal zone of Portugal, between Douro River mouth and Cape Mondego, which is under the territory management unit of the Aveiro's Lagoon Municipalities Association (CIRA). This area consists of 11 municipalities, with a total surface area of 1601.6 km², in which six are coastal (Ovar, Murtosa, Aveiro, Ílhavo, Vagos and Mira), with an area of 783 km², and five are non-coastal (Sever do Vouga, Estarreja, Albergaria-a-Velha, Oliveira do Bairro and Águeda), with an area of 818.6 km².

Obviously, the non-coastal municipalities do not present any erosion problems; however, taking into account the nature of Aveiro's Lagoon Municipalities Association, which advocates an integrated management of resources and territory problems, they have been integrated in order to achieve an effective contribution to the deciding process at an inter-municipality level. In 2001, there were 345953 inhabitants in the study area, in which 209709 (61%) lived in the coastal municipalities. A large part of the referred area showed a very high population density,
classified as the higher level to the central zone (> 120 inhab/km²).

This study area is selected due to the fact that it has been mentioned in several studies and scientific reports as a place with important coastal erosion problems. In a regional level study, Barbosa (2003) stated that several locations of this coastline stretch has been suffering from general erosion process, such as Furadouro (Ovar), Costa Nova (Ílhavo) and Vagueira (Vagos). The Coastal Zone Risk Map (INAG/CEHIDRO, 1998) defines the risk zoning of sea wave attack to all Portuguese coastal territory, categorizing them into high, medium and low levels. According to this document, the stretches of Ovar/ Murtosa and Ílhavo/Mira present high risk of swash and erosion.

An European level study (EU, 2003), quantifies the state of erosion, impact and tendencies in Europe, and defines this stretch as being in a general erosion process, with the south of Vagueira being the most severe.

This project is cofinanced by the ERDF and made possible by the INTERREG IVC programme.

Data

Regardless of the process or phenomenon that is to be modelled, the reliability of the output depends directly on the quality of the input. Consequently, in order to competently model the vulnerability of the coastal zone, geographic data from reliable sources is used whenever possible. Not all vulnerability parameters referred above are a result of map geoprocessing operations. There were cases where it was necessary to resort to data contained in technical and scientific reports (e.g. average rates of erosion/accretion and anthropogenic actions) or even from time series records stored in database that do not have geographic reference, that were later incorporated onto the base map.

Methodology

This project involves four main phases: gathering of the materials and base data processing, map building using vulnerability parameters, derivation of the municipal-wide vulnerability map, and evaluation and comparison of the results with the Coastal Zone Risk Map.

During the first phase, data related to past erosion and accretion medium rates and to the effects of the anthropogenic actions on this coastline was gathered from technical reports and scientific papers. This information was subsequently incorporated into the cartography database to develop maps that display the erosion /accretion rates and anthropogenic actions. The maps showing waves' height and tide range are developed using the same process, using data from the wave buoy time-series records of Leixões Harbour and tide predictions, made available by the Hydrographic Institute.

Vulnerability parameters / factors map

In this phase, the vulnerability factors maps were developed according to the evaluation defined by Coelho (2005). Table 1 shows the characteristics of each factor for each vulnerability class. All maps presented in this phase were developed using geoprocessing tools in ArcGIS 9.X.
Some of the parameters, particularly those built on the basis of additional non-cartographic information (Anthropogenic actions, Maximum wave height, Maximum tidal range and Average rates of erosion/accretion), presented a linear representation, at the shoreline. In these cases and, attending to the combination of all parameters through the map algebra, it was decided that the behaviour verified throughout the coastline maintained itself unaltered in the inside of the study area.

Table 1: Characteristics of each factor for each vulnerability class (Coelho, 2005)

		Vulnerability level				
		Very low (1)	**Low** (2)	**Moderate** (3)	**High** (4)	**Very high** (5)
Vulnerability Factors	**TE** (m)	> 30	> 20 to ≤ 30	> 10 to ≤ 20	> 5 to ≤ 10	≤ 5
	DS (m)	> 1000	> 200 to ≤ 1000	> 50 to ≤ 200	> 20 to ≤ 50	≤ 20
	GL	Magmatic rocks	Metamorphic rocks	Sedimentary rocks	Non consolidated coarse sediments	Non consolidated fine sediments
	GM	Mountains	Rocky cliffs	Erosive cliffs, sheltered beaches	Exposed beaches plain	Dunes, river mouths, estuaries
	LC	Forest	Vegetation	Non covered	Rural urbanized	Urbanized, industrial
	AA	Shoreline stabilization intervention	Intervention without sediment reduction	Intervention with sediment reduction	Without intervention or sediment reduction	Without intervention but with sediment reduction
	WH (m)	< 3,0	≥ 3,0 to < 5,0	≥ 5,0 to < 6,0	≥ 6,0 to < 6,9	≥ 6,9
	TR (m)	< 0,0	≥ 1,0 to < 2,0	≥ 2,0 to < 4,0	≥ 4,0 to < 6,0	≥ 6,0
	EA (m)	> 0 to accretion	> -1 to ≤ 0	> -3 to ≤ -1	> -5 to ≤ -3	≤ -5 to erosion

Results and Analysis

The GIS tool offers a relative easy and quick way to test and evaluate several scenarios by varying the weight given to each parameter. All the scenarios were then evaluated empirically.

After several studies and attempts, the nine parameters were divided into three groups, corresponding to three levels of importance: least important, with a weight of 0.04 (TR and AA); moderate important with 0.07 (WH, EA, GM and LC) and; most important with a weight of 0.21 (TE, DS and GL). With these weight distributions, five levels of vulnerability throughout the study area were generated. However, the most of the inland zones which should be classified as very low vulnerability were classified only as low vulnerability. A vulnerability diminishing pattern was not explicit. The vulnerability classification in the inland areas needed to be refined from low to very low vulnerability.

Focusing the analysis on this specific objective, the last approach incorporates a new parameter, linear distance to coastline, in the map algebra expression. This new parameter represents all the study area as a function of linear distance to coastline. As a result of this supplemental information, was possible to define very low vulnerabilities in all areas there are more than 5000 meters from the actual shoreline, while maintaining all weightings of the other parameters unchanged.

The municipal-wide vulnerability map

The final simulation contains all the essential assumptions. This simulation clearly illustrates the existence of five vulnerability levels; the high and very high vulnerabilities are along the coastline and; from around 5000 meters far from the coastline, the vulnerability is very low independently on the vulnerability value given at each individual factor. Also from this map, a diminishing vulnerability pattern almost parallel to the coastline is distinctly displayed. So, this attempt is the most representative model to simulate coastal zone vulnerabilities to energetic sea actions. Figure 1 shows the final map of municipal-wide vulnerability to sea energetic actions.

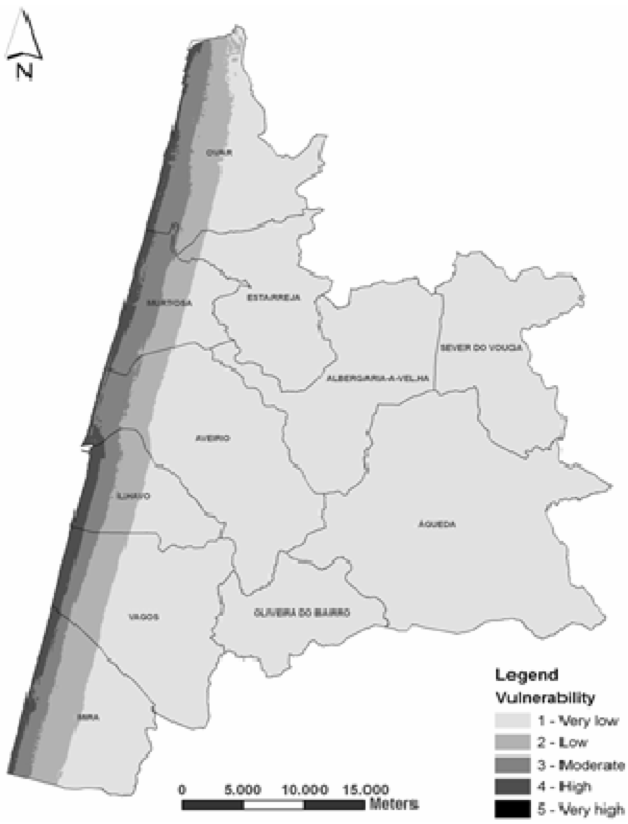

Figure 1. Global vulnerability map

From the map analysis, it is shown that very high vulnerability areas exist in prompt situations along the coastline, representing 0.04% (around 70 ha) of the total surface area of the study area.

The high, moderate and low vulnerability areas are more significant in the AMRIA area, corresponding to 3.2% (around 5100 ha), 6.4% (around 10200 ha) and 9.3% (14900 ha), respectively. Conversely, it is the very low vulnerability areas that represent the biggest part of the entire study area at 81%, corresponding to approximately 130000 ha.

Assuming an equal distribution on the number of inhabitants around the entire study area there are, according to this model, about 1384 inhabitants living in very high vulnerability areas. If we analysed together the very high, high and moderate vulnerabilities the result shows that there are 34388 inhabitants living in these areas. On the other hand, 312361 live in low and very low vulnerability areas.

Despite all the coastal erosion problems associated to this study area, taking into account the results of the presented model, only a small portion of this territory is effectively characterized with vulnerability levels, namely, around 3% of entire area.

The vulnerability model and the coastal zone risk map

Comparison of the municipal-wide vulnerability map to parts of the Coastal Zone Risk Map (INAG/CEHIDRO, 1998) was also performed. This risk map can be interpreted as the map of coastal territory vulnerability to the sea action. Human occupation and soil usage were not taken into account during the development of these maps (Trigo-Teixeira et al., 2002). It was observed that a relatively narrow belt of high vulnerability updrift of the Harbour coincides with the low risk zoning of the Coastal Zone Risk Map, while a relatively wide belt of high vulnerability coincides with the high risk zoning as shown at the southern part of the Aveiro's Harbour.

The proposed methodology provides an improved version of the Coastal Zone Risk Map because the map of INAG/CEHIDRO (1998) does not represent risk variations in inland areas.

Lessons learnt

During the development of this study the following lessons were learned:

- the contribution of models to understand the coastal dynamics;
- the importance of analyse different parameters to caracterised the vulnerability phenomena;
- how science can support the coastal manegment;
- the importance of compare different coastal risk maps methodologies with different information in different times;
- and the importance of an inter-municipality level of management in what concern the coastal planning and management.

Literature cited

Alves, M.F.L., 2006. Gestão Sustentável da Zona Costeira: Contributos para um modelo de avaliação. Portugal: University of Aveiro, Ph.D Thesis, 252p.
Alves, M.F.L and Ferreira, J.C., 2006. 10 years after the Rio summit the assessment of Portuguese coastal zone planning system. Journal of Coastal Research, Special Issue N.º 39, Volume 2, pp. 935-940.
Alves, M.F.L., Pereira da Silva, C. and Pinto, P., 2007. The Assessment of Coastal Zone Development at a Regional Level – the case study of the Portuguese Central Area. Journal of Coastal Research, Special Issue Nº. 50, pp. 72-76.
Barbosa, J.P., 2003. Aplicação dos Sistemas de Informação Geográfica na Zona Costeira. Portugal: FEUP, Master's thesis.
Berry, J.K., 1987. Fundamental operations in computer-assisted map analysis. International Journal of Geographic Information Systems 2, pp.119-136.
Bruns, H.T. and Egenhofer, M.J., 1997. User Interfaces for Map Algebra. Journal of the Urban and Regional Information Systems Association, Vol.9, No. 1, pp. 44-54.
Calado, H.; Quintela, A. and Porteiro, P., 2007. Integrated Coastal Zone Management Strategies on Small Islands. Journal of Coastal Research, Special Issue N.º 50, pp.125-129.
INAG/CEHIDRO, 1998. Cartas de Risco do Litoral, Trecho2: Foz do Douro-Nazaré. Centro de Estudos de Hidrosistemas, Instituto Superior Técnico, Instituto da Água.
CNADS, 2001. Reflexão sobre o desenvolvimento sustentável da zona costeira. Grupo de trabalho da zona costeira, Conselho Nacional do Ambiente e do Desenvolvimento Sustentável, 50p.
Coelho, C.D., 2005. Riscos de exposição de frentes urbanas para diferentes intervenções de defesa costeira. Portugal: University of Aveiro, Ph.D. thesis, 404p.
Coelho, C.; Cabarrão, M. and Veloso-Gomes, F., 2006. Aplicação de uma Classificação de Vulnerabilidades às Zonas Costeiras do Noroeste Português. 8º Congresso Nacional da Água, Figueira da Foz, 12 p.
EU, 2003. EUrosion Project – Guidelines for Developing Local Information Systems. Universitat Autònoma de Barcelona, Instituto de Hidráulica e Recursos Hídricos.
Pereira da Silva, C.; Alves, M.F.L. and Rocha, R, 2007. The Management of Beach Carrying Capacity: The case of northern Portugal. Journal of Coastal Research, Special Issue N.º 50, pp.135-139.
Pinto, P.; Cabral, P.; Caetano, M.; and Alves, F.L.; 2009. Urban Growth on Coastal Erosion Vulnerable Stretches. Journal of Coastal Research, Special Issue N.º 56, Volume 2, pp.1567-1571.
Segurado-Silva, C. and Granjo, M.J., 2006. Vulnerabilidades das zonas costeiras às acções energéticas do mar. Portugal: University of Aveiro, Master's thesis.
Tomlin, C.D., 1990. Geographic information systems and cartographic modelling, Prentice Hall, New Jersey, United States, 572p.
Trigo-Teixeira, A.; Matos, J; Pimentel,C. and Pinheiro, J., 2002. A Map of Land at Risk on the Portuguese Coast. International Workshop of Good Practices on Coastal Zone Management and Coastal Defence, Porto.

Contact information

Fátima Lopes Alves, project manager,
Assistant Professor
Department of Environment and Planning - CESAM, University of Aveiro
Campus Universitário de Santiago
Aveiro - Portugal
malves@ua.pt

Carlos Daniel Coelho,
Department of Civil Engineering - CESAM, University of Aveiro
Campus Universitário de Santiago
Aveiro – Portugal
coelho@ua.pt

Note by authors:

This text is part of a publish article: Alves, F.L., Coelho, C., Coelho, C.D. and Pinto, P., 2011. Modelling Coastal Vulnerabilities – Tool for Decision Support System at Inter-municipality Level. Journal of Coastal Research, SI 64 (Proceedings of the 11th International Coastal Symposium), 966– 970. Szczecin, Poland, ISSN 0749-0208

The MiSRaR project

The MiSRaR project is about Mitigation of Spatial Relevant Risks in European Regions and Towns. The project is a cooperation between seven partners in six EU member states:

- *the Safety Region South-Holland South, The Netherlands (lead partner)*
- *the city of Tallinn, Estonia*
- *the region of Epirus, Greece*
- *the province of Forlì-Cesena, Italy*
- *the municipality of Aveiro, Portugal*
- *the municipality of Mirandela, Portugal*
- *the Euro Perspectives Foundation (EPF), Bulgaria.*

The goal of the project is to exchange knowledge and experiences on risk mitigation in spatial policies. The project will result in a handbook in which the lessons on the mitigation process are described and the good practices from the partners are presented. The Risk Assessment and Mapping Guidelines for Disaster Management of the European Commission will be implemented in the handbook. The MiSRaR project is cofinanced by the European Regional Development Fund and made possible by the INTERREG IVC programme.
www.misrar.eu

Contact information

Nico van Os, general project manager MiSRaR,
Safety Region South-Holland South,
The Netherlands

n.van.os@vrzhz.nl

Rita Seabra,
Architect and project manager MiSRaR,
Municipality of Aveiro,
Portugal

misrar@cm-aveiro.pt