

## Cost-benefit analysis of (past) coastal erosion and (future) coastal protection interventions in Central Portugal

The Central Portuguese coast is recognized as one of the regions in Europe most vulnerable to coastal erosion. Although the impacts of coastal erosion are confined to coastal areas, these areas host 15-40% of the world population as well as a wide variety of terrestrial, aquatic and coastal ecosystems that provide a series of ecosystem services. These ecosystems and associated ecosystem services values may be lost due to coastal erosion. In this study we not only estimate the historical (1975-2006) ecosystem service value losses from coastal erosion, but also assess the costs and benefits of various coastal protection investment options in Central Portugal.

### Coastal erosion risks in Central Portugal

The Central Portuguese coast between Porto and Nazaré (see Figure 1) is a highly energetic sandy coast, with a typical wave direction from the North-West, a wave height of 2 meters (up to 8 meters during storms) and a semi-diurnal tidal regime with a tidal range of 2 meters (up to 4 meters during spring tides). The potential alongshore sediment transport (loss) is

mainly due to wave action, with values of 1-2 million m<sup>3</sup>/year.

Coastal erosion in Central Portugal is mainly due to rising sea levels, increased storm surge frequencies, reduced sediment deliveries to the coast and anthropogenic transformations of

natural coastal areas. The region is characterized by the highest rates of coastal erosion in Portugal, with most severe shoreline retreat along the Costa Nova - Vagueira coast (8 m/year) and at Furadouro beach (9 m/year).

Portuguese coastal zone management plans have resulted in notable coastal protection investments for the Central Portuguese coast, with an average of about 4,5 m€/year over the period 1998 to 2006. These investments have, however, mostly been targeted towards strategic protection, emergency interventions and rehabilitation works for urban territory protection. It is argued that it may be worthwhile to protect not

only urban territory, but also natural areas given the extensive ecosystem service values they provide.

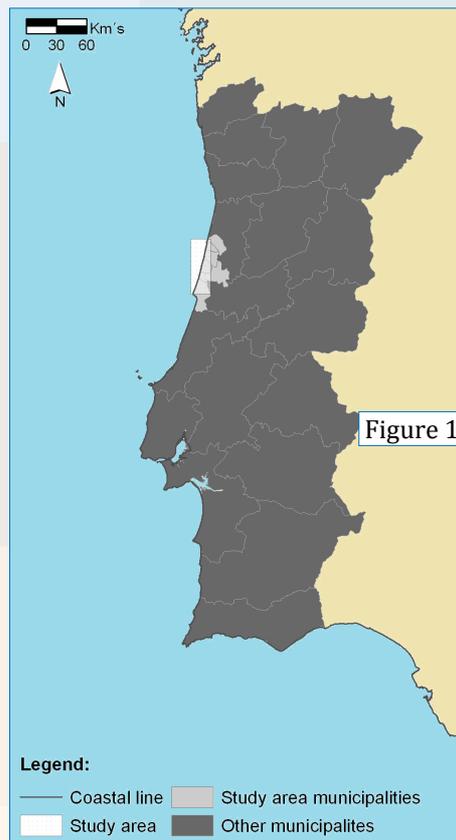


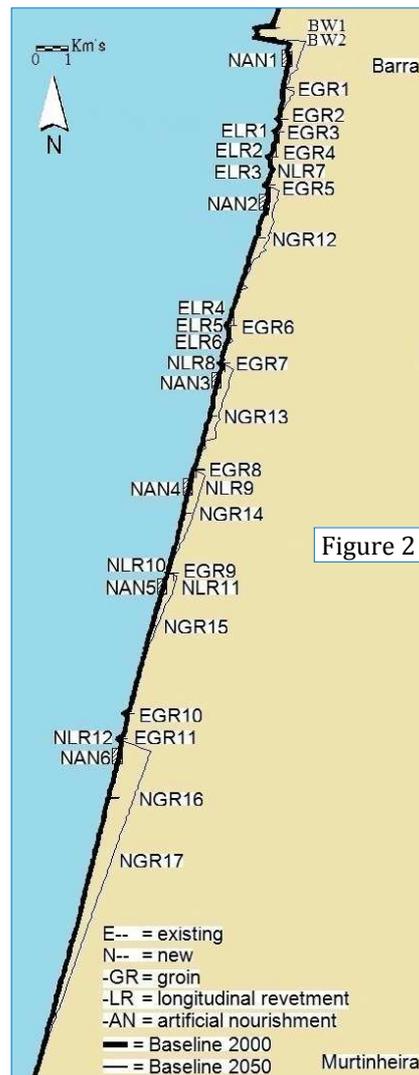
Figure 1

## Methodology

An interdisciplinary team of civil engineers, environmental economists and geographers was formed, to: i) estimate the historical (1975-2006) ecosystem service value losses from coastal erosion, and ii) assess the costs and benefits of a wide range of types, locations and combinations of coastal protection investment options. We consider only part of the Central Portuguese coast - i.e. the coastal zone between Ovar and Murtinheira (Figure 1).

To estimate historical (1975-2006) land use and ecosystem service value losses from coastal erosion along the Central Portuguese coast, the team combined historical coastal land use maps (for the determination of historical land use losses) and benefit transfer techniques (for the valuation of coastal ecosystem services). The coastal zone is 10 km wide; all values in Euros (€) for the year 2000.

To assess the costs and benefits of a wide range of types, locations and combinations of coastal protection investment options along the Central Portuguese coast, the team used the shoreline evolution model LTC (Long-Term Configuration; for the assessment of future land use losses as a function of coastal protection interventions) and benefit transfer techniques (for the valuation of coastal ecosystem services as well as investment and maintenance costs) in combination with cost-benefit analysis. Assessed protection interventions include groins (-GR), longitudinal revetments (-LR) and artificial nourishments (-AN) that are additional to the existing coastal protection interventions - thereby differentiating be-



tween extending existing (E--) and establishing new (N--) coastal protection interventions (see Figure 2 for specific locations).

## Key findings

In 1975, the value of coastal ecosystems in Central Portugal amounted to, about, 290 m€/year. This value has, however, decreased over the years - down to almost 245 m€/year by 2006 - due to changes in land use as well as coastal erosion (Table 1). Total cumulative losses in coastal ecosystem values, over the period 1975-2006, amount to 1,003 m€.

Coastal erosion between 1975 and 2006 amounted to 160 ha of beach and dune area - representing a reduction in coastal ecosystem values of just over 3,5 m€/year. Corresponding total cumulative losses in coastal ecosystem values, over the period 1975-2006, amount to almost 80 m€. Hence, it is estimated that nearly 10% of

the losses in coastal ecosystem service values in Central Portugal are due to coastal erosion.

**Table 1: Historical (1975, 1990 and 2006) coastal ecosystem service values per land use type.**

Land use type	Code	Ecosystem value (m€/yr)		
		1975	1990	2006
<b>Level 1</b>				
<b>Artificial areas</b>	111-142	0.00	0.00	0.00
<b>Agricultural areas</b>	211-213	1.86	1.28	1.27
	231	0.04	0.07	0.08
	241-244	0.32	0.43	0.43
<b>Forests and semi-natural areas</b>	311-313	7.13	7.51	6.33
	321-324	0.84	0.81	1.42
	331	70.54	28.50	26.29
<b>Wetlands</b>	421	67.84	75.24	73.07
	422	16.13	10.51	11.30
<b>Water bodies</b>	521-522	124.56	124.57	124.57
<b>Total</b>		289.25	248.92	244.76



Future coastal erosion is expected to lead to area losses of over 850 ha by 2050, despite the currently installed coastal protection interventions. The cost-benefit analysis is performed relative to this base situation.

From a physical perspective, it is shown that all assessed coastal protection interventions lead to reduced territory losses - with longitudinal revetments and artificial nourishments being most effective (Table 2). None of the interventions completely halt territory losses, while interventions are more effective when located further North as the main sediment transport occurs from North to South.

**Table 2: Area not lost by 20XX (in ha), net present value (NPV) and internal rate of return (IRR).**

Scenario*	Area (ha) not lost by			NPV (m€)	IRR (%)
	2010	2030	2050		
<b>EGR5+100m</b>	108	341	416	34.8	39.6%
<b>EGR11+100m</b>	9	148	204	10.4	14.9%
<b>EGR5,7,9,11+100m</b>	113	432	619	38.7	18.1%
<b>NGR14@300m</b>	35	57	48	1.7	7.1%
<b>NGR13,15,17@300m</b>	10	101	215	-10.3	1.4%
<b>NGR12-17@300m</b>	12	195	332	-22.3	0.7%
<b>ELR3+200m</b>	271	673	788	73.9	52.0%
<b>NLR7@600m</b>	291	696	828	70.3	26.6%
<b>NLR8@300m</b>	93	435	553	37.6	22.0%
<b>NAN1@1*10<sup>6</sup>m<sup>3</sup></b>	112	480	633	42.4	16.9%
<b>NAN1,3,5@1*10<sup>6</sup>m<sup>3</sup></b>	135	498	649	34.0	10.1%
<b>NAN1-6@1*10<sup>6</sup>m<sup>3</sup></b>	181	517	665	21.3	7.1%

**Note:** \* E-- = existing, N-- = new; -GR = groin, -LR = longitudinal revetment, -AN = artificial nourishment.

From a financial-economic perspective, however, it is shown that the construction of new groins is not attractive (low or even negative NPVs and IRRs), while artificial nourishments, the extension of existing groins and, especially, the construction of longitudinal revetments provide positive returns to investment (Table 2). Not surprisingly, coastal protection interventions located further North are more attractive.

## Lessons learnt

Coastal protection in Central Portugal is mainly targeted towards the protection of urban areas. This study shows that:

- Coastal ecosystems provide services with a value of ~290 m€/yr (1975);
- Historical (1975-2006) coastal erosion resulted in a territory loss of ~160 ha;
- This corresponds with a reduction in ecosystem service values of ~3,6 m€/yr compared to 1975, and a total cumulative loss in coastal ecosystem values of ~80 m€ since 1975.

Hence, it may be worthwhile to protect not only urban but also natural areas from coastal erosion.

Coastal erosion in Central Portugal is likely to continue despite coastal protection interventions. However, this study shows that:

- Coastal protection interventions reduce the rate at which land is lost due to erosion;
- Those areas that are not yet lost due to coastal erosion provide significant ecosystem service values.

Hence, even when coastal erosion occurs sooner or later in time, it may be worthwhile to protect coastal areas as benefits obtained from not (yet) eroded areas may outweigh costs foregone through their (yet temporary) protection.

## Sources

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### **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](http://www.misrar.eu)

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