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Valuing Ecosystem Service Losses from Coastal Erosion Using a Benefits Transfer Approach: a Case Study for the Central Portuguese Coast

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ABSTRACT

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The central Portuguese coast is recognized as the region most vulnerable to coastal erosion in Portugal, with the actual loss of territory exceeding the forecasts used in the 2010-2050 Coastal Zone Management Plan for the Ovar-Marinha sector. Coastal zones do, however, host a wide variety of ecosystems that provide associated services which, as a result, may be lost due to coastal erosion. This study presents the first step in the development of the COastal Protection Investment Support Tool (COPIST), which aids coastal zone managers identifying cost-effective locations for coastal protection works. The objective of this paper is to assess likely ecosystem service value losses resulting from coastal erosion patterns, thereby using a benefits transfer approach in combination with coastal erosion projections. For a case study of the central Portuguese coast it is shown that the total value of coastal ecosystem services equals about €193 million per year, while expected ecosystem service value losses from coastal erosion amount to over €45 million per year by 2058 (i.e. 25% of the concerned coastal ecosystem service values). Given the value of coastal ecosystem services it may, therefore, be worthwhile to protect not only urban territory but also natural and altered coastal ecosystems.

ADITIONAL INDEX WORDS: *Coastal erosion, Ecosystem service values, Coastal zone management*

INTRODUCTION

Coastal zones around the world experience increased rates of coastal erosion which is, amongst others, attributed to rising sea levels, the reduced amount of sediment delivery to the coast as well as the anthropogenic degradation and transformation of natural coastal areas (DIAS, 1994; EEA, 2006a, 2006b; SANTOS and MIRANDA, 2006). However, coastal zones do host a wide variety of ecosystems that provide associated ecosystem services (MARTINEZ *et al*., 2007) which, as a consequence, may be lost due to coastal erosion (VELOSO-GOMES *et al*., 2004; ALVES, 2006].

In Portugal, the first instrument for planning and management of coastal zones linking concerns regarding coastal land use, was established in 1993 and resulted in the development of Coastal Zone Management Plans (CZMP). In turn, and in line with the European Directive (2002/413/CE), the Portuguese government developed the basis for a national strategy on Integrated Coastal Zone Management presenting the development and implementation guidelines of sustainable coastal zone management plans and policies (MAOTDR, 2007). In their review of the Portuguese coastal zone planning system, however, ALVES *et al*. (2007) argue that there is an urgent need for integrated decision support tools that are based in scientific knowledge and methodologies, allowing consistent and objective identification as well as assessment of sustainable coastal zone management plans and policies.

This paper presents the first step in the development of the COastal Protection Investment Support Tool (COPIST), which aids coastal zone managers in the identification of the most cost-effective locations for the establishment of coastal protection works. The objective of this paper is to assess whether, where and to what extent expected coastal erosion patterns lead to losses in

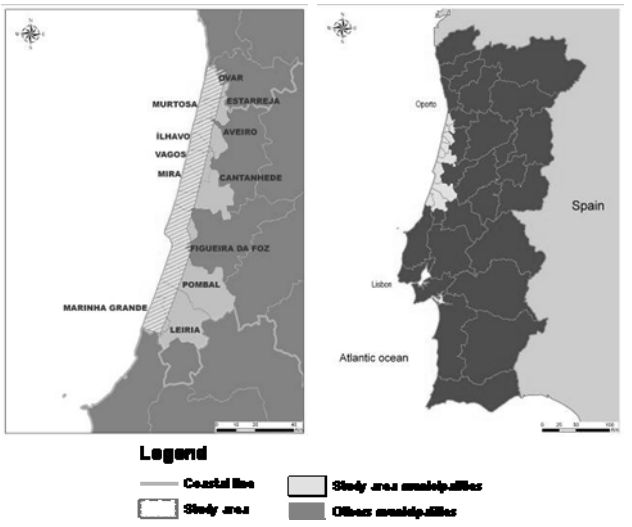

Figure 1/2. Central Portuguese coast case study area

ecosystem service values. For this purpose, a benefits transfer approach was used for the valuation of ecosystem services in combination with projected coastal erosion patterns, thus allowing for the spatially explicit assessment of changes in ecosystems service values resulting from coastal erosion. A case study is provided for the central Portuguese coast.

The next section provides an introduction to the applied benefit transfer approach and describes how it's linked to the coastal erosion projections for the central Portuguese coast case study area. In the Results section, the baseline land use and ecosystem service values for the central Portuguese coast are estimated and, in turn, projections are provide for coastal erosion and associated ecosystem service value losses for 2008, 2028 and 2058. Finally, concluding remarks and critical observations are provided in the Conclusion and Discussion section.

METHODOLOGY

Benefit transfer Approach

Benefit transfer (BT) is an economic valuation tool that uses valuation estimates from other areas (study sites) and applies them to a similar location (policy site) (BROUWER, 2000). The key to BT is to accept that a "perfect" estimate of economic service value cannot be obtained due to time and/or budget constraints and to, therefore, make the best possible use of the existing literature in order to evaluate the economic importance of a natural area. This is done by adapting and applying estimates from existing studies that best suit the new context, using one or more of the following BT methods (DOWNING and OZUNA, 1996; BERGSTROM and DE CIVITA, 1999; GROOTHUIS, 2003): i) benefit estimate transfer, which involves the extrapolation of estimates from one site to another (i.e. values are directly substituted from the study site to the policy site without amendments), ii) benefit function transfer, which involves the transfer of economic functions between the sites (i.e. coefficients are used to determine the policy site values), iii) meta-analysis, which combines the findings of independent studies related to the research topic as to summarise the body of evidence relating to a particular issue, and iv) preference calibration, which uses existing benefit estimates derived from different methodologies and combines them to develop a theoretically consistent estimate for policy site values.

The most recognised ecosystem valuation study utilising the BT technique to date is the study by COSTANZA *et al*. (1997), who estimated the annual value of 17 ecosystem services for 16 ecosystem types and aggregated totals to produce an economic value of the world's ecosystems. This was done through the analysis of existing 'willingness-to-pay' studies to produce estimates for ecosystem service valuations on a global scale. In this paper we use the ecosystem service values from COSTANZA *et al*. (1997) and match these to the Corine Land Cover (CLC) ecosystem land use typologies (BOSSARD *et al*., 2000) – Figure 3 and Table 1 gives an overview of coastal zone ecosystem service values.

Table 1: Ecosystem service values

CLC ecosystem land use typology	Area Ha	Ecosystem service value (m€/yr)
Arable land	22,877	2.36
Pastures	284	0.07
Heterogeneous agricultural areas	12,120	1.24
Forests	63,106	21.27
Shrub/herbaceous vegetation	15,540	4.57
Open spaces with little vegetation	3,234	70.59
Coastal wetlands	8,126	90.49
Inland waters	195	1.85
Total	125,482	192.43

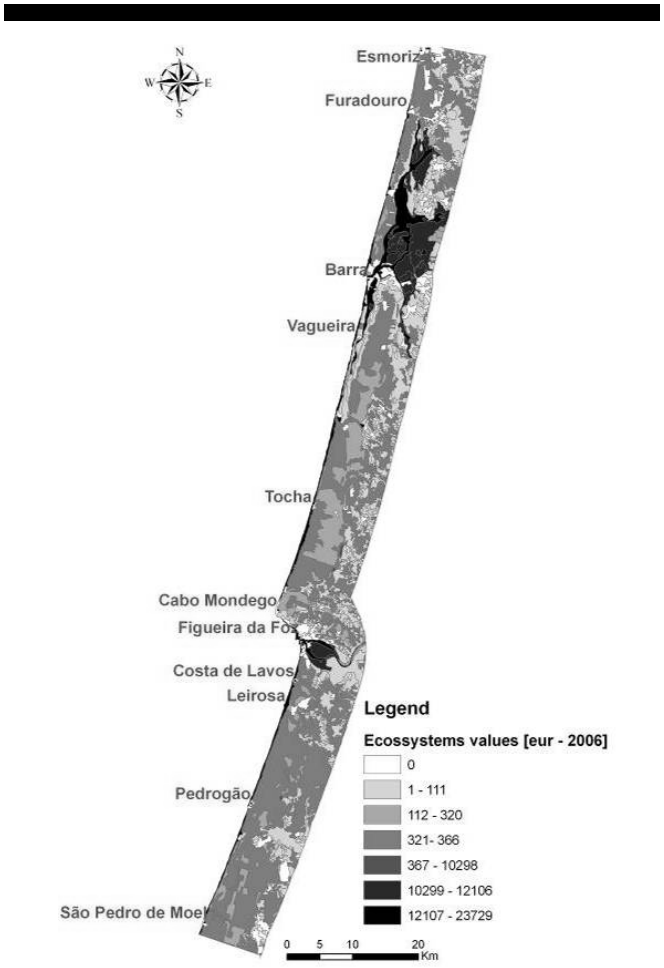

Figure 3 Baseline (2000) land use and ecosystem service values

Coastal erosion projections for case study area

To obtain insight in the scale and location of coastal erosion as well as the subsequent typologies and dimensions of ecosystem losses along the Portuguese coast for 2008, 2028 and 2058, we use the coastal erosion projection cartography from the National Water Board (Instituto Nacional da Água – INAG). These coastal erosion projections are based on expert analysis and extrapolation of (high-quality) time-series coastline photography and measurements since 1950 (MA/INAG, 1998).

For the central Portuguese coast case study area, the terrestrial coastal zone was defined as the area within 10km from the coastline (EEA, 2006a). This area covers 142,794 ha and represents almost 60% of the concerned coastal municipalities –

including Ovar, Estarreja, Murtosa, Aveiro, Ílhavo, Vagos, Mira, Cantanhede, Figueira da Foz, Pombal, Leiria and Marinha Grande (see Figure 1/2).

The baseline (year 2000) ecosystem land use pattern for the central Portuguese coastal zone case study area was determined using the CLC ecosystem cartography (BOSSARD *et al*., 2000) and, in turn, coastal erosion and associated ecosystem land use typology losses for 2008, 2028 and 2058 were determined through intersection of the baseline land use pattern and the INAG coastal erosion projections (MA/INAG, 1998).

RESULTS

Baseline land use and ecosystem service values

The baseline situation is given for the year 2000 – the year for which the latest CLC ecosystem cartography for Portugal could be obtained (MA/INAG, 1998). Table 1 summarizes the baseline (2000) land use and ecosystems service values for the central Portuguese case study area.

Ecosystem land use in the case study area is dominated by forests, agricultural areas (including arable land, pastures and heterogeneous agricultural areas) and shrub/herbaceous vegetation, covering respectively 50%, 28% and 13% of the total case study area (125,482 ha). Open spaces with little vegetation (including beaches, dunes and sand plains) cover only 2.5% of the case study area, while coastal wetlands account for 6.5% of the case study area.

Total ecosystem service values for the central Portuguese coastal zone equal about €193 million per year. In contrast with the land use distribution, forests only provide 11% of total ecosystem service values while coastal wetlands and open spaces with little vegetation (including beaches, dunes and sand plains) provide no less than 47% and 37% of total ecosystem service values. Figure 3 clearly shows that largest ecosystem service values are located directly on the coastline (beach and dune areas) or linked to coastal wetland systems (Vouga and Mondego river estuaries).

Coastal erosion projections for case study area

Coastal erosion projections from MA/INAG (1998) in combination with benefits transfer (see Methodology) were used to determine ecosystem land use and ecosystem service value losses along the Portuguese central coast for 2008, 2028 and 2058 – results are summarized in Table 2.

Erosion along the central Portuguese coast is expected to lead to a coastal territory loss of almost 4% (4,700 ha) over the next 50 years, with open spaced vegetation (including beaches, dunes and sand plains) and forest ecosystems being affected most severely (-2,049 ha and -2,189 ha, respectively). Further ecosystems affected by coastal erosion include heterogeneous agricultural areas (-312 ha) and shrub/herbaceous vegetation (-137 ha).

Expected ecosystem service value losses along the central Portuguese coast increase from approximately €30 million per year in 2028 to over €45 million per year by 2058 – a decrease in coastal ecosystem service values of almost 25%. Over 95% of these ecosystem service losses are attributed to the erosion of open spaced vegetation ecosystems (including beaches, dunes and sand plains), which provide important water supply, disturbance regulation and cultural ecosystem services (COSTANZA *et al*. 1997; MARTÍNEZ *et al*., 2007).

DISCUSSION

This study presents the first step in the development of the COastal Protection Investment Support Tool (COPIST), and provides projections for ecosystem type losses as well as associated ecosystem service value losses resulting from coastal erosion along the central Portuguese coast over the next 50 years. Using a benefit transfer approach, it was shown that the value of coastal ecosystem services in central Portugal equals close to €195 million per year – an estimate well in line with MARTÍNEZ *et al*. (2007) who value coastal ecosystem services for all of Portugal at around €1,100 million per year. Based on coastal erosion projections, in turn, its clear that erosion along the central Portuguese coast is expected to lead to a territory loss of almost 4% (4,700 ha) over the next 50 years, with in particular beach, dune, sand plain and forest ecosystems being lost (see also VELOSO-GOMES *et al*., 2004). Finally, combining the benefit transfer approach and coastal erosion projections, shows that associated ecosystem service value losses amount to over €45 million per year by 2058 – i.e. an almost 25% decrease in coastal ecosystem service values.

Coastal Zone Management Plans (CZMP) for Portugal provide the planning and regulatory framework for coastal land use management, development and transformation (TAVEIRA-PINTO, 2004) and have resulted in notable coastal protection investments for the central Portuguese coast (see Figure 4, for next four years investments), with an average of about €4.5 million per year over the period 1998 to 2006 (MAOTDR, 2006). These investments have, however, mostly been targeted towards strategic protection, emergency interventions and rehabilitation works for urban territory protection (VELOSO-GOMES *et al*., 2004). This study provides evidence that it may be worthwhile not only to protect urban territory but also natural and altered coastal ecosystems given the extensive ecosystem service values they provide.

Table 2: Projected land use and ecosystem service values for 2008, 2028 and 2058 coastal erosion projections.

CLC ecosystem land use typology	2000 (baseline)		2008		2028		2058	
	Area Ha	Value (m€/yr)	Area Ha	Value (m€/yr)	Area Ha	Value (m€/yr)	Area Ha	Value (m€/yr)
Arable land	22,877	2.36	22,877	2.36	22,877	2.36	22,877	2.36
Pastures	284	0.07	284	0.07	284	0.07	284	0.07
Heterogen. agricultural areas	12,120	1.24	12,120	1.24	11,808	1.20	11,808	1.20
Forests	63,106	21.27	63,046	21.25	63,046	21.25	60,917	20.53
Shrub/herbaceous vegetation	15,540	4.57	15,540	4.57	15,403	4.53	15,403	4.53
Open spaces - little vegetation	3,234	70.59	3,145	68.65	1,748	38.15	1,185	25.86
Coastal wetlands	8,126	90.49	8,126	90.49	8,126	90.49	8,126	90.49
Inland waters	195	1.85	195	1.85	195	1.85	195	1.85
Total	125,482	192.43	125,333	190.47	123,487	159.90	120,795	146.90

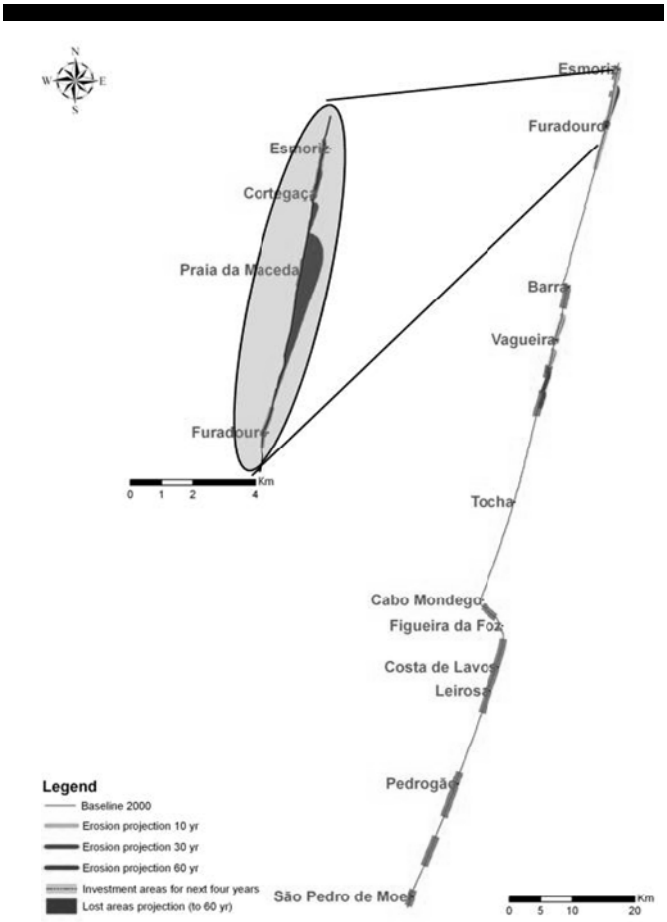

Figure 4. Erosion and investment projections

A number of caveats to this study need to be mentioned. First, coastal ecosystem service values used in this study are derived using the benefit transfer approach and, consequently, estimates may include errors related to quality of underlying valuation studies, extrapolation of values between sites, conceptual differences between underlying valuation studies and differences in the scale of environmental services between sites (BROUWER, 2000; WILSON AND HOEHN, 2006]. Second, the nature of the analysis is static and partial-equilibrium and, as a result, neither dynamic non-linearities nor interdependencies between ecosystem functions and services are taken into account (COSTANZA *et al*., 1997). Finally, it needs to be emphasized that, in line with COSTANZA *et al*. (1997) and MARTÍNEZ *et al*. (2007), this study focuses on 'non-market' ecosystem service values alone and, consequently, 'market' ecosystem service values are not considered. Self-evidently, coastal protection investment decisions should be based on total economic values of coastal ecosystems.

CONCLUSION

This paper focused one important methodology to valuing ecosystem service losses, which is vital for the next steps in the development of the COastal Protection Investment Support Tool (COPIST). Next work include: i) updating (total) economic values of coastal ecosystems, ii) estimating costs of coastal protection works, and iii) assessing the effectiveness of coastal protection works. Subsequent integration into the COPIST spatial environmental-economic modelling approach allows for the equation of coastal protection costs and corresponding (total) economic benefits, thus supporting coastal zone managers in responding to coastal erosion and climate change impacts through the ex-ante cost-effectiveness assessment of IPCC coastal protection and/or retreat adaptation strategies.

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