

## **EUROSION: Coastal erosion measures, knowledge and results acquired through 60 studies**

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### **Abstract**

Approximately twenty percent of the European Union's coast is currently eroding despite the development of a wide range of measures to protect shorelines from eroding and flooding. The prospect of further sea level rise due to climate change and the heritage of mismanagement in the past – such as inappropriate infrastructure – imply that coastal erosion will be a growing concern in the future. This is why DG Environment of the European Commission tendered the EUROSION project, which was realised by a consortium led by the National Institute for Coastal and Marine Management of the Dutch Ministry of Transport, Public Works and Water Management.

A state of the art report was compiled, based on a Europe wide review of successful and unsuccessful strategies, measures and experiments to prevent or manage erosion for different types of coast. This paper presents the main lessons learned from the practical level of coastal erosion management. It aims to provide an overview to coastal managers at the European, national and regional and municipal levels with a state-of-the-art of coastal erosion management solutions in Europe, based on the review of 60 case studies. The case studies along the European coast have been selected on the following criteria: coastal erosion, land use and geographical distribution. The cases, scattered around Europe, are meant to illustrate the different situations on the assessment levels: coastal classification, existing policy, technical measures and socio-economic backgrounds. This paper focuses on the practical lessons learned and their possible utilisation in coastal erosion management. To a lesser extent the relationship between the perspective provided by the European database and the EUROSION policy recommendations is discussed.

### **Introduction**

Coastal erosion is a natural phenomenon, which has always existed and has contributed throughout history to shape European coastal landscapes. Coastal erosion, as well as soil erosion in water catchments, are the main processes which provide terrestrial sediment to the coastal systems including beaches, dunes, reefs, mud flats, and marshes. In turn, coastal systems provide a wide range of functions including absorption of wave energies, nesting and hatching of fauna, protection of fresh water, or places for recreational activities. However, migration of human population towards the coast, together with its ever growing interference in the coastal zone has also turned coastal erosion into a problem of growing intensity.

Coastal erosion is usually the result of a combination of factors – both natural and human induced – that operate on different scales. EUROSION has undertaken a review of factors responsible for coastal erosion in about 60 case studies representative of European coastal diversity (Fig. 1).



Fig. 1. Location of the 60 case studies reviewed during EUROSION study (with average erosion rate per year for selected cases).

Coastal erosion figures depend on time and spatial scales of observation. The sedimentary coastline exists in an environment that is fluctuating over different timescales with periods relating to waves (seconds), tides (twice daily), seasons and longer timescales, as for example changes in sea level.

The case study review as such does not pass judgement on the success or failure of coastal erosion management solutions implemented. It attempted to highlight those objectives that were initially assigned to such solutions and how far such objectives have been reached.

It is assumed that with such an approach the coastal manager, specialist or non-specialist coastal engineer, would be in a position to understand the major obstacles that may be encountered in deciding which coastal erosion management design is most appropriate for a particular area, bearing in mind the wide range of European experiences.

According to the DPSIR-methodology (Drivers, Pressure, State, Impact, Responses) the review addressed the following issues: the known causes of coastal erosion and their current and anticipated impact on social and economic assets, the technical specifications of the solutions proposed as well as their positive and negative effects from the perspective of local inhabitants. Furthermore, the role of innovative measures, monitoring and modelling prior to the design of measures was studied. The lessons learned that are presented reflect these issues.

## **Main EUROSION case studies results**

The EUROSION case studies have been analysed thoroughly, taking all the influencing factors into account. This has been incorporated into both the EUROSION findings and policy recommendations. An extensive analysis was executed (EUROSION, 2004), including various consortium and international expert meetings. The main lessons drawn are briefly described below:

### ***Erosion types, occurrence and the human driver***

Human influence, particularly urbanisation and economic activities in the coastal zone, has turned coastal erosion from a natural phenomenon into a problem of growing intensity. Adverse impacts of coastal erosion most frequently encountered in Europe can be grouped in three categories: (i) coastal flooding as a result of dune erosion, (ii) undermining of sea defence associated with foreshore erosion and coastal squeeze\*, and (iii) retreating cliffs, beaches and dunes causing loss of land of economic and ecological values.

\*‘Coastal squeeze’. Habitats are lost as a result of a combination of land claim, sea level rise or reduction in sediment availability.

### ***Erosion origins, natural and human-induced***

Coastal erosion results from a combination of factors – both natural and human-induced – which have different patterns in time and space (Figs 2 and 3) and can be continuous or incidental, reversible or non-reversible. In addition, uncertainties still remain about the interactions of the forcing agents, as well as on the significance of non-local causes of erosion.

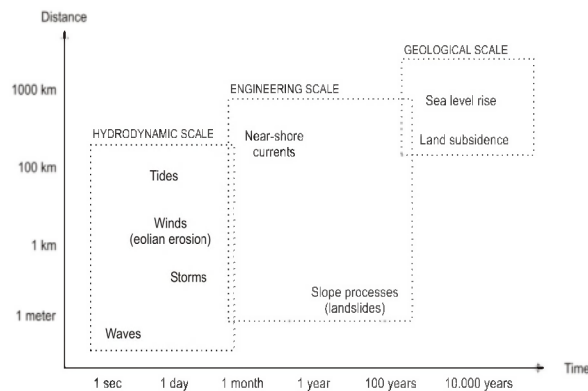


Fig. 2. Time and space patterns of natural factors of coastal erosion (note that 'distance' and 'time' reflect the extents within which the factor occurs and causes erosion).

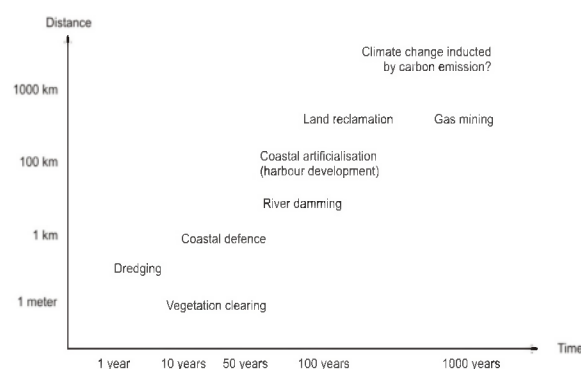


Fig. 3. Time and space patterns of human induced factors of coastal erosion.

### **Environmental Impact Assessment and coastal erosion**

Coastal erosion induced by human activities in Europe has surpassed coastal erosion driven by natural factors. Human-induced coastal erosion mainly proceeds from the cumulative and indirect impacts of small and medium size projects, as well as from river damming. However, little attention is paid to these impacts by project developers, Environmental Impact Assessment (EIA) practitioners and competent authorities.

### **Knowledge of erosion processes**

Knowledge on the forcing agents of coastal erosion and their complex interaction tends to increase over time. However, this knowledge is fragmented and empirical as reflected by the many different models commonly used throughout Europe to anticipate coastal morphological changes. Secondly the usage of knowledge in the decision making

process is lacking, resulting in inadequate decisions and sometimes huge adaptation and compensation costs.

### ***Local management action in broader perspective***

Past measures to manage coastal erosion have generally been designed from a local perspective: they have ignored the influence of non-local forcing agents and have disregarded the sediment transport processes within the larger coastal system. As a consequence, they have locally aggravated coastal erosion problems, and triggered new erosion problems in other places. They still influence the design of present measures.

### ***The coastal sediment cell***

In an attempt to respond more effectively locally to non-local causes of coastal erosion and to anticipate the impact of erosion management measures a number of cases, mainly in northern Europe, have built their coastal erosion management strategies upon the concept of “sediment cell”. This has been accompanied by a better understanding of sediment transport patterns within the sediment cell (Fig. 4). Such approaches require a strong cooperation between regions, which share a same sediment cell.

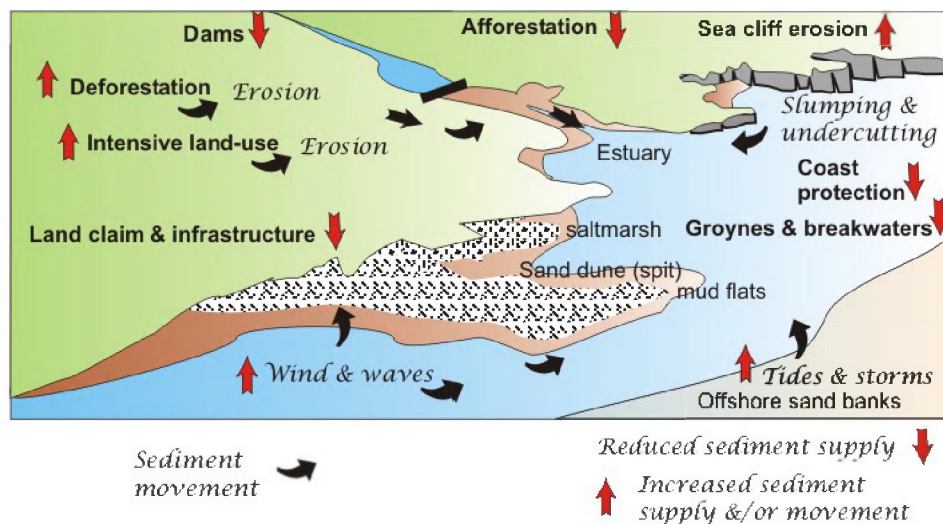


Fig. 4. Some of the principal causes of change in sediment movement in a 'sediment system' (Doody 2001). In this diagram the coast is taken to include the sea cliffs and sand dunes, tidal saltmarshes and mud/sand flats. Nearshore marine waters (blue) and the hinterland (green) make up the 'sediment system'. In the diagram sediment movement is tending towards 'sediment sinks' associated with a coastal embayment, such as an estuary.

### ***No miracle solutions, but learning through experience and applying multi-functional design and acceptability***

Experience has shown that, at the present time, there is no miracle solution to counteract the adverse effects of coastal erosion. Best results have been achieved by combining different types of coastal defence including hard and soft solutions, taking advantage of their respective benefits though mitigating their respective drawbacks. Multi-functional technical designs, *i.e.* which fulfils social and economic functions in addition to coastal protection, are more easily accepted by local population and more viable economically.

### ***The setting of clear objectives, towards accountability through cost-benefit analysis***

Assignment of clear and measurable objectives to coastal erosion management solutions – expressed for example in terms of accepted level of risk, tolerated loss of land, or beach/dune carrying capacity – optimises their long-term cost-effectiveness and their social acceptability. This has been facilitated by the decrease of costs related to monitoring tools.

Though critical for decision-making, the balance of coastal defence costs and their associated benefits is – in general – poorly addressed in Europe. This may lead to expenses, which are at the long run unacceptable for the society compared to the benefits.

### **The EUROSION database and natural assets**

The European dimension of sediments and soils: sediments that are important for future coastal resilience are sealed within water catchments that in many instances extend over several Member States. River regulation works can also have impacts on coastal zones of other Member States. The Water Framework Directive is an important instrument in which this can be addressed. In addition, sediments also cross borders in the coastal zone; coastal management actions can easily have cross-border impacts, not only along dunes and beaches but also in estuaries (*e.g.* dredging works in transboundary zones).

Current coastal erosion management practice tends to use Natura 2000 sites as Strategic sediment reservoirs. This will have long term and possibly irreversible implications for the Natura 2000 Network. EUROSION suggests that designated natural habitats should not be the source of sediments to compensate for chronic deficits of sediment due to human interventions, because this would undermine coastal resilience and community environmental policy objectives. At the EU-level this can be approached through the Habitats Directive.

Within EUROSION a Europe wide database has been realized assessing the European magnitude of coastal erosion. This assessment included both the sensitivity and impact analysis of coastal erosion and flooding events. Approximately 40.000 km<sup>2</sup> wetlands under the influence of coastal erosion are considered to be at risk. Studies for the UN-IPCC estimate that the number of people subject to an actual coastal erosion or flood risk

in 2020 would exceed 158,000, while half of Europe's coastal wetlands are expected to disappear as a result of sea level rise (Salman *et al.*, 2002).

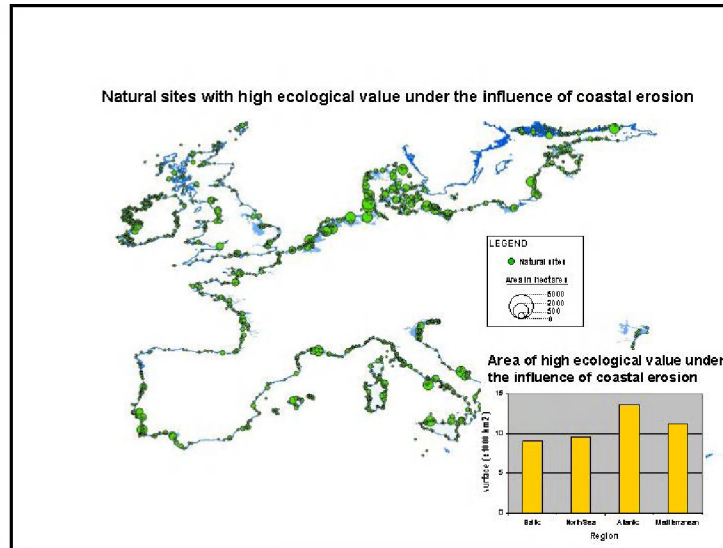


Fig. 5. Natural sites with high ecological value under the influence of coastal erosion.

### Major concerns: what is at stake?

For the next 50 years, EUROSION is particularly concerned with the following trends:

- Loss of sediment: the amount of sediments will continue to be at risk due to ongoing trends, especially in river regulation works and coastal urbanisation;
- Loss of dynamic coastlines and natural habitats;
- Loss of resilience;
- The impacts of climate change.

Apart from hazards and risks that tend to be unpredictable, coastal erosion will result in an increasing cost to society involving:

- Increasing risk to lives and economic assets;
- More habitat loss;
- Greater mitigation and management cost.

### EUROSION major findings

With regard to the underlying mechanisms responsible for the problems in the field of coastal erosion EUROSION has identified the following major findings:

***Finding 1: on coastal squeeze and the loss of sediment***

Urbanisation of the coast has turned coastal erosion from a natural phenomenon into a problem of growing intensity. The majority of coastal erosion problems are now induced by human activities and artificially stabilised seafronts are progressively encroaching on sedimentary coastlines and cliffs. Dynamic ecosystems and their undeveloped coastal landscapes are gradually disappearing, due to a lack of sediment. In many places the process of ‘coastal squeeze’ is responsible for this phenomenon.

***Finding 2: on environmental and economic assessment***

Environmental Impact Assessment (EIA) procedures – as implemented under the terms of the directive 85/337/EEC – have been insufficient in addressing the impact of human activities, such as development, on the wider coastal environment. Subsequently, the cost of attempting to reduce coastal erosion has increased considerably in relation to the assets requiring protection. Consequently it has resulted in a need to transfer the cost of coastal erosion mitigation measures to such activities.

***Finding 3: on coastal erosion risk***

The cost of reducing coastal erosion risk is mainly supported by national or regional budgets, hardly ever by the local community and almost never by the owners of assets at risk or by the party responsible for coastal erosion. This is emphasized by the fact that coastal erosion risk assessment has not been incorporated in decision-making processes at the local level and risk information to the public remains poor.

***Finding 4: on the mitigation of coastal erosion***

Over the past hundred years the limited knowledge of coastal sediment transport processes at the local authority level has resulted in inappropriate measures of coastal erosion mitigation. In a considerable number of cases, measures may have solved coastal erosion locally but have exacerbated coastal erosion problems at other locations – up to tens of kilometres away – or have generated other environmental problems.

***Finding 5: on information management***

In spite of the availability of tremendous amounts of data, information gaps continue to exist. Practices of coastal information management – from raw data acquisition to aggregated information dissemination - suffer from major shortcomings, which result in inadequate decisions. Surprisingly, sharing and dissemination of coastal data, information, knowledge and experiences are hardly ever considered by regional and local stakeholders. The use of a better knowledge base when coastal development is proposed provides an opportunity, which could help reduce technical and environmental costs of human activities (including measures for coastal erosion mitigation) and could help anticipate future trends and risks.



## Coastal resilience

Understanding the dynamic nature of the coastal margin is a key factor in managing coastal erosion. In the past development has encroached upon coastlines, resulting in a sometimes dramatic loss of habitats and with them a reduction in their natural dynamic characteristics. EUROSION has shown that whilst protection is possible, extreme events undermine and/or overtop coastal defences. Long term trends and knock-on effects from the structures themselves also often result in negative effects on the resilience of much larger coastal units. It is anticipated that this situation will be aggravated by climate change, resulting in an increase in sea levels and a more unpredictable and extreme storm climate. This will result in a long term threat to the safety of people, to the sustainability of many coastal activities, to coastal biodiversity and to the ability of the coast to provide a 'natural' coastal defence.

EUROSION recognises the sustainable development of coastal zones and the conservation of dynamic habitats, especially on the remaining undeveloped coast, as important long term goals for European coastal zones. This requires a respect for, and in many cases restoration of, the natural functioning of the coastal system and hence its natural resilience to erosion. EUROSION defines coastal resilience as the inherent ability of the coast to accommodate changes induced by sea level rise, extreme events and occasional human impacts, whilst maintaining the functions fulfilled by the coastal system in the longer term. The concept of resilience is particularly important in the light of the predictions for climate change.

Resilience depends on two key factors: *sediments* and *space for coastal processes*.

Coastal resilience will decrease as a result of:

- Chronic losses of sediments and
- Limitations set to the space that is required to accommodate:
  - natural retreat of cliffs and sedimentary systems
  - redistribution of sediments as a result of this retreat.

These aspects need to be recognised as most fundamental conditions for sustainable coastal planning in general and shoreline management in particular. In order to make link the elements 'sediments' and 'space' EUROSION proposes the concept of 'strategic sediment reservoirs'.

## Strategic sediment reservoirs

The need to counteract a negative sediment balance in a particular coastal zone will require a source of sediment to be identified. To facilitate the future availability of such an 'appropriate' sediment supply, EUROSION proposes the concept of 'strategic sediment reservoirs'. These are defined as: supplies of sediment of 'appropriate' characteristics that are available for replenishment of the coastal zone, either temporarily (to compensate for losses due to extreme storms) or in the long term (at least 100 years). They can be identified offshore, in the coastal zone (both above and below low water) and in the hinterland. After designation of strategic sediment reservoirs their availability should be ensured by leaving them undeveloped.

## **EUROSION policy recommendations**

On the basis of the findings and the EUROSION vision four key recommendations are proposed that, once implemented as a package, will make coastal erosion problems and risks in Europe manageable. For each recommendation an indication is given of its implications at the level of the European Union, Member States and coastal regions (local government).

### ***Recommendation No. 1: Increase coastal resilience by restoring the sediment balance and providing space for coastal processes***

A more strategic and proactive approach to coastal erosion is needed for a sustainable development of vulnerable coastal zones and for the conservation of coastal biodiversity. In the light of climate change it is recommended that coastal resilience is enhanced by: (a) restoring the sediment balance; (b) allocating space necessary to accommodate natural erosion and coastal sediment processes and (c) the designation of strategic sediment reservoirs. In view of the importance of the availability of sediments and space for sediment transport (from rivers, along the shore and between coastal system and seabed) EUROSION proposes the concept of a 'favourable sediment status' for coastal systems. This concept can help form the basis for shoreline and water catchment management. Favourable sediment status may be defined as the situation of 'coastal sediments' that will permit or facilitate meeting the objective of supporting coastal resilience in general and of preserving dynamic coastlines in particular.

### ***Recommendation No. 2: Internalise coastal erosion cost and risk in planning and investment decisions***

The impact, cost and risk of human induced coastal erosion should be controlled through better internalization of coastal erosion concerns in planning and investment decisions. Public responsibility for coastal erosion risk (through the taxation system) should be limited and an appropriate part of the risk should be transferred to direct beneficiaries and investors. Environmental Assessment instruments should be applied to achieve this. Risks should be monitored and mapped, evaluated and incorporated into planning and investment policies.

### ***Recommendation No. 3: Make responses to coastal erosion accountable***

Coastal erosion management should move away from piecemeal solutions to a planned approach based upon accountability principles. These would help optimise investment costs against values at risk, increase the social acceptability of actions and keep options open for the future. EUROSION proposes a more proactive approach based on planning and accountability of achievements in the fields of coastal erosion management.

***Recommendation No. 4: Strengthen the knowledge base of coastal erosion management and planning***

The knowledge base of coastal erosion management and planning should be strengthened through the development of information governance strategies. These should be the starting point with information on 'best practice' (including learning from failures), for a proactive approach to data and information management and for an institutional leadership at the regional level.

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