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INTEGRATING SCIENCE AND POLICY FOR CREATING TOOLS FOR SAFER EUROPEAN COASTS IN A CHANGING CLIMATE

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ABSTRACT

Coastal areas are vital economic hubs in terms of settlement, industry, agriculture, trade and tourism. These densely populated areas face many problems, including erosion, flood risk and habitat deterioration. As economies develop, the asset base at risk increases. Simultaneously, effects of climate change will lead to more extreme events, thus more damage and habitat decline. Existing management and defence approaches are not well tuned to these challenges, as most assume static situations.

In the EU project THESEUS¹ (2009 – 2013), 31 partners work together in an interdisciplinary way to develop instruments for realising low risk coasts for human use and healthy habitats (www.theseusproject.eu).

To contribute directly towards practical flood defence planning, eight study sites were identified across Europe, with specific attention to the most vulnerable coastal environments such as deltas, estuaries and wetlands, where many large cities and industrial areas are located. These sites are: Vistula Delta Plain (Poland), Elbe Estuary (Germany), Plymouth Sound to Exe Estuary (UK), Santander Bay (Spain), Scheldt Estuary (Belgium-Netherlands), Varna Coast (Bulgaria), Gironde Estuary (France), Po Delta and adjoining coast (Italy).

In the first phase of the THESEUS project, the authors have assessed the coastal systems of these sites, as to provide an overview and insight in the total system and to determine where policy changes, organizational and/or mitigation measures may be significant from the perspective of the risk assessment due by every Member State by 2011. A questionnaire was developed and interviews formed the input for a systems analysis, for which the coastal systems were divided into subsystems following the risk function (chance x consequences), physical elements (sea, foreshore, flood defence, protected area) and land use. Based on these analyses, a first impression of possible policy changes, organizational and/or mitigation measures have been identified. The paper presents the results of these eight analyses.

THE THESEUS PROJECT

In the EU project THESEUS (2010 – 2013), a framework is being developed that aims at providing instruments for realising low-risk coasts for human use and healthy habitats. Innovative combined mitigation and adaptation technologies are being identified, including ecological mitigation measures and actions reducing the impact. A decision support system for

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flood and erosion defence planning and guidelines will be developed, that will integrate the best of these measures in a strategic policy context. The challenge is to identify the universal keys, with which decision makers throughout Europe and the rest of the world can fine tune their policies.

In 2010, the first step was taken with the identification of the policy aspects and possible organizational and mitigation measures that are crucial in planning a sustainable coast. For this, potential THESEUS end users of eight European sites were interviewed on the basis of a questionnaire. This paper presents the results of these interviews. Conclusions are based on the threat levels, policy strategies and the current level of sustainability that have been observed.

Any assessment of a coastal system consists of an analysis of the physical characteristics of the coastal area, its land uses and the coastal defence policies and management strategies. In THESEUS, the implementation needs of the European Flood Directive are also considered.

STUDY SITES

In order to be able to test and validate tools, techniques, models and decision support systems, eight sites with specific problems are provided within the project. These study sites were selected in large European urban or industrial areas located in estuaries, deltas and coastal areas. The presence of flood risk management challenges and/or erosion problems were used as criteria to choose the sites. Additional criteria are the level of social, economical and ecological vulnerability to climate change and the availability of data. The eight sites are (see also Figure 1):

1. Vistula Delta Plain, Poland;
2. Elbe Estuary, Germany;
3. Plymouth Sound to Exe Estuaries, UK;
4. Santander Bay, Spain;
5. Scheldt Estuary, Belgium/The Netherlands;
6. Varna Coast, Bulgaria;
7. Gironde Estuary, France;
8. Po Delta and adjoining coast, Italy.



Figure 1. THESEUS study sites

These sites show a variety of environments from estuaries, deltas and coastal lagoons to protected and unprotected beaches. Each site has its own concerns in terms of potential hydraulic loads on the coastal zone. Important factors are water levels and wave climate caused by the specifics of the regional weather systems, tidal characteristics and scale of open waters (Atlantic Ocean, North Sea, English Channel, Mediterranean Sea, Black Sea and Baltic Sea) and their respective geographical orientations relative to the study site.

At each site, a direct link is established between the members and the end users of the THESEUS project. The aim is to motivate the established groups of stakeholders to participate in the project by giving them immediate access. This is needed in order to deliver results which are of real value, practicable and usable.

ASSESSMENT OF CURRENT POLICY, MANAGEMENT AND PLANNING STRATEGY AND DURABILITY OF STRATEGIES ON COASTAL DEFENSES

The ultimate THESEUS goal is to create a generic method and to provide guidance on how to use this generic method for particular sites. The assessment of current policy, management and planning strategy as well as the durability of the strategy can be considered the first step in the development of this generic tool. It provides insight in the level of information available for each site. From there it can be derived which information is crucial for this tool as well as which information is missing and has to be provided with the model.

Questionnaire

The starting point of the assessment was the development of a questionnaire. The questionnaire focuses on obtaining sufficient information to allow for a systems analysis per study site, with land use as a starting point. The questionnaire consists of five parts:

1. *Systems analysis*: Description of land use and spatial planning;
2. *Physical characteristics*, including hydraulic loads and the flood defence system;
3. *Policy, management and planning strategy*, in relation to flood defence;
4. *Institutional map*, of all parties of relevance for the coastal management per site, including their responsibilities;
5. *Sustainability of the flood defence infrastructure and coastal policies*, at the long term.

Selection of interviewees

Prior to each visit, the questionnaire was sent to the site champion (i.e. the local THESEUS representative). He identified potential end users of the THESEUS project, and arranged the interview program during the visit, for which the questionnaire was used. In this way, policy and decision makers, managerial authorities and administrators at various levels (national, regional, provincial, municipal, port authorities, NGO's) active in the management of the coastal region were interviewed.

Field visits

From February to October 2010, all eight THESEUS sites were visited by the authors. Each visit lasted for 3 – 4 days, during which some 5 – 7 interviews were held with potential end users and stakeholders and specific data could be obtained. In the week after each visit, a draft report containing the findings was sent through the site champion to the interviewees for their comments and approval (which could take up to 4 months).

RESULTS

From the synthesis of the eight site reports, the following observations could be made.

Area of the sites

The area of the sites ranges from approximately 100 km² (Santander Bay, Varna Coast) to several thousands km² (Gulf of Gdansk, Gironde Estuary, Plymouth Sound to Exe Estuaries, Scheldt Estuary, Po Delta and adjoining coast, Elbe Estuary).

SPRC approach

One of the major challenges of THESEUS is the multi-disciplinary and multi-cultural approach in which the work on the European coast is carried out. Because of this, a common framework is needed that structures the information and developed knowledge. It should also function as a common platform on which all different experts can contribute their knowledge and experience to reach the common THESEUS goal.

To realise this overall aim, the conceptual model for coastal risk assessment proposed in THESEUS is based on the Source-Pathway-Receptor-Consequence (SPRC) model that is widely used in the fields of waste and pollution management (DEFRA, 2002; Cowell et al., 2003; Thorne et al., 2007; FLOODsite, 2009). The SPRC model is a linear conceptual model for representing flood systems and processes that lead to a particular flooding consequence. It provides in both visual and written form the current understanding of the system under investigation (see Figure 2). The identified elements can be described in terms of *Sources* (waves, currents, water levels), which after passing the *Pathways* (the natural or manmade defences) and flooding the *Receptors* (towns, industries, agricultural areas, nature areas, etc.) may lead to unwanted *Consequences* (casualties, injuries and/or damage). An important aspect of the SPRC model is that it relates potential consequences to the nature of the source. Also, there may be a number of sources, areas affected (receptors), type and nature of consequences as well as linking pathways.

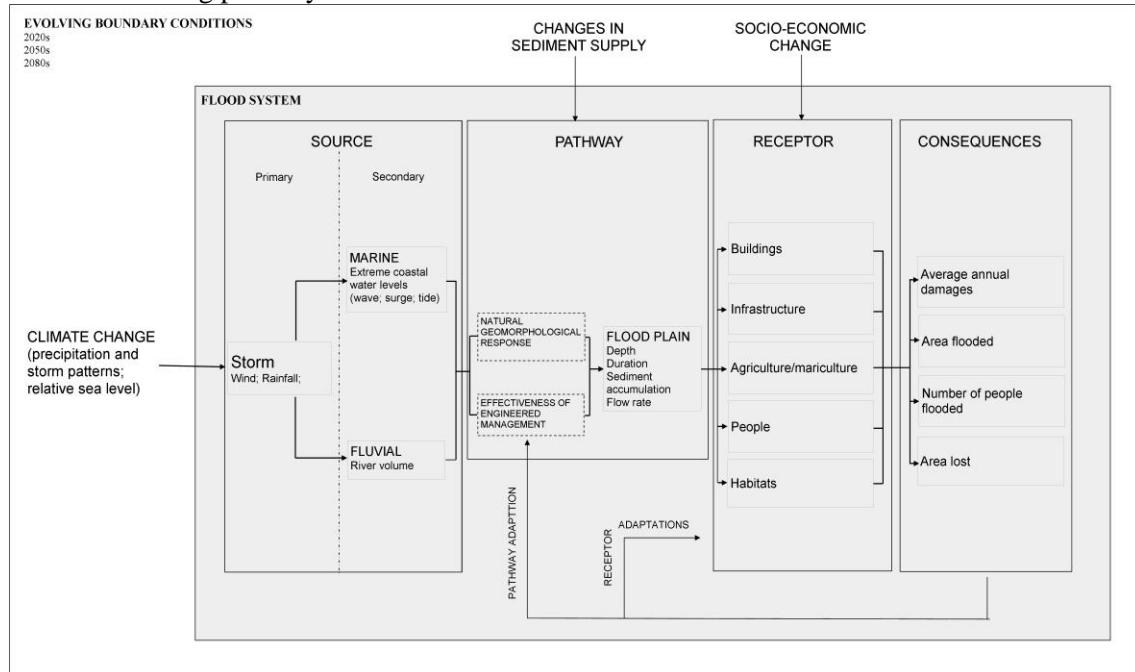


Figure 2. Sources – Pathway – Receptor – Consequence (SPRC) Model

It proved difficult to formulate general conclusions on sources, pathways, receptors and consequences that extend beyond a self-evident level. The following observations can however be made.

Sources

The sources show a wide range, varying from storm surges with or without tidal influence, resulting waves, currents, etc. that originate from large bodies of water. The magnitude of the influence of the sea varies from site to site. The estuaries (Elbe, Plymouth Sound to Exe, Scheldt, Gironde) are under combined influence of rivers (discharges, sediment loads, currents) and sea (tides, winds, currents). In the bays (Santander, Gdansk), the sea dominates; the bay areas profit from the shelter in the bays. The coasts of SE England, Varna and NW Adriatic Sea are under direct influence of the respective seas. And of course, the tides are of minor influence of the loads for the Baltic, Black and Adriatic Seas. Here, storm surges and currents dominate.

Pathways

Artificial *flood defences* are present at all sites, varying from dikes, quay walls, (detached) breakwaters, dune systems and sand nourishment.

There is a preference for *soft engineering solutions* (sand nourishment) over hard structures.

All sites face problems related to disturbed *erosion and sedimentation processes*. Again, magnitude and effects differ between the sites.

Degradation. A next threat of the coast is degradation. Four types of threats can be distinguished: retreat of the coastline, erosion of flood protection structures, erosion of natural habitats and erosion of economic and social important assets like beaches. The first, retreat of the coastline may lead to loss of land and assets. Erosion of flood protections like a dune system may cause an enlarged risk of flooding of protected areas.

The *design approach* of the flood defences shows a wide variety. The return period shows a range from 4000 years (Western Scheldt, prescribed by law) to 25 years and smaller. This wide range could be caused by:

- differences in *flood risk* (change of occurrence, economic value of the protected area, combination);
- *perception* to and *history* of floods. For instance, in The Netherlands the flood risk dominates the overall risk. In other areas, flood risk is of similar or lower importance in relation to other risks;
- possibilities for *adaptation, evacuation, insurance*. This refers to flood proof building (Hamburg Haafen City), compensation measures and the like.

Time horizon and sea level rise. Next to differences in safety standards, the time horizon and the way how sea level rise is taken into account in the design differs from site to site. Time horizons are commonly in the range of 50 – 100 years.

Receptors

The delineation of receptors is not straightforward, as it strongly depends on the type of consequence that is considered. For instance, a delineation of an urban area would essentially differ from the delineation of a natural area.

Consequences

For an explicit flood risk approach ($\text{risk} = \text{probability of occurrence} \times \text{consequences}$) the consequences need to be identified. However, data on consequences of flooding are not

abundantly available. This is no real surprise, given the fact that flooding is the unwanted event, and that there is (luckily) little experience with floods and consequences. Within the framework of the EU Flood Directive, it may be expected that data on consequences will become available.

Given the experience in the Scheldt and Elbe area with the floods of several decades ago, the insight in consequences of large scale flooding is present. In other sites, the flood risk is just one of the societal risks that are in mutual competition for obtaining scarce funds.

Institutions and responsibilities

The many land uses identified at all sites illustrate that coastal areas offer favourable conditions for living, working and recreation. There are ports, marina's, (heavy and chemical) industry, beaches, urban areas, valuable nature reserves, fisheries, and agricultural activities. Consequently there are many institutions and companies involved in managing these uses in these areas. The way this is organised differs from site to site. Where the port is an important economic factor, it is reflected in its tasks and responsibilities, for instance the power to issue permits. The same is true for an area where recreational beaches have the highest relative value.

In all sites, government institutes at state, regional and municipal level play a role and have a responsibility in the management of the coastal zone. This refers to preparing laws (national water laws, spatial planning laws), policy documents, master plans, physical planning as well as enforcing these rules and regulations. Some observations are:

- *multiple uses result in many institutes responsible.* Characteristic for the coastal zones are the multiple land uses (urban, industry, port, tourism, agriculture, fisheries) and high pressure on land. This multiple use automatically results in a high number of institutes, that are in one way or another responsible for (parts of) the management of the coast(line). One could even observe that the higher the number of institutions involved, the less effective the management of the coastal area becomes. In such cases it is a real challenge to realise a sound communication and clear structure of responsibilities. Coordinating institutes, like the Smiddest in the Gironde area, may facilitate this. Where such coordination is lacking, it will be relatively easy to deny responsibility and consider other institutes being responsible for countering unwanted developments;
- *communication necessary.* Good communication and well defined responsibilities may address one or more of the following items:
 - knowledge exchange, for instance on type of flood defence, maintenance strategies;
 - structured and free access to information of the right quality and at the right moment, like weather forecasts, tidal predictions, flood warnings, historic data;
 - relation between the profits made in the coastal zone (for instance the tourist sector) and the investments needed to protect it;
 - invest in the acceptance of the coastal related policy, through for instance meetings with different stakeholders.
- *involvement of the public.* In smaller sites, flood protection is at a more local level organised. Here, local stakeholders have a direct interest in the coastal management and have a direct influence in the effectiveness of the (small) flood protection works.

Nature areas

Wetlands are natural habitats in the study sites. These wetlands are protected either by natural sand spits (Vistula Delta Plain, Exe estuary, Santander Bay) or by manmade dike systems (agricultural areas at the mouth of the Elbe, some islands in the Gironde, along the Scheldt). But in some cases concerns unprotected natural areas (islands in the Elbe estuary, the Gironde estuary, wetlands in the Scheldt estuary and along the Po Delta coast). Also unprotected sandy foreshores are to be considered important natural habitats (Scheldt, Po Delta, Elbe, Gironde, Vistula Delta plain, Varna coast, sand areas at mouths of rivers and rocky coast at between the Plymouth Sound to Exe Estuaries).

Long term developments

Sea level rise

Climate change is expected to lead to sea level rise and more severe storms in all of the mentioned sites. The policy approach to climate change and sea level rise is, however, not uniform through the sites. Some interviewees opt for responding reactively (wait for the flood), where others have formulated policies in a proactive way and incorporate sea level rise in the design of the flood defences. This difference in attitude might be explained by:

- uncertainty in or even denial of sea level rise;
- lack of funds. These only become available after a disaster;
- difference in time horizons. The longer the time horizon is, the higher the expected sea level rise that has to be taken into account in the design.

Spatial planning

In most of the sites, urban growth is expected. Governments at various levels try to control spatial activities by laws, spatial plans and building regulations. In situation where there are no legal restrictions for building in flood prone areas, like in SW England, it is still ‘strongly recommended not to do so’ (by the Environmental Agency). The many claims on the land make it necessary to reserve space for future reinforcements of the flood defences. In most of the sites these spatial reservations are implemented, sometimes in combination with a zoning plan with an increasing set of restriction per zone. This is for example the case in Santander. In most sites the spatial planning is the responsibility of the municipality (they have to follow the national guidelines, of course).

Land subsidence

The level of resilience against flooding of coastal areas, especially of the low lying areas, is often negatively affected by land subsidence. This is in most sites a slow process, which is hardly mentioned as an important factor influencing coastal protection. However, in areas with methane abstraction (Po Delta along the Emilia Romagna Region, Varna Region) and/or extensive land drainage (Scheldt), this phenomenon is increasingly receiving attention.

EU Flood Directive

The EU Flood Directive will be incorporated in the national laws. In most of the sites, the activities for the Flood Directive are well ahead, so flood maps and risk inventories are being made. It is hoped for that this information becomes available to the THESEUS project.

It was observed that the majority of the interviewees are well aware of the EU Water Framework Directive (WFD) but not of the EU Flood Directive. It seems that a lesson can possibly be learned from the implementation strategy of the WFD.

Flood safety aspects

Layered approach

Flood safety can be realised through (a combination of):

- a physical flood defence system, which needs to be able to protect an area against flooding to a certain level;
- spatial planning, which aims at reducing the consequences (reduction of the number of casualties/affected people and/or economic damage) by taking flood safety as starting point in decision making on future developments;
- acting effectively during a flood event (emergency) and in the recovery phase (resilience).

Warning systems

At all sites there are forecasts for weather, wind and water levels. These forecasts are in most cases combined with flood warning systems. This does not always guarantee that the right measures are taken in case a flood is likely to occur. In the Gironde area, for instance, a wind warning was given for the Xynthia storm early 2010. This did however not result in a proper flood warning and consequently no appropriate measures were taken.

Damage compensation

In most sites, (it is expected that) the national government will compensate for damage resulting from floods. At some sites, erosion may also lead to damage, like South Devon and along Varna coast. Damages caused by erosion processes are usually not compensated for by the government.

Hold the line approach

In all sites, a preference to (dynamically) fix the coastline can be observed. For this a certain coastline of the past serves as a reference and this line is kept within a certain bandwidth. Retreat and erosion are wave and current induced phenomena. Protection against retreat of the coastline often consists of structures which cause guidance or redirection of flow, or moderation of waves in order to reduce energy from these waves and thus reducing their erosive impact. In some cases no structures are present and restoration measures (beach nourishments) are made in order to restore the line periodically.

Data availability

The availability of information differs highly between the sites. At some sites, the results of high tech models and techniques are freely available and offer real time information. Here, also historical data on weather systems, wave climate and storm surge are available. In other sites, these data are not (freely) available.

Data on economic assets and economic processes in the area, sociological structures and ecological values show a lesser availability.

CONCLUSIONS

To overcome the problems of integrating science into practice, THESEUS is developing a fully participatory approach to coastal defence planning and design. The project starting point is the analysis of present conditions in study sites, including existing defences, policies and regulations through direct contacts and meetings with stakeholders and coastal authorities.

A questionnaire was used during the first project year for interviewing local policy makers and managerial authorities and administrators to gather data for a systems analysis in the eight study sites. The goal was to obtain sufficient information to assess per study site the coastal system (including its flood defence systems) and its resilience on the short, medium and long terms.

A flood risk analysis, institutional map, inventory of coastal policies and an estimate of their sustainability have been obtained in each study site. Moreover, the observation of the local situation in the sites prompts the following recommendations to strength synergies between policy and science:

- clearly define national and regional coastal risk management goals in a broad and long-term perspective;
- reduce and better manage uncertainties in coastal flood and erosion risk assessments;
- further develop the integrated planning approach to manage coastal risks;
- increase the focus of coastal planning procedures at the participation of local communities and authorities;

- continue the international cooperation and learning process, due to the similarities in coastal problems and possible solutions, and the commonality in methodological approaches.

In a later stage of the project (2012) an additional questionnaire and analysis will be carried out to determine how long the current policies, defence management and strategies will remain effective with respect to the possible climate change, demographic, ecological and economic developments, subsidence, changes in social values and so on.

The mitigation measures developed within the project will be also discussed with local authorities in order to identify the best solutions for each study site, providing a very useful feedback of local policy makers and managerial authorities on the research.

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