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Economic aspects of global change impacts and response strategies in the coastal zone of The Netherlands

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Abstract. Economic aspects of possible land use strategies and protection measures in coastal zones as a response to global environmental change are examined. First, some key elements are mentioned that are of critical importance for water and land management in coastal zones. Next, various socio-economic repercussions are discussed. In this context, research needs will be addressed. Subsequently, these issues are considered for the case of The Netherlands. It is concluded that integrated modelling and analysis is just starting and needs to receive more attention in order to study long run economic costs, benefits and changes in coastal zones.

Keywords: Cost-benefit analysis; Economic valuation; Integrated modelling and assessment; Environmental economics; Resource economics.

Abbreviation: ICZM = Integrated Coastal Zone Management; IPCC = Intergovernmental Panel on Climate Change.

Introduction

In the past decades, coastal zones have become a focal point of policy interest. For example, in the years 1973-1993 some 25 main European policy initiatives concerning coastal zone management have been formulated, reflected *i.a.* in resolutions, declarations, directives, task forces and recommendations (see Anon. 1992a, 1993a, 1994, 1995). Most of these policy initiaives addressed issues like the environment or safety, with a particular view on the international governance of coastal areas (in terms of competence, liability or coordination). Much less attention has been devoted to the (socio-)economic potential of coastal zones as sources for balanced development opportunities, given the productive forces offered by the physical and geomorphological features of such areas. Only in recent years we observe more interest in coastal zone management with a focus on the functional synergy of land and water, as it is increasingly recognized that a significant part of our industrial world is located at, or nearby, coastal zones.

Two-thirds of the earth's surface are made up of oceans and seas and one-third of land. The perimeter of the earth's coastline is as much as ca. 1 million km. While ca. 15 % of the land surface on earth (or 5 % of the total earth' surface) may be considered as coastal zone, it is the habitat for more than 60 % of the world population; many industrial activities are concentrated in the coastal zone; it is a zone of communication and transportation for a large share of our goods and services; and last but not least it is a vulnerable ecological system of an invaluable quality. A focus on coastal zones means essentially a focus on the most dynamic parts of our global economy and ecology (see van der Plas 1996).

Coastal areas have a diversity of different - sometimes complementary, sometimes conflicting - functions. Such areas are not only environmentally fragile regions, but they offer also many opportunities for both economic development and environmental sustainability. A balanced development of complex mutual interaction between man and nature in bio-geophysical systems presupposes feasible policy strategies which are compatible with human behaviour and environmental sustainability. The latter may be defined as the ability of a natural system to maintain ecological processes and functions for an indefinite period of time. The notion of Integrated Coastal Zone Management (ICZM) has been developed to focus on sustainability in coastal zones. It is characterized by a political agenda, which may include items such as industrial progress, transportation efficiency, human health, resource conservation, hydro-electric energy supply, recreational values, international importance of species in coastal zones, hazard risks, environmental quality etc. (see Giaoutzi & Nijkamp 1993).

Coastal zones offer thus an opportunity space at the interface of land and water (see Fig. 1). These zones are usually open systems with a variety of functions, both economical and environmental. In Fig. 2, various economic-environmental interactions in coastal areas are presented. All these interactions are directly or indirectly associated with the above-mentioned permeability, accessibility, potentiality, habitat, nature and governance functions.

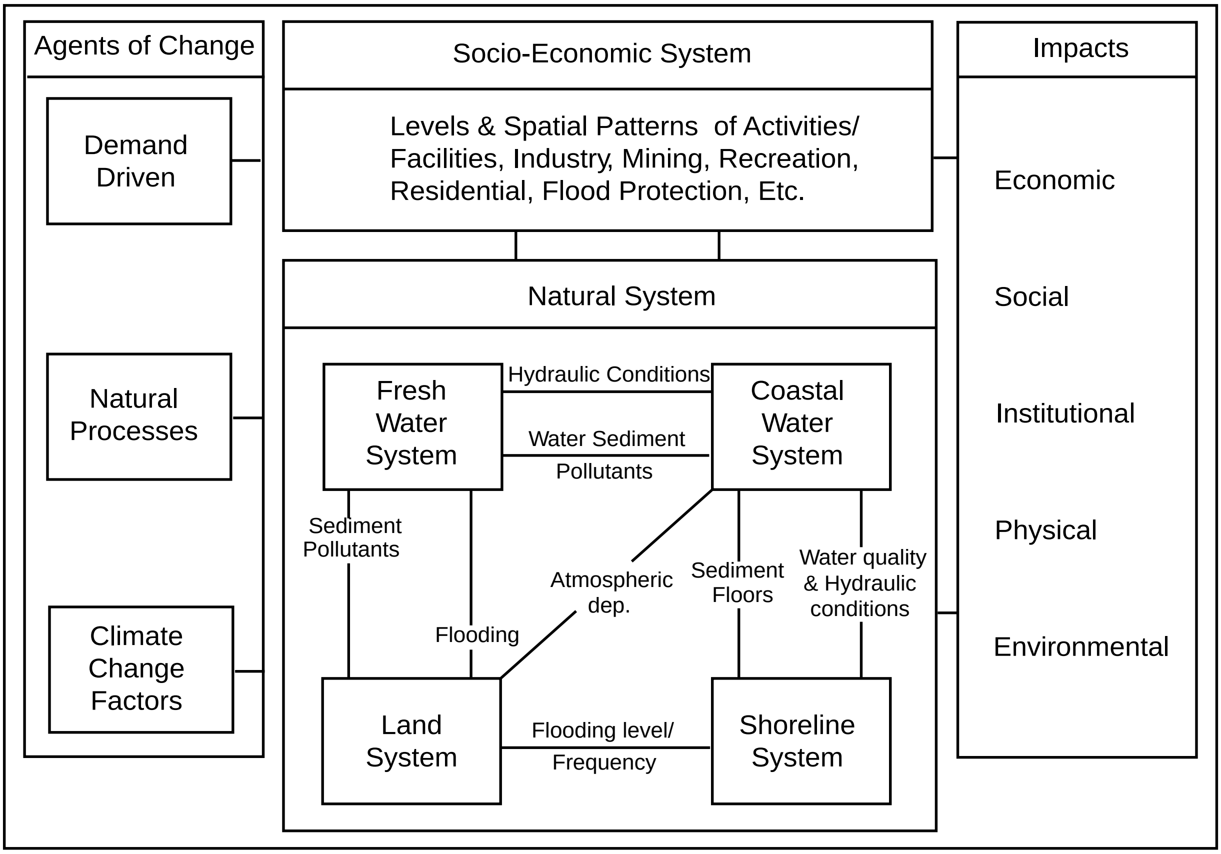

Fig. 1. The coastal zone and its subsystems. Source: Fabbri (1995)**.**

Coastal zones and the environment

The concept of 'coastal zone' is somewhat ambiguously defined. One pragmatic definition was adopted by the U.S. Commission on Marine Science, Engineering and Resources in 1969: "the part of the land affected by its proximity to the sea, and that part of the sea affected by its proximity to the land as the extent to which man's land-based activities have a measurable influence on water chemistry and marine ecology". However, the sphere of influence of the coastal zone cannot be quantified in this way, while in particular a reference to social-economic spheres is missing. Assuming a radius of action of 50 km, ca. 30 % of the entire population of Europe live in the coastal zone. The growing pressure on coastal areas, as a result of urbanization, industrialization, transportation and tourism, has led to a rapid deterioration of the environmental quality at both the land and sea side of the coastal zone.

Environmental problems in coastal zones are manifold because of the many interactions between biogeochemical conditions and human activities (Anon. 1995; Tolba & El-Kholy 1994). They include, *i.a.*, marine pollution and contamination, overexploitation of marine resources, high pressure from tourism and recreation, and coastal erosion.

A significant part of these problems is caused by exterior forces, such as pollution from catchment areas located far away and in other countries. Notably, the pollution of the river Rhine from Swiss, German and French sources cause major problems to coastal areas in the North Sea basin. It is not surprising that many European countries have tried to cope with trans-border coastal zone problems, and a broad variety of initiatives has been launched. Unfortunately, the firm statements in many policy declarations and resolutions have not been followed up by firm policy implementation. Nevertheless, ICZM should actively be designed and implemented in order to achieve various ICZM sustainability targets.

The most serious threat to coastal areas is the sea-level rise as a result of climate change (global warming). Even though the current rise is small (only ca. 2 mm/yr on average), a continuation of the thermal expansion of the oceans and the increased melting of glaciers and the polar icecap in the Northern hemisphere may cause long-range security problems for most coastal zones (see also Fig. 1). Publications of the Intergovernmental Panel on Climate Change (Anon. 1994) present some

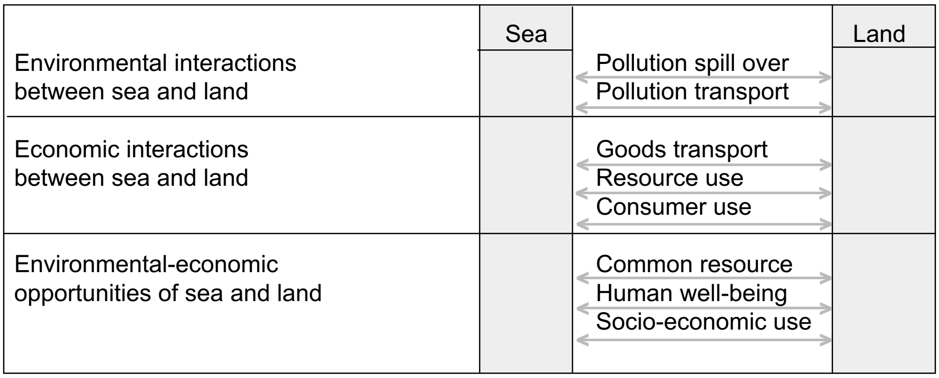

Fig. 2. Economic-environmental interactions in the coastal zone.

empirical support for the expected sea-level rise in the next century. In any case, it is evident that such a trend may imply many safety issues: inundation, temporarily flooding, coastal erosion and salinization. Consequently, seen from the perspective of both environmental sustainability and security, a pro-active rather than responsive governance of coastal zones is needed. This also implies that sufficient scientific knowledge should be available on both the physical and the social science aspects of the complex interface of land and sea.

This issue is particularly relevant to The Netherlands, where population density, industrial concentration and infrastructure in the coastal zone are the highest in the country. This does not only imply issues of safety, but also of land use planning and urbanization in the western part of the country (i.e., the so-called Randstad). In the recent past, the location of infrastructure (rail, airports and harbours) and of new urban concentrations has led to intensified debates on the socio-economic and environmental significance of the so-called Green Heart of the Randstad. There is indeed a need for more strategic thinking on coastal zones.

Impacts of global change on coastal zones and response measures

Various classifications of impacts of global change are possible, each of them useful for a particular purpose. Biophysical assessments of effects may include the following items (Parry & Carter 1998):
1. The level of productivity of the system, based on population density, or the planned yield of a crop may be negatively influenced by global change.
2. The range of existence of a regional population, such as the region inhabited or the zone of cultivation, may be affected.
3. Quality aspects such as the health of a population or the quality of a crop yield may also be at stake.

To these economic categories values can be attached, in a sequential procedure (assessing physical effects or dose-response relating; then translating these to monetary values via market prices) or directly, such as economic valuation based on stated preferences by individual people. An economic classification of effects may be as follows (Parry & Carter 1998): costs, benefits, levels of income, fertility, morbidity, mortality. Economic impacts may also be categorized according to traditional sectors or activities, such as agriculture, water extraction, industry, housing, infrastructure and recreation.

Another, more general, distinction is between direct and indirect impacts, the latter being often manifest in the future, and conditional on a direct impact. Some effects may be more indirect than others. For instance human health effects will be more direct than different location opportunities for housing and industries. This is linked to the issue of time scales, which are different for distinct effects; they may range from seconds to centuries. Economically relevant time scales will more likely range from years to decades.

Vulnerability is a much used concept that can be measured in terms of the relative sensitivity of specific activities to changing climate and sea level. Agriculture, forestry and infrastructure/transport come first to mind in this respect. It should be noted that the vulnerability depends on other conditions as well, such as the quality of technology used in the sectors, the profitability of the activities, the time horizon of the decision makers, and the social or public support. In this respect, specific activities in developed countries will generally have a lower impact than similar activities in developing countries.

Adaptations to the effects of climate change in coastal zones may be either autonomous, e.g. resulting from individual behavioural responses and market forces (price mechanisms) or from policies. They may involve retreat as well as accommodation to changing circumstances due to global change. It should be noted that policies often studied by economists, such as those aimed at reducing greenhouse gas emissions through various economic activities, are usually not considered as adaptation responses, but as mitigation strategies (Parry & Carter 1998).

Finally, the common scale needed in economic studies of effects requires that changes on a micro-level – of individuals, households, firms – are aggregated, via regions (including countries) to the global scale.

The question emerges which new cultural, social, economic and political structures, institutions and value systems would be needed to induce a flexible behavioural change, also taking into account the role of environmental education. Environmental and resource economics have gained insight in the efficiency and effectiveness of particular instruments, such as pollution charges, tradeable pollution permits – which combine advantages of charges and standards (Baumol & Oates 1988; Opschoor et al. 1994). This would need research at the interface of political science, management science, pedagogy, demography, law, sociology, psychology and economics.

Next, if we look at the environment and the coastal zones as a 'collective' good, it is necessary to also consider ownership rules, which should be imposed as restrictive measures by public bodies. Such measures will demand a high degree of social acceptance. Therefore, effectiveness studies of such measures are absolutely necessary. In such acceptance and evaluation studies it is important to examine the extent of 'free rider' behaviour, i.e. enjoying a public good but not paying for it. Such goods can be used by many persons simultaneously, for instance clean air and national defence. An additional problem is formed by the possibility that unforeseen changes in the external environment may also generate new attitudes, intentions and behaviour, which might sometimes be at odds with an environmentally favourable policy.

It should be noted that our current way of economic thinking and evaluating prevents us from adopting a long-term time horizon, due to short-sighted behaviour following from time discounting; the latter means, for instance, that one 'Euro' (the new European currency) in the future is less valuable than one 'Euro' now. Discounting may have a significant impact upon our behaviour that influences long-run processes. This may be studied with experimental economic methods, where consumption and savings behaviour is examined in laboratory settings that allow for actual financial transactions. Such experimental economics means a merger of economics and psychology.

Methods for analysis of the socio-economic system in coastal zones

Economics comes in at various stages in integrated research of coastal zone management and response strategies: social science research of coastal change has to focus attention on human needs and attitudes, conditioned by both psychological, cultural, economic, political and historical factors. It also has to focus on institutions and structures influencing human behaviour. Systems analytic research – as an interplay of economists, demographers, geographers and historians – would then be extremely fruitful, in order to identify the main causes of coastal change, such as demographic growth, industrial development, economic growth, spatial mobility, and agriculture, and its geographical distribution.

Various models are available to study economic dimensions of changes in coastal zones. They may include both purely economic and integrated models (see van den Bergh 1996). The first type includes various subcategories. Partial (incomplete sets of markets) and general (complete sets of markets) equilibrium models may be used to calculate economic changes that operate through well-established markets, or study policies that make use of so-called market-based instruments, such as charges, taxes and tradeable permits. General equilibrium models are all-encompassing descriptions while partial equilibrium models are restricted to a subset of all markets, possibly a single market. Statistical-econometric macro-economic (national or regional) models may be used to address trend-like behaviour. Input-output models are suitable for the analysis of disaggregate interactions between economic sectors, and are especially useful when indirect economic effects from one sector onto others are to be examined. Finally, optimization models (linear or non-linear programming) may be used to study optimal changes or compositions, such as relating to resource use, including land use. Special categories are formed by (1) policy-optimization models that have been developed for integrated assessment on a global scale (for an overview, see Tol 1996) and (2) dynamic models which seem almost inevitable when studying long-term issues as in the context of potential climate change and sea level rise. They may either focus on optimization – as is common in economic growth and investment theories – or on description, as in scenario simulation type of studies. Dynamic models may study development of single sectors or the entire economy.

Integrated models may be based on systems theory, combining logical and statistical relationships in a common mathematical format (analytical integration), or combining modules of a different mathematical format (optimization, simulation, static, dynamic, etc.) in a heuristic and possibly iterative manner (van den Bergh 1996).

Examples of the first type in the context of socioeconomic modelling for climate change (integrated assessment) are Nordhaus (1994), and of the second type Rotmans & de Vries (1997).

Impacts can be evaluated on the basis of monetized indicators, cost-benefit analysis, thereby making use of some of the purely economic models mentioned above. Tol (1996) discussed a range of cost categories associated with climate change. Economic valuation techniques are useful in this respect. They are divided into (1) indirect or revealed preference methods – e.g. relating market-based property values to values of marginal changes in environmental indicators; (2) indirect or stated preference methods – e.g. based on questionnaires, such as contingent valuation (Hanley & Spash 1993; Freeman 1993). Alternatively, integrated models, and some of the purely economic models, generate other indicators. Evaluation may here be done on the basis of multi-criteria methods (Janssen 1992). This has not been rigorously applied yet. Of course, it is not necessary to evaluate. One can simply present a range of core indicators to the public and politicians in the hope that they will understand their differences and complementarity, and therefore know how to aggregate them so as to come to balanced decisions.

A special problem relates to the evaluation of long-run impacts of climate change, namely discounting. This is not only relevant to the policy optimization approach and economic cost-benefit analysis, where it is explicitly included if a future stream of monetized indicators is aggregated into a single net present value or internal rate of return. Also in multi-criteria evaluation one has to decide about weights for indicator values at different times. There has been a long debate about what the impacts of discounting are and whether social discount rates should be corrected downwards for ethical reasons, i.e. to give more importance to future generations. However, conflicts between social discount rates and market interest rates may then arise. See Lind (1982) and Markandya & Pearce (1988) for a discussion. For more details on economic impact analysis and evaluation in the context of climate change see Bruce et al. (1996).

There is also a need for social impact studies, such as socio-psychological stimulus-response techniques, qualitative impact analysis, and attitude-behaviour relationships with intervening factors. In addition, barriers and potentials in the transition towards sustainable development paths must be identified: effectiveness of individual behaviour responses; acceptance of combined group and individual responsibility; and an assessment of the distribution of costs and benefits over space and groups of socioeconomic agents. From a practical perspective, modern geographic information systems and related expert systems would have to be developed to generate site-specific information.

Economic consequences of sea level rise for The Netherlands

During the 1990s, in the slipstream of the IPCC, various reports have been written about the consequences of sea level rise for the Netherlands (Anon. 1990,1991, 1992b). The Netherlands are dominated by the Delta region with the rivers Rhine, Meuse and Scheldt. About half of its area is presently below sea level. Studies up till now have addressed mainly natural science aspects. Social and economic sciences have contributed relatively little so far. Where costs have been estimated, the type of impacts considered are very restricted, mainly including protection measures. Changes in geographical distribution or organization of human activities (retreat) have not been attached costs to. Effects of risen sea levels on the productivity of specific economic sectors, such as agriculture, have neither been addressed.

What has been the starting point? Various models have calculated possible trajectories for sea level rise due to a number of crucial factors: thermal expansion of water in the world's oceans; changes in the mass of land ice of Greenland and Antarctica; and changes of smaller ice-masses and glaciers. As always, different models generate a different expected general sea level rise for the world. The IPCC model predicts for the year 2100 a rise of 49 - 55 cm, while the prediction by the IMAU (Instituut voor Marien en Atmospherisch Onderzoek, University of Utrecht) stays somewhat lower: 27-49 cm (the range being determined by development of atmospheric concentration of aerosols). Of course, geographical differences in sea level rise will occur. Following a precautionary approach, Rijkswaterstaat uses an expected relative sea level rise of 60 cm for The Netherlands. Of course there is also a change in the weather pattern expected, which can be less easily captured in a single quantitative indicator – it includes, *i.a.*, wind speed, wind direction, precipitation, evaporation, discharge, temperature, as well as seasonal variations of these factors.

As to the sea level rise indications, which impacts can be expected for The Netherlands? IPCC (Anon. 1994) mentioned five categories, given that no measures are taken: (1) the number of people affected; (2) the number of people at risk; (3) capital value at loss; (4) land at loss; and (5) wetlands at loss. The number of people at risk, now estimated at 1200, may rise to 24 000 if the sea level rises with 1 m, and to 3.7 million if the protecting dunes are subject to progressive erosion (Anon. 1994, App. 1, p. 7). The capital value at loss is estimated at $186 \cdot 10^{9}$ USD (69 % of the BNP of The Netherlands). Land at loss is estimated at 2165 km^2 (almost 6 % of the total area), and wetlands at loss at 642 km^2. Coastal wetlands are separately included, first of all as they clearly are in the danger zone being at the interface of land and water, and because they are recognized for their ecological importance as breeding, feeding and nursing grounds for many bird species, as well as for their economic importance due to the great number of functions and services associated with their presence (Turner et al. 1998).

Capital value losses can be based on estimates of capital values for specific types of land use. RA/DH/R (Anon.1992) lists such estimates, where the losses may be ca. 75% of the total capital value. Per ha the loss is the highest for the residential area (7 million NLG/ha) and harbours/industrial area (4.5 million NLG/ha), and low for pasture land, arable land, nature area, wetland and intertidal area (ranging from 10-64 NLG/ha). These figures may however be doubted. For instance, wetlands are assigned much higher values in recent research (Turner et al. 1998).

What concrete policy measures have been studied to counter the negative impacts of a sea level rise for The Netherlands? They include dike raising (presently 2800 km), dune maintenance (250 km), beach nourishment, discharge sluices, pumping stations, and raising flood-prone areas, including harbours (Anon. 1991). For different scenarios (with sea level rise ranging between 0.6 and 0.85 m over the next century) the costs have been estimated to range from 11 to about 18 billion NLG (approximately half in dollar values). The largest part of these costs (about two thirds) is associated with dike raising. These measures have been selected on the basis of two aims (DH/R Anon. 1991, p.3): minimizing the risk of taking premature or unnecessary measures, i.e. not wasting financial resources; and minimizing the risk of adopting measures too late. The analysis has been based on distinguishing between the following subsystems or subnational regions: land, coastal zone, delta area, Wadden Sea, lower rivers, upper rivers and Lake IJssel and Lake Marker. Users and costs associated with these have been divided into seven categories: (1) infrastructure and navigation, (2) agriculture and horticulture, (3) industry, (4) fishery, (5) nature conservation, (6) recreation and housing and (7) society infrastructure (Anon. 1991, p. 10). Water management is separately examined. It covers drought damage and salinity damage to agriculture, sprinkler irrigation costs, discharge pumping capacity and costs.

Let us consider the costs of raising dikes in more detail. The so-called 'dike-ring' is regarded safe if all its dike sections are safe. The dike ring runs through the different zones or subsystems mentioned. Table 1 indicates which costs are associated with dike raising in one step, for the most favourable and least favourable scenarios. It may be argued that such a one-step approach is not necessarily cost-efficient, given the gradual increase of the sea level over a period of 100 years.

Table 1. Costs in millions NLG of dike raising in one step per subsystem.

Subsystem	Climate scenario	
	Most favourable	Most unfavourable
Coast	51	842
Delta	261	1021
Wadden Sea	471	2299
Lower rivers	0	2468
Upper rivers	0	2545
Lakes	98	3205
Total	881	12380

Source: Table 5.3, Anon. (1991, p. 67).

The awareness of the threats of sea level rise has grown significantly in the past years. In many cases, there is not an immediate danger, but politicians and the public at large are concerned about the question how to ensure maximum safety against floods and inundation. This issue of threats posed by global change to coastal zones is particularly important for The Netherlands, as more than 50 percent of the country is below sea level, including the densely populated economic heartland, the Randstad. With rising sea levels, the risks will increase considerably in the future. Relevant questions are thus: what is a meaningful response strategy? What are the costs and benefits of these? What are the uncertainties involved?

This is essentially a matter of economic valuation and risk assessment, which normally has three aspects: how predictable or foreseeable are certain events (i.e. sea level rise)? How predictable are the consequences of the occurrence of such events (e.g. loss of life, damages to artefacts, new infrastructure, protection)? What are

Table 2. Predictability and policy response for sea level events.

Policy response	Event	Consequence
Prevention	Difficult to predict	Main features predictable, details less predictable
Abatement	Difficult to predict	Details difficult to predict
Compensation for damage	Possible (ex post)	Possible (ex post)

the costs and benefits associated with these consequences (in physical terms)?

It should be noted that uncertainty is also caused by the fact that the policy responses to the threats to coastal zones may range from prevention policies to abatement policies or even financial compensation policies for damage. Various combinations of predictability of phenomena and policy responses can be found in Table 2. Tools to analyse the various impacts involved are systems impact assessment, scenario analysis and cost-efficiency analysis. We will present here a combination of these analysis frameworks, with a particular view on the cost aspects.

Four main cost categories can be distinguished: damage costs to the areas concerned; loss of productive potential of the areas; safety and protection costs; financial compensation and redistribution costs. The order of magnitude of these costs depends on both the occurrence of events and the nature of policy responses (see Table 2). In our analysis we have made a distinction between event scenarios (i.e., different possibilities of future sea level rise) and policy response scenarios.

The following event scenarios are distinguished:
1. Mean 0.2-m rise per century in the period 2000-2100;
2. 0.5-m sudden rise in the next century plus a gradual rise of 0.2 m per century;
3. 1-m meter sudden rise in the next century plus a gradual rise of 0.2 m per century.

In view of these event scenarios, four policy response scenarios can be distinguished:
1. Passive: do not take any precautionary measure until the event actually happens;
2. Traditional Dutch defence attitude: do not overact, but be alert and take counter measures in time;
3. Ring dike: build a wall around The Netherlands in order to be 100% protected against the worst possible case scenario of sea level rise;
4. Neo-Atlantis: “the sea has given, the sea has taken”; accept the loss of the battle against the sea as given.

Next, these classes of scenarios can be combined in a matrix of compound scenarios where the entries in the matrix represent the expected cost implications of each combined scenario, measured in a qualitative sense (see Table 3).

It can easily be seen from Table 3 that the traditional Dutch coastal zone policy, viz. do not overreact and do not over-invest in costly infrastructure unless the need is there, seems to be the most cost-efficient approach to a proper policy on coping with the sea level rise.

Table 3. Matrix of cost implications of compound scenarios.

Event	Passive	Tradition	Ring dike	Neo-atlantis
1.	+	+	+++	++
2.	++++	+	+++	+++
3.	+++++	++++	+++	+++++

Note: an additional ‘+’ indicates a higher cost.

Concluding remarks

The range of coastal change problems is so wide, that a uniform research strategy is not feasible for the time being. Nevertheless, it would be interesting to start with a set of carefully selected pilot and experiment studies in which knowledge from different research centres could be pooled. Interesting candidate areas might be delta areas (in relation to sea level rise). Such experimental studies could easily be undertaken as a collaborative effort of research institutes where a strong tradition in the area of social science analysis of environmental problems already exists.

We may conclude that the immense complexity of the biogeophysical and human activities in coastal zone regions leads to difficult management tasks. There is a need to seek for feasible strategies that are compatible with the indigenous features of both natural and human systems. This requires a sound spatial-economic and environmental database, a clear identification of the various functions of coastal zones (based on unequivocal indicators), a clear definition of the competence of and opportunities for both private and public actors, and most of all a behaviour-oriented analysis of resilience strategies in coastal zones.

It is clear that The Netherlands will face major problems in case of a further sea level rise. There will be a need for more accurate prediction and simulation models, at the interface of engineering and behavioural modelling. The main question will be: how to use the synergy between water and land as a source of new socio-economic and environmental opportunities? Clearly, quite some imagination supported by creative scenario building and integrated modelling will be needed in the next decades in order to keep the dynamics of coastal zone development under control.

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