kculteit der Economische Wetenschappen en **Econometrie**

Serie Research Memoranda

Global Environmental Change, Logal Land Use Impacts and Socio-economic Response Strategies in Coastal Regions

Jeroen C.J.M. van den Bergh
Peter Nijkamp

Research Memorandum 1997-2

January 1997

vrije **Universiteit** *amsterdam*

GLOBAL ENVIRONMENTAL CHANGE, LOCAL LAND USE IMPACTS AND SOCIO-ECONOMIC RESPONSE STRATEGIES IN COASTAL REGIONS

Jeroen C.J.M. van den Bergh
Peter Nijkamp

Department of Spatial Economics
Vrije Universiteit
De Boelelaan 1 105
1081 HV Amsterdam
Fax: + 3 l-20-4446004
Email: jvdbergh @econ. vu. nl

Contribution to Symposium on "The Netherlands, Dynamic Lowlands - The Role of Water in the Developments of the Netherlands: Past, Present and Future", August 7, 1996. International Geographical Congress, Den Haag, August 5-l 0, 1996.

pn669.3

GLOBAL ENVIRONMENTAL CHANGE, LOCAL LAND USE IMPACTS AND SOCIO-ECONOMIC RESPONSE STRATEGIES IN COASTAL REGIONS

Abstract

This paper addresses the issue of possible land use strategies and responses in coastal zones as a consequence of global environmental change. It will first set out some key elements in global change that are of critical importance for the water and land management in such areas. Next, it will map out in more detail the various environmental and socio-economic repercussions of such megatrends. This will then be followed by a discussion of the necessity to develop proper coastal zone management policy strategies in order to cope with uncertain challenges. In particular, the research needs will be addressed. The paper will then illustrate the potential of integrated coastal zone dynamic and spatial modelling and evaluation, on the basis of an empirical case study for a coastal region. Furthermore, a number of spatio-economic scenarios related to sea level issues in the Netherlands will be presented. In this context also risk assessment is shortly discussed in relation to sea level rise.

1. Setting the Scene

In the past decades coastal zones have become a focal point of policy interest. For example, in the years 1973-1993 already some 25 main European policy initiatives concerning coastal zone management have been formulated, reflected inter alia in resolutions, declarations, directives, task forces and recommendations (see Dobris, 1995). Most of these policy initiatives 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-third of the surface of our earth is composed of sea waters and only one-third of land. The perimeter of the coastline on our earth reaches astronomical figures, viz. approximately 1 million km. It seems plausible that at least some 15 percent of the land surface on earth (or 5 percent of the total earth' surface) may be coined a coastal zone. But this zone is the habitat for more than 60 percent of the world population; it is a concentration point of many industrial activities; it is a communication and transportation area for a large share of our goods and services; and it is a vulnerable ecosystem 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).

A coastal zone is not only a nexus where land and sea meet; it is in particular a nexus where man tries to maximize the synergy offered by the significant difference in potential of two different 'contact spaces'. This synergy explains why so many human and industrial activities are directly or indirectly connected with coastal zones. Such areas have in the past been of strategic importance and will continue to be focal points of living and working, as they offer a great multiplicity of complementary functions for a broad set of actors:

- meeting and exchange place of different nations and cultures: the permeability function;
- transshipment place for people and commodities from a long distance: the accessibility function;
- location area for industrial and economic activities: the potentiality function;
- settlement area for households: the habitat function;
- a high quality of life area based on an enormous diversity in marine and terrestrial ecosystems: the nature function.

Coastal zones offer thus a great variety of important functions which makes them often more attractive than other regions. This attractiveness causes at the same time a sustainability problem: the dense concentration of many activities in coastal areas may be at odds with fragile environmental and natural values in these areas (see GESAMP 1990; Hinrichsen 1990) This is once more causing a widely shared concern, as coastal zones are highly sensitive to changes induced by human activities: water pollution, noise, landscape destruction, natural and human hazards, human interventions in the seashore etc. Sustainable coastal zone development is thus a policy activity marked by multiple conflicts in a rapidly changing and vulnerable environment. Policy response strategies to sustain the quality of coastal areas are no doubt needed, but require a balance in a complex and intricately interwoven policy setting. In the next section we will address more explicitly the environmental threats and challenges coastal areas are faced with today.

2. Coastal Zones and the Environment

The concept of 'coastal zones' is not unambiguously defined, but a practical definition is the one given by the US Commission on Marine Science, Engineering and Resources (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". Clearly, this is not a measurable description of coastal zones, while in particular a reference to social-economic spheres of influence is missing. But it can easily be understood that, assuming a radius for the sphere of influence of 50 km, some 30 percent of the entire population of Europe lives in coastal areas. The rising pressure on coastal areas - as a result of urbanisation, industrialisation, transportation and tourism - has led to a rapid decay in environmental quality at both the land and sea side of coastal zones.

The environmental problems of coastal zones are - in light of their biogeochemical nature and human contact space - manifold (Dobris Assessment 1995; Tolba and El-Kholy 1994):

- marine pollution and contamination;
- overexploitation of marine resources;
- high pressures from tourism and recreation;
- coastal erosion;
- habitat loss and degradation;
- visual intrusion resulting from landscape or 'seascape' destruction (cf. Walker 1988);
- air, water and surface pollution at the landward side.

A major problem of coastal areas is that a significant part of their environmental decay is caused by exterior forces, e.g., pollution resulting from catchment areas often located at a long distance and belonging to other nations. The river Rhine is a glaring example of this phenomenon causing major problems to coastal areas in the North Sea basin. It is thus no surprise that many European countries have tried to cope with trans-border coastal zone problems, and that a broad variety of initiatives has been launched in this respect. Unfortunately, the firm statements in many policy declarations and resolutions has not been followed up by firm policy implementation. Nevertheless, coastal zone management (CZM) should actively be designed and implemented in order to achieve various CZM sustainability targets. Necessary policy steps to realize such goals are (see Dobris Assessment 1994):

- determine human desires for using the coastal zone;
- determine the (carrying) capacity of the coastal zone to meet these desires;
- determine to what extent various uses balance capacities and how uses affect the coastal zone;
- solve eventual conflicts of uses and capacities pro-actively;
- rely on reliable, comparable and quantitative data for decisions and control measures;
- rely on active participation of a well informed public;
- integrate environmental priorities into coastal development objectives at the local, national and international levels;
- integrate seaward and landward aspects; and
- encourage the establishment of CZM ecological or administrative units (e.g., as already exists with the Wadden Sea collaboration between The Netherlands, Germany and Denmark).

This list of steps to be undertaken to gather strategic knowledge on CZM takes for granted the bio-physical nature of coastal zone processes, but addresses in particular the question of the ‘human factor’ in such processes, viz. the cause of the various pressures and the impact of mankind (including recovery policies and trans-border cooperation). Clearly, ‘positive’ public intervention will only come into being, if there is sufficient awareness of the high social costs of environmental externalities in coastal zone development.

Another problem which may in the long run mean a serious threat to coastal zone areas is the sea-level rise as a result of global warming and climate change. Even though the current rise in sea levels is on average small (in the past century some 2 mm per year), it goes without saying that 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. The recent published IPCC report tries to give some empirical underpinning for the expected sea-level rise in the next century, which may exceed the average 2 mm per annum. In any case, it is evident that such a structural trend may lead to many safety issues: inundation, temporarily flooding, coastal erosion and salinisation. Consequently, seen from the perspective of both environmental sustainability and environmental security, a pro-active governance of coastal zones is warranted. This also implies that sufficient scientific knowledge should be collected on both the physical and the social science aspects of the complex interface of land and sea.

This issue is particularly relevant for the Netherlands, where the highest population density, industrial concentration and infrastructure supply can be found in the coastal zone of the country. This does not only provoke issues of safety, but also of land use planning and urbanization in the Western part of the country (i.e. the 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.

3. Coastal Zones as Open Multifunctional Systems

Coastal areas have a diversity of different - sometimes complementary, sometimes conflicting - functions. Such areas are not only environmentally fragile regions, but offer also many opportunities, for both economic development and environmental sustainability. A balanced co-evolution of the complex mutual interaction in bio-geophysical systems presupposes feasible policy strategies which are compatible with human behaviour and ecological sustainability. CZM is thus also characterized by the political agenda, which may include items like 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 and Nijkamp 1993).

Coastal zones offer thus an opportunity space at the interface of land and water. These zones are usually open systems with a variety of functions, both economically and environmentally. In Figure 1, an illustrative picture of various economic-environmental interactions in coastal areas are mapped out. All these interactions are directly or indirectly associated with the above mentioned permeability, accessibility, potentiality, habitat, nature and governance functions.

Figure 1. Economic Environmental Interactions in Coastal Zones

	Sea		Land
Environmental interactions between sea and land		Pollution spill over < ------------------------ > Pollution transport < ------------------------ >	
Economic interactions between sea and land		Goods transport < ------------------------ > Resource use < ------------------------ > Consumer use < ------------------------ >	
Environmental-economic opportunities of sea and land		Common resource < ------------------------ > Human well-being < ------------------------ > Socio-economic use < ------------------------ >	

To obtain in-depth knowledge of the functioning of coastal systems, to understand the interference with human behaviour, and to develop and assess policy strategies focused on sustainable development of coastal areas, a series of research tasks would have to be fulfilled (see LOICZ 1996):

- development of data-bases for available land/ocean/atmosphere input records (carbon, nutrients, pollutants, sediment); for ecological and morphological system characteristics (GIS); for coastal resources and their uses; for fluxes, sources and sinks of particulate and dissolved substances;
- assessment of variability and trends;
- development of consistent scenarios for change;
- identification and description of key processes and feed-back for sediment-biota interaction;
- identification and description of key processes and feed-backs for the coupled natural and socio-economic coastal system components;
- modelling of transport, storage and transformation of particulate and dissolved substances;
- morphodynamic response models to anthropogenic change and sea level rise;
- biogeochemical modelling of cycling of matter, in particular carbon;

- economic evaluation of coastal resources and uses;
- identification of environmental indices of sustainable use;
- development of an integrated model of the natural and socio-economic components of the coastal system;
- development of a framework for vulnerability analysis and integrated coastal zone management.

It is evident that the fulfilment of such research tasks is fraught with many problems, as a systematic framework of analysis for the interface of human and biogeophysical processes is needed, taking into account different space-time scales and site specific economic-environmental mechanisms.

4. Towards a Multifunctional CZM Research Methodology

Coastal zones are thus force fields of human and biophysical interactions, and mirror an unprecedented dynamics caused by a worldwide tendency towards over-use of such areas. This has brought about a multitude of negative environmental impacts, such as the effects of dumping of industrial and human waste, erosion and deposition, eutrophication, pollution, destruction of marine life and overall decrease of biodiversity (cf. Cooke and Doornkamp 1990; Fischer 1985). As mentioned above, coastal zones offer a wide spectrum of functions which are used or affected by a large variety of different actors.

Such actors may be: households, tourists, industries, travellers, recreationers, fisherman, all of them contributing in various ways to the positive opportunities and the negative externalities in coastal zones. Consequently, there is a need for more integrated and cohesive policy strategies for coastal areas (cf. OECD 1993). Integration may refer here to policy coordination between different agencies and institutions, to uniform concepts and strategies among different tasks of CZM, to multi-layer organization of governments, to harmonisation of multisectoral interests, or to spatial and temporal coordination. The fulfilment of this policy challenge requires undoubtedly a wide variety of scientific insights, as CZM is marked by complicated spatio-temporal and intersectoral trade-offs.

It seems thus necessary to undertake a rigorous effort to develop applicable analysis frameworks for the following issues:

- design of a relevant indicator system;
- development of a reliable monitoring system;
- exploratory and explanatory data analysis and modelling;
- development of an operational impact assessment system;
- application of predictive simulation and conditional scenario experiments;
- assessment of costs of scenarios and strategies, including climate change impacts (e.g., Fankhauser and Tol, 1995);
- policy analysis of alternative CZM options;

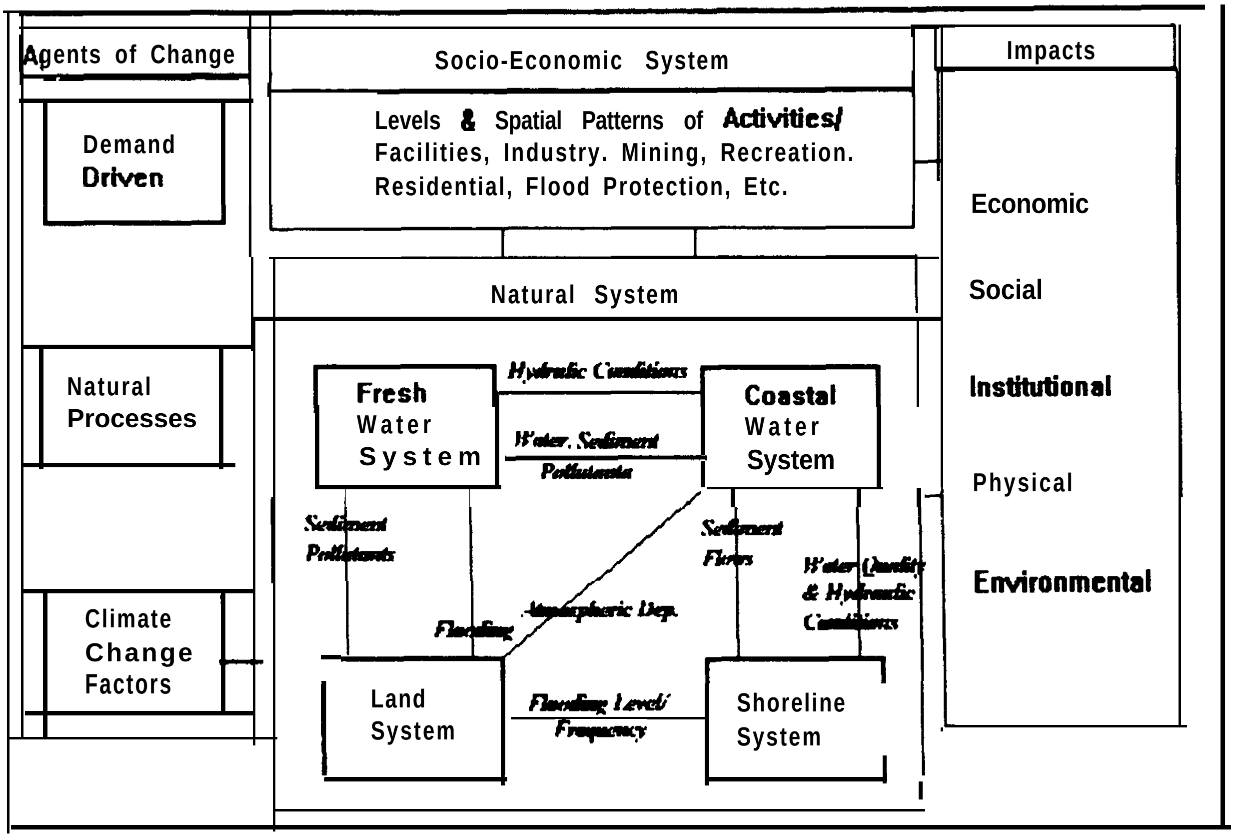
- risk analysis of foreseeable futures on coastal areas.

The various research tasks may be summarized in a concise way in Figure 2. This figure takes for granted that coastal zones are complex and vulnerable areas exposed to many force fields, in which both the natural and the socio-economic system play a role. The natural system comprises inter alia land, shoreline, fresh water and coastal water subsystems, while the socio-economic system is characterized by a multitude of functions as expiained above. A systematic presentation of various interactions in coastal zones can be found in Figure 3 (see also Fabbri 1995). By confronting next Figure 2 with Figure 3, we may try to design more systematically various research tasks for the social sciences in the area of CZM with a particular view on the various functions distinguished in Section 1. These will now briefly be elaborated.

Figure 2. A research structure for integrated CZM

EFFECTS OF THE SOCIO-ECONOMIC SYSTEM ON COASTAL ZONES	(1)
↓	
GEOMORPHOLOGICAL CHANGES IN COASTAL SYSTEMS	(2)
↓	
HUMAN BEHAVIOURAL IMPACTS CAUSED BY COASTAL CHANGES	(3)
↓	
POLICY RESPONSES AND CZM SUSTAINABILITY STRATEGIES	(4)
↓	
ANALYSIS FRAMEWORK AND METHODOLOGY FOR CZM	(5)

Figure 3. The Costal Zone System and its Subsystems



Source: WCC, 1993

(1) **Effects of the socio-economic system on coastal zones**

As far as coastal change has a societal background, social science research in this field has to focus attention on human needs and attitudes, conditioned by both psychological, cultural, economic, political and historical factors as well as on institutions and structures influencing human behaviour. Systems-analytic research - as an interplay of economists, demographers, geographers and historians (and of course natural scientists) - would then be extremely fruitful, in order to identify also the main causes of coastal change (e.g., demographic growth, industrial development, economic growth, spatial mobility, or agriculture) and its geographical distribution. Despite the important cumulative effects of human behaviour at large on coastal zones, it should be recognized that the impact of one individual actor is usually negligible. Thus the complex chain of individual action to integral change is hardly traceable, which causes great difficulties in increasing the awareness of environmental effects and of the need for a reorientation and drastic changes in human behaviour. In this vein there is a need for new social impact studies (e.g., socio-psychological stimulus-response techniques, qualitative impact analysis, attitude-behaviour relationships with intervening factors). Particular attention would have to be given to social experimentation: to identify barriers and potentials in the transition towards sustainable development paths (e.g., measuring effectiveness of individual behaviour responses; acceptance of combined group and individual responsibility; individual cost-benefit assessment of changes in behaviour). From a practical perspective, modern geographic information systems (GIS) and related expert systems would have to be developed to generate site-specific, tailor-made information.

(2) Geomorphological changes in coastal systems

This part deserves due attention of natural scientists, but falls outside the scope of social scientists. The main concern here is to look for methodological consistency in an interdisciplinary context.

(3) Human behavioural impacts caused by coastal changes

Elimination of uncertainty and risk assessment - from the viewpoint of ecologically sustainable economic development - are necessary items on a research agenda for sustainable CZM. Traditional scenario experiments (ranging from 'business as usual' scenarios to 'doomsday' scenarios) can certainly be helpful in this respect, while also resort could be taken to recently developed mathematical models for treating unpredictable dynamics (e.g., chaos theory, fractal theory). Such approaches might be supplemented with socio-psychological risk perception analysis and socioeconomic evaluation analyses. The 'social dilemma' alluded to above causes the need to develop incentives to change human behaviour, even though the direct impacts of such changes are not immediately observable. This lack of direct visibility requires social research methods which would be able to demonstrate convincingly the relevance of a drastic orientation in attitudes and behaviour. In this context, new environmental education systems - design and implementation - are a major challenge for the social sciences. This would need a focus on motivations and objectives of individuals and groups, as well as on stimuli inducing behaviourial responses, taking into consideration psychological, economic, cultural, anthropological and historical factors. It might also be interesting to investigate which driving forces have in the past been able to generate resilience in human behaviour, to remove inertia and to overcome major developmental barriers to individuals, groups and societies (including the role of institutions).

(4) Policy responses and CZM sustainability strategies

Two contextual factors play a role here. First, the role and impact of established institutions and existing regulations with regard to rigidity or flexibility in human behaviour regarding consumption patterns, including resource use or space consumption, especially from the viewpoint of the 'tragedy of the commons'. Here is a clear case for socio-economic research into market and government failures. Secondly, the question emerges which new cultural, social, economic and political structures, institutions and value systems would be needed to induce a flexible behaviourial change, taking into account also the role of environmental education. 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, then it is necessary to consider also ownership rules to 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 a conditio sine qua non. In such acceptance and evaluation studies also 'free rider' behaviour would be a central component. An additional problem may be formed by the fact that unforeseen changes in the external environment may also generate new attitudes, intentions and behaviour, which might sometimes be at odds with an environmentally benign policy. In this context strategic contingency studies may be a very helpful tool in social science research. And finally, the 'tragedy of the commons' is caused by the fact that the high social costs of coastal change are not borne by the source of the evil. Is it possible to develop market incentives to induce behaviourial change? Our current way of economic thinking and evaluating prevents us from taking into account a very long-term time horizon caused by a myopic use of the social rate of discount. Multigenerational evaluation studies would then need to be developed from the viewpoint of an ecologically sustainable pathway. The way such incentives might influence our current behaviour requires new analytical tools, where especially experimental economics may provide new contributions. This would need a merger of economics, social psychology, law, political science and management science.

(5) Analysis framework and methodology for CZM

A great diversity of methodological contributions in the social sciences can be distinguished which all aim to map out the complex human-environmental interactions in coastal areas. Examples are:

- the development of spatial externality theory and models;
- resource management models;
- applied input-output models;
- materials balance models;

- multi-objective decision models;
- spatial negotiation and bargaining theory;
- intergenerational resource allocation models;
- system dynamics simulation models;
- scenario design for seashore development;
- computable general equilibrium models;
- meta-analysis of comparative CZM policies.

Some of these methods can also be combined, for instance, for description, analysis, and evaluation (see Van den Bergh 1996). In the following two sections some illustrative applications of such methods are given. The first one concerns a systems-analytic approach to a marine environment; the second one addresses the issue of policies on sea level rise in the Netherlands.

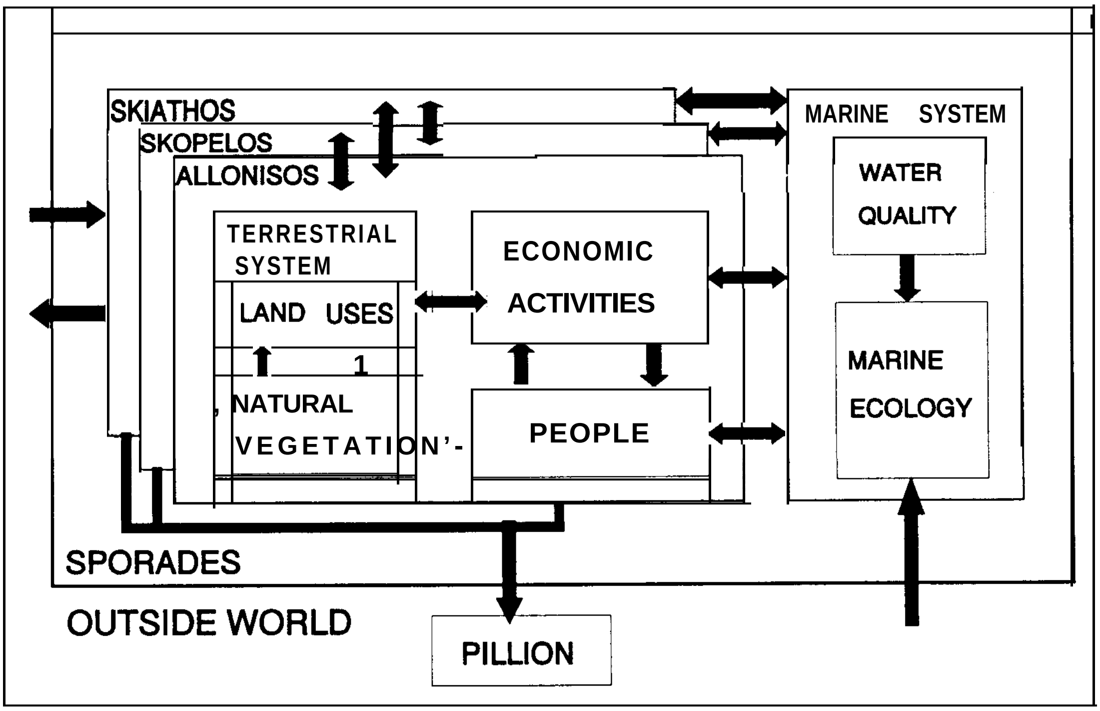
5. An Illustration of a Systems-Analytic Application to a Marine Park Region

In this section some flavour is given of the application of various methods, in particular integrated dynamic modelling, spatial modelling and multicriteria evaluation, to study regional sustainable development of a particular coastal zone, viz. the island region of the Sporades in Greece. Like many coastal areas, a potential conflict exists here between environmental conservation, local interests and rapid growth in tourism. A dynamic model was used to depict the development of the economies of three main islands and their interactions with the terrestrial and marine environment. For more details see Giaoutzi and Nijkamp (1993), Van den Bergh and Nijkamp (1994) and Van den Bergh (1996, Ch. 11).

The model of the island region focuses on the interaction of land-based and marine-based activities, considering marine park policies in a wider economic, coastal zone perspective. The past directions of development of the islands (Skiathos, Skopelos and Allonisos) have been greatly influenced by the pattern of tourism. However, the development stages of the three islands differ significantly. The island economies are rather small-sized. The following economic sectors can be distinguished: local services, fishery, agriculture, public sector, construction and two tourism based sectors (accommodation and services). Trade and transport are arranged by mainland firms, leaving no special benefits for the local population otherwise than via the local services. This sectoral disaggregation is based on a combination of considerations: labour market operation, interdependencies between activities, and economic-environmental relationships. The model is descriptive and used for dynamic simulation based on well-chosen development and policy scenarios. For further details the reader is referred to Van den Bergh (1991, Ch. 9) and Van den Bergh and Nijkamp (1994).

In Figure 4 the overall structure of the model is shown, which is designed according to interactive modular components. On this highest modular level descriptions are given of the three main island economies, the socio-economic relationships with the outside world, the influence on the nearby area Pillion, and the impact of the mainland on the marine system. The three main islands in the region are separately treated for three reasons. First, their development levels differ. Second, only the Allonisos module includes a terrestrial submodule with a description of land use and natural vegetation cover. And finally, Allonisos receives special attention in the study from the policy perspective. The economy and people modules are set up for each of the islands.

Figure 4. Structure of the economic-environmental model



Many scenario simulation results are available. One interesting indicator, in view of the foregoing discussion, is the population (size) of Monk Seals. In addition to such dynamic patterns for specific indicators, a multicriteria analysis (MCA) and geographic information systems (GIS) analysis were performed, which can serve as input for a decision support system (DSS) for sustainable development (SD) planning of the islands' region. The MCA can generate a ranking of policies or scenarios under different preference structures of decision-makers (e.g., policy makers or politicians). A detailed spatial evaluation of these alternatives is however not possible. As various development options may be judged in a different way if their geographical patterns differ significantly, it seems useful to evaluate these alternatives also from a geographical perspective. Therefore, spatially different policies (called land use alternatives) were considered and developed focusing on the growth of urban areas on the island of Allonisos (see for details Despotakis 1991). These policies can be combined with general development alternatives, which leads to combined alternatives. Various judgement criteria can be used to evaluate the alternative land use maps, for instance, based on land use suitable for tourism, nature, landscape, and transportation. The resulting GIS maps can be translated into numerical information so that also multicriteria analysis of spatial scenario outcomes can be performed. More details are offered in Van den Bergh (1996, Ch. 11).

This illustrative study makes clear that decision support for coastal zone management can be based on systems-analytic tools of dynamic modelling, multicriteria analysis and geographical information evaluation. This may increase awareness of current frictions and future incompatibilities in economic development, environmental sustainability, land use shifts and marine park policies. Such detailed integrated modelling efforts have unfortunately not yet been undertaken in the Netherlands.

6. Risk Assessment for Dutch Coastal Zones Facing Future Sea Level Rise

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 is particularly important for the Netherlands, where more than 50 percent of the country is below sea level (including the densely populated economic heartland, the Randstad). With increasing sea levels, the risks become higher and higher in the future. Thus the question is: what is a meaningful response strategy?

This is essentially a matter of risk assessment, which normally has two 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, costs)?

Next, the policy responses to such questions may be different, ranging 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 1. Tools to analyze 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 costs aspects.

Table 1. Predictability and Policy Response for Sea Level Events

	PREDICTABILITY	
POLICY RESPONSE	EVENT	CONSEQUENCE
PREVENTION		
ABATEMENT		
COMPENSATION FOR DAMAGE		

TOOLS:

- Impact Assessment
- Scenario Analysis
- Cost-effectiveness Analysis

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 1). 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:

- average .2 meter rise per century in the period 2000-2 100;
- 1 meter sudden rise in the next century plus a gradual rise of .2 meter per century;
- 2 meter sudden rise in the next century plus a gradual rise of .2 meter per century.

In view of these event scenarios, four policy response scenarios can be distinguished:

- passive: do not take any precautionary measure until the event actually happens;
- traditional Dutch defense attitude: do not overact, but be alert and take in time counter measures;
- rind dike: build a wall around the Netherlands in order to be hundred percent protected against the worst possible case sce-

nario of sea level rise;
- neo-Atlantis: 'the sea has given, the sea has taken'; accept the loss of the battle against the sea as given.

These classes of scenarios can next be combined in a matrix of compound scenario's, where the entries in the matrix represent the expected cost implications of each combined scenario, measured in a qualitative sense (see Table 2)

Table 2. Matrix of Compound Scenarios

POLICY RESPONSE

EVENT	PASSIVE	TRADITION	RINGDIKE	NEO-ATLANTIS
(1)	+	+	+ + +	+ +
(2)	+ + + +	+	+ + +	+ + +
(3)	+ + + + +	+ + + +	+ + +	+ + + + +

Need For:
- Long-term Modelling
- Socio-economic/psychological Response Mechanism
- Long-term Global Change and Risk Evaluation

It can easily be seen from Table 2 that the traditional Dutch coastal zone policy, viz. do not over react 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.

7. Concluding Remarks

The range of coastal change problems is so wide and diverse, 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 already a strong tradition in the area of social science analysis of environmental problems 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 competencies and opportunities of 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 predictions 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 will be needed in the next decades in order to keep the dynamics of coastal zone development under control.

References

Bergh, J.C.J.M. van den, Dynamic Models for Sustainable Development, Thesis Publishers, Amsterdam, 199 1.

Bergh, J.C.J.M. van den, Ecological Economics and Sustainable Development: Theory, Methods and Applications, Edward Elgar, Aldershot, 1996.

Bergh, J.C.J.M. van den and P. Nijkamp, 1994, An Integrated Model for Economic Develop ment and Natural Environment: An Application to the Greek Sporades Islands, The Annals of Operations Research, Vol. 54: 143-174.

Cooke, R.U. and J.C. Doornkamp, Geomorphology in Environmental Management, Clarendon Press, Oxford, 1990.

Despotakis, V.K., Sustainable Development Planning Using Geographical Information Systems, Ph.D. dissertation, Free University, Amsterdam, 1991.

Dobris Assessment, Europe's Environment, European Environment Agency, Copenhagen, 1995.

Fabbri, K., Development of a Spatial Decision Support System for Integrated Coastal Zone Management, Research paper, JRC, Ispra, 1995 (mimeographed).

Fankhauser, S. and R.S.J. Tol, The Social Costs of Climate Change: The IPCC Second Assessment Report and Beyond, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, report W-95/34, 1995.

Fischer, D.W., Shoreline Erosion: A Management Framework, Journal of Shoreline Manage ment, vol. I, 1985, pp. 37-50.

Giaoutzi, M. and P. Nijkamp, Decision Support Models for Regional Sustainable Develop ment, Avebury, Aldershot, UK, 1993.

Hinrichsen, D., Our Common Seas: Coasts in Crisis, UNEP, Earthscan, London, 1990.
LOICZ, Outline of the National Science Plan, KNAW, Amsterdam, 1996.

OECD, Coastal Zone Management: Integrated Policies, Paris, 1993.

Plas, S.B.M. van der, Integrated Multifunctional Sustainable Coastal Development, Urban Habitat: The Environment of Tomorrow (G. van der Meulen, ed.), Series Bouwstenen, Eindhoven University of Technology, Eindhoven, 1996, pp. 256-265.

Tolba, M.K., and O.A. El-Kholy feds.), The World Environment 1972-1992, UNEP, Chapman & Hall, London, 1994.

GESAMP, The State of the Marine Environment, UNEP, Blackwell, Oxford, 1990.

Walker, H.J. (ed.), Artificial Structures and Shorelines, Kluwer, Dordrecht, 1988.

WCC (World Coast Conference), How to Account for Impacts of Climate Change in ICZM, 1993, version 2.