Climate change, sea level rise and Dutch defense strategies

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CLIMATE CHANGE, SEA LEVEL RISE

AND DUTCH DEFENSE STRATEGIES

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Abstract

This paper provides a concise evaluation of Dutch defense strategies against the threats of the sea level rise as a consequence of global climate change. A set of (external) event scenarios for sea level rise is described ranging from a modest to a dramatic rise. Next, four different policy response scenarios are presented, while their related costs are confronted with the threats of the event scenarios. It is concluded that - seen from a cost-effectiveness approach to various defense strategies - the traditional Dutch defense strategy is for the time being the most proper response to the sea level rise.

1. Introduction

In recent years the notion of 'sustainable development', advocated by the World Commission on Environment and Development in its so-called Brundtland Report (1987), has attracted world-wide interest. It is increasingly recognized that current economic and industrial activity has reached a critical level that threatens the stability of the atmosphere-biosphere system (see e.g. Archibugi and Nijkamp, 1989). This threat is inter alia reflected in the greenhouse phenomenon, i.e., the buildup of concentrations of several trace gases in the atmosphere, notably carbon dioxide, nitrous oxide, methane, tropospheric ozone, and chlorofluor carbons. These gases are known to change the radiative balance of the earth in such a way that a high degree of infra-red radiation is trapped, leading inter alia to a significant increase of average temperature on earth (see also Barth and Titus, 1984 and Walter and Ayres, 1990).

As a result of the warming of the climate a variety of atmos-pheric and biospheric changes may be expected, one of them being a rise in the sea level caused in particular by an accelerated thermal expansion of the ocean water (see among others Bolin et al, 1986, and Rosenberg, 1988). Although there are evidently many uncertainties in the assessments of the extent to which the sea level will rise(ranging from 0.2 to 1.65 meters in one century), there is a common acceptance of the fact that the level of oceans will indeed increase in the near future (cf. Hekstra, 1986). Current mathematical models are however unable to provide accurate predictions, because of the highly non-linear synergetic processes involved in the complex greenhouse phenomenon (cf. Salomon and Kauppi, 1990). As yet there is no scientific evidence as to the exact rate of sea level rise; recently several interesting sea level rise scenario's have been made by the IPCC.

It is clear that sea level rise will mainly have an impact on low coastal areas, such as Denmark, The Netherlands, Egypt, Bangladesh, India, Indonesia, the Maldive Atolls, and Thailand. Apart from risks of flood and inundation (implying a loss of - usually fertile - lowland), there will also be a massive rise in salinity levels, as salt water will move upstream via rivers and delta areas. It needs no further arguments that the social costs of sea level rise may become formidable, in terms of both damage costs (e.g., loss of productive land, wetland ecosystems or coastal lagoons) and abatement costs (e.g., construction of new dikes).

It is clear that not all economic sectors will suffer from the sea level rise to the same extent, but agriculture, housing (and other property) and forestry are among the sectors which most likely will incur high costs, depending of course on their geographical location. Besides, it should be noted that the above costs may be aggravated by other climatic changes such as changes in the hydrological regime, wind and wave climate, etc.

In this paper - of a case study nature - we will first provide a concise overview of various consequences of sea level rise for the Netherlands by describing main types of effects by means of so-called event scenarios. Next, in Section 3 we will describe potential policy responses to these events by a set of policy scenarios with respect to the sea level rise. This will then be followed by a consideration of policy evaluation problems in this field;based on cost-effectiveness analysis, various policy scenarios will systematically be examined in order to identify the most plausible one, seen from the viewpoint of current information and policy interest. The paper will be concluded with some retrospective and prospective remarks.

2. Event Scenarios for Impacts of Sea Level Rise

The knowledge concerning the impacts of climatic changes on the level of oceans is still in its infancy. The same holds for our knowledge of the impacts of sea level rise upon our economic and ecological systems. This unusually complex problem is even more difficult to handle because of the long time periods involved, in terms of both impacts on our living system and of effective impacts of (international) government responses. Given the high social costs involved in a long-term continuing sea level rise, and given the high risk of misinvestments in extremely expensive coastal infrastructure and coastal protection works, it is evident that we are facing here a very difficult choice problem for planners. At present, various vulnerability assessments of coastal areas are carried out by various organizations in order to reduce risks of misinvestments.

Despite the great many uncertainties in predicting future events and appropriate government actions, it is clear that an alert attitude is needed, as the number of coastal areas at risk is quite large (see, for instance, Figure 1 derived from Wind, 1987, and Delft Hydraulics and Rijkswaterstaat, 1986).

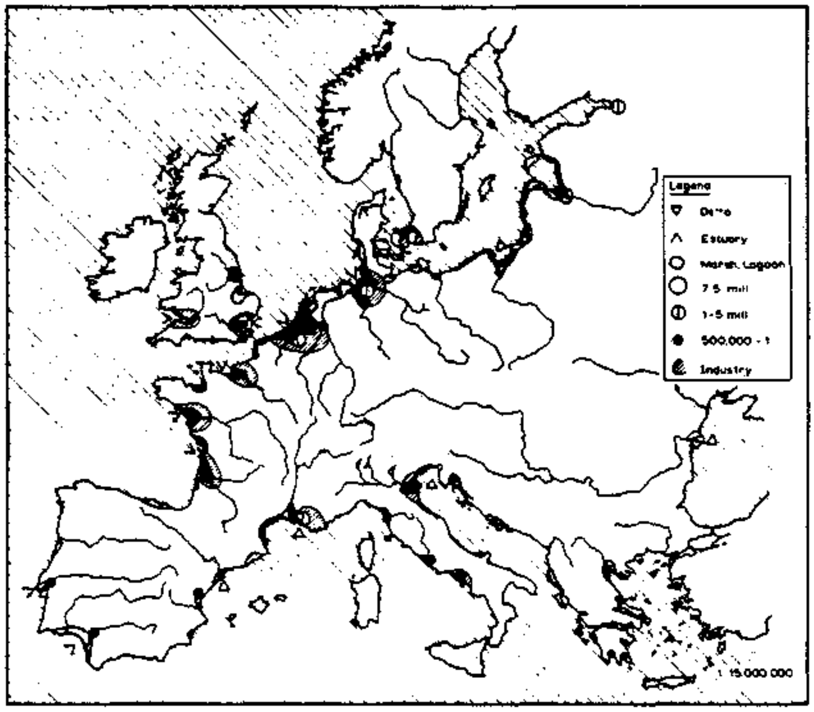

Figure 1.
Source: Wind (1987)

It is conceivable that the expected rise of the sea level has caused much concern in the Netherlands, as significant parts of the country - notably the Western densely populated area - are threatened by a significant rise in water levels. As mentioned before, the extent and the speed with which this rise will take place is largely unknown. Therefore, it is a reasonable research strategy to develop various scenario's in order to investigate how serious certain events may be and which policy responses are plausible or likely. We will refer to these scenarios as <u>event</u> scenarios, as they describe the foreseeable consequences of external events, i.e. various time paths and intensities of a sea level rise.

Clearly, such event scenarios are generic in nature (as they stem from global impacts), but their regional impact may differ considerably. For the Netherlands, for example, it has been estimated that the probability of a catastrophic storm surge along the coastal areas will - in case of a sea level rise of 1.5 m - be one in every three years (cf. Vreugdenhil and Wind, 1977). This high probability is caused by its delta structure which causes a significant danger for considerable parts of the country which are now already below sea level (the lowlands often consisting of reclaimed land), but protected by an extensive system of dikes and other hydrological works. Loss of these areas which have a high population density, but at the same time an extremely high productivity per hectare (for both agriculture and industry) would lead to enormous socio-economic and financial costs (see for an overview Titus, 1977). Such costs would involve inter alia inundation of wetlands and lowlands in the Netherlands, accelerated coastal erosion, increased flood disasters for remaining areas, rapid salt water intrusion into groundwater, rivers, bays and farmland, damage to port facilities in the Netherlands, disruption of fisheries and bird habitats, and loss of recreational beaches. All such costs would have to be considered in event scenarios for the rise of the sea level (see also Figure 2).

In a study on event scenarios for the Netherlands three such alternatives have been distinguished by van der Kley (1977). Details can also be found in this reference. These scenarios will concisely be described here, as they will be used in the sequel of this paper.

Event scenario 1

Continuation of the present trend of 0.2 m rise of the sea level per century. This scenario is essentially a linear extrapolation of current trends and is used as a reference scenario. This scenario will cause local problems, but countermeasures can be taken along the lines of the present Dutch strategy for flood protection and water management. A maintenance of the current intensity of flood protection and water management schemes is sufficient.

Figure 2. Inundation areas of the Netherlands

inundation area at present sea level

inundation area at 1 meter rise in sea level

inundation area at 5 meter rise in sea level

Source: De Bruin and Pepping (1989)

Event scenario 2

Additional sea level rise of 1 m between 2000 and 2100, followed by a continuation of the current trend of 0.2 m per century after that time. This scenario has more drastic impacts and will require considerable efforts, but it will not dramatically change the face of the Netherlands. Significant morphological changes (e.g., in intertidal zones and offshore shoals) may take place, which require intensive countermeasures which are likely very expensive. Both the system of water management and of dikes will have to be drastically adjusted, while large-scale impacts on the hydrological system of the Netherlands are to be expected.

Event scenario 3

A similar pattern as in event scenario 2 until the year 2100, followed by a continuation of the rise of the sea level up to 5 m until 2300. This scenario is difficult to imagine, but according to some experts it cannot be neglected. In case of this scenario the face of the Netherlands will dramatically change, especially in the coastal zones. Although a forced migration to higher lands is not necessary, it is clear that the costs involved (both damage costs and protection costs) are formidable, as the entire hydrological system of the Netherlands will be affected, while certain vulnerable ares (e.g., the islands) would have to be given up.

The geographical pattern of the inundated areas in the Netherlands for various event scenario's are given in Figure 2. Each of these event scenario's will have more or less drastic implications in terms of (1) safety and protection, (2) direct and indirect investment costs of hydrological infrastructure, (3) regional economic development and (4) financial distributive consequences. These policy evaluation criteria will briefly be described here.

A reduced safety and protection level may in case of a fatality have far reaching impacts on human life, environmental goods, capital goods and consumption goods, which - depending on the risk level of each event scenario - may lead to formidable amounts of social costs incurred.

Direct and indirect costs of hydrological infrastructure refer to new investments and maintenance or operating costs, respectively. Most of such costs will have to be borne by the public sector.

Regional-economic effects may be diverse in nature and vary according to the economic activities or sectors at risk in a certain area. Important sectors in this context are agriculture and horticulture, navigation (including inland and coastal transport), fishing, and recreation. Although most effects will be negative, in some sectors (e.g., fishery, recreation) both negative and positive impacts may be anticipated.

The financial distribution of all policy measures involved has various dimensions: space, time and sector-wise (see Kuik and Perrels, 1986). In this context also the use of a proper social rate of discount for long-term project evaluation is in order (see also Gijsbers and Nijkamp, 1990).

From the previous descriptions it has become clear that the lack of empirical evidence is a very severe bottleneck in analyzing sea level rise consequences. The impacts of the various event scenarios outlined above lead to the evident conclusion that a careful monitoring of all processes and phenomena that have an impact on sea level rise is necessary, both for improving our predictive tools and for assisting decision-makers. The latter problem, how to evaluate the various possible alternatives, will be discussed in the next section.

3. Policy Scenarios for Coping with Sea Level Rise

Despite the great many uncertainties regarding the long term effects of the greenhouse effect, it seems a rational policy to explore at least various event scenarios and to seek possible policy scenarios which might be adopted, should any of the above mentioned event scenarios become a real-world threat. In the framework of this paper four alternative policy strategies will be explored, ranging from 'do nothing' to dramatic choices. Detailed estimations of all figures can be found in De Bruin and Pepping (1989) and will not be repeated here.

A. Passive Scenario

This extreme scenario does not presuppose any additional policy effort to cope with the threat of a sea level rise. Of course, the normal maintenance activities for the Dutch coastal and hydrological system will continue as usual, but the additional costs amount to zero. This scenario, which mainly functions as a reference scenario, has various consequences, depending on the occurrence of one of the above mentioned event scenarios (see for details De Bruin and Pepping, 1989, and Den Elzen and Rotman, 1988).

The total costs of an occurrence in any of the 3 event scenarios have been estimated for the most important effects, given a pre-specified probability of a fatality for each event scenario. These costs included in particular loss of human life (estimated as 1 million Dfl for productivity losses caused by the death of a human being) and destruction of man-made capital (industrial and urban as well as agricultural area), and environmental capital (natural area).

(1) event scenario 1

Given a chance of an occurrence (a major flood) of one in every 10.000 years (the current so-called Delta norm for the Netherlands) and a survival rate of 90% for people living in an inundation area at risk, the total costs of an occurrence amount to approximately 33 billion Dfl.

(2) event scenario 2

Assuming an average occurrence rate over the whole period of 0.0006 (instead of 0.0001 as in event scenario 1) and the same survival rate as above, the total costs would amount to approximately 210 billion Dfl. In case of drastic measures to cope with salinity and drinking water problems, these costs would rise to approximately 221 billion Dfl.

(3) event scenario 3

In this case the occurrence rate by the year 2200 will be equal to 1. Since the area at risk is now much larger, the survival rate will be much lower and is assumed to be equal to 0.5. Then the total social costs for the Dutch economy appear to amount to 4,070 billion Dfl. at least.

B. Traditional Dutch Strategy

The second policy response discussed here is 'business as usual', based on a reinforcement and raising of all seadikes and dunes near the coast. This is more or less a traditional defense strategy in the Netherlands in the battle against the sea, as during many centuries, land was protected against the threat of the sea by building higher dikes. The advantage of this strategy is that it can be done in a flexible and phase-wise manner, implying a lower risk of misinvestments, a more adequate allocation of expenditures over time, and a tuning of technological progress toward hydrological needs. The implication would be that the occurrence rate of a flood would remain constant (i.e., equal to the present Delta norm of 0.0001).

(1) event scenario 1

Since the risk levels would remain equal in case of a traditional policy response and the remaining investment costs would be smoothed over a longer period, the total costs of this scenario would be equal to that of A(1).

(2) event scenario 2

In order to quarantee a safety level of 0.0001, a drastic improvement and heightening of dikes, dams and dunes would be necessary. The estimated costs appear then to be equal to approximately 58 billion Dfl.

(3) event scenario 3

In case of scenario B (3) the total social costs are difficult to assess and appear to range from 201 to 259 billion Dfl.

The conclusion from the second policy strategy is that - apart from a marginal rise in sea level (scenario 1) - all other strategies are much more expensive than the passive scenario.

C. Ring Dike Strategy

The ring dike strategy is a more drastic defense strategy. Apart from a significant improvement of the current hydrological and water defense systems in the Delta area an entirely new dike protecting the provinces of North-Holland and South-Holland will be built. Also the defense system near the northern Wadden Sea and the interior lake, the Ysselmeer, will be dramatically improved. It is clear that the risks of such a defense strategy are difficult to assess, as this is an entirely new system. In view of this uncertainty, it is in general plausible to put the safety norms much higher (in this case these norms are put equal to 0.0, 0.000001 and 0.00001 for event scenarios 1, 2 and 3, respectively).

(1) event scenario 1

In case of scenario C (1) the total estimated costs appear to be ranging from a minimum of 125 billion Dfl to a maximum of 196 billion Dfl.

(2) event scenario 2

The estimated costs are more or less the same, as this third defense scenario provides also sufficient safety in case of event scenario 2, so that the costs range again from 125 to 196 billion Dfl.

(3) event scenario 3

In this case the number of people at risk in case of an occurrence is higher; hence these costs range from 133 billion Dfl to 204 billion Dfl.

D. Neo-Atlantis strategy

The Neo-Atlantis strategy takes for granted that in the long-run mankind will be a loser in his battle against the sea and that considerable parts of the current areas have to be given up. In this surrender strategy the remaining part of the country will have to be defended according to traditional defense strategies. In this concept however, the Randstad (the Western urbanized area) of the Netherlands would still be retained. The consequences for each event scenario will again be spelled out.

(1) <u>event scenario 1</u>

In this case the loss of land may cause relatively high costs, which range from 58 to 118 billion Dfl.

(2) <u>event scenario 2</u>

This scenario leads to somewhat higher costs, ranging from 70 billion Dfl to 138 billion Dfl.

(3) <u>event scenario 3</u>

This extreme scenario will of course lead to drastic losses of fertile and/or productive land and hence the costs will be much higher; they appear to range from 158 billion Dfl to 259 billion Dfl.

Having described now the estimated effects of each of these scenarios, we will give an evaluation of these results in the next section.

4. Evaluation of Compound Scenarios

The evaluation of appropriate policy strategies has to be based on a simultaneous consideration of 'external' event scenarios and policy response scenarios. Such combined scenarios will be called here compound scenarios. The results of all these 4x3-12 compound scenarios are included in survey table 1. This table provides an interesting game-strategic survey of various scenarios, taking into account the uncertainty in the long run of the various event scenarios.

Policy Scenario

event scenario	Do nothing (A)	Raise dikes (B)	Ring dike (C)	Retreat (D)
Same historical rate (1)	33	33	125 - 196	58 - 118
Increase till 2100 then historical rate (2)	221	58	125 - 196	70 - 138
continuous increase rate (3)	> 4,070	201-259	133 - 204	159 -259

Table 1. Estimated costs of sea level rise for various compound scenarios

Which results can now be drawn from this survey table summarizing the above cost estimates?

The best policy strategy in case of event scenario 1 (marginal increase of sea level) is either 'do nothing' or 'traditional Dutch defense strategy', as these two options are the least expensive.

In case of event scenario 2 (a rise of 1 meter of the sea level) the best choice appears to be the traditional Dutch policy of adjusting gradually the protection system (dikes, dams, dunes, sluices etc) according to the needs of the moment.

Finally, the extreme case of a 5 meter rise in the sea level would make the construction of the Ring dike the most plausible one. The passive scenario would be unacceptable here, while the traditional Dutch policy would be too risky and the Neo-Atlantis strategy too costly in terms of land loss.

The conclusion is that in any case the Neo-Atlantis strategy does not seem to be an economically viable option. This is for all event scenarios an inferior solution. From the remaining three, the Ring dike strategy would only make sense in case of a dramatic rise of the sea level. Recent investigations have shown that the probability of such an event are almost negligibly small in the foreseeable future (see Figure 3).

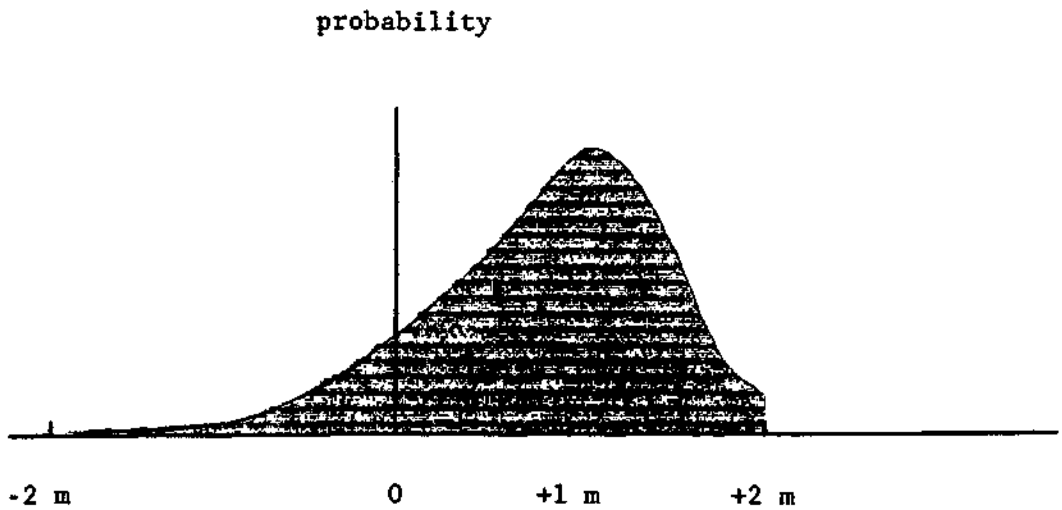

Figure 3. Estimated probability distribution of a sea level rise until the year 2080 (compared to 1980).
Source: Burger and Vellinga (1987)

As a result, we may therefore conclude that for the next century strategy 3, the Ring dike solution, does not seem to be a meaningful policy choice. This means that only policy strategies 1 and 2 remain; if we do not have any further empirical evidence regarding the probability of event scenarios 1 and 2, it is clear that the safest strategy is the traditional Dutch defense strategy, which is flexible and adjusts the flood protection system according to the urgency of needs at any moment in time. This policy is of course also an appropriate one (and the least expensive one), should the sea level decline in the next century (a situation which can never be assumed away in the light of the great many uncertainties regarding the effects of the greenhouse effect).

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