CLIMATE CHANGE

SCIENTIFIC ASSESSMENT AND POLICY ANALYSIS

# Climate adaptation in the Netherlands

**Report**
500102 003

**Editors**

E.E.M. Nillesen
E.C. van Ierland

**Authors**

R.S. de Groot
E.C. van Ierland
P.J. Kuikman
E.E.M. Nillesen
M. Platteeuw
V.C. Tassone
A.J.A. Verhagen
S. Verzandvoort-van Dijck

**May 2006**

This study has been performed within the framework of the Netherlands Programme Scientific Assessment and Policy Analysis Climate Change

**Wetenschappelijke Assessment en Beleidsanalyse (WAB) Klimaatverandering**
Het programma Wetenschappelijke Assessment en Beleidsanalyse Klimaatverandering in opdracht van het ministerie van VROM heeft tot doel:

- Het bijeenbrengen en evalueren van relevante wetenschappelijke informatie ten behoeve van beleidsontwikkeling en besluitvorming op het terrein van klimaatverandering;
- Het analyseren van voornemens en besluiten in het kader van de internationale klimaatonderhandelingen op hun consequenties.

De analyses en assessments beogen een gebalanceerde beoordeling te geven van de stand van de kennis ten behoeve van de onderbouwing van beleidsmatige keuzes. De activiteiten hebben een looptijd van enkele maanden tot maximaal ca. een jaar, afhankelijk van de complexiteit en de urgentie van de beleidsvraag. Per onderwerp wordt een assessment team samengesteld bestaande uit de beste Nederlandse en zonodig buitenlandse experts. Het gaat om incidenteel en additioneel gefinancierde werkzaamheden, te onderscheiden van de reguliere, structureel gefinancierde activiteiten van de deelnemers van het consortium op het gebied van klimaatonderzoek. Er dient steeds te worden uitgegaan van de actuele stand der wetenschap. Doelgroep zijn met name de NMP-departementen, met VROM in een coördinerende rol, maar tevens maatschappelijke groeperingen die een belangrijke rol spelen bij de besluitvorming over en uitvoering van het klimaatbeleid.
De verantwoordelijkheid voor de uitvoering berust bij een consortium bestaande uit MNP, KNMI, CCB Wageningen-UR, ECN, Vrije Universiteit/CCVUA, UM/ICIS en UU/Copernicus Instituut. Het MNP is hoofdaannemer en fungeert als voorzitter van de Stuurgroep.

**Scientific Assessment and Policy Analysis (WAB) Climate Change**
The Netherlands Programme on Scientific Assessment and Policy Analysis Climate Change has the following objectives:

- Collection and evaluation of relevant scientific information for policy development and decision–making in the field of climate change;
- Analysis of resolutions and decisions in the framework of international climate negotiations and their implications.

We are concerned here with analyses and assessments intended for a balanced evaluation of the state of the art for underpinning policy choices. These analyses and assessment activities are carried out in periods of several months to a maximum of one year, depending on the complexity and the urgency of the policy issue. Assessment teams organised to handle the various topics consist of the best Dutch experts in their fields. Teams work on incidental and additionally financed activities, as opposed to the regular, structurally financed activities of the climate research consortium. The work should reflect the current state of science on the relevant topic. The main commissioning bodies are the National Environmental Policy Plan departments, with the Ministry of Housing, Spatial Planning and the Environment assuming a coordinating role. Work is also commissioned by organisations in society playing an important role in the decision-making process concerned with and the implementation of the climate policy. A consortium consisting of the Netherlands Environmental Assessment Agency, the Royal Dutch Meteorological Institute, the Climate Change and Biosphere Research Centre (CCB) of the Wageningen University and Research Centre (WUR), the Netherlands Energy Research Foundation (ECN), the Netherlands Research Programme on Climate Change Centre of the Vrije Universiteit in Amsterdam (CCVUA), the International Centre for Integrative Studies of the University of Maastricht (UM/ICIS) and the Copernicus Institute of the Utrecht University (UU) is responsible for the implementation. The Netherlands Environmental Assessment Agency as main contracting body is chairing the steering committee.

For further information:
Netherlands Environmental Assessment Agency, WAB secretariate (ipc 90), P.O. Box 303, 3720 AH Bilthoven, tel. +31 30 274 3728 or email: wab-info@mnp.nl.
This report in pdf-format is available at www.mnp.nl

## Abstract

In spite of various mitigation strategies that are being implemented to reduce and prevent future adverse effects of climate change, there is widespread agreement that climate change will nonetheless take place. This report anticipates on the urgent need to respond adequately to climate change in the Netherlands by identifying adaptation strategies both for the public and private sector. In the analysis we focus on sector-specific adaptation options and explore some of the synergies that may exist amongst the various policy options.

Wageningen UR
Environmental Economics and Natural Resources Group
P.O. Box 8130
6700 EW Wageningen
tel: +31 317 48 42 55
fax: +31 317 48 49 33

## Preface

In this report we explore new and available adaptation options to impacts of climate change in the Netherlands. We would like to thank all that have assisted in providing information relevant for writing this report, including KNMI, the Climate Centre, and the WAB secretariat. All support was highly appreciated. With this report we wish to provide some further steps for a systematic socio-economic assessment of adaptation options in the Netherlands.

Wageningen, May 2006

E.C. van Ierland (ed.)
E. Nillesen (ed.)

D.S. de Groot
P.J. Kuikman
M. Platteeuw
V. Tassone
J. Verhagen
S. Verzandvoort-van Dijck

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# Summary and main conclusions of the project

The aim of this report was to collect existing and new information on adaptation options with respect to climate change in the Netherlands. Van Ierland *et al.* (2001) commenced on this task in 2001 by making an inventory of vulnerability of human and natural systems to climate change, and by identifying possible adaptation options. We now review the information gathered in 2001, and make an attempt to extend the analysis by describing incremental costs and benefits of the options. To the extent that this is available, we provide quantitative estimates of these costs and benefits. The analysis was done for those sectors that in Van Ierland *et al.* (2001) were identified as being most vulnerable to climate change, which included agriculture (including forestry and fisheries), nature and ecosystems, water, transport and energy. The study was explicitly restricted to these sectors.

A more detailed study on the costs of adaptation options was performed in the context of the Routeplanner project in the Netherlands. The results of this study are reported in E.C. van Ierland, K. de Bruin, R.B. Dellink and A. Ruijs (eds), 2006, A qualitative assessment of climate adaptation options and some estimates of adaptation costs, Environmental Economics and Natural Resources Group, Wageningen University, Wageningen, the Netherlands.

## General conclusions

The study shows that the Netherlands is particularly vulnerable to climate change in agriculture, ecosystems and the water system. The agricultural sector (including forestry and fisheries) is vulnerable to climate change and adaptation is necessary in these sectors. Detailed analysis of the various options is given below and in the chapters of the report. For the water system a wide variety of options exist and some of the adaptation options are already starting to be implemented. In addition, impacts will occur on ecosystems, but the options to adapt the management of ecosystems are limited other than considering the management of the national ecological network (NEN).

## Agricultural sector

The choice of crop variety and genotype would be the most important adaptation strategy in the agricultural sector. Growing different crops that are more resilient to environmental pressure may also serve other purposes for example, when energy crops are being grown. Benefits can be approximated by avoided damage due to yield losses.

In addition, water management is important. For instance, water storage on farmland in times of excess water supply is an important strategy with large spill-over effects to the water sector. While land values may decrease due to inundation, diversification of farmer’s risk, improved recreational and nature development opportunities are important potential benefits that may very well off-set the loss of land values. The costs of water storage on farmland are relatively easy to calculate, but benefits are more difficult to quantify especially those for which no market exists (e.g. nature development and recreational), or that may only appear after several years (e.g. nature development).

## Forestry sector

Adaptation options in the forestry sector refer to species composition, spacing, thinning, and water management, including introducing new, more environmental stress resistant species; limiting timber imports to prevent the spread of pests and diseases from southern regions; and retention of winter precipitation to relieve summer drought stress are also mentioned. None of these strategies have been implemented yet, and hence costs and benefits of these strategies are unknown, and need to be explored in specific scenario studies.

### Fishery sector

Important adaptation options for the fishery sector include adjusting fishing quota due to climate change induced decreased fish stocks; eco-labelling; reduced industrial use of freshwater preventing fish mortality; aquaculture on agricultural land, thereby increasing the economic value of otherwise inundated grassland. For adaptation options in the fishery sector benefits and costs are not known yet, and detailed studies are required to shed light on these issues.

### Nature and ecosystems

The direct impacts on ecosystems include foremost rising temperatures that lead to changes in life-cycle timing (date of flowering, ripening of fruits, leaf unfolding and species migration) which impact entire ecosystems. Indirect impacts include changes in precipitation and drought frequency, changing water levels that may result in increased risk of flooding, and extreme weather events including frost, fire and storms. The most important adaptation options include a change in design and implementation of the National Ecological Network (NEN) to make it climate proof. To date estimates of the incremental costs and benefits associated with making the NEN climate proof are unknown. In addition to the NEN, establishment and management of other protected areas that are most appropriate to develop and maintain when taking climate change into consideration is proposed. However, one should bear in mind that these options have not been designed to adapt to climate change per se but rather to prevent and mitigate damage to nature and ecosystems in general; hence it will be difficult to identify costs and benefits that are specifically attributable to making the NEN and other nature areas climate change proof.

### Water

For the water sector important consequences of climate change are expected to result from sealevel rise; increased winter precipitation that induces flooding, prolonged periods of drought during summer that hampers (drinking) water availability.

The adaptation options identified for the water sector all aim at improved spatial planning and design. Considering the increased anticipation on greater variability, flexibility in spatial design of water systems is key to successful adaptation to climate change.

Adaptation options for the water sector include designing areas for land retention and storage of surplus fresh water. This will however result in increased competition for land that would otherwise mainly be used for agricultural purposes and will affect some residential areas as well. Thus, farmers may need to diversify and get compensated for foregone production and possible investment costs that are needed to specialize in other functions. Benefits of this option include increased safety, enhanced recreational, real estate and nature conservation values. These benefits however to date are largely unquantified.

An adaptation option specifically related to the Dutch coast is to improve on coastal defence by developing extra sand dunes and artificial reefs. The costs of sand dunes and the construction of artificial reefs are expected to be relatively high, but exact cost estimates are at this moment not yet available.

Adaptation measures with respect to water management in the built environment include ‘floating houses and industrial buildings’, and re-enforcing existing dikes and dams. To date this type of floating housing and infrastructure has hardly been applied, except for some permanent and some recreational houses, hence incremental costs and benefits associated with this type of spatial design are not available yet, and they will strongly depend on local circumstances. By contrast, re-enforcement of dikes and dams are well-known and frequently applied measures. Costs for improving dikes amount to about EUR 4-8 billion. Benefits include foremost increased safety and hence reduced risk of damage and life-threatening situations, but these cannot easily be estimated in monetary terms.

## Energy

The impacts of climate change on the energy and transport sector are expected to be of lesser importance than for example changes in consumer preferences, world oil prices and technological change. Among the important climatic impacts for energy are reduced water availability for cooling purposes, that may severely hamper a stable supply of electricity for households and the industry if no adaptation occurs. Changing climate conditions are expected to have a positive impact on several forms of renewable energy; e.g. increasing wind speeds enhance the wind energy potential by making more locations economically viable for producing wind energy; the anticipated increase in number of hours of sunshine could provide for some more solar energy; and changing growing seasons, and changes in temperature may generate favourable conditions for growing biomass crops. Adaptation options to sustain a stable supply of energy might include a policy-oriented method by relaxing the law on cooling water temperature levels. It is also possible to target at consumers energy demand for cooling and heating purposes by developing intelligent buildings and houses that provide for a constant year-round temperature by design and do not require additional heating. In addition, a large set of options for mitigation strategies exist, such as energy-saving products including for example, energy-saving light bulbs, rechargable batteries, technical devices (e.g. refrigerators, t.v.'s etc.) or to increase consumer awareness to save energy through government campaigns. Finally, production of sustainable energy systems will contribute to mitigating adverse effects of climate change.

## Transport

Impacts of climate change for the transport sector include physical damage (e.g. more road accidents under wet weather circumstances) and economic damage resulting from traffic (e.g. delays, congestion). Also damage may occur to electricity-, road-, train- and air traffic networks due to increased frequency and intensity of storms and increased risk of flooding with rising sea levels. In addition increased negative effects may occur in terms of corrosion of vehicles, trains and infrastructure.

On the positive side increasing temperatures will lead to less frosting days hence less roads need to be salted during winter; or more journeys will be undertaken in summer providing economic benefits.

Most notable adaptation options for the transport sector include the development of more intelligent infrastructure including road and vehicle sensors serving as early warning indicators providing for adjustments in driving, and hence a decrease in the number of road accidents.
Another option is to make existing infrastructure more robust to increased wind speeds and possibly higher frequency of storms. This option extends also to improving vessels or oil platforms at sea, making them storm-proof. This will reduce the economic damage that would otherwise occur.

## Overall conclusion

In order to adapt to climate change in a way that minimizes adverse environmental and economic impacts of both climate change and the adaptation options itself, a first need arises to assess the incremental costs and benefits associated with the different adaptation options. This requires consensus, at least to some extent, about the (un)certainty with which climatic impacts take place as different probabilities may lead to substantially different conclusions on what would be the best option to implement. The impacts of climate change are, even when only focussing on the Netherlands, surrounded by considerable uncertainties and its consequences are subject to debate. The report has dealt with this problem in two complementing ways. First, we have used the KNMI climate scenarios as a baseline[1]. That is we take the estimated changes on their main indicators of climate change (including temperature, precipitation, and sea-level rise) as given. Secondly, given these scenarios we proceeded by reviewing the literature and consulting experts by means of a workshop.

During the writing of the report two important observations were made. First, the literature on adaptation options for the Netherlands to date has a qualitative focus; to a very small extent costs of implementing the options have been roughly estimated, and their benefits are at best somewhat described in a qualitative way. Secondly, so far little attention has been given to spatial planning for the long run, i.e. for the period beyond 2050. *This stresses the need for a more systematic research on and analysis of adaptation options, their costs and benefits, and their interactions.*

We would like to emphasize that this report is based on climate scenarios that show a gradual change of the climate. This means that unexpected events, or very rapid climate change or issues such as the slow down of the North Atlantic gulfstream are not considered in this report.

[1] The new KNMI climate scenarios that were reported on 30 May 2006 were not yet available at the time of writing this report, but they do not affect the main adaptatation options as described in this report, because the differences with other scenarios are relatively small.

# 1 Introduction

***Adaptating to climate change***

Possible consequences of climate change for the Netherlands have been documented in various reports including the Environmental Balance (RIVM, 2004), The Climate Policy report commissioned by Parliament (Rooijers *et al.,* 2004) and the Climate report (KNMI, 2003). Most studies seem to agree on the fact that climate change will take place, in spite of all mitigation strategies to be implemented in order to prevent certain climatic changes and to reduce climate change impacts. Climate change impacts on water and ecosystems are already visible or, have been accepted as being nearly inevitable (VROM, 2005). Thus, mitigation while necessary, is not a sufficient condition to cope with climate change.

*Adaptation* to climate change receives therefore increased attention in the scientific and policy debate, complementary to mitigation (UNFCCC, 1997). Adaptation is defined as adjustment in ecological, social or economic systems in response to actual or expected climatic stimuli and their efforts or impacts (Smith *et al*., 1999). The related 'adaptive capacity' refers to the 'potential or ability of a system, region, or community to adapt to the effects or impacts of climate change' (Smith *et al*., 2001). Progress towards a systematic assessment of adaptation in terms of technical, economic and institutional feasibility however has been slow and most strongly developed in the water sector. In the climate change context, adaptation can take the form of autonomous, reactive or anticipatory adaptation. *Autonomous* adaptation to climate change is essentially an unconscious process of system-wide coping, most commonly understood in terms of ecosystem adjustment. *Reactive* adaptation involves a deliberate response to a climatic shock or impact, in order to recover and to prevent similar impacts in the future. Lastly, *anticipatory* adaptation involves planned action ex-ante of climate change to prepare for its adverse impacts and attempt to minimize those (Abramovitz *et al*., 2002).

***Economic efficiency***

In assessing the economic efficiency of various adaptation options a distinction is made between 'no regret' strategies and 'co-benefit' strategies. No-regret strategies are those adaptation strategies for which the non-climate related benefits will exceed the costs of implementation; hence they will be beneficial irrespective of future climate change taking place. 'Co-benefit' strategies on the other hand are specifically designed to reduce climate-change related vulnerability while also producing corollary benefits that are not related to climate change (Abramovitz et al., 2002).

***Background***

Against this background, the Dutch government launched a national research program on transboundary air pollution and climatic change (NOP). The program was specifically targeted at supporting climate policy in the Netherlands and at promoting research related to climate change. The program distinguished between four themes: Theme I 'Behavior of the climatic system as a whole and in parts'; theme II 'Vulnerability of natural and societal systems to climate change'; theme III 'Societal causes and consequences' and theme IV 'Integration and Assessment'. Van Ierland et al., (2001) made an inventory of vulnerability of human and natural systems to climate change and possible adaptation options, relating to theme II. The study was based on a literature review and in-depth interviews with experts and discussions with stakeholders in a workshop. The resulting report served as a useful background for the present study.

The present study aims to provide a 'systematic assessment' of potential adaptation strategies to respond to climate change in the Netherlands for four key sectors which have proven to be most vulnerable to climate change, i.e., agriculture, including fisheries and forestry; ecosystems and nature; energy supply; and water management and insurance (Van Ierland et al., 2001). The systematic assessment includes the following aspects: 1) identification of new and existing adaptation options to climate change in the Netherlands; 2) provision of a qualitative assessment of their direct and indirect effects; 3) identification and where possible, a quantification of direct and indirect costs and benefits associated with the individual adaptation measures; and 4) institutional aspects related to the implementation of adaptation options. The project was coordinated and executed by the Environmental Economics and Natural Resources Group at Wageningen University in collaboration with four partner institutes. In addition to the overall implementation and coordination of the project, the Environmental Economics and Natural Resources Group has been responsible for the information on adaptation options provided for the energy sector. The partner institutes included Plant Research International (Wageningen University and Research Center) and Alterra (Wageningen University and Research Center), responsible for the agricultural sector; RIZA (Institute for Inland Water Management and Waste Water Treatment) responsible for the water management and insurance sector; and the Environmental System Analysis group (Wageningen University) responsible for the input on adaptation options for ecosystems and nature.

## 1.1 Rationale

Until recently, the strategy of mitigation dominated the research agenda for climate change, most notably analyses on reduction methods and their impacts. During the eighth session of the Conference of the Parties, within the United Nations Framework Convention on Climate Change (UNFCC) especially developing countries have made a plea for adaptation strategies. In the near future it is expected that there may be a trade-off between mitigation and adaptation despite the fact that they are complements rather than substitutes. In order to make a well-informed decision on how to adapt to climatic change, there is a need to collect information on adaptation options and to systematically assess its impact in terms of effects, costs and benefits. Also the institutional aspects deserve attention. Existing knowledge about adaptation options in the Netherlands is, however, scattered; overviews are outdated and often incomplete. In addition, there seems to be a huge discrepancy between what would be viable adaptation measures from a scientific (technical) perspective and what policymakers perceive as being realistic measures to implement. The latter issue is often closely linked to the costs and benefits associated with adaptation. As of today, there is little insight in these types of costs and benefits. While some calculations are available for the costs of implementing adaptation measures, most notably investment costs, much less is known about (future) benefits which may be valued at avoided damage costs. Lastly, comparing different options requires consideration of the timing of adaptations. Hence, systematic assessment of options that are technically, economically, and politically feasible will enable policymakers to make well-informed choices about all possible different adaptation strategies. The challenge for the Netherlands is how to harmonize a national adaptation policy with a spatial planning policy.

What are the costs and benefits of adaptation for the different sectors and to what extent does this lead to barriers to implement adaptation measures? The focus will be on developing more robust systems including technical solutions and improved control and management systems. This necessitates the development of early-warning systems, appropriate insurance arrangements and a harmonization across different policies.

Current insights show that adaptation is easier to implement in sectors and systems where depreciation and capital replacement are quick compared to those sectors that require long-term investments (e.g. the water sector). Relevant questions are; who should be held responsible for the costs of implementing the adaptation measures and what is the role of insurance companies in this matter? Another important aspect concerns the harmonization of adaptation and mitigation measures. As money can only be spent once, a trade-off needs to be made between mitigation for which benefits are expected mainly in the far future, and adaptation which generates immediate benefits, but which may be insufficient in the long run to prevent excessive future costs as a result of ongoing climate change impacts. Recommended is to pursue these options that provide both adaptation and mitigation benefits.

## 1.2 Objective

The aim of the study was to review the literature and to consult stakeholders to provide a systematic assessment and overview on adaptation options in the Netherlands for the following four sectors: agriculture (including fisheries and forestry); ecosystems and nature; water; and energy. These sectors have been identified as being the most vulnerable to climate change. We attempted to make an inventory of existing and new options and their associated incremental costs and benefits.2 This could be used by policymakers to decide which options to choose from a socio-economic perspective.

## 1.3 The NRP-CC-WAB project related to the BSIK program

The results of the study may provide a useful starting point for projects within the long-term BSIK program concerned with adaptation options in the Netherlands, most notably ‘Living with Water’ and ‘Climate changes Spatial Planning’. The study will be complementary to the BSIK program as the current project focuses mainly on decisions that need to be made within the policy arena within the next four years, whereas the BSIK projects are primarily concerned with a scientific assessment of innovative adaptation options. The current state-of-the art then provides a useful overview of which options have been explored and may spark ideas as whereto new research may be directed.

## 1.4 Methodology

The project comprised the following three parts:

1. A detailed review of sector-specific literature on climate change and related adaptation options including: general international and national policy documents; scientific and policy assessments published in academic reports and journal articles; non-academic reports by, government institutes, consultancy groups, and non-governmental organizations;
2. The organization of a workshop with stakeholders to discuss existing adaptation measures, identify new ones and obtain a qualitative and quantitative assessment of the effects and incremental costs and benefits of the individual adaptation measures;
3. A database to summarize the identified adaptation options and the associated effects, costs and benefits, and institutional aspects related to their implementation, as far as available on the basis of existing studies.

The key assumption underlying the study was that climate change would take place according to the three climate scenarios (high- medium-low) developed by the Royal Dutch Meteorological Institute (KNMI) in 2001, supplemented with a fourth, ‘dry’ scenario. The scenarios are discussed in detail in chapter 2. Many adaptation measures however seem to be generally applicable in a sense that they would apply to all three climate scenarios rather than to any specific one.

A half-day workshop was organized for 35 invited stakeholders. Participation of stakeholders was considered essential in order to be sure that all existing adaptation options were taken into consideration and preliminary evaluated in an early stage, and that potential new ideas could be identified and shared. The selection of invitations was based on a balanced distribution per sector (agriculture; ecosystems and nature; water; and energy), and a share of participants representing the government, the research institutes, the non-governmental organizations and the corporate companies.

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[2] Incremental costs and benefits refer to those costs and benefits that are attributable to the adaptation easure only, and will not occur if the adaptation measure is not implemented.

The workshop started with a plenary session followed by three sector-specific parallel sessions (agriculture also including forestry and fisheries; ecosystems and water; and energy and transport) with on average 10 participants per parallel session. In each session participants were asked to identify one or more adaptation measures for the particular sector, to discuss its potential effects, and to provide ideas as how to identify and estimate relevant costs and benefits. The workshop ended with a second plenary session to discuss the outcomes. One week after the workshop, the summarized outcomes were sent to the participants who were invited to react and provide additional information/comments. Annex II includes the list of participants of the workshop.

## 1.5 Deliverables

Overview of important impacts.

- Insight in adaptation options and their characteristics based on international and national literature and consultation of stakeholders.
- A database designed for adaptation options with a focus on the associated incremental costs and benefits that can be systematically updated and extended in future projects.
- Insight in possible interactions between various adaptation options (e.g. relations between water management options, recreation, nature conservation and other activities and possible 'spill-over effects').
- Identification of institutional aspects (threats and opportunities) related to the implementation of the various options.
- Identification of knowledge gaps and suggestions for further future research per sector.
- Integration of information and relevance for various policy domains.
- Conclusions on policy and management options for various stakeholders, based on the current state of knowledge.
- A workshop to discuss the identified adaptation options (existing and new ones) a qualitative and where possible quantitative assessment of its effects, and identification of incremental type of costs and benefits with stakeholders.
- Fact sheets and publication of fact sheets in 'klimaatportaal'.

## 1.6 Outline of the report

Chapter 2 presents a discussion of the issues at stake with respect to adapting to climate change, its relation to mitigating strategies, the relevant climate change scenarios, and the methodology of identifying adaptation options in detail. In chapter 3 the outcomes for each sector are analyzed and discussed. Chapter 4 provides a description of the cross sectoral impacts and the conclusion.

# 2 Climate change scenarios and methodology

This chapter provides an overview of the general issues at stake with respect to adapting to climate change, discusses the relation between mitigating and adaptation options, and presents the methodology used in this report, starting with a description of the climate change scenarios that have been used as our point of departure.

As certain impacts and consequences of climate change are becoming increasingly visible and irreversible, there is a need to develop a sound integrated policy that takes these issues into account.

## 2.1 Climate Change Scenarios

The adaptation options identified in this report are based on the climate change scenarios as identified by the KNMI in 2001, based on the third IPCC report, including the 'dry scenario' that has been developed in 2003 and added to the existing scenarios. It is important to note though that the adaptation options in most cases are applicable to all scenarios, with the exception of the dry scenario, unless stated otherwise. This is because at this stage adaptation options are still in the early stage of identification, rather than fully developed and implemented. Additionally, as climate scenarios are surrounded with great uncertainty it is important to identify options that are robust to (small) changes in impacts of climate change. Table 2-1 below presents the conventional KNMI climate change scenarios.

*Table 2-1 KNMI climate change scenarios for the Netherlands for the year 2100*

| | **Low estimate** | **Central estimate** | **High estimate** |
|---|---|---|---|
| Temperature | + 1 ºC | + 2 ºC | + 4 to 6 ºC |
| Average summer precipitation | + 1% | + 2% | + 4% |
| Average summer evaporation | + 4% | + 8% | + 16% |
| Average winter precipitation | + 6% | + 12% | + 25% |
| Annual maximum of the 10 – days sum of winter precipitation in the Netherlands | + 10% | + 20% | + 25% |
| Repetition of the 10 –days sum which now occurs once every 100 years (≥ 140 mm) | 47 years | 25 years | 9 years |
| Sea level rise | + 20 cm | + 60 cm | + 110 cm |

*Source:* KNMI (2003)

The projections for temperature increase have been based on world estimates as reported in the third IPCC report. The table shows that in all three scenarios temperature is expected to rise. The figures for precipitation have been extrapolated using the presently observed relationship between precipitation and temperature in the Netherlands. We hereby assume that this relationship is robust to changing climate conditions (KNMI, 2003). The expected average increase in summer precipitation will coincide with periods of extreme rainfall and increased chances on wet years (KNMI 2003). Part of this effect will be counteracted by increased evaporation due to higher summer temperatures; hence the net effect will be smaller. The annual maximum of the 10-days sum of winter precipitation gives some idea on the severity of extreme rainfall. The column 'repetition of the 10- days sum that now occurs once every 100 years' provides some idea on the chances of occurrence of extreme rainfall conditions. The sea-level rise has been corrected for time-lags and subsidence of land.

The dry scenario has been developed to make an integrated assessment of water policy for periods where water availability is scarce, in order to reduce damage due to extreme draught. Table 2-2 presents the dry scenario.

*Table 2-2 Indicators for climate change in the 'dry scenario'*

| Indicator | Dry scenario |
|---|---|
| Temperature | + 4-6 ºC |
| Average summer precipitation | -15% |
| Average summer evaporation | + 19% |
| Average winter precipitation | n.a. |
| Annual maximum of the 10 –days sum of winter precipitation in the Netherlands | n.a. |
| Repetition of the 10 –days sum which now occurs once every 100 years (≥ 140 mm) | n.a. |
| Sea level rise | n.a. |

*n.a. = not available

*Source:* MNP (2005)

## 2.2 Methods to identify adaptation strategies

The adaptation options have been identified using two methods. We commenced by collecting and consulting the relevant national and international literature for climate change impacts and adaptation options that had been identified for the four sectors. The results were described and complemented with a qualitative description of the effects of the identified strategy, its costs and benefits, which were described in qualitative terms, and where possible in quantitative terms. Next we described potential institutional barriers, and spill-over effects to other sectors. We listed them in an Excel-database. This provided a good starting point for discussing the options with experts during a half-day workshop. In addition to the expert judgments of adaptation options that had already been identified, participants of the workshop were requested to come up with new options and strategies. In this manner a start is made with the implementation of a consistent database on adaptation options for various sectors. Annex I provides an overview of the database per sector.

# 3 Adaptation options for four sectors

This chapter presents the identified adaptation strategies for agriculture, fisheries and forestry; nature and ecosystems; water; and energy and transport. Each subsection starts with a description of the impacts of climate change, its sector-specific effects, relevant adaptation options, its costs and benefits, priority setting and associated institutional aspects. We emphasize that a selection of sectors has been made, as commissioned by the WAB secretariat. In other sectors other problems may occur and other adaptation options are prevalent. They are however not described in this report.

## 3.1 The agricultural, forestry and fisheries sector

It is clear that in addition to mitigation, adaptation to climate change is an essential part of the intentions of the Climate Change Convention. Adaptation includes any measure which is justified to minimize any reported and predicted impact of climate change, including 'no-regret' and anticipating strategies (Kok et al., 2001). Adaptation is needed to reduce adverse impacts of climate change in several economic sectors (e.g. flood protection, agriculture and forestry, water resource management, health) (IPCC, 2001b; Kuik et al., 2005). It is an important part of societal response to global climate change. Besides responding to adverse effects, adaptation has the potential to realize new opportunities for technological, institutional and societal innovations (IPCC, 2001b; Kabat et al., 2005). Some adaptation options have a mitigation potential as well and as such reduce the need for ongoing and continuously stronger adaptation measures as defense against negative impacts of climate changes.
However, an assessment of alternative proposals for post-2012 international climate policy architectures (Kuik et al., 2005) revealed that most climate policies are traditionally targeted at mitigating greenhouse gases only and that adaptation to climate variability and change has only played a minor role sofar. The most important reason for the low ranking of adaptation on the policy agenda is uncertainty over the magnitude of future climate variability and its impact at regional and local scales (Kuik et al., 2005).
An example of recent European research in response to this knowledge gap is the Advanced Terrestrial Ecosystem Analysis and Modelling project (2001-2003) (ATEAM) addressing the vulnerability of European regions to climate change.

Since 2004 adaptation policy has appeared slowly on the agenda of several ministries or regional and local authorities in the Netherlands. Adaptation is most strongly developed in the water management and spatial planning sectors. It is often still seen as a responsibility of the government, but private actors are also involved in adaptation. Implementation is to be done by local authorities (Werners et al., 2004) and private actors. Experiments with public-private partnerships and other implementation schemes are sofar rare. Subsidies to encourage private sector initiatives are limited to the WaterINNovation program WINN (www.waterinnovatiebron.nl) and perhaps the payments for green and blue services paid to farmers, landowners and recreation for their contribution to water and ecosystem management (Werners et al., 2004).

Several initiatives by Dutch ministries to strengthen adaptation policy were launched over the last few years. The most recent initiative for adaptation policy is the Adaptatieprogramma Ruimte en Klimaat (ARK), to be initiated in the near future by several ministries pertaining to climate policy.

In this chapter anticipated or already implemented adaptation strategies in agriculture, forestry and the fisheries sectors in the Netherlands are assessed. The assessment is based on a short literature review and interviews with experts. For each sector, the inventory of adaptation strategies is introduced by descriptions of the relevant future climate conditions and their impacts on the sector.

### 3.1.1 Impacts and strategies for the agricultural sector

Climatic parameters relevant to the agricultural sector include changes in amount, frequency and period of precipitation, hail, storms, late frost, and an increased temperature and changes in atmospheric $CO_2$-concentration. The impacts related to these climate parameters vary per region and agroecosystem.
Besides effects of climate change on the yield and quality of harvested products, damage to crops and build structures are of importance to agriculture. Impacts of climate change are crop and region specific and can be direct (e.g. via temperature and rainfall) or indirect (e.g. via flooding, saline intrusion or changes in pests and diseases).

Clearly, in the Netherlands, water plays an important role in the relation between agriculture and climate change. For the low lying areas in the western and in the northern part of the Netherlands and in river valleys, wet conditions related to heavy showers and the increased frequency of peak discharges of the main rivers Rhine and Meuse will most likely result in more frequent events of water nuisance on farmland, and salinisation of ground- and surface water in the coastal zones. These impacts are reinforced by sealevel rise. The peat-grassland area in the western part of the Netherlands is mentioned separately, because in this region several problems areas come together: climate change, the subsidence of land, water shortage in the agricultural and forestry sectors and salinisation (Kwakernaak and Rienks, 2005). In contrast to the lower parts of the Netherlands the higher parts will suffer from water shortage. Dry periods already affect the sensitive sandy areas. In relation to heavy showers erosion is expected to increase on löss soils in the southern part of the Netherlands (Van Ierland et al., 2001; MNP, 2005).
Adaptation to climate change can not be seen in isolation. The dynamic socio-cultural and economic contexts determine to a large extent the adaptive capacity of the sectors. Economic factors (costs, price, subsidies or the volume of world trade), the EU Common Agricultural Policy (CAP) and environmental policies as well as national policies in the fields of spatial planning, water, nature and environment also determine the economic effects for the agricultural sector (Van Ierland et al., 2001; Kok et al., 2001). No studies exist to date showing the relative weights of these influences, but it seems that the influence of the CAP and the market are dominant for the agricultural sector in the Netherlands (MNP, 2005). Ewert et al. (2005) developed a simple static approach to estimate future changes in the productivity of food crops in Europe. They found that changes in crop productivity, over the period 1961 – 1990, were strongest related to technology development and that effects of climate change were relatively small. Ewert et al. (2005) estimated an increase in crop productivity (till 2080) between 25% and 163%, the contribution of technological development to this increase is between 20% and 143%, the remainder (5- 20%) is attributed to climate change and $CO_2$ fertilisation. The contribution of climate change just by itself is approximately a minor 1%.

Adapting to changing conditions is to a large extent normal agricultural practice. Dutch farmers have been highly successful in doing so given that they have adequate technical training and financial resources. Whether and when climate change will overrule a current agricultural practice is unclear. It seems that gradual changes will not impose insurmountable problems. The consequences of more rapid changes and changes in frequency and intensity of extremes and extreme events are less well understood. Furthermore, current scientific insight in changes of occurrence and frequency of extreme weather events is very limited.

Related to the ongoing and expected impacts of climate change, a number of adaptation strategies are identified which we have arranged based on the impact and spatial area. We identify three major impact areas: i) Yield reducing impacts; ii) Quality reducing impacts iii) Damage to crops and built structures. For the geographical areas we use the classification: i) Nation wide; ii) Low lying parts and iii) Higher parts of the Netherlands. For each strategy special attention will be given to the role of an actor and the timing of the implementation of an adaptation strategy. Not only changes in magnitude and direction of change of the impacts are important, but also changes in variability or stability are important. We group the adaptation strategies based on the level at which the adaptation takes place.

***Crops and tillage level***

Adaptation strategies at the level of crops and tillage respond to changes in crop production which are expected to occur due to direct or indirect effects of climate change. The combined effect of an increasing $CO_2$ concentration and a temperature rise of up to 2-3°C can lead to increased potential yields of wheat, seed, consumable and industrial potato and sugar beet in the Netherlands (Ewert et al., 2005; Kok et al., 2001; Schapendonk et al., 1998). Temperature increases beyond 3-4°C will negatively influence crop yields, except for maize (Parry et al., 2000; Kok et al., 2001, IPCC, 2001b). According to a study into the future crop productivity of wheat in Europe by Ewert et al. (2005), the effects of $CO_2$ and climate change on crop productivity are, however, expected to remain small compared to the effect of future technology development.

For the higher parts of the Netherlands, especially for arable land on sandy soils, crop yields may decrease due to expected decreased summer precipitation and an increased frequency of high-intensity rain showers (Van Ierland et al., 2001). Among the most drought sensitive crops are summer vegetables, leaf vegetables, flower bulbs, fruit and tree crops. The potential gross yield of these crops may decrease by 9 to 38% due to drought stress according to calculations by Clevering (2005b) using the updated HELP tables (Brouwer and Huinink, 2002).
Besides the direct effects, indirect effects such as saline intrusion and changes in abundance and pressure of pest and diseases can locally have a dramatic effect on production levels. It is however unclear how these will develop.

The productivity of rainfed, arable crops in southern Europe may decrease due to shortening of the growing season as a result of decreasing precipitation and increasing evapotransipration. This may have a negative impact on yields in these regions, but positive effects on agricultural economic returns in northern European regions, among which the Netherlands (MNP, 2005).

***Adjusting crop rotation schemes and planting and harvesting dates***

This strategy is based on the selection of crop rotation schemes and timing of planting and harvesting to respond to local changes in environmental conditions (Van Ierland et al., 2001; Kok et al., 2001; Parry et al., 2000). In the lower parts of the Netherlands, especially the peat-grassland area (Kwakernaak and Rienks, 2005), soils may become too wet in spring and autumn for soil management operations (sowing, planting, cultivation or fertilization) and harvest with the equipment and machinery currently used. The effects of the adjustment of crop rotation schemes and planting and harvesting dates are to minimize production losses and avoid decreased workability and trafficability in early spring and autumn.

No quantitative information was found on the benefits of adjusting dates of planting and harvesting. The loss of income and damage to the harvest due to extreme rainfall in the Netherlands in 1998 amounted to 600 M€ (Van Duin et al., 1999; in: MNP, 2005). This amount could be theoretically saved if planting and harvesting dates could be shifted in response to the soil moisture conditions in autumn and spring. With respect to the costs we can safely say that this is a low cost activity; it is part of the operational planning at the field level.
As an adaptation measure that can be implemented by the private sector, the priority is high but it requires no action at higher scales.

Contract workers could face more and more problems in planning. If the time window for the activity is small it maybe difficult to get all the work done in time. The actors involved include farmers, product boards and the retail sector. Effects are expected on the transport and trading sector with regard to the changes in delivery times of crops and produce.

***Choice of crop variety and genotype***

Future climate features can be included in breeding and selection strategies and genetic manipulation through the choice of crop variety and genotype. Effects are to preserve the productivity of crop land by growing crops or trees which better resist saline conditions, wetness, drought, pests, diseases, frost and a shorter growing season (Van Ierland et al., 2001). The choice of crop variety and genotype is considered the most important adaptation strategy to climate change in the agricultural sector (Verhagen et al., 2002).

Benefits can be approximated by the avoided damage costs of climate change. Based on experiences from other countries, the maize wortelkever may cause harvest losses of 6.5 to 13%. Applied to the full area of silage maize in the Netherlands (200.000 ha), this would imply an economic loss of 15 to 30 M€ on an annual base (at the commercial value of € 1550,- per ha) (MNP, 2005). Benefits of adaptation options therefore critically depend on market development.

Availability of the different varieties is not clear and we should be aware that it takes time to develop new crop varieties. Diversification at the crop level is a risk diverting strategy which is not yet fully explored. Information on local varieties is not always clear.

Developing crops to cope with environmental stresses like saline conditions, drought, flooding and high temperatures offers opportunities for crop breeders and farmers. It is most likely to be important in keeping global food production on pace with the growing population. Other opportunities arise when new markets can be served e.g. the energy market.

Actors include farmers, farmer organisations, product boards, consumers, national government, EU and research. This adaptation strategy requires a public effort (Van Ierland et al., 2001). Institutional aspects include national agricultural laws, EU CAP, cross-compliance measures, publicity and the capability of the agricultural sector to adjust to the changes. Effects are expected on the trading sector, through the changed demand and supply of agricultural products, and on the health sector, through the introduction of new food products.

***Development and growing of crops for biomass production***

This is a special case that combines adaptation and mitigation in one strategy. Using crops and crop residues for industrial processes and fuel is not new, but when markets for renewable energy grow and markets for conventional products are decreasing biomass production may be a viable alternative. Using existing crops but also the development of starch, sugar and oil crops which are resistant to salt, drought or wetness may contribute to the production of biomass for the production of energy and raw materials (Langeveld et al., 2005). Benefits for this strategy critically depend on market development.

When using readily available crops (e.g. reed, willow) costs can be low. When crops are grown in areas along the main rivers, the crops may have negative effects on the flow capacity during discharge peaks (Luttik and Rijk, 2000). Such problems were reported for willow plantations in the Mariënwaard river foreland along the river Waal.

Opportunities related to this strategy are the combination of agriculture with other land functions, like water storage, erosion control, soil cleaning or the creation of attractive landscapes. Examples of such crops are (silage) beet resistant to salt and providing amino-acids and sugar, multi-annual oil or protein crops resistant to drought, and trees resistant to salinization or wetting while providing suitable construction wood and lignocellulose for biomass production (e.g. willows) (Langeveld et al., 2005). The reduction of $CO_2$ emissions is an opportunity of the biomass production using stress resistant crops.

According to Langeveld et al. (2005), the growing of stress resistant crops will remain limited in the Netherlands. The opportunities for the Dutch agricultural and business sectors in this field are mainly in the development of high quality genetic material and in the added value of the production and sale of seeds for the production of stress resistant crops at international scale.

The initiative for sustainable energy management based on biomass production comes from the Ministry of Economic Affairs. Other actors are the business sector, energy companies, research institutes (a.o. ECN, TNO-MEP, WUR), universities (Delft, Twente, Eindhoven, Groningen), other ministries (VROM, LNV), and the DEN-, BSIK- and NEO-programs. Furthermore, the agricultural and agri-business sectors (i.e. processors of starch, sugar and oil crops, e.g. Nedalco, Purac) are important actors as suppliers of biomass.

The agricultural sector needs stronger linkages between the sub-sectors arable farming, forestry, horticulture, livestock farming and fisheries in order to use waste flows of one sub-sector in another as sources of energy, heat, $CO_2$, fertilizer, feed proteins and peat replacements.
The production of crops for biomass may contribute to the energy and industrial sectors and to the nature sector if combined with other land use functions.

***Soil moisture conservation practices***
Soil moisture conservation practices may serve as adaptation strategies to reduced rainfall during the summer period. Examples are conservation tillage methods (Parry et al., 2000). In conservation tillage, some or all the previous season's crop residue is left on the soil surface. This may protect the soil from wind and water erosion and retain moisture by reducing evaporation and increasing infiltration. Increased soil organic matter will not only improve the water holding capacity but also improve soil structure.

***Irrigation***
Irrigation is required for the profitable growing of fruit trees, vegetable crops and flower bulbs. Due to climate change irrigation demand is expected to increase. Depending on how climate will impact other regions and market development irrigation may be profitable for other crops as well (Clevering, 2005b).
Irrigation management practices include irrigation scheduling and the monitoring of soil moisture status. Irrigation scheduling is the tuning of the timing and amount of water.
An example of an innovative irrigation management system is a recently developed system for golf courses in the USA (Ritsema, pers. comm.). This irrigation management system consists of an irrigation system and a soil moisture monitoring network in the field with an online connection to a base station through the internet. Based on real-time soil moisture conditions and weather predictions for the next 5 days an irrigation advice is provided.

Costs of the irrigation of arable crops (potato, sugar beet, wheat), vegetable crops (carrot, onion, sprout, cauliflower) and flower bulbs using surface water range from € 90,- to € 300,-/ha per year, assuming three irrigation gifts (Clevering, 2005b; Brouwer and Huinink, 2002). Irrigation costs are highest for vegetable crops.

The investment costs of a complete set-up and implementation of the automated irrigation management system amount to € 10.000,- one-off, and to at most € 10.000,- annually recurring per ha. Costs for training are low as the system is user friendly.

The benefits of the efficient extension of irrigation from surface water3 in the Netherlands were quantified by RIZA et al. (2005b) in the Water Shortage Task for the agricultural sector ('Watertekortopgave'). The increase in profit for the agricultural sector due to the reduction of water shortage, converted to the total area of agricultural land in the Netherlands, was estimated at 4 billion euros per year.
Clevering (2005b) found that irrigation for the purpose of increasing crop yield solely (apart from crop quality) is only profitable for arable farms if a considerable part of the crop rotation consists of vegetable crops or flower bulbs. Based on calculations for arable farms in the southwestern part of the Netherlands (Clevering, 2005b), increases of farm income for such crop rotations due to irrigation range from € 175,- to € 743,- per ha per year under the current climate conditions. Under the 'controlist' climate scenario (central IPCC estimate; increase of yield loss

[3] Irrigation from groundwater sources is not considered in the 'Watertekortopgave' because it does not fit in the policy of provinces and water boards. Besides, the use of groundwater for irrigation and tapwater in greenhouses are considered unsuitable adaptation strategies for arable farming and greenhouse growing due to high exploitation costs (Veeneklaas *et al*., 2000).

due to drought of 22%) and ‘environmentalist’ climate scenario (upper IPCC estimate; increase of yield loss due to drought of 37%) used in the Droogtestudie Nederland (RIZA et al., 2005a; Droogtestudie Nederland, 2003), annual benefits from irrigation of between € 213,- and € 1045,- per hectare are expected.

With regard to the use of irrigation management systems very substantial savings on the costs of irrigation were demonstrated in the application of the automated irrigation system to golf courses. When applied to farmland, the reduced costs for irrigation enable the farmer to stay within irrigation quota. Other benefits include the increase of crop production because situations of stress due to drought or salty conditions are avoided on time. Costs of maintenance are lower. The experience from the golf courses has learned that the investment costs are small compared to the benefits of cost reduction for irrigation and increase of crop production.
A barrier to the use of irrigation as an adaptation strategy to climate change is the increasing difficulty for vegetable growers to meet quality demands given the expected increased frequency of dry summers and extreme rainfall events. Also, the extension of the area of irrigated crops enabled by improved irrigation management may result in an over-production of highly profitable crops, leading in turn to a decrease of their profitability (Clevering, 2005b).
Implementation of the automated irrigation management system has few barriers, except for the necessity of the farmer to have a PC with a continuous connection to the internet.

An irrigation management system gives the farmer insight in the response of his land to the weather conditions and the irrigation chosen and applied. In addition, the system offers the farmer the possibility to predict crop yields based on the model calculations behind the irrigation advice. Actors in this adaptation strategy include farmers, business sector and the water boards. Spill over effects to water and nature are expected. Nature may actually benefit through a reduced extraction volume of surface water for irrigation.

***Self sufficiency in production of roughage***
The aim of this strategy is to create self-sufficiency in roughage by locally produced roughage, instead of relying on insecure availability of roughage from abroad due to climate change (Van Ierland et al., 2001; Veeneklaas et al., 2000). The production of roughage in the Netherlands (wheat and silage beet) could be improved as a result of climate change, given optimised water management (Veeneklaas et al., 2000).

In an open market it will be difficult to achieve self sufficiency. It is unclear what the effects of climate change are on roughage production. Currently most roughage is derived from by-products of e.g. citrus production.
The production of roughage in the Netherlands would provide the opportunity to exploit Dutch expertise in primary production and subsequent stages in the processing and distribution chain (Veeneklaas et al., 2000). The actors involved include farmers and product boards.

***Water storage on farmland***
Water storage on farmland is defined as the storage of excess water either in the soil under low groundwater conditions in open water like ditches, water courses, lakes and ponds or on the soil surface in case the soil and open water offer insufficient storage capacity (LTO Nederland, 2003). Water storage on farmland refers to overflow polders and retention areas, where the land remains property of the farmer and is used for temporary water storage. Overflow polders are put to service when the water storage system (‘boezem’) cannot discharge the water and needs to be unburdened. Retention areas are meant to receive the peak discharge of rivers to prevent flooding elsewhere. Emergency retention areas allocated along the major rivers to receive large quantities of water in extreme conditions to prevent life-threatening situations and large damage elsewhere in e.g. urban or agricultural areas.

Water storage is one of the blue services provided by the agricultural sector. Blue services are defined as voluntary contributions of private parties to legal assignments of water boards for compensations in conformance with the market (Schouwenaars, 2005). The Dutch agricultural and horticultural organisation (LTO) developed guidelines for the compensation to farmers of water storage on farmland (LTO Nederland, 2003). Several water boards have regulations for the compensation of so called blue services (Veluwe, Wetterskip Fryslân, Vallei en Eem, Hollands Noorderkwartier) (www.blauweengroenediensten.nl) (Schouwenaars, 2005).

The costs of blue services consist of the costs incurred by a farm for offering the blue service, expressed in the loss of labour profit, and on top of that a compensation to the farm for granting the blue service (LTO Nederland, 2003; Durksz and Braker, 2005). The costs incurred by a farm for offering the service to store water were estimated for an example dairy farm in the northern peat-grassland area with the Farm Budget Programme for Cattle (BBPR, 2001) by Durksz and Braker (2005). Costs of construction, maintenance, cleaning of garbage and consequences for animal health are not included in the model estimates.

*Table 3-1 Costs for offering water storage on farmland incurred by a typical dairy farm in the northern peat-grassland area.*

| Water storage measure | Loss of labour profit (€/year) |
|---|---|
| Widening ditches | 400,- |
| Converting land to water buffer + increasing ditch water level to 60 cm –gs* | 1.700,- |
| Taking land out of production | 1.200,- |
| Retention polder | 1.300,- |

* gs = ground surface

* Note: based on Durksz and Braker (2005)

The compensation to a farm for executing a blue service consists of an annual compensation for damage to crops or a single benefit for the decrease of the value of the land. Both types of costs depend on the probability of inundation.

In the regulation of the Waterboard Vallei and Eem, the annual compensation for damage to crops ranges from € 300,- per ha for a probability of inundation of once a year to € 3,- per ha for a probability of inundation between once every 50 and once every 100 years. The single benefit for the decrease of land value ranges from € 2700,-/ha for a probability of inundation of once a year, to € 550,-/ha for probabilities of inundation between once every 10 years and once every 100 years. These amounts are based on a land price of € 20.000,-/ha (Schouwenaars, 2005).

There are also examples of open tendering for blue services in order to stimulate private parties to identify more cost-efficient measures for water retention than the government, like the project ‘Blue services in the Langbroekerwetering area’ (Province of Utrecht, Water Board De Stichtse Rijnlanden, farmers, Ministry of Agriculture, Nature Conservation and Food Quality and the European Commission) (Werners et al., 2004).

Costs and benefits of the conversion of grassland along the main rivers into (emergency) retention areas depend on the monetary value of the land, the duration of inundation and possible compensations for green (nature management on farmland) or blue services. The balance of these costs and benefits for grassland with a land value of k€ 19-25 were estimated at € +45,-/ha, versus € -115,- to € -430,-/ha for land with a value of k€ 10-16 by Luttik and Rijk, 2000), based on a land value of k€ 32 with no yield loss, and maximum compensations for green and blue services of € 680,-/ha/year.

The average utility value of grassland in river forelands is about 70-80% that of grassland inside the dikes. The utility value of emergency retention areas ranges from 9% to 75% of the utility value of grassland in river forelands (Klijn and De Vries, 1997). In general, river forelands in the upstream reaches of the rivers can be considerably digged off without negative effects on the land utility value (Luttik and Rijk, 2000).

Barriers to the implementation of water storage on farmland may include bottlenecks in local markets for roughage (due to the decreased possibilities for grazing) and upper limits to compensations for blue or green services (€ 4500,- per farm per year in 2000, Luttik and Rijk, 2000).

Retention areas create additional income for farmers (for example Kerkmeijer farm in Salland, project Waternood). Opportunities for the creation of (emergency) retention areas on farmland along the main rivers include the possibility to deploy these areas for recreation, nature development and management, and as water stocks for the fruit growing sector to combat night frost in spring. Seepage areas just inside the dikes originating from the digging off of river forelands can be used for growing crops which benefit from wet conditions (e.g. rice, watercress).
However, water storage can also be realised in other joint ventures with private partners instead of legal agreements between the water board and land owners. Examples are mentioned in Van Bommel et al. (2003).

The policy frameworks for blue services in the Netherlands include the Starting Agreement for Water Policy in the 21st century between the national government, the inter-provincial consulation (IPO), the Union of Water Boards and the Association of Dutch municipalities (2001) and the National Administrative Agreement on Water (NBW, 2003). Blue services require a legal agreement based on private law between the landowner (e.g. the farmer) and the water board (Schouwenaars et al., 2005).
Water storage on farmland may be combined with the development of aquatic nature.

***Subsoil drainage of peatlands***
Subsoil drainage is a recently introduced adaptation strategy to combat subsidence and oxidation of peat related to lowering of groundwater tables during periods of drought. Drainage tubes are laid out in the field perpendicularly to ditches, below the water level in the ditches. The water from ditches infiltrates into the subsoil with the purpose to increase the groundwater level. The measure is currently tested at the Zegveld experimental farm as part of the research project ‘Where to go with peat’ by the Practical Research Group of the Animal Sciences Group and Alterra (WUR), financed by the Dairy Product Board (Hoving and Van den Akker, 2005).

Based on the available information to date, costs are € 0,85 ex. BTW per meter of subsoil drainage network (Van den Akker, pers. comm.). Tubes are laid out at 4-6 m distance, resulting in about 2600 m or € 2210,- ex. BTW for 1 ha of treated land. Soil subsidence up to more than 40 cm is expected to occur until 2050 in all organic soils and peat soils with a clay top layer (TNO, 2003; in: MNP, 2005). These cover ca 265.000 ha (De Vries and Brouwer, 2005, in: Rienks and Gerritsen, 2005). If subsoil drainage is applied to the entire surface of peat soils susceptible to subsidence, the associated costs would be approximately 583 M€. A benefit could be lower emissions of CO2 from oxidation of organic matter from the peat layers; it is more difficult to estimate costs as both lower emissions and prices of emissions are uncertain.

Detailed calculations of costs under optimal drain distance, depth and water level in ditches will provide information on the effect on farm income and the cost-effectiveness of an investment in subsoil drainage (ongoing project ‘Where to go with peat’, ASG and Alterra).

Income reductions due to subsoil drainage were investigated in field experiments on arable land on sandy soils in Vredepeel and Veulen. Income reductions from maize, beets beans and potatoes range from 3% under recommended fertilisation to 15% without fertilisation (Clevering, 2005a).
The local priority setting of adaptation strategies to soil subsidence in the peat-grassland area is high.
The measures are put in place to continue with existing land use management and may only offer temporarily relieve as groundwater level for grassland and dairy farming still results in subsidence of peat. In addition to mitigating soil subsidence, subsoil drainage reduces the emission of CO2 and the runoff of manure to the surface water by enabling the filling up of ditches, levelling of the soil surface and realising a dryer topsoil (Hoving and Van den Akker, 2005).
Major actors in this strategy are farmers, water boards and local governments.

***Insurance***

Insurance is the most important anticipating adaptation strategy (Kok et al., 2001). Damage due to storms and floods are expected to be the largest loss-making items. Due to the unknown effects of climate change on weather extremes it is difficult to adjust insurance contributions to increased risks. Currently, farmers can only insure damage due to rain and hail storms, not due to snow storms.

Ongoing initiatives include the AquaPol insurance scheme for farmers against damage by rainstorms (Werners et al., 2004), and the BSIK project 'Financial arrangements for disaster losses under climate change'. This latter project aims at identifying and evaluating insurance adaptation strategies which respond to risks and damage from extreme weather events in the Netherlands (Werners et al., 2004).

Recently, growers of ornamental trees in the eastern part of the Netherlands claimed compensation for damage incurred during a snow storm in November 2005, which amounted to 30% of their annual income (Radio 1 News, 17-1-2006).

***Changes in farming systems***

In many regions of Europe, including the Netherlands, farms have, in response to policy and market incentives, become highly specialized enterprises.
Farms can also adapt to the constraints of climate change to the productivity by replacing part of their production activities by alternative, income generating activities like nature management and development, biological farming in water extraction areas, processing and sale of products on the farm, agro-tourism, health care (Luttik and Rijk, 2000). In 1998, only 9% of the Dutch farms implemented these activities in their farm management (CBS Landbouwtelling 1998). Besides income diversification changes in crop e.g. move to biomass production or crop diversification are farm level strategies that could increase resilience and reduce vulnerability to external shocks. Whether changing farming systems from conventional to organic farming will reduce or increase the vulnerability to climate change is not clear.

***Water management and agriculture***

The fen-meadow areas in the western part of the Netherlands experiences several interconnected problems: the subsidence of farmland, water shortage during the dry summer period, excess water during wet periods and salinization related to sea level rise. Groundwater levels are kept low in agricultural land and high in natural areas, which creates a scattered pattern of groundwater levels and gradients from natural areas to polders. Low groundwater levels in agricultural areas result in accelerated oxidation of peat and soil subsidence. This effect amplifies the scattered pattern of groundwater levels between agricultural and natural areas (Kwakernaak and Rienks, 2005).
Farmland on high areas on sandy soils in the Netherlands is expected to suffer from summer drought under climate change, causing yield loss and loss of income (RIZA et al., 2005a).

Water level management involves the increase of ditch and groundwater levels, and is also referred to as 'wetting of farmland'. This measure has the following benefits: (1) peak water discharges can be captured, (2) high groundwater levels can be maintained in adjacent nature areas (Kwakernaak and Rienks, 2005; Clevering, 2005a), (3) a groundwater stock can be maintained at the start of the dry summer period (RIZA et al., 2005b), and (4) soil subsidence due to the oxidation of peat is reduced (Kwakernaak and Rienks, 2005; Hoving and Van den Akker, 2005).

Wetting of farmland can be realized through structural or periodical wetting (Clevering, 2005a). Structural wetting involves the raising of ditch bottoms or the lowering of the drainage depth in combination with an increase of the drainage density. In the high areas on sandy soils, structural wetting is not designed to solve water shortage in extremely dry situations, but to retain water to restore groundwater levels in average dry situations (RIZA et al., 2005b). Periodical wetting involves the increase of the groundwater water level in fields with or without water supply from ditches. The latter form is also referred to as 'under water drainage' (Hoving and Van den Akker, 2005, see also section 2.3.3).

The benefits of water level management on farmland in the high areas on sandy soils through structural wetting were quantified by RIZA et al. (2005b) in the Water Shortage Task for the agricultural sector ('Watertekortopgave'). The increase in profit for the agricultural sector due to the reduction of water shortage, converted to the total area of agricultural land in the Netherlands, was estimated at 1 billion euros per year. A possible increase in the costs of damage due to the wetting of farmland is not taken into account in the estimation of benefits.

Costs associated with water level management include costs of productivity loss in case of structural wetting, and costs of a blue service in case of periodical wetting. Examples of cost calculations of productivity loss caused by structural wetting are available using the HELP-tables, based on groundwater levels, and the Waterpas-model (De Vos et al., in prep.), a dynamical, integrated model for the calculation of farm management and returns as a function of changing water levels. The costs of productivity loss caused by structural wetting of farmland by bringing the groundwater step from VI to III* were estimated to range from € 216,- to € 355,- per ha throughout Dutch regions using the HELP and HELP+ tables by Van Wenum (2003, in: Clevering, 2005a). Using the Waterpas-model, De Vos et al. (2004) estimated an average annual decrease of the net farm return by € 222,- per ha for a typical dairy farm in the polder Zegveld-Oud Kamerik (Water Board Stichtse Rijnlanden) as a result of bringing the surface water level from 60 to 40 cm below the ground surface level.

The costs of periodical wetting as a blue service were estimated for an example dairy farm in the northern peat-grassland area with the Farm Budget Programme for Cattle (BBPR, 2001) by Durksz and Braker (2005). Setting the groundwater level from 90 cm below the ground surface to respectively 45 and 30 cm was estimated to cause a lowering of the labour profit by respectively € 7.700,- and € 10.700,- per year. Rienks and Gerritsen (2005) quantified the costs of compensation of the agricultural sector for several wetting strategies in the peat-grassland area in Friesland, departing from year round surface water levels of 90 cm below the ground surface in the original situation. These costs were estimated at € 677,-/ha per year for converting farmland to puddle-marshland by setting surface water levels to 0-20 cm below the ground surface, and € 200,-/ha per year for maintaining surface water levels between 25 and 55 cm below the ground surface for nature management purposes.
Stakeholders involved are water boards and farmers.
The enforcement of higher groundwater levels in farmland evens out the currently scattered pattern of groundwater levels due to differences between farmland and natural land in the peat-grassland area. This prevents the flow of high quality water from natural areas to adjacent farmland, and helps to prevent water shortage in parts of the area used for forest production (Kwakernaak and Rienks, 2005).

***Regional adaptation strategies for the fen meadow area***
The fen meadow area of the Netherlands is characterized by scattered groundwater levels because groundwater levels are kept low in agricultural land and high in natural areas. This results in the sinking down of water from natural areas in polders due to the gradient between natural and agricultural areas with soil subsidence in the agricultural areas, and water shortage in summer in both the agricultural and natural areas. The subsidence can be prevented by creating water basins between the polders and the natural areas. Such basins can also supply water in the summer, when water shortages are expected due to decreased precipitation, and to buffer effects of intruding salt water through seepage and the surface water system. The rearrangement of the fen meadow area seems the best adaptation strategy to even out scattered groundwater levels (Kwakernaak and Rienks, 2005).

The costs of a rearrangement of land use in the peat-grassland area must be compared to the actual costs for the management of infrastructure and sewage resulting from the sinking of roads and pipings. This comparison is currently done in the BSIK project 'Where to go with peat', financed by the Dutch Ministry of Agriculture, Nature and Food Quality (Kwakernaak and Rienks, 2005). Scenarios for large scale rearrangements of land use include the cooperation of farms in mega dairy farms covering 2000 ha and the development of 'slow regions', in which nature, water management, recreation and biological farming are combined.

Barriers to the rearrangement of peat-grassland area are the inflexibility of the urban area with regard to changing land use, the presence of expensive infrastructure and buildings, the resistance of farmers to a large scale reallocation of land, the difficulty to buy out landowners due to high land prices, and the financial losses and societal opposition to recent large infrastructural projects like the Betuwe railway line and the Southern High Speed Line (Kwakernaak and Rienks, 2005).
The stakeholders include the national government, all land owners involved in land rearrangement.

Institutional aspects related to adaptation strategies for the peat-grassland area are the mandatory rules from the European Union, such as the Water Framework Directive, the Bird Directive and the Habitat Directive.
Both the creation of buffering water basins and the rearrangement of the peat-grassland area would have positive effects on the nature sector by improving the retention of water in natural areas within peat-grassland area.

***Relocation or mobilization of farms***
Relocation or mobilization of farms and greenhouses are adaptation strategies related to problems like soil subsidence, decreased accessibility of farmland for cattle and machinery, and damage from high and saline groundwater. The relocation of farms and greenhouses involves the displacement of entire farms or enterprises to other parts of the Netherlands, where the mentioned problems do not occur. This strategy is very difficult to implement due to the large number of sectors and interests involved (Werners et al., 2004; Van Ierland et al., 2001). Little information is available to date on the relocation of farms. The mobilization of farms could include mobile milking stables, in which the cows and milking system are displaced together. This would enable large-scale dairy farming due to the shortening of cattle course tracks and reduced trampling. Mobile milking stables have been realized in Canada and Denmark (Galama and Lenssinck, 2005).

***Floating greenhouses***
Floating greenhouses are greenhouses on the water surface, which move up and down with the water level, while offering space for water storage in low-lying polders. Floating greenhouses are an integrated and flexible adaptation strategy to the increased need of space for the storage of water under climate change and to changing groundwater levels (Langeveld et al., 2005). In addition, the risk of damage to the greenhouse sector due to flooding is significantly reduced in low lying areas and polders (Werners et al., 2004).

The technical concept of the floating greenhouse is available, and is currently tested for feasibility and profitability. A prototype of a floating greenhouse has been developed in the project ‘Floating Greenhouse’, realised by the private sector, researchers, and supported by the Ministry of Economic Affairs (Werners et al., 2004). A prototype is currently constructed in the pond at the Flora Holland mart. Planned locations for the realisation of floating greenhouses include the greenhouse location Rijsenhout and the Zuidplaspolder. Investment costs of floating greenhouses are high: additional investment costs compared to usual greenhouses amount to at least € 100,- per $m^2$ (Langeveld et al., 2005).
Floating greenhouses offer the opportunity to combine crop production and aquaculture, which is interesting due to the high demand for fish, shellfish and crustaceans of high commercial value (Langeveld et al., 2005). Vegetable products may serve as fish bait, while fish may enhance crop productivity as a natural source of fertilizer. Floating greenhouses may also be used for the storage of water and heat exchange.

Construction projects for floating greenhouses are currently developed by the construction company Dura Vermeer, which has formed consortia with partners like NUON, Delfts cluster, Delft Hydraulics. Other important actors are the greenhouse product boards, provincial governments and water boards. The actual implementation of floating greenhouses depends on the willingness of water boards to allocate space to the greenhouses (Langeveld et al., 2005).

***Land use change***

Land use change substitutes the productivity loss of crops with shortening growing seasons and overproduction of wheat by economic value of new urban, recreational land, forest, or land for bioenergy crops (Ewert et al., 2005). Based on a study on effects of climate change on crop productivity, Ewert et al. (2005) forecasted that the estimated increases in the productivity of several crops are likely to result in further abandonment of agricultural land in Europe, as observed in the past decades. A decrease of the agricultural area in the Netherlands is also foreseen in the 'controlist scenario' for 2050, used in the Droogtestudie Nederland (RIZA et al., 2005a) (by 17%, mainly referring to arable land), and in scenarios for future agricultural land use in Europe in 2080 by Rounsevell et al. (2005).

The transformation of farmland offers the opportunity to generate income by carbon credits for reduced CO2 emissions. The current emission trading price of a ton CO2 under the Kyoto Protocol is € 23,-. Assuming that future emissions trading would cover all greenhouses gases and sectors, an income of € 414,- per ha per year could be generated by the transformation of farmland (Kabat et al., 2005).

***Adaptation strategies to salinization of agricultural land***

Sealevel rise will cause an increase of the salt water seepage in the coastal zones of the Netherlands, and an increase of the salt water intrusion in the main rivers in combination with lower river discharges in summer. Both types of salinization can harm salt sensitive crops in agriculture and horticulture. However, recent findings show that damage to crops due to salinization, in areas with a freshwater lens and well drained fields, are relatively low (Clevering et al., 2005c).

RIZA (2005b) reports that salt water seepage during the summer period is expected to increase under future climate through an increased seepage pressure, a decrease of the effective precipitation, soil subsidence and sealevel rise. The agricultural areas in the provinces Groningen, Friesland, Noord- and Zuid-Holland are considered to be most sensitive to damage by salinization due to their dependency on the supply of fresh surface water (MNP, 2005).

Adaptation strategies include activities at the crop level and at the regional/national level. Currently available or conceivable adaptation strategies to the salinization of agricultural land are:

- improving the efficiency of freshwater use in areas subject to salinization (Fiselier et al., 2003);
- the growing of halophyte cultures (Langeveld et al., 2005);
- the growing of macro- and micro-algae (Langeveld et al., 2005);
- the growing of bait for fish in saltwater basins on the land and fish+ (Langeveld et al., 2005);
- the conversion of salted arable land to grassland, nature or sea culture parks (Langeveld et al., 2005);
- irrigation using brackish water (Clevering, 2005b);
- use or design of salt tolerant crops;
- changing land use.

In areas subject to salinization, the available freshwater can be used more efficiently (Fiselier et al., 2003). Flushing of polders with freshwater is often inefficient if the salt intrusion comes from the groundwater, or if the competition for freshwater in summer is high (Veeneklaas et al., 2000). Rain water is often directly discharged, giving way to the seepage of salt water. Options to use freshwater in areas subject to salinization include the retention and storage of rain water, a better separation of fresh and salt water, and the increase of surface water levels to suppress salt water seepage (Fiselier et al., 2003).

The growing of halophyte cultures is currently limited to vegetables (zeekraal, zeekool, zee-aster) (Langeveld et al., 2005). Due to the limited market for salty vegetables, the controlled culture of these crops in the open air or in greenhouses is not a suitable strategy to create new destinations for salted soils (Langeveld et al., 2005; Kennissprong Zilte Zoom, 2005).

The conversion to grassland joins with the traditional use of salty crops for grazing by sheep and cows.
Sea culture parks are parks in the transitional zone between land and sea, where agriculture in the form of sea food production is combined with other functions, like the production of sustainable energy, nature development, water storage, housing and recreation (Langeveld et al., 2005).

Irrigation using brackish water is an attractive adaptation strategy, because the largest part of the freshwater supply for the agricultural sector in the Netherlands is allocated to the flushing of water courses (78%), and only 3% is allocated to irrigation (Droogtestudie Nederland, 2003). In addition, irrigation from freshwater sources is not profitable for dairy farming (Huinink et al., 1998).

A recent study into the possibility to use brackish rainwater for irrigation in Zeeland and west Brabant showed that, in contrast to the established knowledge, irrigation using brackish water is profitable for flower bulb growing, vegetable growing and salt-sensitive arable crops like onion and carrot (Clevering, 2005b). The upper limits for chloride concentrations in the irrigation water for these crop types may amount to respectively 300, 900 and 600 mg/l.

Costs of irrigation using brackish water compare to those for irrigation using freshwater. Estimated costs for the south western part of the Netherlands are € 135,- to € 300,- per ha per year, assuming three irrigation gifts (Brouwer and Huinink, 2002; Huinink et al., 1998).

The success of sea culture parks depends on the availability of sufficiently strong economic carriers. In the case of the densely populated Dutch coastal area these are provided by housing and recreational functions.

Benefits of irrigation using brackish water were quantified by Clevering (2005b) for arable, vegetable and bulb-flower farms in Zeeland and western Brabant. Increases in farm income amount to between € 127,- and € 743,- per ha per year for irrigation water with chloride concentrations between 300 and 600 mg/l, and between € 102,- and € 722,- per ha per year for chloride concentrations between 600 and 900 mg/l.

Barriers to using brackish irrigation water include the difficulty for farmers to comply with the high quality demands for vegetables and the risk for overproduction of highly profitable crops due to the extension of the irrigated area (Clevering, 2005b). Also, higher rainfall intensities under future climate in combination with the use of brackish water may result in the decay of soil structure. Drip irrigation may solve this barrier (Clevering, 2005b). Salty diets can pose health risks.

### 3.1.2 Strategies and impacts for the forestry sector

Forests are likely to be particularly vulnerable to climate change due to the longevity of trees and the extent of the expected climate change within their life span. On the other hand, forests are also resistant to large variability of the climate they experience during their life span (Kuikman et al. 1999). Adaptation strategies to climate change for the forestry sector refer to forest management (species composition, spacing, thinning, and water management), influences on the trade of timber and the multi-functional use of forests. Most strategies fit in the recent shift of orientation in production forest management from monocultures to natural compositions. However, the support for adaptation to climate change is weak in the production forestry sector (Nabuurs, in: Brinkman, 2002). In this section the focus is on production forests. Production forests in the Netherlands are of limited economic importance as far as timber production is concerned. Most adaptation strategies will have to integrate other functions, besides production, to be economically feasible in Dutch economic conditions.

***Increasing genetic and species diversity in forests***

The genetic variability of the most common tree species is probably large enough to allow acclimatization to changes in average temperature and precipitation (Parry et al., 2000). Yet, promoting broad genetic variation and diversified species composition in forests are appropriate strategies to spread the risk of extinction of species and to increase the resilience of production forests (Kramer, 1996; Nabuurs et al., 1997). Diverse forests are stable and less susceptible to storms and pest and diseases, and have a higher value for nature and recreation (Analyse uitvoering GBB, Alterra rapport 242). Costs are involved in planning and management. Lower economic return related to mixed stands with lower volume of harvested products (Analyse uitvoering GBB, Alterra rapport 242).Forests with higher genetic and species diversity are also more suitable to fulfil natural functions than monoculture forests. Forests with higher species diversity have a higher recreational value. Effects of changing genetic and species diversity in production forests are expected on the nature and recreation sectors and on the industrial sector through the supply of different timber species.

***Introduction of southern provenances of tree species and drought resistant species***

The introduction of tree provenance of more southern origin and the planting of drought tolerant species may be appropriate adaptation strategies to a reduced natural regeneration of forests due to drought stress in summer (Nabuurs et al., 1997; Parry et al., 2000; Kramer, 2001). Examples of southern species are the walnut tree, Robinia, maple, hornbeam, plane tree and several species of lime tree (Kramer, 2001).

Introduction of new species will require investments in plant material. Moreover the processing industry may have to adapt to the new wood supply. It is unclear what the effect of new species on the pressure of pest and diseases will be.

***Limiting the import of timber***

The northbound spread of pests and diseases from southern regions can be slowed by restricting import of fresh timber from areas with pests (Parry et al., 2000; Kramer, 2001). Such a policy would require a strong control by all actors in the value chain: national government, forest product boards, timber processing industry. Whether such import restriction will be accepted in a globalizing market is uncertain.

***Retention of winter precipitation in forests***

Winter precipitation retained in forests may be used to relieve drought stress during dry summers (Van Ierland et al., 2001; Kramer, 2001). This option could reduce or increase drought related production losses. For the lower parts of the Netherlands retention of winter precipitation in forests may increase the sensitivity to storm damage. Water management in the Netherlands is coordinated via water boards. Because of the weak position of production forest in relation to nature, recreation and agriculture decisions related to water retention in production forest will often be evaluated by including the effects on other sectors.

***Acceptation of changes in species composition***

The acceptation of changes in species composition with respect to the natural, recreational and production functions of forests seems an unavoidable strategy to adapt to climate and the change in species composition is also part of the natural process of forest development (Van Ierland et al., 2001). More natural and better adapted forests require acceptance of a dynamic species composition and acceptance of associated costs with changed commercial value of production wood, as new timber species may not fit the demands of the timber processing industry.

### 3.1.3 Strategies and impacts for the fishery sector

The main future climate conditions relevant to the fisheries sector are the increase of water temperature of the North Sea, estuaries, rivers and lakes (MNP, 2005), the increasing frequency of storms, and changing transitions between salt and freshwater due to sealevel rise and changed river discharges in summer and winter (Van Ierland et al., 2001; Kok et al., 2001).

At the European level, changes in aquatic biodiversity and fish production were identified as the key impacts of climate change on the future European fisheries sector by Parry et al. (2000). Short-term climate variability is expected to affect both the geographical distributions of fish and shellfish species and their productivity. The most vulnerable species were found to be those with juvenile stages in freshwaters (migratory salmonid, alewives and sturgein species), where air temperature rise will lead to local extinction (Parry et al., 2000).

Until 2001, changes in fish stock in the North Sea were mainly attributed to over-fishing. This view was also propagated in the NRP-CC inventory of adaptation options for climate change by Van Ierland et al. (2001). Among the major effects are the decrease of vegetable plankton and changes in compositions of animal plankton, fish, birds and mammals, and the decrease of shell fish stocks. Relevant to the fisheries sector is the decrease of codfish (MNP, 2005).

The adaptability of the fisheries sector (capture and culture) to climate change in Europe in 2000 was reduced by market demand, environmental pressure, unsustainable extraction/production practices and a rigid policy framework (Parry et al., 2000). Adaptation strategies need more industry participation to emerge, as well as more coherence between European agriculture, environment, fisheries and regional development policies.

In the Netherlands in 2004, policy plans for the fisheries sector did not foresee specific measures for adaptation to climate change (Werners et al., 2004). The decision to reduce shellfish fisheries in the Waddensea was at the same time an adaptation to the anticipated decline in the mussel production due to the increase of storm frequency and the changes in the salt water-freshwater gradient due to changed river discharges (Van Ierland et al., 2001).

***Adjusting fishing quota***
Current insights have shown the important influence of climate change on the decreasing fish stocks in the North Sea besides unsustainable fishing (MNP, 2005.). Therefore fishing quota should not only be based on the actual levels of fish stocks and fish capture, but also on the expected shifts in species ranges.

***Adaptation of target species and fishing techniques***
Adaptation of target species and techniques in the fishing industry may help to prevent the loss of productivity as a result of the reduction in current target species. Moving away from the single-species stock assessment and allocations to species groups or assemblages will provide the fishing industry with more flexibility (Parry et al., 2000). No clear economic incentives for the fishery industry to switch to other target species or to use other gear exist (Parry et al., 2000). Besides, changing the target species requires changes in consumer preference, away from traditional species like cod fish. Changing the value chain and moving to other target fish species and techniques will have to comply with European legislation and agreements.

***Introduction of ecosystem management***
The introduction of ecosystem management in the fisheries sector will enable a more active and direct participation of the fishing industry. The fishing and aquaculture industries have a long-term self-interest in integrated coastal and marine developments, and regularly collect information on the local aquatic climate, which could be of help to managers. Ecosystem management in fisheries should include biodiversity conservation plans for freshwater and marine fish and shellfish at the genetic, species and ecosystem levels (Parry et al., 2000).

***Eco-labelling and certification of fish***
Eco-labelling and certification are adaptation strategies on the demand side of the fisheries sector, which aim to raise recognition by policy makers and the public at large of the necessity of sustainable use of fish resources (Parry et al., 2000). Certification of fish, the process of cheking and verifying the sustainable manner of fisheries and the advertisement of the certificate to the public. An increasing emphasis on product quality in terms of sustainability of the production process as opposed to quantity and price aspects will help fishermen to cope with scarcer resources and decrease waste of by catches.

***Reallocation of mussel nursery plots***
The dynamic reallocation of mussel nursery plots after storms avoids loss of productivity (Van Ierland et al., 2001).
Synergies occur when offshore windmill parks offer another possibility to locate mussel nursery plots. The underwater foundation of offshore windmill has proven to be a suitable place to grow mussels, analogous to the pending mussel culture. This strategy offers the possibility to combine mussel production with the production of electricity. The growing of mussels in windmill parks is currently tested in the Netherlands by the company E-connection in the design of the Q7-WP offshore windmill park (Langeveld et al., 2005).

The benefits of mussel growing at € 10.000,- per windmill are, however, still limited compared to the benefits of the electricity production (€ 700.000,- per year including subvention). But once the development of the combined production system has proven successful, it may serve as a stepping stone to the large-scale production of shellfish in windmill parks (Langeveld et al., 2005).

***Aquaculture on former grassland***
Fish production by means of aquaculture in seawater basins on former grassland may increase the economic value of otherwise inundated grassland. This is an adaptation strategy to undesired changes in species ranges on sea. Aquaculture in basins on land is actually happening in the Netherlands for sole and turbot (Langeveld et al., 2005).

***Workshop***
The results of the workshop session on identifying adaptation options for the agricultural, fisheries and forestry sectors are presented in the tables below. The entry point or discussion was the expected impact. So for each impact several strategies were identified. We added the earlier presented impact and strategy relations (reduced Crop productivity (Y.1) and Economic return (Y.2), impacts on Quality (Q) and Damage to crops (D.1) and buildings and structures (D.2)) to further categorize the results.

*Table 3-2 Results of the workshop for the agricultural sector*

| Impact | Impact on | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|---|
| **Crops and tillage (C.)** | | | | | |
| Higher production level for grasslands related to longer growing season. | Y.1 | Adjust field management | | | |
| Water shortage during summer period/lack of water counter act saline intrusion. | Y.1/Y.2 | Salt tolerant biofuels | | | biobased economy |
| | Y.1 | Lower risk of failure via an increase in varieties/species. | | | |
| Salt water intrusion reduction of production or loss of production areas. | Y.1/Y.2 | relocate sensitive crops (e.g. tree crops) | | | |
| Salt water intrusion reduction of production or loss of production areas. | Y.1/Y.2 | develop salt resistant crops (also for biomass production) | | | biofuels |

| Impact | Impact on | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|---|
| Regional water excess with larger chance of flooding will result in yield reduction. | Y.1 | Adjust timing of operational management. Because of hired labour timing of work is difficult to manage. | | | |
| Wet/moist conditions can result in an increase in pests & diseases. | Q/D.1 | Control of (fungi etc). | | | |
| **Farm level (F.)** | | | | | |
| Low production levels related to shorter growing season (higher temperatures) | Y.1 | Reduce risk of crop failure by increasing species diversity. Organic farming may be a viable option. | | | |
| Fen meadow areas with high water tables during winter period. | Y.1 | Livestock that can cope with wet conditions. Main problem is yield loss related to fungi and tampling of grassland. | | | |
| Damage to crops related to increase in extreme weather events. | D.1 | Insurance | high premiums. | | |
| **Regional and national (R.)** | | | | | |
| Water shortage during summer period/lack of water counter act saline intrusion. | Y.1 | Develop/breed new varieties | | | |
| | Y.1 | Invest in local water storage for irrigation (may not be efficient) | | Depends critically on who is allowed to use the stored water in case of drought. | |
| Regional water excess-> flooding | Y.1 | Small scale water storage via enlargement of ditches.(is more expensive than allocating flooding areas. Excess occurs during the winter and spring period shortage during the summer is it possible to retain water long enough.) | Costs of development/construction of storage systems. (costs could be very high because land is needed.) | New storage technologies could be sold elsewhere. Waterstorage areas could be used as recreational areas. | |

| Impact | Impact on | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|---|
| | Y.1 | | An estimated 4 to 7 billion euro is needed for The Netherlands (noorderkwartier calculated at: +700 milj.). Is more expensive than large scale flooding areas but relatively easy to realise. Large scale flooding is difficult because of NIMBY principle. | Need new technologies for water storage. | Technolog y water storage and reuse of water. |
| | Y.1 | water storage in urban areas | Costs of development/constr uction of storage systems. (costs could be very high) | | |
| | Y.1 | Production levels are low; the Netherlands should focus on food crops. Land and labour are too expensive for low quality biomass production. | | | |
| | Y.1 | regulation of water storage and water supply | | | |
| | Y.1 | different/ new varieties equipped to deal with the new situation. | | If there are no limitations the new species could provide new source of income. | Need to restructure the value chain (trade, processing industry) |
| Salt water intrusion reduction of production or loss of production areas. | Y.1/D.2 | flood low polders and use for floating greenhouses. | | | |

*Table 3-3 Results of the workshop for the forestry sector*

| Impact | Impact on | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|---|
| Desiccation of forests. | Y.1 | | | | |
| Increased vulnerability to pest and diseases. | Y.1 | combine forestry with waterstorage. | | | |
| Increased vulnerability to pest and diseases. | Q | mixed forest stands | selective logging will increase costs. | ecological richer forest | |
| More and different pests | Y.1 | | | | |
| Salt water intrusion reduction of production or loss of production areas. | Y.2 | Salt tolerant biofuels | | | biobased economy |
| Salt water intrusion reduction of production or loss of production areas. | Y.1 | | relocate sensitive crops (e.g. tree crops) | | |

*Table 3-4 Results of the workshop for the fisheries sector*

| Impact | Impact on | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|---|
| Rise in temperature in large waterbodies will result in a different type of fishery. | Y.2 | develop cooling technology or heat extraction. | | | |
| | Y.2 | catch new fish species. | adjust technology (fishing gear, boats).These measure will not result in higher fish production. | | |
| Rise in temperature is not relevant for inland fishing. | | | | | |
| Lower mussel production in the Waddenzee, as a consequence of higher temperatures. | Y.1 | New species will also include new pests which could offer new opportunities for new markets. | | | |
| Reducting of production of plaice related to temperature increase. | Y.1 | Start fishing on new species as commercially interesting species are already overfished | | | |

### 3.1.4 Discussion and conclusions for the agricultural sector

For agriculture Van Ierland *et al*. (2001) already identified several adaptation strategies and indicated that the capacity to adapt is strongly determined by financial, technological and knowledge aspects. The identified knowledge gap was not only limited to the possible effects of various management strategies but also included knowledge on when to act or when not to act in order to improve effectiveness of management and policies. These management strategies require a continuous awareness of the possible and actual impacts of climate change and the time frame needed to develop, implement and activate adaptation strategies.

Modeling studies indicate a yield increase in response to a global average temperature rise of about 2 or 3 degrees and a decrease for higher temperature rises (IPCC, 2001). The global picture indicates that the temperate zones are better of in terms of predicted temperature rise and yield response. In Europe the southern parts will be more vulnerable to droughts and this gives a competitive advantage to agriculture in the northern parts (Olesen and Bindi 2002). Also in the Netherlands the picture is more diverse in that the higher sandy areas are more susceptible to drought while the lower areas are more vulnerable to flooding. But so far the evidence suggests that gradual climate change is of low importance to agricultural development and success in the Netherlands as it is overruled by changes in market and technological development (Ewert et al, 2005).

The impacts of the frequency and intensity of extreme weather events and the rate, at which the climate changes, however, are not well understood and can have major consequences for the development opportunities of agriculture at the local and regional level. In any case agriculture will not develop in isolation and besides changes in climate extremes also changes in societal demands and market changes will co-determine the direction of development in agriculture. Beside the impacts of extremes and rate of climate change other crucial questions that remain are related to timing of development, implementation and activation and costs of adaptation strategies.

In table 3.5 we elaborate on the identified adaptation strategies for agriculture. Using the three major impacts domains yield (Y), quality (Q) and damage (D).

Most strategies we identified focus on crop production and damage to crops. Emerging topics are adaptation strategies related to quality and farm level oriented strategies. Both relate to changing priorities in agriculture quality and service based activities are becoming increasingly important in a consumer driven market.

Field level decisions by farmers can be made within the growing season; more strategic decisions at the farm level will have a longer timeframe of 1 – 5 years. Adaptation strategies that require changes in crop breeding, financial institutions or policy makers and industries will have a time horizon that is even further away and may be as long as 10 years. In any scenario, management skills, surprises, luck and setbacks will be part of the equation. Early adaptation can avoid costs yet no clear guidelines exist on how to determine the timing of the various strategies in relation to the risk taken by in – action or lack of response.

The impression of the workshop where stakeholders were questioned and challenged to respond to adaptation need and opportunities is as follows. Urgency and awareness is still in its infancy. Within the sector agriculture, water is most recognized as area where action is desired and beneficial. Management in agriculture has many opportunities yet not identified as effective adaptation options. Many technical options that allow or support effective management, cost and benefits have not yet been specified For some adaptation strategies. In the sector fisheries and forestry participants recognized a lack of options for pro – active management as we concluded in our assessment.

*Table 3-5 Relation between impact and strategy for the agricultural sector*

| | Y.1 | Y.2 | Q | D.1 | D.2 |
|---|---|---|---|---|---|
| **Crops and tillage level (C.)** | | | | | |
| Adjustment of crop rotation schemes and planting and harvesting dates (C.1) | ■ | | | | |
| Choice of crop variety and genotype (C.2) | ■ | ■ | ■ | ■ | |
| Development and growing of crops for biomass production (C.3) | ■ | ■ | | | |
| Soil moisture conservation practices (C.4) | ■ | | | | |
| Irrigation (C.5) | \|\|\| | | | | |
| **Farm level (F.)** | | | | | |
| Self sufficiency in production of roughage (F.1) | | ■ | | | |
| Water storage on farmland (F.2) | | | | ≡ | ≡ |
| Subsoil drainage of peatlands (F.3) | ≡ | | | ≡ | |
| Insurance (F.4) | | | | | |
| Changes in farming systems (F.5) | | ■ | | | |
| **Regional and national (R.)** | | | | | |
| Water management (R.1) | ■ | | | ■ | ■ |
| Regional adaptation strategies for the fen meadow area (R.2) | ■ | | | ■ | ■ |
| Relocation or mobilization of farms (R.3) | | | | | ■ |
| Floating greenhouses (R.4) | | | | | ■ |
| Land use change (R.5) | | | | ■ | ■ |
| Adaptation strategies to salinization of agricultural land (R.6) | ≡ | | | ≡ | |

≡ Low coastal and river areas
||| Higher sandy areas

* *Note:* impacts on yield (Y) divided into reduced crop productivity (Y.1) and economic return (Y.2), on quality (Q) and damage (D) to crops (D.1) and buildings and structures (D.2) (grey areas indicate a clear strategy - impact relation does exist).

The main conclusion of this report is that the insights in adaptation for agriculture have not changed a lot since the study by Van Ierland et al. (2001). But awareness of climate change has increased and stakeholders express and researchers see willingness to learn and define adaptation strategies within the sector. The uncertainty in the magnitude and direction and possible impacts of climate change remain the main obstacles in defining appropriate adaptation strategies. Applying the no-regrets and precautionary principle does allow for the formulation of integrated strategies in which climate change has a place among other issues. Again, the urgency is not felt as changes in frequency and intensity of extreme events are not well recognized and understood.

In the forestry and fishery sectors adaptation is currently not yet part of existing operational management, but it is becoming more important in long term visions. Changing from production forest to multi-functional forests offers opportunities to factor in climate change as a possible driver in decisions related to selection of tree species and definition of management regime.
For the fishery sector implementation of policies related to fish quota and target species require better understanding of the possible impacts of climate change in order to improve policy effectiveness. So far the required knowledge to formulate adequate adaptation strategies is lacking in this sector. Moving to aquaculture, which may be necessary to meet increasing demand for fisheries products in a sustainable way, seems a logical step as these managed systems allow for proactive interventions.

## 3.2 Nature and ecosystems

The Netherlands contains 51 natural habitat types (NMP, 2003), a relatively high amount if we consider that it represents almost a quarter of all habitat types listed in Europe. The Netherlands contains important areas of salt meadows, coastal dunes, dry sand heath on inland dunes, natural eutrophic lakes and raised bogs. It provides habitat to 28 species of wild plants and animals, mentioned in the Annexes of the EU Habitat Directive (92/43/ECC), and to about 100 species of birds, mentioned in the Annexes of the EU Birds Directive (79/409/ECC). The Wadden Sea ecosystem, along the coast of the Netherlands, Germany and Denmark is a 'Wetland of International Importance' according to the Convention of Ramsar (1975) and has been recognized as a Biosphere Reserve by UNESCO (1990). Dutch wetlands and grasslands are of great international importance for water birds, partly because the Netherlands is located at the junction of flyways between the Arctic tundra and the African continent.

Climate (esp. temperature and precipitation) directly affects several biological processes like photosynthesis, respiration, reproduction, growth, distribution; and indirectly affects ecosystems through changes in water availability and quality, air quality, fires or soil erosion. The ecological impacts of current climatic changes have been demonstrated across different natural systems (Walther et al., 2002; Parmesan and Yohe, 2003; Leemans and Eickout, 2003; Leemans and Eickout, 2004; Mooij et al., 2005;).

To be able to adapt, species have to have traits that enable them to survive and reproduce under new environmental conditions. The rate at which environmental changes occur is therefore very relevant. The higher the speed of the change the lower is the chance that species are able to survive and adapt (Wright, 2005). The second article of the United Nations Framework Convention on Climate Change (UNFCCC) mentions that ecosystems should be allowed to adapt naturally to climate change. There is, however, general consensus (Parmesan and Yohe, 2003; Tamis, 2005) that ecosystems cannot adapt fast enough given the high pace of climatic changes. Moreover extreme weather events (such as excessive rainfall, droughts, fires or hurricanes) can cause disasters which are difficult to predict.

Recently, adaptation measures, as part of 'no regret' strategies, are gaining attention on the Dutch political agenda (EEA, 2005). For natural ecosystems this means reducing vulnerability and enhancing adaptability and robustness. Usually, adaptation measures are not taken for the benefit of one sector only but they aim at achieving multiple goals simultaneously. An example is the attempt to combine nature development with water management as mentioned by the Dutch government in the policy document 'Nature for People, People for Nature'.

### 3.2.1 Direct and indirect impacts for ecosystems

The direct impacts of climate change on Dutch ecosystems refer mainly to phenological changes (related to the timing of life cycle events), changes in distribution, abundance of species and food availability. The indirect impacts considered are related to drought, flooding, sea level rise, changes in water table levels, salt intrusion and extreme events.

### Direct impacts

*(a) Changes in phenology*

Climate has an impact on phenological processes like the date of flowering, leaf unfolding, leaf fall, ripening of fruits or species migration (van Vliet et al., 2002; Leemans and van Vliet, 2004). Currently several monitoring networks are involved, at a national and a European level, in monitoring, assessing and predicting climate change impacts on plant and wildlife behaviour (e.g European Phenology Network) Observations, available from various sources, including the Dutch Phenological Network (http://www.natuurkalender.nl) show that several phenological changes are currently taking place in the Netherlands as a response to climate change. In 2004, the timing of life cycle events in plants was about 16 days earlier than the timing observed during the period 1868-1968. The time of flowering varied according to the species. The Blackthorn (Prunus spinosa) has anticipated its time of flowering of 39 days whereas the White Water-Lily (Nymphaea alba) only of 4 days. The Beech (Fagus sylvatica) unfolded its leaves 15 days earlier, the Bird Cherry (Prunus padus) only 3 days earlier. The ripening of fruits occurred 27 days earlier in the Rowan (Sorbus aucuparia). The start of the pollen season in the Netherlands has advanced, between 1969 and 2000, from a minimum of 3 days (i.e. Ash – Fraxinus excelsior) to a maximum of 22 days (i.e. Elm – Ulmus procera). Moreover most of the butterflies appeared early in the last few years. The above changes are likely to be attributed to a rise in temperature (Leemans and van Vliet, 2004).

*(b) Changes in species distribution*

Changes in the distribution of species are occurring as a result of climate change (EEA, 2004). To cope with climatic changes, species are expected to shift from Southwest to Northeast Europe, as has already been observed for several plant, animal and lichen species, with high reproducing and/or dispersal capabilities (van Oene et al, 1999). However species with much lower adaptation capabilities are at risk, for example some butterflies of peat moors that are not very mobile, and moor frogs who may not tolerate rising water temperature.

*(c) Change in species abundance*

A study by Van Herk et al. (2002) suggests that in the past two decades the increasing temperature has caused dramatic changes in the lichen flora. Results show an increase in abundance for the majority of species. Temperature is also affecting fish populations. Higher water temperature cause a decrease in the amount of oxygen available to fish in rivers and lakes and therefore some species with high oxygen requirements (e.g. Pike Esox lucius, Perch Perca fluciatilis) may not be able to survive under rising temperatures. In lake IJsselmeer, as a consequence of higher water temperatures during summer, the Smelt (Osmerus eperlanus) is becoming scarcer because of a faster development of first-year Pikeperch (Stizostedion lucioperca). Also the highly productive benthic fauna of the Wadden Sea Ecosystem may not be able to adapt to higher temperature (van Geijn, 1998). Biodiversity is expected to decline in freshwater habitats at a greater scale than what is expected for the most affected terrestrial ecosystems (Mooij et al., 2005). According to the Dutch Butterfly Foundation (De Vries et al., 2003) the butterfly population numbers in the Netherlands declined 30-40% in the last few decades. However, the dragon fly population is apparently stable. Possible reasons for the difference between these insects groups may be due to the improvement of dragonfly habitats as a consequence of a better water management or to the good capability of dragonflies to reach new habitats. A recent study (Tamis, 2005) assessed the effects of climate change on the flora of the Netherlands in the 20th century. The most relevant response of Dutch flora to the change in climate is a marked and quick increase of thermophile (warmth-loving) plant species as recorded from 1980 to 2000. Interestingly the timing of the response of thermophilic species followed almost the same trend observed for lichens in the Netherlands (Herk et al, 2002). However no decline was recorded yet for psychrophilic (cold-loving) species. Another major concern is the threat posed by invasive species to indigenous species (Tamis, 2005).

*(d) Disturbance of food chain relations*

Food chain is directly affected by climate and as a consequence some species may encounter problems with regard to food availability. Different parts in the food chain respond differently to variations in temperature: plants, insects, vertebrates are likely to have different mechanisms underlying their phenology. As a consequence, if the phenology of the various species is shifting at a different rate this may lead to mis-timing of seasonal activities. Dutch researchers (Visser and Both, 2005) have assessed how much a species should respond in order to optimally adapt to the shifts in its food availability due to climate change. They have considered 11 cases ranging from zooplankton to birds, in eight cases they found that species are responding too soon or too late compared to the timing of food availability. For example monitoring activities showed that the response of some insectivorous forest birds (i.e. Great Tits Parus major and Pied Flycatchers Ficedula hypoleuca), which feed their nestlings on caterpillars, does not seem to match with caterpillars production. During the past twenty years, the biomass peak date of caterpillars is getting earlier, but the Hoge Veluwe Great Tits have not advanced their laying date, whereas the Hoge Veluwe Pied Flycatchers have advanced their laying date but not enough to match the shift in caterpillars' phenology.

Also avian migration phenology is suffering from this type of time mismatching. For example the arrival date of the Honey Buzzard (Pernis apivorus), a bird of prey, in the Netherlands does not seem to change, although wasps, its main prey, are appearing earlier. Likewise, the arrival date of the Pied Flycatcher in the Netherlands did not change whereas caterpillars peak date has advanced. It is interesting to notice that the Pied Flycatchers, although not advancing their arrival date, are anyhow advancing their laying date. This means that they have shortened the interval between arrival and breeding to a few days. But breeding cannot advance further unless the Pied Flycatcher shifts its arrival date. There is a mismatch among species phenology and there is an insufficient response of the majority of species to their food availability. It seems that the majority of species are not adapting to the speed of climate change. The current conditions represent a threat for the future survival of species. The more restricted the preferences in the food chain, the higher is the chance that species will not survive.

*(e) Changes in occurrence of pests and diseases*

Changes in temperature and humidity are expected to promote pests and diseases in the Netherlands (Mooij et al, 2005). Changes in food-chain-interactions and possible invasions may lead to explosions of certain pest species and may cause an increase in the occurrence of certain diseases (e.g. botulism/liverworth). In the Netherlands, and also the UK, France and Germany, changes in weather pattern favors the development of pathogens causing bleeding canker disease in Horse Chestnut (Aesculus Hippocastanum). In many areas of the Netherlands currently 1 of 3 trees is affected by this disease (Forestry and British Timber magazine, March 2006).

## Indirect impacts

*(a) Changes in drought frequency and intensity*

Increased occurrence of drought can cause an impoverishment of habitats, affects the flora and fauna and represents a threat for biodiversity (Van Ierland et al., 2001). The flexibility and resilience of systems like peat moors, wet heathlands and grassland is reduced under drought condition. In these systems plants and animals with high water requirements are under threat (Roos and Vintges, 1992): some plants (Bog-cotton, Cotton-grass, Heather, Gentian, Rosemary) show a risk to disappear whereas some others (e.g. Molinea, Common rush) are expanding. Several birds and butterfly species, very sensitive to drought, are threatened. Snails are expected to increase in peat moors (Van Ierland et al., 2001). In brooks accompanying forests and grasslands, drought causes a decrease in species preferring moist conditions (Roos and Vintges, 1992; Roos et al., 2000). Moreover several nitrogen species expand at the expense of the local flora. Drought is currently affecting 50% of deciduous forests, especially deciduous forests on sandy soils in the southern and eastern parts of the Netherlands are sensitive to lack of water. Some trees, like Beech and Birch suffer very much from drought whereas Oaks have difficulties to adapt to changing water tables (Van Ierland et al., 2001).

*(b) Changes in water tables and -fluxes*

In lower-lying parts of the Netherlands and areas next to the rivers Rhine and Meuse, flooding events increase. An increase in the duration of flooding can cause serious problems for plants and animals in wetlands including disappearance of trees that will likely be replaced by herbal vegetation (Van Ierland et al., 2001).

Groundwater tables are expected to become more complex to manage due to the more extreme shifts between summer and winter temperature and precipitation patterns. Low ground water tables can cause serious ecological damage as mentioned in the policy document 'Agenda for a living countryside' (Ministerie van LNV, 2004). During the dry season, the water level will drop, and in areas with controlled water level there is the risk that water of low quality will be allowed in, causing further damages. Sea level rise can cause coastline erosion, salinization and

fluctuations in the water table. Life communities in estuaries, salt marshes and other coastal ecosystems, such as dunes, are at risk under climate change (De Groot and Stortenbeker, 1992). In the Wadden Sea ecosystem, sea level rise would influence the delicate balance of sediment supply and erosion in the entire system with consequences for shore vegetation, benthic animals and their predators (birds and fish) and seals (van Geijn, 1998).
Higher sea levels, in combination with summer droughts encourage salt intrusion especially in the lower part of the Netherlands. The northern provinces of the Netherlands (Friesland and Groningen) are considered the most sensitive to salt intrusion during dry season. Very sensitive are also the IJsselmeerpolders, the Haarlemmermeerpolder, and the Zeeland province's polders. During the hot summer of 2003 because of dehydrated embankments a dike broke in Wilnis, and brackish water mixed with fresh water causing serious problems to the ecosystem (VROM, 2004). Towards the coasts, changes in salt-intrusion regime may greatly affect the life communities both in the rivers and in the bordering vegetation belts. The intrusion of salt water via the groundwater, even if small, is an irreversible process, which is difficult to stop (van Geijn, 1998). On the other hand, if allowed to occur on a more regular basis, the salinization of Dutch lowland polders might lead to an enhancement of the typical brackish meadow habitat types, which are nowadays relatively rare and threatened on a European scale.

*(c) Changes in extreme events*

Extreme events like fire and storms can cause damages to the ecosystem composition of forests and it is very likely that species will have problems to recover because of landscape fragmentation in the Netherlands (Van Ierland et al., 2001). In case of successive years with extreme events, such as excessive night frost in spring or severe storms, an increase in mortality of trees is likely to occur (De Groot and Ketner, 1991).

### 3.2.2 Adaptation measures for ecosystems

This section presents the main adaptation strategies for ecosystems and species found in literature. It also highlights the most important effects of the adaptation strategies and describes the involved costs and benefits, mainly in qualitative terms because little quantitative information is available.
Most adaptation measures for natural systems, like improvement of connectivity or integrated water management strategies, are already being implemented as part of policies aiming to improve general environmental quality and robustness of ecosystems. In order to ensure the effectiveness of these measures under changing climatic conditions, relatively small adaptations might be sufficient.

***Design and Implementation of ecological networks (green corridors and ecological zones)***

Considering the expected speed of future climate changes, there will be little time to adapt to new conditions within the present home range, both behaviorally and/or evolutionary. Without special measures, extinctions of local populations are very likely to increase. Often due to the isolation of most nature areas, migration and adjustment of distribution ranges will be difficult for most species. The establishment of green corridors and ecological zones are very important to support adaptation of species especially those with low migration capabilities (De Groot and Ketner, 1991).

Ecological networks are a set of ecosystems, linked through robust corridors, providing space for species and allowing them to easily shift their habitat. As mentioned by Opdam et al. (2006), local extinction of species can be acceptable as long as the population at a regional level persists. The ecological networks could therefore represent a way to spread the risk of such local changes over a wider regional scale, by linking local sites in a larger coherent ensemble of sites (Fig. 3-1).

The National Ecological Network (NEN), introduced in 1990 by the Nature Policy Plan, has been designed with the main purpose of restoring natural ecosystems lost during the past years as a consequence of human actions. Although the NEN was not originally meant as a climate adaptation measure, the creation of the NEN can enhance the adaptation capacity of species to climate change. Some policy documents, like ‘Nature for People, People for Nature’ and the ‘Agenda for a living countryside’, give a thorough description of the design and the effects of the NEN, but very little or no attention is given to the role of the NEN in supporting species to adapt to changes in climate. The current design of the ecological network should therefore be reconsidered to take better account of the pressures imposed by climatic change. It is very important to improve existing corridors between green areas, and establish new ones, to allow plants and animals, especially those with low migration capabilities, to follow favorable environmental circumstances. Particular attention should be given to lowland forest and marsh ecosystems that are high fragmented (MNP, 2004). New corridors can be created through rehabilitation of degraded areas or conversion of areas which were used for other purposes (e.g. agriculture). Emphasis should also be given to maintaining a certain environmental quality in these areas. Policy plans could focus on safeguarding from development those areas that could be required for wildlife in the future, or promoting wildlife-friendly environments in both rural and urban locations for threatened species to move into or through.

It is important to take into account that species differ with respect to the spatial dimension of their network (Vos et al., 2001). For some species, sustainable ecosystem networks have a local to regional spatial scale; for other species ecosystem networks have a larger scale that may encompass different countries (Opdam et al., 2006). Shift in species territories is therefore expected to go beyond national borders. In order to increase the robustness of the NEN, actions are required at a broader, international level (Van Ierland et al., 2001). Currently some initiatives (e.g. the Pan-European Ecological Network (PEEN)) have been taken in order to establish a wide network of ecological areas within Europe. Information about ecological network programmes in Central and Northern Europe can be found at http://iucn-ce.org/econets/database/.

The Netherlands Environmental Assessment Agency (MNP, 2004) has assessed the changes in the spatial connectivity of some ecosystems during the period 1990-2000. It appears that the spatial connectivity of forest and woodland ecosystems in the higher parts of the Netherlands, already good in 1990, has further improved. Lowland forest and marsh ecosystems are still high fragmented although the situation has improved since 1990. Heath ecosystems do not show any change along the years and are still very much fragmented.
Some on going research could provide, once completed, interesting insights about the effectiveness of the ecological networks as adaptation strategy. Currently a team of experts of different countries (INTERREG III project) is reviewing policy plans across the UK, France and the Netherlands to examine what provision is already being made to enable biodiversity to adapt to climate change and to identify approaches which can assist wildlife to survive. The aim is to find solutions that minimize the impacts of climate change on biodiversity. The modeled scenarios and potential adaptation solutions will be tested in the province of Limburg and also in other areas in the UK and Germany (more information at http://branchproject.org/). Moreover Alterra Green World research is currently analyzing strategies (e.g. Project: Adapting to climate change, strategies for optimizing the nature conservation potential of the Dutch National Ecological Network) in order to optimize the potential of the NEN under predicted climate change scenarios (more information can be found at http://www.onderzoekinformatie.nl/en/).

The costs for the design and the implementation of a climate change proof NEN are unknown. Currently there are no studies providing this type of information. Research is needed to assess the types and entity of costs involved to adjust the NEN in order to take into account climate change. The governmental budget available for the implementation of the NEN amounts to approximately EURO 285 million in 2005, and EURO 357 million in 2007 (Kampf and Stavast, 2005). The costs include acquisition, construction and management. These costs however are due to the implementation of the NEN as a whole and therefore do not refer specifically to the creation of a NEN meant as a climate adaptation strategy. The high land use prices are a barrier to the realization of new ecological zones and corridors.

Ecological corridors and ecological zones can provide several benefits to the natural system. They are expected to maintain biodiversity, facilitate migration of species and increase robustness of the ecosystem under climatic changes. According to Sijtsma and Strijker (1995) the NEN leads to a biodiversity increase of 15 to 20% compared to the situation without this network. At present there is a lack of study focused on the monetary valuation of these benefits. Additional benefits are given by the enhancement of recreation and the improvement of air quality.

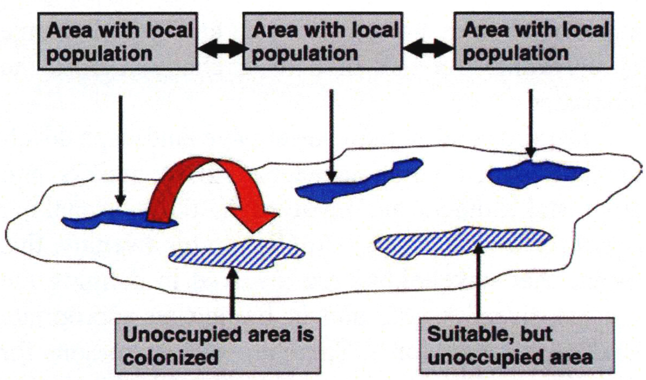


*Figure 3-1 Ecological Network*

*Note: The local population in the three occupied sites constitute a network of populations. The arrow indicates a recolonization event from one of the occupied sites. In ecological networks local risks are spread over the whole network. If such recolonization are frequent enough in comparison to local extinction, then the network population in the ecosystem network can be persistent.

*Source:* Opdam *et al.*, 2006.

### *Establishment and Management of Protected Areas*

In combination with the development of a robust Ecological Network (see figure 3.1), the location, surface area and management of protected areas should be screened on their suitability under changing climatic conditions. In general, climate change will lead to more instability in nature, which requires more 'adaptive management' and more space for species to allow them to adjust their distribution and/or phenology to changing environmental conditions.

The selection of sites should focus on areas which have the highest potential to provide suitable habitats to threatened species under changing climatic conditions. In Europe, this will usually be to the north of the current distribution limit of the species (De Groot and Ketner, 1991). These areas can contribute to the expansion and robustness of the NEN, and can assure long-term protection of species and maintain biodiversity, not only within the Netherlands but in connection with other European countries (Van Ierland, 2001; Milieu en Natuur Planbureau, 2005).

In order to increase the robustness of ecosystems, it is also necessary to adjust management strategies for protected areas, e.g. to ensure certain environmental conditions, take into account pest-control measures or adjust water management.

New protected areas can be developed through acquisition of land and change in land use. The costs of land in the Netherlands are currently very high due to the scarce land availability. A change in land use will very likely lead to a loss of agricultural income or income derived from other activities. Additional costs to be taken into account are due to research activities, design, actual implementation and management of protected areas.

The establishment of protected areas is also expected to generate several benefits. It maintains biodiversity, increases the robustness of the ecosystems and supports the development of the NEN. Moreover it can enhance recreation and improve water and air quality. There is a lack of studies about the monetary quantification of the costs and the benefits pertaining to protected areas in the context of climate change.

### *Afforestation and adjustment of mix of tree species*

As often the dispersal rates of trees is very slow compared to the expected speed of climatic changes, corridors may not be able to counteract the negative effects on some tree species, calling for active afforestation measures.

Afforestation can contribute to create new green areas and increase the robustness of existing forest ecosystems. New forest areas will also counteract the loss of forest caused by excessive drought in summer. When planting a forest, particular attention should be given to the *selection of species*. Some trees, like Beech and Birch that suffer very much from drought should be avoided in areas very sensitive to drought (Van Ierland, 2001). In these areas it is advised to afforest with low moist requirements species. Some species with northern distribution limit just south of the Netherlands can be planted in the Netherlands and expand here their distribution (Nabuurs *et al*. 1997). *Southern species can be introduced* to maintain sufficient genetic variation in the forest (Van Ierland, 2001). Some species already under threat because of the increase of *pests* due to climate change, should be avoided. This is for example the case of the Horse Chestnut (*Aesculus Hippocastanum*) affected by bleeding canker disease (Forestry and British Timber magazine, March 2006).
The expansion of the forest areas will contribute to the development of ecological corridors and ecological zones. New forest land will offer refuge to several plants and animals and may ensure the survival of several species like Bittern (*Botaurus stellaris*), Otter (*Lutra lutra*) and Red Deer (*Cervus elaphus*).
Currently, each year between 500-1000 ha of new forest is being established. The government plan is to add 40.000 ha of new woodland between 2000 and 2020 (VROM, 2004, 2005). However in the policy plans, it is not mentioned which types of species should be planted when taking into account climate change.

Afforestation costs include purchasing of new land, site preparation, selection of suitable species, purchasing, transportation and installation of bedding plants, form pruning and irrigation (if necessary).
New plantation forests provide various benefits: they can play an important role in maintaining and/or enhancing genetic variation in the forest, can provide space to several plants and animals living in the forest and can contribute to the expansion of ecological corridors. Moreover the new forest land can provide carbon sequestration and recreation opportunities and support the economy of the country by increasing the annual timber production.

### *Adjustment of forest management*

Adjustment of forest management can occur in already existing forests for the main purpose of decreasing the vulnerability of the ecosystem. For example a *switch from single-stand to mixed forests*, a *switch from drought sensitive species to more resistant species* and the *use of a more broad range of specie*s will help to spread the risk of possible negative effects. *Pest control measures* should be taken into account in order to counteract the increase of pests and contain diseases. Trees under stress from drought are more likely to suffer from the attacks of pathogens (Urbio magazine, 2005), see also section 3.1.2.

A *reduction in nitrogen deposition* is advised in order to reduce the effects of drought especially on well-drained soil (Van Ierland *et al*., 2001). Management practices should take into account *fire prevention measures* (e.g. thinning, removal of leaves, firebreaks). In fact a change in temperature and humidity may lead to changes in the (natural) occurrence of fires, as well as in the susceptibility of forests to fire (De Groot and Ketner, 1991).

When the forest management is adjusted in order to cope with climatic change, there are several costs to be taken into account. The costs will vary according to the measure considered. For example a switch from a single stand to a mixed forest implies costs for careful planning, selection of suitable species, plantation costs and of course management costs. Other costs include, for example, establishment of firebreaks.

The main benefit provided as a consequence of forest management is the maintenance/increase of species richness and resilience and thus protection of biodiversity. Moreover forests can support the objectives of the NEN, can provide carbon sequestration opportunities enhancing mitigation and can favor timber production and recreation.

***Artificial translocation of plants and animals***

Recently some researchers (Paerson and Dawson, 2005) showed concerns about the efficiency of the ecological corridors and protected areas networks in supporting adaptation of species to climate change. They argue that the networks may have limited effects as migration of species along the corridors may not be able to keep pace with the climatic changes. They have analyzed the role of long-distance dispersal (LDD) events in contributing to species preservation. Palaeoecological evidence shows that species, even the ones with low migration capabilities, adapted to past climatic changes by rare long-distance dispersal events such as transportation of seeds in updraft and dispersal by birds and mammals. Researchers have developed a stochastic spatially explicit model to simulate plant dispersal across artificial fragmented landscapes. Results show 1) that LDD has the potential to greatly contribute to migration of species through fragmented landscape; 2) that the higher is the potential for LDD the lower is the importance of landscape structure in determining migration ability. While in some cases LDD of plants may be supported by corridors (e.g. seed attached to the fur of mammals), in many other cases (e.g. seed dispersal in wind updraft, translocation by humans) corridors are unlikely to facilitate LDD. The results of this study lead the authors to propose artificial translocation of plants and animals as a way of preserving species under climate change. They also emphasize the importance of using various management approaches according to specie's climatic tolerances and dispersal abilities. For example, for the conservation of many mammals, artificial translocation may be more useful than the creation of large-scale migration corridors; whereas wind-dispersed plants may be best conserved in disjunctive reserves aligned in the direction of projected climate change.

The investment costs of this measure are expected to be very high and include research, design, actual implementation, management and purchase of new land (if necessary).
The main benefit is expected to be the protection of biodiversity and associated ecological and economic services.

***Implementation of effective agri-environmental measures***

Agri-environmental schemes are implemented within the European Union since 1992. Farmers are paid to modify their farming practice in order to protect wildlife and habitats and increase the environmental quality of their agricultural land by reducing the nutrient and pesticides emission. Although not meant as an adaptation strategy to climate change, agri-environmental schemes could contribute in maintaining a variety of valuable semi-natural habitats, maintaining or increasing species richness and thus enhancing the resilience of the natural system against climate change. These measures, however, are not always effective in conserving and promoting biodiversity. A more accurate design of the measures is needed in order to obtain positive impacts on biodiversity. Kleijn and Sutherland (2003) suggests that in some cases agri-environmental schemes that aim to protect biodiversity in extensively farmed areas can be more effective than those aiming to improve biodiversity in intensively farmed areas; in some cases the success of the scheme may depend on the motivation of the farmers and on the amount of support, feedback, encouragement and supervision that they receive. A more detailed description of the effects of agri-environmental schemes on species can be found in Kleijn and Sutherland (2003). Currently at Alterra Green World Research (Project: Omslag en Robuuste Verbindingen) a group of researchers is studying the relation between the agri-environmental schemes and the realisation of robust ecological connections in the Netherlands (more information can be found at http://www.onderzoekinformatie.nl/en/). Completion of the study is expected by the end of 2006.

Farmers are required to adapt the management on their farms to the benefit of biodiversity and the environment. Next to the management costs, this change implies often a reduction in terms of agricultural production (due to the reduced space for agriculture). However farmers receive compensation for the management costs, costs for nature conservation and loss of income.
If the agri-environmental schemes are well functioning the main benefit expected is the protection of biodiversity and associated landscape and environmental services.

***Integrated water management for ecosystems***

The Dutch water policy recognizes the necessity of dealing with changes in water levels. Sea level is expected to rise as well as peak discharges of the rivers. Moreover, there is the necessity of storing water from heavy rains and counteracting drought, both likely consequences of climate change. Next to safety issues, conservation of the ecosystems is considered an important goal. After the major floods of 1993 and 1995, traditional ways of managing water (i.e. building higher dikes) are not considered the best options. The notion of fighting against possible events like flooding is been replaced with the notion of adapting to changes. Instead of thinking of creating new heavy infrastructures, which have severe consequences for the environment, a new vision started to develop. In 1998, the fourth national policy for water management proposed *integrated water management* as a way of dealing with water issues. In 2000 the Cabinet issued the directive ‘dealing with water differently’, where it indicates the wish to provide more space for water and combine water management with other functions.

Creating more space for water, besides increasing the water storage capacity and benefiting landscape, can offer space to plant and animal species. Appropriate water management can allow adequate storage of water from heavy rains and can help in counteracting drought, both likely consequences of climate change. However, it should be realized that existing natural habitats are likely to disappear when faced with increasing incidence and/or magnitude of inundations. Reviews of the opportunities and threats of spatial water management solutions for ecosystem conservation or development are provided by Platteeuw and Iedema (2001, 2002) and even more extensively by Runhaar *et al*. (2004). General conclusions are that the less eutrophic (semi-terrestrial) ecosystems are likely to degrade as a consequence of storage of extra water, particularly if it is of a more eutrophic nature. Nonetheless, in more eutrophic situations the conversion of pastures to wetlands (particularly for birds) by allowing seasonal inundations offers interesting perspectives. A combination between water storage and ecological functions requires therefore careful planning. Possibilities of using new ecological zones also to improve water management are currently being considered (VROM, 2004).

Some examples of possible combinations between the function of water storage and ecological functions for the *Gelderse Rivierengebied* are (ESPACE project, 2004):

- The creation of *wet banks*. The drainage system in lower parts of the Netherlands consists mainly of areas that are drained (polders) and that expel water into waterways. To optimize the ecological functions, waterways could be widened with wet banks (e.g. water meadows) which can periodically store extra water. This can contribute to expand the ecological network in the inner dyke area and can support other functions like recreation. The higher the length of the banks the higher is the ecological contribution.
- The *construction of floating areas* which could be used not only for greenhouse horticulture business but could also provide new space for ecological development and even recreation. Of course the level of water fluctuation admissible should vary according to the type of goals taken into account.

Recently the Dutch cabinet has proposed a ‘Spatial Planning Key Decision’ in which an integrated spatial planning is presented for the *river Rhine*. This integrated planning aims at flood protection and the overall ecological conditions. Within this ‘Key Decision’, however, not necessarily all measures proposed are strengthening the robustness of the natural ecosystems under climate change. In recent Dutch history, the original surface area of natural river floodplains has decreased by more than 90%, which has contributed to both the lessened resilience of the river system to high peak discharges and the development of valuable ecosystems and habitats in close proximity to the river that do, however, not allow frequent inundations. Moreover, riverine forests are considered a threat to water quantity managers, because they increase the so-called ‘roughness’ of the floodplain and thus enhance any occurring discharge peaks. Therefore, although more ‘space’ for the natural river does offer opportunities for enhancing ‘robustness’ of riverine nature, the programme as a whole will have to be carefully implemented in order to avoid irreversible damages to existing conservation values (cf. Pelk *et al*., 2003; Pelsma *et al*., 2003; Blackwell *et al*., 2005).

Costs will depend on the strategy taken into account. ‘More space’ for water and nature implies the acquisition of land and the potential loss of income due to a change in land use. Due to the high costs of land, the investment costs are expected to be high. Particular attention should be given to the design of suitable strategies in order to integrate successfully water management and nature. Next to the costs for designing a successful strategy, there will be construction and management costs to take into account.
If well planned integrated water management can provide benefits in many ways. It can increase the space available for species, create opportunities for the development of new nature areas and contribute to the expansion of the ecological corridors enabling thus migration of species. Indirectly, integrated water management can help in counteracting flooding and drought and thus can prevent damages to the ecosystem. Moreover it can enhance recreation.

***Integrated Coastal management***

Sea level rise and flooding are main threats in the coastal areas, especially in low-lying areas. The following adaptation strategies can be considered:

- *Re-establishment of the natural dynamics of the dunes.* This can create opportunities for nature development and can reduce the risk of flooding, thus can prevent damages to the ecosystems.
- *Use of natural areas* (e.g. peatlands). These natural areas, besides enhancing the natural functions of the coastline, can increase the water retention capacity of the coastal zone, reduce the risk of salt water intrusion caused by sea level rise (Van Ierland, 2001) and prevent damage to the natural system.

An expert group (CPSL, 2005) investigated some solutions for coastal protection and sea level rise in the *Wadden Sea*. Some of the measures combine the social and economic requests with the ecological function. They can protect valuable habitats and biodiversity enhancing resilience against climate change. Some measures considered are:

- *Enhancement and maintenance of salt marshes.* Salt marshes have a high ecological value since they constitute the habitat for several types of birds, for halophytic plant species and partly highly specialized invertebrate fauna (e.g. arthropod species). Ways to enhance and maintain salt marshes are: 1) O*utbanking of summer polders.* This is the complete or partial removal of summer dikes in order to allow normal tides to enter the summer polders. These areas could keep up with sea level rise through higher sedimentation rates. This strategy can increase the area of mainland salt marshes, enhance nature quality and compensate for the loss of salt marshes habitat as a consequence of cliff erosion and sea level rise. 2) *Salt marsh management.* This strategy comprises a number of techniques that have been developed to enhance and maintain salt marshes.
- *Development of mussel beds and sea grass fields*. Besides helping to safeguard, on a local scale, inter tidal areas from drowning, this measure can provide favorable conditions for other species and is therefore enhancing biodiversity.

Costs depend on the strategy considered. In general the costs to take into account are due to design, construction, management and when necessary land acquisition, followed by income losses due to conversion of land use.
Benefits include maintenance of biodiversity, reduced risk of salt intrusion and flooding damages, enhancement of recreation.

***Restoration of ecosystems directly depending on water quantity or quality***

In autumn 2000 the EU Water Framework Directive (WFD) was published, obliging all European Community member states to implement an effective legislation for the conservation and, where necessary, restoration of natural aquatic and wetland ecosystems as well as terrestrial ecosystems that directly depend on water quantity or quality, its aim being 'to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater'. Though not explicitly designed as an adaptation strategy for coping with climate change impacts, the WFD does explicitly state that: '[it] contributes to mitigating the effects of floods and droughts'. Moreover, it also aims at 'preventing further deterioration and protecting and enhancing the status of aquatic ecosystems and, with regard to their water needs, terrestrial ecosystems and wetlands directly depending on the aquatic ecosystems'. Thus the WFD may be considered to be one of the means to enhance resilience of nature against any change, including impacts of climate change.

The adaptation costs are related to possible adjustments in protection, restoration, and management measures.
The benefits are derived from better functioning and enhanced resilience of the ecosystem and associated goods and services (reduced flooding risk and less damage).

### 3.2.3 Effectiveness of strategies and economic aspects

Based on the literature review, and discussions during a half-day workshop conducted in March 2006 with several stakeholders, table 3.6 gives a very rough indication of the potential effectiveness of some adaptation measures in alleviating some of the expected climate change impacts. It shows that most adaptation measures have multiple effects and that especially the development of the Netherlands Ecological Network is an effective instrument to allow ecosystems to adapt to climate change.

*Table 3-6 Potential effectiveness of adaptation measures*

| | Ecological Networks | Protected areas | Artificial translocation of plants and animals | Afforestation and mix of tree species | Adjustment of forest Management | Agri-environmental schemes | Integrated water management | Integrated coastal management | Restoration of ecosystem depending on water |
|---|---|---|---|---|---|---|---|---|---|
| **Direct impacts** | | | | | | | | | |
| *Distribution* | ++ | + | + | + | + | + | + | + | + |
| *Abundance* | ++ | ++ | + | ++ | + | + | + | + | + |
| *Food availability* | ++ | ++ | + | + | + | + | + | + | + |
| **Indirect impacts** | | | | | | | | | |
| *Drought* | ++ | + | + | ++ | ++ | | ++ | | + |
| *Flooding* | ++ | + | | + | + | | ++ | ++ | + |

* *Note:* The signs + or ++ indicate the strength of the relation between adaptation measures few direct/indirect impacts of climate change to the ecosystem.

At present there is a lack of studies focusing on the socio-economic valuation of adaptation options for ecosystems in the Netherlands. In the previous chapter costs and benefits were assessed in qualitative terms, according to the information available. Some socio-economic studies, however, have focused on valuation of nature protection and/or restoration measures. In table 3.7 are presented the benefits provided, and for one study also the costs incurred, as a consequence of development and protection of nature areas, increase of defragmentation, maintenance of biodiversity, etc. Although these are also objectives of adaptation strategies, it should be clear that the studies listed below are not making an assessment from a climate change perspective and therefore do not provide information about costs/benefits of adaptation strategies under climate change scenario's. They could however provide a starting point and methodological framework to analyse the monetary benefits/costs from climate change adaptation strategies.

***Monitoring and Awareness raising***

Monitoring nature is essential to understand the dynamics of the natural systems and their reactions to climatic changes. Monitoring activities have the objective of detecting impacts of climatic changes and the response from the natural environment. Since 1990, monitoring effects of climate change on nature has become a major conservation activity and the number of monitoring programs has increased. The majority of them (e.g. the Dutch Phenological Network, NatuurKalender) are focusing on detecting phenological changes due to climate. After monitoring it is necessary to interpret the changes in the ecosystem and to inform policy makers, managers, professionals or citizens. This is important in order to design and take suitable measures (e.g. adaptation strategies) to cope with climatic changes. Once measures like adaptation strategies are applied, monitoring can play once again a very important role in measuring/controlling the effects of adaptation measures.
As pointed out in some studies (Legg and Nagy, 2006; Visser and Both, 2005; Tamis, 2005) at this stage it is necessary to refine the quality and the effectiveness of the monitoring program. It is advised to improve the precision and accuracy of the information collected, the hypothesis formulation, the survey design, and the statistical analysis. Some researchers (Visser and Both, 2005) mentioned that is important to make clear how to interpret the many reported changes in phenology and on which basis they should be assessed. If, for example, plants and animals are changing their behaviour in response to climate, it is not always clear how to interpret these changes. Are they a positive sign of an ongoing adaptation, or they represent a bad sign showing the negative impact of climate change on the living system? For example, if a species is advancing the date of breeding this does not necessarily mean that the species is adapting, in fact breeding activities may not match with the time of peak food availability. This mismatch can therefore have detrimental effects on species survival. To be able to assess if shifts in phenology are sufficient Visser and Both (2005) propose to use a yardstick – a measure of how much a species should shift to match the change in its environment (like food availability) caused by climate change. Researchers or organizations with long-term datasets on phenology are urged to link their data with those that can serve as a yardstick.

Very often monitoring activities are undertaken by volunteers. They record changes in nature like changes in the date of arrival and departure of migratory birds, date of flowering, leaf unfolding, leaf fall etc. In this case the costs for monitoring and recording information are very low. When the monitoring activities are carried out by specialists and professionals the costs raise considerably. It requires long-term commitment and funding to allocate time and funds to carry out monitoring activities with high standards. Moreover there are other additional costs due to interpreting the recorded changes and conveying them to the public. The entity of the costs depends on the quality and the level of the accuracy of the information delivered.

Monitoring, interpreting changes and informing can provide several benefits. They can directly contribute to the daily activities of farmers, foresters, medical doctors, etc. As a matter of fact knowing about the dynamics of plants and animals can support farmers and foresters in planning their management activities; doctors can improve the diagnosis of hay-fever (pollinosis) and plan time and intensity of medication for their patients; tourist organizations, nature lovers, photographers, film makers can plan on time recreational and or educational activities like bird watching, and so forth. Moreover knowing about the effects of climate on the ecosystem can support policy makers, consultants, managers to design suitable adaptation strategies.

*Table 3-7 Reported costs and benefits from nature conservation and restoration **

| Theme | Reported costs and benefits from nature | Methodology used for the assessment | Reference |
|---|---|---|---|
| More space for nature | The net benefit from changing an hectare of agricultural land into nature area is estimated at Dfl 309 (study area: Dutch Vecht wetlands area) . The figure is calculated by subtracting the nature management costs and the loss of agricultural income from the net benefits from recreation. | Market price, benefit transfer | Bos et al., 2002 (Edward Elgar Publishing) |
| Habitat defragmentation | The total economic value of defragmenting a Veluwe area (Renkums Beekdal) by creating ecological corridors and removing a factory, was estimated at Dfl. 177 mln./yr. | Contingent valuation method and market analysis | Ruijgrok, 2001 (Ministerie LNV) |
| Maintain biodiversity | Maintaining a nature area, instead of constructing a railroad in "Het Groene Hart", provide benefits in terms of biodiversity that are equal to EUR 17.6 mln./yr | Contingent valuation method, travel cost, benefit transfer | Bos, 2004 (Landbouw Economish Instituut - LEI) |
| More space for natural river dynamics | The non use value of nature, when providing more space for natural river dynamics in the Netherlands, is estimated at Euro 75 mln per year; whereas the recreational value is estimated at Euro 30 mln. per year (2002), the positive effect of nature on the value of property varies between Euro 22 to 266 mln. | Market analysis, contingent valuation method, hedonic pricing method, benefit transfer | Kind, 2002 (RIZA) |
| Value of the Dutch Wadden Sea | The total economic value od the Dutch Wadden Sea is estimated at US $ 2.3 mln. per year | Benefit transfer | Schuyt and Brander, 2004 (WWF, Free University Amsterdam) |
| Flexible water levels | Larger water fluctations generate benefits, in terms of a better functioning of the ecosystem, that were estimated at Euro 0.3 mln/yr (study area: Amstelmeerboezem) | Benefit transfer | Schmitz and Ruijgrok, 2002. (Witteveen en Bos) |
| Contribution of nature to public sector | The contribution of existing nature to various public sectors (environment, health, recreation, water management, housing) in the Netherlands is estimated at Euro 13 to 21 billion/yr | Contingent valuation method, hedonic pricing and travel cost | Botterweg and Briene, 2002 (Ecorys-NEI) |
| Improvement of quality of nature | Management costs, due to improving the quality of nature in the Roerdal area, are estimated at Euro 2.1 mln. for the years 1994-2000. Financial benefits due to additional profits for recreation and increase in property values are equal to Euro 4.5 mln. for the years 1994-2000. The non-use value of the area is estimated at Euro 7.5 mln. for the year 2001. | Market analysis, contingent valuation method | Wijnen et al., 2002 (Landbouw Economish Instituut - LEI) |

* *Note:* The full reference of each study can be found in the list of literature
*Source:* compilation mainly based on Ruijgrok (2004).

### *Educational programs*

In recent years the considerable losses due to extreme weather events, have increased public interests in climate change as well as public awareness of potential and actual risks associated with climate and extreme weather. Educational programs could be delivered in schools, institutions, or to a broader public for instance through radio, television, newspapers or road signs. Through these programs people, regardless of age, can be first of all informed on how to contribute to nature protection, prevent disturbances and manage recreational activities. But besides informing, educational programs are actually raising an interest and involving citizens in the protection of the environment. Every citizen can thus do his part to increase the robustness of the ecosystem. This strategy is in line with Dutch policy. With the statement ‘Nature is not confined to the National Ecological Network but starts right at our doorstep’ the Dutch government (People for Nature, Nature for People) is making clear the importance of involving citizens in the protection of the environment.

The costs will vary according to the type of educational program. High costs are expected for high quality programs. In this case experts will collect background information, elaborate and propose simple and concrete actions to protect the ecosystems and prevent disturbances, and convey the message to the public. Costs will depend also on the selected communication media. Costs could be much lower when relying on the work of volunteers, very often nature lovers with a very genuine interest for the environment and willing to contribute to the realization of these types of programs. The benefits are given by the contribution of the citizens to the maintenance and/or enhancement of the environmental quality, protection of species and proper management of recreational activities.

***Financial mechanisms***

Although most adaptation measures will require additional funding, most measures build on already existing activities aiming at increasing the robustness of Dutch natural ecosystems (even without climate change) and taking the climate change dimension into account can thus be done in a rather cost-effective manner (like adjustment of the ecological main structure and water management measures). Unfortunately, very little information is available about the additional costs (and benefits) of these added climate adaptation measures (see section 4). In addition to government funding, new financial mechanisms should be identified in order to involve all sectors in society in the implementation of actions to allow ecosystems to adapt naturally to climate change. Investors, businesses, non-profit environmental organizations, landowners, farmers, citizens, are all involved in both the causes of climate change as well as being exposed to the effects and should also be involved in the solutions. Many of the benefits identified in sections 3 and 4 (like increased ecosystem health, better air and water quality, more opportunities for recreation) should be seen as ‘services’ provided by natural systems (MEA, 2005), and for many of these services it is possible to identify the main beneficiaries who could, and should be involved in their maintenance.
Further investigation is necessary with regard to the type of environmental services that could be financed and under what type of mechanism. Possibilities are currently explored whether authorities and agencies other than the Dutch central government would be interested in financing programs for the protection of ecosystems (Ministerie LNV, 2004). More information about financing mechanisms and payments/rewards for ecosystem services can be found at http://www.naturevaluation.org. Some attempts to involve the private sector have been made within the WINN program (http://www.waterinnovatiebron.nl), however the program pertains mainly to the water sector.

### 3.2.4 Discussion and conclusions for nature and ecosystems

This study gives an overview of the impacts of climate change on natural ecosystems and biodiversity in the Netherlands, highlights the main possible adaptation measures and provides an indication of the costs and the benefits of adaptation strategies. A change in climate has several impacts on ecosystems. It causes changes in phenology, in the distribution and abundance of species, in food availability, and in the occurrence of pests and diseases. It also causes changes in ecosystems as a consequence of drought, flooding, sea level rise, salt intrusion, and extreme events. Possible adaptation strategies are meant to support ecosystems to adapt to climatic change by decreasing their vulnerability and increase their robustness. The main adaptation measures for ecosystems, identified by this study based on literature and expert consultation, are: creation of green corridors and ecological zones, establishment and management of protected areas, afforestation, adjustment of mix of tree species, adjustment of forest management, artificial translocation of plants and animals, implementation of effective agri-environmental measures, integrated water management, integrated coastal management, and restoration of ecosystems.
Unlike the impacts of climate change on ecosystems, which are quite well studied, very little is known about adaptation options. The few studies available are often providing very general information and are characterized by a high degree of uncertainty, which makes it difficult to assess the effects and effectiveness of adaptation measures. It should also be realized that many adaptation strategies for nature were not originally meant as strategies to cope with climatic changes. These strategies have often been designed at a policy level with the aim of preventing or containing environmental degradation in general and restoring ecosystems that were lost as a consequence of human actions.
Moreover, it is unclear to which extent strategies can support adaptation given the high pace of climate change: for example it is not known to which extent it is possible to deal with disturbances in food chain relations considering that the phenology of various species is shifting at different rates (e.g. the egg-laying date of Pied Flycatchers who feed their nestling on

caterpillars does not match the shift in caterpillar phenology) and this can therefore result in a mis-timing of seasonal activities. Furthermore some problems are insufficiently addressed: for example some studies have shown that several fish species in rivers and lakes (e.g. Pike, Perch, Smelt) are at risk due to the rising temperature but it is unclear what and if something could be done to maintain biodiversity in marine ecosystems; it is unclear how to deal with the increase of pest species due to the change in weather pattern and the consequent increase of certain disease (e.g. bleeding canker disease in Horse Chestnut); very little is know about how to deal with extreme events (e.g. fire, storms).

Below the main conclusions regarding the eight adaptation options identified in this study are briefly summarized.

(1) Creation of *green corridors and the ecological zones* are (usually) part of the National Ecological Network (NEN) that has been developed, designed and implemented as a means to restore natural ecosystems that have become lost due to human impacts on the landscape in the past irrespective of climate change. Nevertheless the design and application of the NEN can allow migration of species, can increase the robustness of ecosystems, and therefore, with appropriate adjustments, can improve the capacity of ecosystems to adapt to observed and expected climate change impacts. Particular attention should be given to the selection of sites, the design of the ecological corridors and zones, and the environmental quality of these areas. At present there is a lack of studies, especially at a species level, focusing on identifying the effects and effectiveness of this strategy. Some ongoing research could provide interesting insights about strategies for optimizing the nature conservation potential of the NEN under climate change scenarios (e.g. http://branchproject.org/).

(2) The *establishment and management of protected areas* can contribute to protection of biodiversity but in order to make this measure effective from the climate change point of view it is necessary to make some adjustment to current policy (EU Habitats and Birds Directive). For example, the selection of sites should focus on areas with the highest potential to provide suitable habitats to threatened species under climatic change; management strategies should take into account pest-control measures to counteract the increase of pests due to change in temperature and precipitation, etc..

(3) With regard to the forestry sector *afforestation* is included in the climate change policy plans, but very little is known about the selection of suitable species under climate change (e.g. select species with low moist requirements in areas very sensitive to drought and where drought is expected to increase). Afforestation can counteract loss of biodiversity due to climate events as long as changes in temperature and precipitation as well as specie's climatic tolerance are taken into account when planting a new forest. It is also advised to *adjust forest management* in order to favor adaptation of species: for example, a switch from a single-stand to a mixed forest, a reduction in nitrogen deposition, fire prevention and pest control measures can all enhance resilience of the ecosystem against climate change.

(4) A*rtificial translocation of plants and animals*, a strategy not included in policy plans, can allow migration of species through fragmented areas but in order to assess the effectiveness of this strategy further research is needed.

(5) *Agri-environmental schemes*, although not meant as an adaptation strategy to climate change, could potentially increase species richness and enhance resilience of the ecosystem against climate change, but very little is known about the effectiveness of the scheme to support adaptation of the ecosystem.

(6) *Integrated water management strategies* aims at combining more space for water with more space for species. However, a combination between space for water and space for species may not always be effective, therefore current policy plans should be carefully implemented in order to support adaptation of species and ecosystems. For example, some natural habitats such as less eutrophic semi-terrestrial ecosystems are likely to degrade as a

consequence of storage of extra water, particularly if it is of a more eutrophic nature. Some ecosystems, such as riverine forests, which are considered a threat to water managers, can increase the roughness of the natural river floodplain and thus enhance occurring discharge peaks.

(7) *Integrated coastal management* strategies focus mainly on re-establishment of the natural dynamics of the dunes, use of natural areas (e.g. peatlands) to enhance the natural function of the coastline and prevent damage to the ecosystem, enhancement and maintenance of salt marshes, development of mussel beds and grass fields that can preserve biodiversity. More attention should be given to elaborating specific strategies to preserve areas of international importance such as the Wadden Sea Ecosystem.

(8) *Restoration of ecosystems* directly depending on water quality and quantity (Water Framework Directive) could be a means to enhance resilience of nature but very little is known on its effects and effectiveness as adaptation strategy.

In addition to the above mentioned adaptation options, *monitoring nature* and *educational programs* are important measures to improve understanding of the dynamics of the natural system under changing climatic conditions and to increase public awareness.

Finally, information about the *costs* and the *benefits* of the adaptation strategies is rather scarce and mainly qualitative. The few studies that are available about monetary costs and benefits refer either to general policy strategies for nature protection and/or restoration projects and not provide information about the costs and benefits of the strategies meant as adaptation measures to climate change. Socio-economic studies are needed in order to clearly identify the net benefits of selected adaptation strategies and thus accelerate the decision making process. However, in general it can be stated that with timely adjustments in existing nature conservation planning and management, adaptation measures can be very cost-effective and, if all benefits are taken into account, will mostly generate more (ecological and economic) benefits than costs.
New *financial mechanisms* should be further explored, involving the main beneficiaries of the adaptation measures, as they can represent a cost-effective way of dealing with climate change impacts (both in terms of reducing negative effects and taking advantage of opportunities).

The close link between existing policy measures and many adaptation options for the natural systems makes it difficult to evaluate a strategy from the ‘climate change adaptation’ perspective only. It is necessary to identify with more accuracy which adjustments need to take place in the current policy measures in order to support ecosystems to adapt ‘naturally’ to climate change.

## 3.3 Water management

The consequences of global warming are likely to have considerable impacts for the hydrological conditions of low-lying countries like the Netherlands. The most important consequences are likely to result from an increased rate of sea level rise and an increase in winter precipitation throughout the river catchment basins of the rivers Rhine and Meuse, which come together here and then both discharge into the North Sea. It is the combination of these two effects, together with the fact that some two-thirds of the Dutch territory is lying below sea level that causes the main concern. The rise of the sea level, by itself, poses threats upon the coastal defence, but also hampers the possibilities of discharging peak river runoff towards the sea. On the other hand, the rivers themselves will also have to cope periodically with much higher discharges, calling for a much higher flow capacity than they have at present. Over the last few centuries, the Dutch river floodplains have become very much reduced in size, down to some 10% of their original surface area, due to a huge increase in human land use (agriculture, urban and industrial developments, dry infrastructure, etc.). This large reduction in floodplain area by major embankments has provided safety against flooding in the past, preventing the river from running out of its course in periods of peak discharges. However, when due to climatic changes significant increases in incidence, duration and/or volume of peak discharges are to be expected, it becomes likely that the confinement of the main channels of the rivers within the actual embankment areas may be a threat. The reduced floodplain area of the present-day situation is likely to have become too small to warrant sustainable safety during future periods of peak discharges.

Finally, another possible impact of climate change may be that the range in rainfall during the summer months may become much wider, resulting both in more prolonged periods of drought than ever and in occasional heavy showers at times. Periods of drought will cause damage to crops and may even cause problems with the availability of drinking water. Moreover, scarcity of freshwater during summer will lead to a process of salinization in coastal areas all over the Netherlands, due to the incidence of salt seepage water that cannot be flushed away by freshwater. This process is likely to be enhanced by the expected rise of the sea level. On the other hand, an increased likelihood of the incidence of local spells of extremely heavy rainfall is also likely to cause troubles. With the present-day spatial arrangement of human land use it is unlikely that similar amounts of surplus water can be adequately coped with, without causing high economic damage.

Water managers throughout the Netherlands, both Rijkswaterstaat for the large river, lake and coastal water systems and the regional Water Boards for the smaller backwater systems, are currently developing several adaptation strategies, aimed at re-arranging the spatial design of the landscape to enhance its flexibility to retain and store freshwater surpluses at times of high precipitation and/or peak river discharges and, at the meantime, to enhance flow capacities of the river systems to ensure their ability to cope with higher peak discharges. The general outline of this new concept of water management (Water Management of the 21st Century) is described in a policy paper called ‘Treating with water differently’. Adaptation strategies vary from the traditional and conventional forms of flood defences (re-enforcement of dikes and embankments) to rather more innovative ways like enhancing the floodplain areas of the rivers (e.g. by re-allocating the dikes of the major embankments) and designate certain rural areas especially for storage of freshwater surpluses.

The aim of the present chapter is to briefly describe some of these adaptation strategies in terms of their nature, their expected effects, their costs and their benefits. It should be borne in mind that at present new creative solutions are being developed at a rather high pace, which results in an almost limitless amount of plans, concepts and wild ideas that vary greatly in detail of elaboration, possible consequences and side-effects and generally lack any realistic insight in costs and benefits. The overview of adaptation strategies presented here, including the strategies already being applied, should therefore not be considered as an exhaustive one. They just present a number of examples of ways to cope with expected climate impacts in the organisation of future water management.

### 3.3.1 Impacts for water management

In all climate change scenarios it is predicted that the Netherlands will have to cope with rising temperature year round, resulting in both higher precipitation rates.
Apart from these impacts climate change will also result in rising of the sea level in all scenarios under consideration. The amount of this sea level rise is highest in the scenarios ‘market optimist’ and ‘drought’ as the result of the higher temperature rise in these two. Of course, for a low-lying country as the Netherlands (with about two-thirds of its territory below actual sea level) the rising of the sea level poses a large threat and asks for efficient adaptation strategies in water management.

### *Impacts on the large river systems of Rhine and Meuse*

Higher winter precipitation is likely to occur all over Europe, thus involving the entire river catchments of the rivers Rhine and Meuse. Climate change will lead to a change in the discharge regime of the Rhine. The discharge regime will change from a combined rainfall/snowmelt regime to a regime dominated by rainfall. The discharge in winter and spring will increase where as the discharge in summer and autumn might decrease (Middelkoop et al. 2002). The change in the discharge of the river Meuse will be proportional with the change in projected precipitation. The discharge will increase in the winter season. The effect on the summer discharge for the Meuse is however less clear (De Wit et al. 2001, 2002).

### *Impacts on lake IJsselmeer area and connecting water systems*

Due to sea level rise the discharge of water from the lake IJsselmeer into the Wadden Sea and from the North Sea channel into the North Sea is hampered. The amount of water that has to be discharged in winter will increase, while even in the present situation the preferred winter water level can hardly be maintained. This will have the following consequences (Buiteveld & Lorenz 1999):
The extreme levels of IJsselmeer and Markermeer will rise, namely to the same extent as the sea-level rise. In general there will be greater fluctuations in lake levels, especially in the winter. In very dry summers the lake level may even decrease. The average lake levels will increase with half of the sea level rise.
In the North Sea Canal and Amsterdam-Rhine Canal higher water levels will occur more frequently and for longer periods, because at IJmuiden it is becoming more difficult to discharge water by gravity. This means that, in the event of a sea level rise, more will have to be pumped out. The seepage and with that the salinity in areas surrounding the IJsselmeer will increase by 10%. In the summer the limited water supply will result in water shortage.

Due to the changes the following functions are affected:
- Safety;
- Water supply for agriculture;
- Water discharge from the regional water system to the IJsselmeer;
- Functions that will be influenced by the change in lake levels, such as recreation.

### *Rhine en Meuse estuary*

In the lower part of the Rhine and Meuse there are two aspects that likely will change due to climate change (Jacobs et al., 2000). Due to lower summer discharge, in combination with a sea level rise, it will become more difficult to discharge water into the North Sea. As a consequence, there will be more salt-water intrusion, which threatens the fresh water supply in that area. The salinity of the water taken cannot be too high: a critical level equal to 215 mg/kg is presently the upper limit. During periods of very low river flow and high tide, the salinity of the water in the northern part of the estuary may temporarily exceed the critical level for water intake. At the station along the Hollandsche IJssel, water intake becomes limited when the Rhine discharge at Lobith drops below 1200 $m^3/s$.

Higher discharge in combination with sea level rise and possibly more frequent or more intense storm surges will affect the safety, due to the increased difficulty of discharge into the sea by gravity.

### *Coastal defence: sand dunes and dikes*

Due to sea level rise, the natural erosion caused of the natural coastal defence of the Netherlands (mainly sand dunes) by wave action is likely to increase. This poses an increasing threat on the safety for the lower parts of the country.

### *Regional water system*

The regional hydrological systems in the coastal zone are more sensitive to climate change than the regional water systems in the upper part of the Netherlands, because they are exposed to both sea level rise and changed precipitation patterns and to soil subsidence. Due to the increase of the extreme precipitation the discharges from the regional water system will also increase in future by 5 to 20%. The number of bottlenecks where water problems or inundation may occur as well as the frequency of inundations will increase.

***Salt-water intrusion***

Through the estuarine system and through ground water seepage, is expected to increase due to sea level rise.

***Water shortage and low river discharge***

Lower discharge of the river Rhine will affect navigation, the fresh water supply for the regional water system and the supply of drinking water, whereas, as mentioned, the salt-water intrusion will increase.

***Water shortage***

As occurred in the summer 2003 is likely to become more frequent in future. The economical damage will increase up to several billions of € in extreme dry summers. Due to climate change, the available amount of fresh water may decrease during summer. At the same time, it is expected that more fresh water is needed due to the economical growth. The fresh water shortage will therefore increase by 10 to 20% (Table 3.8; Arcadis et al. 2002)

*Table 3-8 Water shortage**

| **Shortage Soil** | | | | **Shortage surface water** | | |
|---|---|---|---|---|---|---|
| Present | Present | 2050 (+1°) | 2050(+2°) | Present | 2050 (+1°) | 2050 (+2°) |
| Average year | 21 | 25 (+19%) | 28 (+36%) | 5,7 | 5,8 (+2%) | 6,0 (+4%) |
| Extreme dry year | 143 | 153 (+8%) | 165 (+17%) | 12,4 | 11,7 (-6%) | 12,2 (-2%) |

**Note*: based on Arcadis *et al*. 2002

***Surface water temperature***

Climate change will affect the impact of water-cooling by industry and energy production. Water shortage will lead to shortage of cooling water. This problem will be enhanced when the water temperature increases due to climate change. The discharged cooling water may not be higher than 30° C. With increasing water temperatures the capacity will decrease and this will affect the energy production.

### 3.3.2 Adaptation strategies for water management

***Land retention and storage***

This strategy consists of the designation of selected areas of land for retention and storage of surplus freshwater originating from either excessive rainfall and/or peak river discharges. Thus, by means of the enhancement of storage capacity where needed (e.g. in polders), it is the intention to avoid inundations and other forms of water nuisance in areas where this is unwanted, as well as to build up reserves of stored freshwater that might be used during the periods of prolonged drought that are also likely to occur with increasing frequency. The mean principle in this strategy consists of a focus on retaining and storing freshwater surpluses in a controlled way, before thinking of discharging water surpluses as quickly as possible towards the sea.

One specific way of achieving an increase in the water storage capacity of the land consists of the disconnecting of the draining ditches in the polders from the main surrounding reservoir systems. Thus, and by increasing the density of ditches, the storage capacity of the polders themselves can be enhance, in order to reduce local damages in more vulnerable areas elsewhere.

Large areas of land, both in agricultural use and nature conservation areas and mostly situated in the lower-lying parts of the Netherlands, will have to be equipped to deal with surplus amounts of local and/or foreign water during periods of excess rainfall and/or periods of peak river discharges. The frequency with which these inundations are likely to be expected varies largely (e.g. between once or twice a year/winter and once every 1250 years, the latter being the official safety standard set for the Dutch downstream sections of Rhine and Meuse), depending upon a series of factors. These factors include required safety standards as well as threats and chances for multiple spatial land use forms in combination with temporal (seasonal) water storage. The main effect of this adaptation strategy thus turns out to be a significant change of land use for large surface areas from traditional agricultural use towards more multi-purpose land use forms, compatible with the function of freshwater retention (e.g. freshwater wetlands with recreational uses).

For water storage in agricultural land the economic costs consist of the sum of the losses of production for all future generations. This does not necessarily equal the sum of the initial investment and the costs of management and maintenance. Costs of initial investment involve the costs of lowering the water table (thus creating room for storage) and the installation of the necessary water works, while the costs of management and maintenance include the use of the water works, the implementation of inline users by means of radar images and the making and application of Decision Support Systems. These so-called financial costs may amount to up to ca. 250.000 €/ha. Enhancing the storage capacity of polder areas by enhancing the number of ditches and disconnecting these from the main receiving reservoirs will cost between € 0.3 to 0.7 billions.

Uncalculated costs include, among others, the loss of surface area for traditional, purely terrestrial forms of land use (particularly including the expected losses of production already mentioned) and a menace to certain types of nature, which are either vulnerable to inundations or broad water table fluctuations or to contact with water of foreign origins (Runhaar et al. 2004).

General benefits of this strategy include:
- The safe build-up of freshwater storage during periods of peak precipitation for use during prolonged periods of drought;
- The allowance of prolonged possibilities for the development of several economic sectors in multiple spatial land use with water as a guiding principle;
- The enhancement of spatial quality in several objectives;
- The reduction of inundation risks;
- The reduction of amount of damage;
- The reduction of victims;
- The enhancement of (certain) nature conservation values (e.g. wetland nature);
- The enhancement of the value of (luxurious) living conditions (e.g. living in or near attractive wetland or water-dominated landscapes);
- The enhancement of recreational values.

More specifically, the enhancement of the recreational value of a newly installed wetland area with multiple-purpose use and a function for freshwater storage can be estimated at an increase in the daily expenditure of € 7,-- per person per day for day-time hiking or biking excursions. However, this estimate is only likely to be valid in cases where the area involved is likely to obtain an incremental attraction for tourists from outside the region. Financial benefits can only be taken into account as economic benefits, if due to the changes in the land use a flow of money can be created from outside the water storage region towards it. Possible incremental values of houses alongside or within the water retention area can be estimated by means of the expected increase in the amount of real estate taxes to be paid. Here too, it is fundamental that the attraction of the area should indeed increase thanks to the combination of natural wetland or water-rich area and water storage area. Even then, the potential increase in real estate value will obviously depend on what the original forms of local land use were and whether or not the houses concerned have actual views of the supposedly beautiful scenery, and may consist of an increase of 2 to 7%.

### *Adaptation of land use allocation policies*

In spatial allocation of different types of (terrestrial) land use in the Netherlands, it is still common use not to take into account considerations concerned with water-related risks. Thus, new locations for industry, urbanisation or infrastructure may still be planned almost anywhere, irrespective of e.g. their location at below sea-level altitude, their proximity to vulnerable parts in the coastal defence or their proximity to embanked floodplain areas. In other EU countries (e.g. France, Italy and Austria) the designation of hazard zones and corresponding regulation of building activities are required by law (Fiselier & Oosterberg 2004). Based on careful risk-management analyses, which account for risks in the appropriate way by multiplying probability with potential impact, it should be possible to identify those areas within the Netherlands where risks are highest and where they are lowest, in order to subsequently allocate water-sensitive types of land use or activities much more prominently to the areas with the lowest risks. In the meantime, the policies should also attempt to discourage existing forms of water-sensitive land use in high-risk areas and stimulate their transference towards higher and safer regions.

The adaptation of land use allocation policies will gradually lead to an increase of the exploitative occupation of the higher parts of the Netherlands, while (probably even more gradually) the lower parts of the country will become increasingly abandoned. Thus, these areas may, automatically, become subject to more natural hydrological regimes and may thus start to function in a very natural way as water storage areas that can relieve the pressure of inundation threats on other areas. Thus, this policy may very well support the realisation of the previous adaptation strategy.

The costs of this strategy involve both costs of the policy changes themselves and those of the measures employed to promote the actual changes. First of all, however, a country-wide spatial risk analysis should be undertaken, in order to identify as exactly as possible which zones can be attributed to which risk class and how zones of different risk classes should be treated with respect to whether or not allow certain types of land use there. When all this is clarified, funds will have to become available for the stimulation of investments in safe areas, while on the other hand investments in vulnerable places should be discouraged or even fined.

The types of benefits of this strategy are likely to be comparable to those of the previous strategy. The main advantage of a more rationalised allocation of water-sensitive land use or activities to the driest and safest regions is likely to be the concurring gradual shift of the bulk human activities from low and hazardous regions towards drier and safer ones, resulting in the maintenance of interesting investment conditions for the whole of the country, while gradually increasing the safety of spatial investments against water-related hazards. In the meantime, the regions that are getting gradually abandoned, may start functioning as natural hydrological units, providing both more resilience to increased hydrological dynamics (a climate change impact) and a more robust ecosystem for wetland ecosystem types.

### *Widening the coastal defence*

The Dutch coastal defence is very narrow, sometimes just consisting of a single line of sand dunes or even a single dike. This evidently poses a serious threat to the safety of the low-lying territories behind, particularly when the climate change impact of an enhanced rise of the sea level is concerned. Thus, widening the coastal defence by e.g. adding more lines of dunes, either inland or offshore, will evidently enhance the safety level and counteract the increasing threat of the rising sea.

The effects of widening the coastal defence will be that either inland or along the original coastline extra sand dunes will be erected. If these measures are carried out inland, this will involve a change of the characteristic features of the land. Otherwise they will result in a relatively small reduction of the surface area of the shallow coastal waters.
The costs of raising artificial extra lines of sand dunes for coastal defence are likely to be very high. The exact amount of money involved per km of coastline to be widened will vary according to whether the widening is designed inland or offshore. While the actual costs of construction

are higher in the case of offshore construction, due to the need of extra defences against the erosive influence of wave action from sea, in the actual calculation of the costs for inland construction, the effects of the necessary change in land use should also be incorporated in the total cost analysis. The land just behind the coastal dunes is often intensively used for various agricultural purposes or for urbanisations. A very frequent land use in precisely these areas is the cultivation of flower bulbs, a very profitable form of land use from an economic perspective. Anyway, the amount of money necessary to raise an extra line of sand dunes is likely to involve several millions of € for every kilometre.

Apart from the evident benefit of the reduction of the threat of the break-through of the coastal defence by the increase of wave attacks of a rising sea, and the corresponding floods that might cause hundreds of thousands of personal casualties as well as several billions of € of material damage, the widening of the coastal defence is bound to offer several extra opportunities for valuable dune-related nature and coast-related types of recreation facilities.

***Artificial reefs in sea along the coastline***

The construction of spatially carefully distributed reefs on strategic points along the Dutch coastline is likely to help reduce the wave action of the sea when it reaches the actual coastline. By this reduction of wave action the erosion of the coastline by the sea can be so drastically reduced, that even a rise in sea level may well be compensated for.

The presence of artificial reefs on carefully selected spots along the coast will undoubtedly affect more than just the wave action on the coastal defence during onshore winds. Shipping, including recreational yaughting and commercial fisheries, should take care not to come too close to the coast to avoid unwanted collision risks. In heavy weather, however, they may not always be able to avoid the reefs, which will cause the damage risks to increase when ships wreck during stormy periods. The reduction of the wave action in the innermost inshore waters might enhance the attraction of the coastal waters for tourists, although the potentials for certain types of recreation (such as surfing) are bound to decrease.

The costs of raising artificial reefs along the coastline are likely to be rather high. In addition to the actual construction costs, the costs of the preparative modelling studies, necessary for the spatial designing of the most effective distribution pattern, the most effective sizes and forms of the reefs and the number of reefs to be installed, should also be taken into account.

Moreover, the potential economic losses of the consequences of the presence of reefs for both professional and recreational shipping should be taken into account.

The benefits of artificial reefs in the Dutch coastal waters would not only help to reduce the erosive powers of the wave action, but might also help to decrease the already existent need of virtually continuous suppletions of sand to maintain the coastal defence intact (compare paragraph 3.2.4). Another potential benefit might be that artificial reefs will enhance the variety of available natural substrates in the rather homogeneous sandy bottoms of Dutch inshore waters. This, in its turn, is likely to lead to a higher and more varied spectrum of marine benthic organisms, presumably attracting new species of fish and thus enhancing marine biodiversity in the Dutch coastal ecosystem. On the other hand, such a development may also be considered less desirable from a more purist point of view.

***Adapted forms of building and construction***

By constructing new houses, urbanisations or even entire cities on floating facilities, it is easily imaginable that these new investments will be safe from any threat imposed by the expected water table changes that climate change may be causing in future. These constructions will have to be robust enough to allow both significantly higher water tables during periods of excessive precipitation and/or peak river runoff and periods of prolonged drought, during which the floating supports would actually be resting on firm ground.

Instead of building on floating supports, it is also possible to re-install the traditional preventive form of building of houses and/or industrial plants in flood-prone areas, namely on artificial mounds. Raising the terrain for construction, both of buildings and of infrastructure, up to above the expected maximum flooding level prior to actual building will provide the required risk standards for the use of buildings and infrastructure.

Building without cellars or crawl spaces below the level of the buildings is a well-accepted and increasingly applied adaptation strategy, by which the vulnerability of the buildings to damage caused by floods or high water tables can be significantly reduced. Providing for roof gardens on flat roofs of houses or industrial buildings will help to cope more adequately with excessive peaks in local rainfall than bare roofs where falling water on a hard substrate is bound to cause damage.

The effects of this type of measures will be mainly a change in the visual aspect of urban areas. Adaptations in these forms are likely to be applicable almost anywhere, irrespective of factors such as elevation, relief of the landscape and/or position with respect to permanent water bodies (rivers, lakes, coastal waters). Of course, special attention will have to be paid to the sustainable accessibility of e.g. floating accommodations throughout the entire range of water table levels. In dry periods, the regular terrestrial infrastructure will suffice, but during (prolonged) periods of inundations or flooding, access by boats will have to be a plausible alternative.

The costs of making floating supports for all constructions for new houses and buildings in areas that are potentially vulnerable to floods are undoubtedly high. If the eventual purpose is to adapt all existing buildings within those areas in a similar way, it will even become excessively high. More exact estimates of the costs are difficult to assess, since for the time being this type of measures has still hardly been applied in reality, neither in the Netherlands nor anywhere else in Europe or elsewhere in the world (e.g. Fiselier & Oosterberg 2004, Van Drimmelen 2004). It is clear that in estimating the costs, the incremental costs of maintenance of accessibility of houses and buildings during inundations and floods should be taken into account.

Evidently, living near or even in water has clear advantages for people, as is shown by examples from all over the world. Many densely populated areas are situated within potential hazardous delta situations, where even in the present situation the benefits of living near the water (e.g. high fertility of the land, close proximity of aquatic infrastructure for relatively cheap transport, availability of drinking water, etc.) apparently compensate for the ever-present threat of floods (Van Drimmelen 2004). The specific measure of constructing on floating devices has the clear specific benefit of its flexibility to a wide range of possible water tables, all within the scope of the prospected increasing future range.

***Re-enforcement of dikes and dams***

By far the most traditional and usual way of human society to cope with (increasing) flood and/or inundation-related risks consists of the construction of dikes and dams, designed to strictly separate the space designated for water bodies from that designated for human uses such as agriculture, urbanisation or infrastructure. Therefore, it is only logical that in response to future prognoses of increasing river runoffs and/or more extreme local precipitation peaks the re-enforcing existing dikes and dams in order to maintain the desired levels of security, pops up as one of the first adaptation strategies to consider.

The effects of re-enforcement of existing dikes of dams are relatively well known. The Dutch have been building, re-building and re-enforcing dikes and dams as long as living history, so the impacts of these activities on landscape, culture and nature have been subject of many studies. Nowadays, with modern technology, dike re-enforcement has become much more impacting on landscape, cultural historic and nature conservation values than it used to be in past centuries. On the other hand, the works can be carried much faster and thus comparatively cheaper than ever, causing trouble to far less people over far shorter periods than ever. One of the main reasons, however, that the mere enforcement of existing dikes and dams has become less popular as a solution to increased water-related threats is that the public as well as the politicians have begun to realise that faced with a trend of rising water tables in existing water bodies, the mere adaptation of height and width of surrounding dikes or dams will not prove to be a sustainable option for the safety of the investments around that water body. The increasing amount of water will ask for regular new adaptations and, even worse, will cause an increasing pressure against dikes of any height, which will result in seepage of water underneath. The wish for more spatial and natural solutions for flooding risks is clearly not only caused by ecological or landscape-related considerations, but also results from purely safety-related sources seeking better sustainability (e.g. Fiselier & Oosterberg, 2004, Blackwell & Maltby, 2005).

The investments for re-enforcement of dikes are likely to amount to 4 – 8 billions of € when all relevant dikes are considered. These, however, are only the financial costs and do not include non-material losses such as lessened values of scenery, cultural historic monuments (buildings on or near the present dikes) and certain specific types of nature. Moreover, the traditional way of protecting the land from river-water by ever higher dikes has proved to be less sustainable than appropriate now that climate changes are likely to enhance the threat of periodic inundation. Thus, a more actualised way of calculating the costs of dike re-enforcement would have to include an estimate of the enhanced risk to which the protected lands are submitted if not protected in a sustainable way as well as the fact that water tends to seep through underneath the dikes irrespective of their height and width.

For the short and middle-long term, the benefits of re-enforcing dikes and dams in order to provide safety against an increase in the incidence of peak river discharges, peaks in excess precipitation and a rising sea level consist of lowering the likelihood of dikes breaking through. In this way, this measure does actually provide more safety and precludes damages to human buildings and traditional terrestrial forms of land use.

***Enhancing capacities of sluices and weirs***

By enhancing the capacity of sluices and weirs, the amount of water that can be safely stored is enhanced as well. Evidently, if this type of measure could be applied over a large enough surface area of potentially flood-prone land, it is likely that so much larger quantities of surplus freshwater may be dealt with safely, that a considerable alleviation be delivered for periods of high precipitation and/or peak river discharges.

The effects of enhancing the capacities of sluices and weirs are that at any time the water storage capacity of the land will be significantly increased. This would enable the country to cope with higher peaks of both precipitation and river discharges.

The costs involved with these measures would include both the adaptation of numerous sluices and weirs and the designation of more space behind the sluices and weirs involved to actually store the higher amounts of water. In fact, this type of measures is one of the technical options possible to achieve the spatial concept of designating more space for water storage.

The benefits of enhancing sluice and weir capacities, in combination with more space for water storage, are already pointed out in adaptation strategy 3.1.1. They mainly amount to achieving a better control over excess water quantities, which may lead to both a decrease in the threat of flooding or water nuisance and the build-up of water reserves for possible periods of drought.

***Adaptations in social, political and financial attitudes: Creating public awareness***

The creation of public awareness is, within the context of modern democratic society, crucial to achieve any change of any magnitude. Thus, even when scientific evidence clearly indicates the need of adopting adaptation strategies for coping with the expected climate change impacts, it will still be necessary to inform the public of both the need and the consequences of any strategy proposed. Without public awareness and general acceptance of the climate problem and its water-related consequences, public support for adaptation strategies will prove to be inconceivable. Campaigns for creating more public awareness have already been launched by the Dutch Ministry for Transport, Public Works and Water Management and have included, so far, announcements in newspapers and on billboards as well as in television spots. In these announcements the prospects of having to deal with higher amounts of water as a consequence of climate change and the need for innovative solutions to this problem have been visualised in a number of ways.

The desired effect of a well-conducted campaign for raising public awareness of the problems for water management caused by climate change impacts would, of course, be that the public becomes more conscious of the fact that precisely the Dutch, living as they do below sea level and within the reach of two major European rivers, should be very well prepared to make these issues into politically ‘hot’ items and to actually pay for possibly unpopular innovative solutions. So far, at least the first aim of the campaigning efforts does not really seem to have touched a crucial nerve, since in recent municipal elections the entire matter of climate change and hydrological consequences does not seem to have played any important role.

The costs of raising public awareness include the set-up and planning of the communication campaign, as well as the actual carrying out of it. Moreover, the effectiveness of the campaign, in terms of amount of outcome (both increase of proportion of public aware of problem and of preparedness to act correspondingly) should be monitored, which also implies direct costs.

The benefits of a successful campaign for obtaining public awareness are incalculable. Of course, there would not be any direct monetary benefits, but undoubtedly the public ‘willingness to pay’ for innovative solutions of any kind is directly proportional to the amount of public awareness. This, in turn, is fundamental for raising the money and the will to actually carry out any adaptation strategy.

***Making new organisational and political alliances (multi-level governance) and enhancing communication between public and private sector***

In order to actually make innovative and effective adaptation strategies really happen, the organisation of new institutional alliances is likely to be instrumental. These would have to include, among others, alliances between water boards and municipalities, between water boards and private parties (citizens, farmers) and among national, provincial and municipal authorities and water boards as well as international alliances (both between the Netherlands and directly neighbouring countries such as Germany and Belgium and between the Netherlands and countries far-away like China, United States and Bangladesh with similar climate and water related problems). At the same time, ties and alliances between municipalities, as well as between towns and countryside (multi-governance) are necessary, e.g. to avoid the natural tendency of local or regional communities to solve their problems by spatially transferring them to other localities or regions. The new organisation structure also aims at improving the communication between the public and the private sector, making it both more accessible and less ‘political’ (more honest). One of the issues in this communication would include the elaboration of operational evacuation plans and the proper way to communicate about these.

The effects of the institutional changes proposed would have to be that organisational and institutional processes become so much smoother, more flexible and more direct, that bureaucratic impediments in effectively realising comprehensive and substantial spatial re-arrangements in the ‘new’ water-governed multi-functional environment. Instead of the traditional ‘project management’, attention would have to focus more on ‘process management’, so that aims and targets would become more flexible. Another effect would be that different re-compensation schemes might be developed, allowing for shifts from traditional terrestrial land use towards multi-purpose forms of land use based on water as a guiding principle. With respect to the improved communication, the effect would be that by and large the public would become as aware of the water-related problems as the local and regional authorities and, thus, better prepared to adopt promising adaptation strategies.

The costs of introducing new and more flexible institutional organisations include those of institutional transition and flexibilisation and of the transactions of new alliances. Moreover, any structural re-organisation of institutes and authorities require a lot of time and energy, before the people involved accept and adapt to the new, supposedly more efficient way of working.

The benefits of multi-governance and the enhanced flexibility in policy goals are quite clear in the matter of dealing with water-related adaptation strategies to climate impacts. Spatial solutions are bound to affect people and their lives over quite considerable distances. This requires close alliances among all of the authorities involved. Moreover, any application of a spatial adaptation strategy requires a flexible attitude among all authorities possibly involved with respect to goals and targets, mainly because of the structural degree of uncertainty related to all climate change issues.

***Creating options for private assurances against inundations and/or drought-related damages***

At present, it is impossible in the Netherlands to insure properties against the risks of flooding or drought. Theoretically this could be changed by creating this possibility. Negotiations between the authorities and the private insurance companies might lead to possibilities for a more appropriate and equalised spread of the financial risks involved in these type of water-related damages.

Of course, a re-allocation of the financial consequences of damages caused by either excesses of water or lack of it could lead to a more balanced and more righteous spread of the costs involved in adjusting for damages. However, since the possibility of private assurances does not structurally solve the climate-induced damages, this measure cannot really be considered as an adequate adaptation strategy. This strategy merely reduces the costs of reconstruction after e.g. a flooding incident for the public sector by spreading them out over the entire society. Thus, it does provide more security for individual households or companies, but it does not diminish the total costs for society by preventing the damages. It may even prove to be essentially counter-productive, since it may mislead the public into thinking that by assuring themselves against possible damages they actually secure themselves against the occurrence of water-related damages or casualties (‘moral hazard’). People might feel safe enough to continue investing in essentially vulnerable parts of the land.

***Reclamation of (parts of) North Sea***

All along the Dutch North Sea coast, the majority of the countryside behind the strip of coastal dunes is potentially vulnerable to inundations provoked by a breakthrough of the sea through any part of dunes or dikes. A very drastic potential measure, in fact the extreme option of adaptation strategy 3.1.3 of widening the coastal defence, would be the reclamation of one or a few gigantic polders in the southern North Sea, parallel to the coast. These polders would have to be protected from the remaining part of the sea by huge and strong dikes in order to keep the rising sea out of it for a prolonged period of time.

The effects of the reclamation of a large part of the North Sea along the present Dutch coastline would be that life in the lower parts of the country could go on developing in much the same way as up till the present time without bothering about the menace of a rising sea level. However, it will become more difficult to discharge the surplus freshwater brought in by the rivers Rhine and Meuse into the sea. Moreover, the opportunities for taking the ‘new land’ into traditional forms of terrestrial land use should be restricted in order to minimise the risks of damage to these uses by future breakdowns of the protection dikes or the incidence of saltwater seepage from under these dikes. Actually, the new ‘North Sea Polder’ would only serve its function as a safety buffer when human activities do not automatically expand into it.

The costs of a land reclamation of these dimensions are likely to be virtually incalculable, amounting to several hundreds of billions of € for the time period after 2100. Initial costs would include the preparation and carrying out of an extensive campaign to achieve political and public support for such a mega-project.

Other future costs, after actual realisation, would include the adaptations necessary to cope with the river discharges, the loss of coastal marine ecosystems (including coastal fisheries), the consequences of changing marine shipping routes, etc.

The benefits of having a large protection polder all along the actual Dutch coastline would include, apart from safety of the low-lying lands against intrusion by the sea, that new possibilities for economic and/or ecological development might occur. Any kind of potentially sea or salt-proof spatial use of (parts of) this polder could be imagined, ranging from large-scale recreational uses and coastal ecosystem wetland development to inundation and salt-proof industrialisation projects.

***Evacuation of the whole of the low-lying parts of the Netherlands***

Another very drastic adaptation strategy would be to actually evacuate the low-lying parts of the Netherlands, at least as far as the functions most vulnerable to water and/or salt damage are concerned. In fact, this would actually be the most sensible and natural adaptation strategy possible, were it not for the immense amount of energy, money and emotional stress involved in actually effectuating this strategy. After all, throughout history mankind, as well as any other life form, has always adapted and its dwellings and its lifestyle to changing environmental circumstances. It is only in the last couple of centuries that man has proved increasingly capable of applying its technological advances in such a way that environmental changes were modified according to man’s short-term needs. It is in, in fact, this astonishing ability of man to cause such fundamental changes in his environment, that has caused the problems of climate change and the concurring hydrological consequences. The actual abandoning of the lower parts of the country and the mass movement of vulnerable functions and land uses to the safer higher grounds would, in the long run, seem the only really sustainable strategy for the long term.

The effects of the almost complete evacuation of the low-lying parts of the Netherlands would be that, little by little, the sea would invade into the countryside, turning two-thirds of the current land territory into a vast inter-tidal wetland area, while in the meantime the nowadays relatively less densely populated higher grounds in the eastern and southern parts of the country would become very densely populated and industrialised. The rivers and their adjacent floodplain areas would have to be avoided for intensive land use purposes as well, so the actual human activities would become concentrated on structurally higher grounds.

Obviously, the costs of an adaptation strategy implying such a radical change in spatial occupation and land use would be almost incalculably high (at least several hundreds of billions of €) and would, thus, necessarily have to be spread out over several decades. The costs would not merely include the breaking down of buildings and infrastructure in the west and northwest and the re-establishment of buildings, towns, infrastructure and industrial plants in the east and southeast, but would also include the loss of productivity of all of the abandoned lands. Moreover, there are would be huge emotional costs involved for all the people that would be forced to give up their generation-long ties to their ancestral low-lying polders. Additional costs of this strategy would also involve the loss of valuable terrestrial ecosystems still present in the higher parts of the country. These nature conservation values, however, are less characteristic for the Netherlands and, therefore, less unique within a broader international context than the wetland values of the coastal regions.

The most marked benefit of the mass movement of human activity from the vulnerable lands near the sea and along the rivers towards the safer, but still more sparsely populated higher parts would, of course, be that the safety against flooding and inundation gained this way is, essentially, sustainable. The abandoning of the lower parts of the Netherlands to the dynamic forces of water, wind, salt and tidal currents would create room for an incredible boost for the development of natural wetland conservation values. An immense variety of gradient-rich inland and coastal marshland types would develop, in which besides a very rich and varied biodiversity economic sectors such as fisheries and certain types of eco-tourism would find ample opportunities.

***Examples of application of adaptation strategies: Room for the Rivers, Maaswerken***

Consists of a wide array of local measures all aiming at enhancing river flow capacity, so that higher peak discharges of Rhine and Meuse can be safely coped with. These measures include:

- Laying back of winter embankments, thus enhancing the effective floodplain area;
- Removal of sediment from the floodplain areas, thus enhancing the flow capacity of the winter bed during periods of peak discharges;
- Removal of (parts of) the summer embankments, thus facilitating the flow of surplus amounts of water during periods of peak discharges;
- Construction of artificial side channels, enhancing flow capacity;
- Removal of obstacles within the floodplain, which might enhance peak water levels and thus increase the risk of the breaking down of winter embankments.

All these measures are visualised in Figure 3-2.

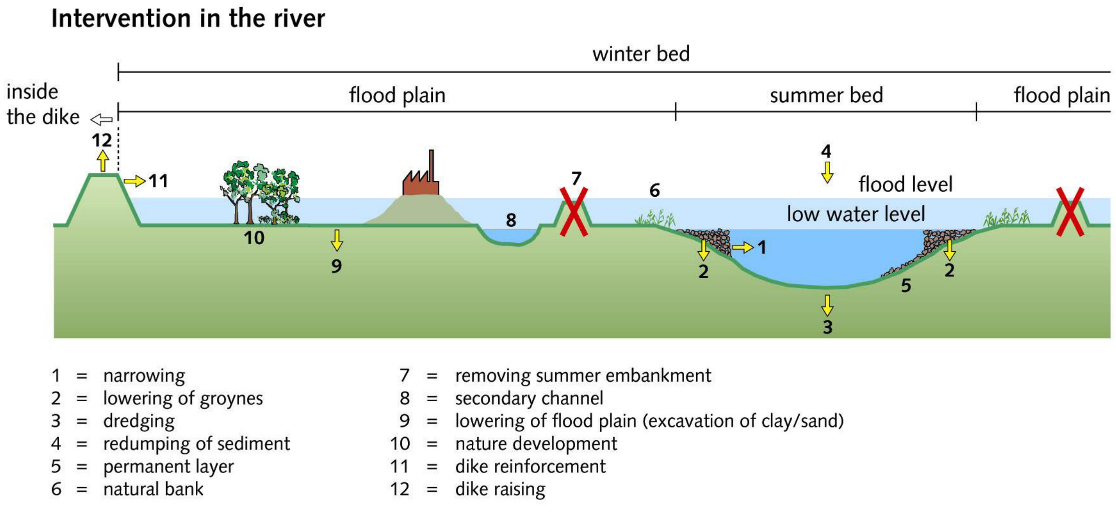


*Figure 3-2 Schematic representation of measures being planned and executed in the programmes 'Room for the Rivers' and 'Maaswerken'*

* Note: aiming at achieving an enhanced capacity of the rivers and their floodplains to cope with excessive discharge peaks (scheme from Iedema et al. 1999).

The main effect of each and every individual measure, and thus even more emphatically of the entire project, is that the expected water levels in the rivers at times of peak discharges decrease. This is precisely the desired effect, since this decrease in so-called 'design water level' allows the entire situation in and along the lower river stretches to cope with an increasing frequency of periods of higher discharge within the desired levels of safety.

Societal costs of providing more space for the lower stretches of Rhine and Meuse include:

- loss of strictly economically exploitable land (e.g. no (further) urban or industrial development in floodplain areas, removal of certain uses from the floodplains, reduced possibilities for agricultural use of floodplains, etc.);

- loss of certain valuable habitats and species confined to the less river-influenced parts of the floodplain, less space for riverine woodland or other rough vegetation types hampering the flow capacity.

Apart from these costs, there are of course the amounts of money directly involved with the research, the providing of the modelling tools and the actual carrying out of the spatial measures identified. Indicative for the magnitude of this type of costs is that, for the time being, a total amount of 2.2 billion € has been designated to the final programme of ‘Room for the Rivers’ (involving the entire Dutch river stretches of the Rhine branches and the lower part of the Meuse). Undoubtedly, Maaswerken will be slightly ‘cheaper’, which is partly due to the fact that here the total area to be re-designed is smaller and partly to the possibilities here to combine spatial measures with daylight mining of sand, clay and gravel.

The most evident benefits of spatial solutions, providing more room for river courses during periods of peak discharges, are:

- an increase in safety against flooding by a decrease in peak water levels;
- a more sustainable form of safety by allowing the rivers more space;
- an enhanced spatial quality of the river landscape in which the natural dynamics of the river can be visibly appreciated;
- an enhancement of habitats and species associated with close proximity to the river;
- an increase in recreational values of the river landscape.

As mentioned in the previous paragraph, in some instances a combination of circumstances may create the possibilities for so-called ‘win-win’ situations, such as where daylight mining of clay, sand and/or gravel with clear economic profits can be shaped in such a way that both more room can be created for handling peak river discharges and that certain types of spatial quality of nature, landscape and/or cultural values can be preserved or even enhanced.

***Enhancing discharge capacity in Afsluitdijk***

The actual discharge sluices present in the Afsluitdijk are no longer capable of discharging sufficient amounts of freshwater into the Wadden Sea to maintain the desired (low) water level on lake IJsselmeer in winter. This relatively low winter water level is important from a safety point of view: in this time of year storms are more likely to occur than in summer and a relatively high water level in combination with increased wind-induced wave action poses a threat to the actual height and strength of surrounding dikes. With the expected further increase of the sea level, combined with an expected enhanced winter water supply from the river IJssel (one of the lower Rhine branches), this situation is bound to become intolerably dangerous over the next couple of decades. Hydrological models have predicted that doubling the discharge capacity by 2013 should be enough to regain the potential control of the safe winter water level. When sea level is rising according to the ‘Controlist’ scenario, it is estimated that only by 2050 we will again have arrived back at the present-day situation where discharge capacity once more precludes the maintenance of the safe level. By that time, therefore, additional measures will prove necessary to warrant prolonged safety around lake IJsselmeer, but until 2050 the doubling of the discharge capacity may readily be considered an adaptation measure.

The presence of twice the actual discharge sluice capacity in the Afsluitdijk by 2013 will lead to a smoother temporal pattern in particularly the winter water table of lake IJsselmeer and, consequently, also of the other hydrologically connected lakes in the same area. Peak river discharges from the IJssel will no longer show as prominently as nowadays in the daily fluctuations of water level. Discharges of freshwater into the Wadden Sea are likely to become more regular and more predictable in size and timing.

The actual instalment of the extra discharge sluices is estimated at € 250 millions. Costs to society and further (macro-) economic costs seem small or even negligible, since no major adaptations for present forms of human exploitative use of the area would seem to be necessary. There are, however, some nature and landscape values that might experience some losses due to the disappearance of the little hydrodynamics the system still has at present. The unprotected grounds on the lakeside of the protection dikes will become less prone to occasional winter inundations, which potentially results in a loss of typical habitats or species of these dynamic conditions.

The present safety standards along lake IJsselmeer area with the present shore defences will be maintainable until 2050. This provides us with more time for adapting the shore defence of the province of Friesland for the water levels that are expected after 2050. Opportunities are created for improving the fish migration between lake IJsselmeer and Wadden Sea, thanks to the instalment of a fish passage as additional measure. Likewise, opportunities are increased for smoothening the salt-fresh water transition between lake IJsselmeer and the Wadden Sea. Finally, the better control of water level agreement provides a better availability of sand banks in lake IJsselmeer, which leads to an increase in habitat for certain species.

***Sand suppletions along Dutch North Sea coast***

Currently, it is already well-accepted practice to regularly carry out localised sand suppletions along the entire Dutch North Sea coast, in order to counterbalance the net erosion of beaches and sand dunes caused by wave action. Evidently, in view of the expected enhanced rate of sea level rise due to climate impact, the need of maintaining and even enhancing this activity is so acute that both the planning and the actual carrying out of this measure are being continued almost automatically.

The effects of sand suppletion are evident, becoming apparent in the local and periodic re-instalment of whole stretches of sandy beaches, which in their turn offer a continued protection of the strips of defending sand dunes behind. Secondary effects of sand suppletion include the continuous availability of sand beaches for recreational use (massive beach tourism throughout the summer months) and for nature (coastal benthic fauna, specific species of fish and birds). Moreover, thanks to regular sand suppletion, the dynamics of erosion and sedimentation in the intertidal regions of the Wadden Sea remain in balance, thus providing a continuous availability of a mosaic of dry, inundated and intertidal habitats which is the home to a huge variety of benthic fauna, fish and birds. On the other hand, sand suppletions may also cause significant local damage to coastal benthic communities by covering them with thick layers of sand of large areas of their original distribution.

The initial costs for additional sand suppletions at least 12 spots along the Dutch North Sea coast are estimated at several tens of millions of € per spot. The extra yearly maintenance necessary would amount to an extra 10% on top of the total yearly budget for coastline management (Commissie Bescherming en Ontwikkeling van Buitendijks gebied in Kustplaatsen 2005). Non-monetary costs include the potential damages to local benthic communities already mentioned.

The benefits of sand suppletions are: the contribution to the maintenance of the safety of the sea defence, despite the increase of erosion due to the sea level rise; the continuous presence of sandy beaches for recreation and nature purposes; the maintenance of a sound balance between erosion and sedimentation in the intertidal areas of the international Wadden Sea.

***Re-enforcement of 'weak spots' along Dutch coastline***

As already mentioned in the preceding paragraph the Dutch coastline had some distinct 'weak spots' with respect to coastal defence. Some examples are the sand dunes between Callantsoog and Den Helder (just one single line of dunes), the dike Hondsbossche Zeewering between Petten and Camperduin and the dunes at Monster, south of The Hague. Within the encompassing framework of 'Water management in the 21st Century' plans are being developed to deal with these weak spots by locally re-enforcing these spots. The measures may consist of either inland re-enforcement or offshore re-enforcement (combined with e.g. localised sand suppletions).

The effects of this adaptation strategy are comparable to those described earlier but are spatially confined to the exact weak spots identified.

The costs of raising artificial extra lines of sand dunes for coastal defence are likely to be very high. The exact amount of money involved per km of coastline to be widened will vary according to whether the widening is designed inland or offshore. While the actual costs of construction are higher in the case of offshore construction, due to the need of extra defences against the erosive influence of wave action from sea, in the actual calculation of the costs for inland construction, the effects of the necessary change in land use should also be incorporated in the total cost analysis. The land just behind the coastal dunes is often intensively used for various agricultural purposes or for urbanisations. A very frequent land use in precisely these areas is the cultivation of flower bulbs, a very profitable form of land use from an economic perspective. Anyway, the amount of money necessary to raise an extra line of sand dunes is likely to involve several millions of € for every kilometre.

Apart from the evident benefit of the reduction of the threat of the break-through of the coastal defence by the increase of wave attacks of a rising sea, and the corresponding floods that might cause hundreds of thousands of personal casualties as well as several billions of € of material damage, the widening of the coastal defence is bound to offer several extra opportunities for valuable dune-related nature and coast-related types of recreation facilities.

### 3.3.3 Discussion and conclusions for water management

Knowledge gaps in the field of climate change adaptation strategies for water management are still numerous. Lots of suggestions and more or less innovative ways of solving the problems related with the expected changes in precipitation and evaporation rates, river runoffs, sea level rise and possible changes in predominant winds are being developed, but are for the time being very diverse with respect to the amount of elaborated detail. The best developed strategies generally refer to the elaborated plans for the areas of the lower Rhine and Meuse. Here, the expected effects of the measures proposed are modelled to a sufficient level of detail and costs of the measures have been calculated with sufficient precision to have achieved a budget of 2.2 billions of € for realisation. Similarly detailed information is available for other aspects of applying the concepts of 'Water Management in the 21st Century', like 'Maaswerken', the instalment of extra discharge capacity in the Afsluitdijk and strengthening the eight 'weak spots' in the Dutch coastal defence. Even in these instances, however, it is not always easy to obtain reliable estimates of the actual costs involved in the adaptation programmes. This is at least partly due to the fact that authorities are reluctant to publish preliminary cost estimates in order to avoid an artificial raise in the actual costs. This type of knowledge gap is, of course, structural and can only partly be overcome by further research.

Further research can, however, shed more light on the prospects, both with respect to costs and to benefits, of other still more tentative or experimental ways of adaptation. Thus, suggestions for further research could include:

- A further enhancement of the climate models in order to obtain more details on expected changes in precipitation, river runoffs, temperature rise, sea level rise and possible shifts in predominating winds and on the time windows involved. Thus, one can be better prepared in the timing of the application of the adaptation strategies;
- More detailed analyses of each and every one of the technological solutions proposed in order to get a better insight into the (initial) financial costs of application as well as in the benefits that should occur;
- Field inventories on the amount of public support in the diverse economic sectors potentially involved in applying adaptation strategies. This should give more insight into the 'willingness to pay' for promising adaptation strategies, which in itself is one of the main knowledge gaps when making assumptions about cost-benefit analyses;
- More insight into the balance of costs and benefits of changing traditional terrestrial forms of land use (mainly based on agriculture) into alternative forms, in which issues such as wetland conservation values, opportunities for water-related recreation and for fisheries or more flexible forms of water-related land use predominate.

## 3.4 Energy and Transport

The energy sector comprises a wide range of activities from small-scale household energy consumption to the large-scale transformation of energy in power plants. The sector is based on the demand from other sectors. In fact, long-term energy demand and supply prospects, to some extent independent of climate change, are subject to numerous uncertainties such as consumer tastes, world oil prices, technological advance and environmental regulations, which are key factors that determine future energy flows. Moreover, the climatic impacts on the level of total energy consumption are likely less significant than those of the factors above. This is important to bear in mind when considering adaptation strategies to climate change for the energy sector into a proper perspective (Slob and Van Hoorn, 1999).

The transport sector is closely interlinked with the energy sector and displays similar properties in that it can hardly be viewed as a stand-alone sector. Instead it is very dependent on the other sectors in the economy.

In this chapter we identify adaptation options to respond to climate change for the energy and transport sector. The structure is as follows: For each adaptation option we describe the impact, the adaptation strategy, the effects of the strategy, the incremental costs and benefits associated with implementing the adaptation measures. These are first described qualitatively and where possible expressed in quantitative terms, next we give some spill-over effects to other sectors and a overview of possible institutional barriers that may emerge when implementing the measures. The second section embeds the identified measures in a broader political context, thereby linking up with current national and international policies concerned with climate change with specific implications for the energy sector. Furthermore, each subsection distinguishes between the following sub-sectors: corporate business; housing; and transport.

### 3.4.1 Impacts and strategies for the energy sector

A wide range of climate variables, most notably temperature change, precipitation, cloud cover, wind speeds and the occurrence of extreme weather events, influences energy use. A distinction is made between effects on energy demand and energy supply.

***Energy demand***

According to the KNMI climate scenarios the earth's temperature will increase the next fifty years by 0.9 – 2.9 degrees Celsius. Impacts on the energy sector include a change in seasonal demand. An increased in temperature will reduce the demand for space heating during cold seasons and lead to increased demand for space cooling (e.g. air-conditioning) during warm seasons. ECN and MNP calculated that an increase in temperature to date has avoided 3 mln ton of CO2-emissions due to less space heating in households, buildings, and greenhouses, which amounted to about 1.5% of total CO2-emissions in the year 2000. However it is not clear whether this is net of the increased demand for air-conditioning.

***Energy supply***

Increased cooling water problems as a result of hot summers. A direct effect of climate change on energy supply is reduced cooling water availability due to higher water temperature. The dry summer of 2003 has resulted in an unstable supply of energy as electricity plants were not able to perform at their maximum capacity. The maximum tolerable river discharge temperature is set at 30 degrees Celsius. The difference between water intake for cooling purposes may be at 7 degrees maximum during summer, meaning that the maximum temperature when taking water may not exceed 23 degrees (Eleveld et al., 2005). During a very hot summer the surface water already reaches nearly 30 degrees before intake. As a result energy plants are not able to use the water for cooling purposes as this water would then exceed the 30 degrees limit when discharged into the river. Consequently, plants only use part of their maximum capacity which may result in a shortage of energy supply. This in turn will enhance the danger of power cuts that may have serious societal impacts on transport, communication or heating. The Rathenau Institute (1994) computed the direct costs of a power cut in the Netherlands lasting more than eight hours, which amounted to about EUR 30 for each non-delivered kWh (ECN, 2004).

Figure 3.3 shows the number of days where the temperature of the water in the river Rhine exceeded the maximum tolerable level of 23 degrees for water to be used for cooling purposes.

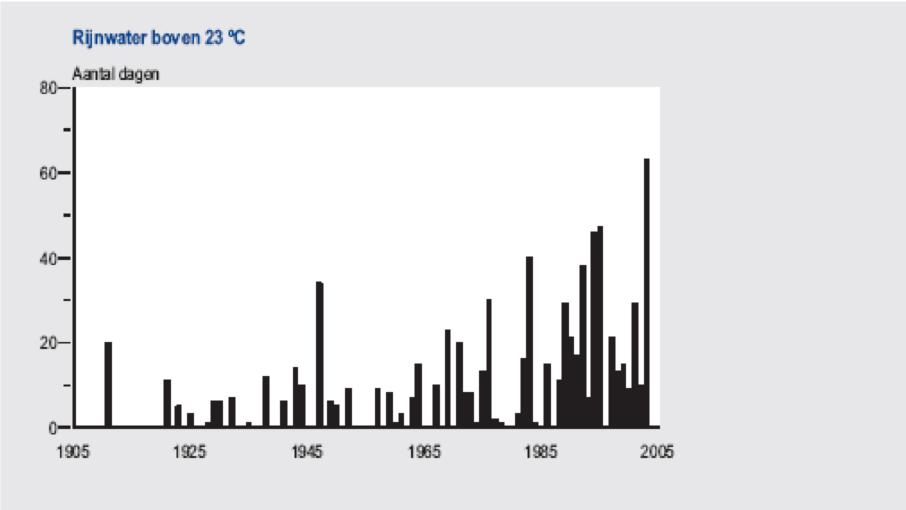


*Figure 3-3 Number of days exceeding 23 °C in the period 1909-2003.*

*Source:* MNP (2005)

Increased wind speeds may also have a positive impact as more opportunities will arise to profitably exploit wind turbines. This will also enhance the flexibility in a geographic sense as whereto place wind turbines, i.e. there will be more locations suitable to have turbines installed.
ECN (2004) calculated the potential and costs for both on-shore and off-shore wind energy. The total land area is divided into four 'bands' classified according to average wind speeds, with band 1 representing the category that is most appropriate for wind sites and band 4 the category that has the least appropriate sites. The realistic potential for the Netherlands has been estimated at 5,949 GWh/a. Investment costs for the Netherlands have been estimated per band for the year 2000 and vary between EUR 941/kW for band 1 to EUR 1220/kW for band 4. The distribution of available land per band in the Netherlands has been assumed at 33%, 50%, 17% and 0% for band 1-4 respectively. Operation and maintenance costs (defined as the average annual costs over the technical lifetime of the installation, needed to keep the installation in operation) have been estimated for the year 2030 and are expressed per band, as percentage of the total investment costs ranging from 2% (band 4) to 4% (band 1) of total investment costs.

A positive impact of climate change may be an increase in the number of hours of sunshine, which enhances the potential for solar energy. The realizable potential in the Netherlands is contingent upon the development of the appropriate infrastructure, the growth rate of the industry of photovoltaic energy (pv), anticipated price reduction and associated consumer and supplier interests. In the PV Convenant of 1997 the PV sector and the Dutch government agreed on targets for the coming decades from 100 in 2007 up to 1400 MWp in 2020. Investment costs for the Netherlands have been estimated at EUR 5-8Wp for the year 2002, where it is expected that investment costs will fall due to learning effects both on the PV modules and inverter and installation costs. Therefore the progress ratio has been estimated at 0.8 up to the year 2050. The operation and maintenance costs for PV have not been calculated separately for the Netherlands, but are available for Europe only. The range varies from 1-3% of total investment costs. The benefits of this technology include a contribution to meeting the target for sustainable energy production, and avoiding purchasing CO2-emission permits, which are valued at the market price for CO2-emission permits.

Rising temperatures may lead to a shift in agricultural production systems. It may be more profitable to choose crops for biomass production. This can also be viewed as being an adaptation strategy rather than an impact.

### 3.4.2 Impacts on the transport sector

To date the consequences for the transport sector have not received much attention in the literature. Still, it is widely known that transport systems on the whole will perform worse under extreme weather conditions, especially in a densely populated country like the Netherlands where one single event often leads to chain reactions hindering the entire transport sector.

Increasing wind speeds as a result of climate change are anticipated across the Netherlands and much of the rest of northern Europe. Extreme windstorms can severely damage overhead electricity networks and as such lead to a less stable supply of energy. Additionally, due to storms there is a greater risk of damage to infrastructure (roads, bridges) houses, buildings, and vehicles. Trees, parts of buildings may be blown on to vehicles directly or in front of them on the road causing hazards to the other traffic. Dorland et al., (1999) report damages due to a severe wind storm in January 1990 to amount to 2.6 billion guilders in 1990 values, with the costs for the repair of dunes estimated at 15 million guilders (RWS, 1990; Volkskrant 1990), damage to forests 13-15 million guilders, (Ekkelboom, 1990) and damage to aeroplanes and buildings at Schiphol airport of 5 million guilders (G&E 1990). Economic losses due to transport delays are estimated at 10 million guilders, while damage to private houses amounted to 1.03 billion guilders, and 0.38 billion guilders to damage to business, industrial and commercial buildings (CVS, 1994). The relatively high frequency of storm occurrence and severity over Europe has not been found to be outside the bounds of natural variability, although the extent of storm damage did increase over the past few decades. Munich Re (1990) and Dlugolecki (1992) report that this is particularly due to increased number of houses, buildings and increased and higher monetary values).

Dorland et al., (1999) estimated the mean damage costs (that can serve as benefits of adaptation using an avoided damage cost approach) of increases in wind intensity for houses and businesses based on a storm-damage model for the Netherlands. Table 3-10 shows the mean damages at six different wind speeds for four demographic and economic growth rate scenarios, as given in Table 3-9.

It however remains difficult to predict damages due to increased wind speeds for two distinct reasons: first, models can be built on limited empirical evidence only and second, there is considerable uncertainty about not only future climatic changes, but also about demographic and economic processes that are being forecasted in order to appropriately estimate future damages (Dorland et al., 1999).

*Table 3-9 Population and economic growth rate scenarios*

| Scenario | Population growth | Economic growth rate |
|---|---|---|
| Global shift | 0.4% | 1.9% |
| European Renaissance | 0.3% | 2.8% |
| Global Crisis | 0.4% | 2.0% |
| Balanced Growth | 0.3% | 3.2% |

*Table 3-10 Mean damage due to percentage increase (1990 Dutch million guilders)*

| **Scenarios/wind increase** | **0%** | **2%** | **4%** | **6%** | **8%** | **10%** |
|---|---|---|---|---|---|---|
| *Houses* | | | | | | |
| No Change | 903 | 1322 | 1937 | 2838 | 4158 | 6094 |
| | (286) | (421) | (620) | (918) | (1346) | (1938) |
| Global shift/ Global | 991 | 1451 | 2125 | 3114 | 4563 | 6687 |
| crises | (314) | (462) | (680) | (1000) | (1476) | (2176) |
| European | 968 | 1418 | 2077 | 3043 | 445 | 6534 |
| Renaissance/ | (307) | (451) | (665) | (979) | (1443) | (2156) |
| Balanced Growth | | | | | | |
| *Businesses* | | | | | | |
| No Change | 202 | 287 | 407 | 578 | 820 | 1164 |
| | (66) | (94) | (135) | (192) | (275) | (393) |
| Global shift | 266 | 377 | 535 | 759 | 1077 | 1529 |
| | (87) | (124) | (177) | (253) | (361) | (516) |
| Global crises | 270 | 382 | 543 | 770 | 1093 | 1551 |
| | (88) | (126) | (180) | (257) | (367) | (524) |
| European | 302 | 428 | 608 | 862 | 1224 | 1737 |
| Renaissance | (99) | (141) | (202) | (288) | (411) | (587) |
| Balanced growth | 319 | 453 | 643 | 912 | 1295 | 1838 |
| | (105) | (149) | (213) | (305) | (435) | (622) |

**Note:* standard errors are included in parentheses

Also bridges may need to be closed during storms causing delays and congestion on other roads. Thus, increased wind speeds may lead to more road accidents.
An indirect effect could be that the development of more energy-efficient light rail systems and double-deck trains will come to an end as there is an increased chance of vehicle overturning (Perry and Symons, 1994; Johnson, 1996). At sea high wind speeds may pose considerable danger to vessels and oil platforms. The number of days for fishermen to go out at sea may be reduced and lead to economic losses. Oil platforms may be damaged, or cannot be operated from, at days with severe winds.

As of today not much information is available yet with respect to potential costs and benefits of off-shore wind energy. Off-shore realistic wind energy potential in the Netherlands has been estimated at between 6 and 30 GW, with 6 GW being the national target. Investment costs have been calculated as a function of sea depth and distance to the shore and vary between EUR 1546/kW to EUR 2428/kW. The annual operating and maintenance costs per kilowatt (here limited to expenditures for operation and maintenance of the wind farm and ground lease) have been estimated at EUR 50 per kW for the year 2005 and falling to EUR 40 per kW for the year 2030.

Increased drought frequencies as anticipated in the dry scenario can have severe impacts on stable energy supplies by hydroelectric power as riverbeds run dry. In addition, low water levels in the rivers may disrupt transport over water as especially in the Netherlands many goods (bulk freight) are transported inland by waterways. Low water levels will force container ships to use only part of their maximum capacity, which will severely increase transportation costs.

Summer heat may have a severe impact on traffic behavior. First, the level of tourist traffic during hot summers may increase, which may lead to congestion and an increased incidence of road accidents (Stern and Zehav, 1990). Second, there may be an effect of hot weather on individual driving performance due to fatigue (Maycock, 1995).
Furthermore, higher temperatures could result in damage to infrastructure which would lead to higher maintenance costs. For example, higher temperatures can cause the road surface to melt, which will require changes in the technical development.

A reduction in the number of frost days is anticipated due to rising temperatures which may have a positive impact on transport. Less roads will need to be salted which provides direct economic benefits. Also, we would expect the number of road accidents during winter to decrease. Parry (2000) notes that during days with snow lying inessential journeys are postponed or curtailed, leading to economic losses, hence a reduction in the number of days of snow would lead to economic gains. Less snow and frost days will also lead to less work in terms of inspecting road surfaces and railways, and removing icicles. Ice loading on wind turbines is expected to become less of a problem with rising temperatures hence there may be a positive effect on the continuity of energy supply.

Increased amount of rain and an increase in the number of rainy days is anticipated in most scenarios except for the dry scenario where only the winter season would have more frequent and more intense rainfall. Changes in frequency and intensity of rainfall can have an effect on the frequency of flooding which in turn may cause a disruption of transportation services. An indirect effect might be that the perceived reliability on public transport decreases and there will be less use of public transportation systems, leading to economic losses. In addition, more rain may lead to higher levels of corrosion of infrastructure, thereby leading to higher maintenance costs and a lower life-span (Chagnon, 1996). Edwards (1996) calculated for England and Wales that the share of traffic accidents due to increased and more frequent rainfall may rise from one out of eight to one out of five. In addition, trees planted too close to railway lines can cause a hazard because of wind-throw and fallen leaves due to higher autumn rainfall, may be a major cause of delay as they become compacted and can result in failure of claps brakes. Also, wet leaves can short the electrical circuits that provide signaling (Kerr et al., 1999).

A large variation in temperature where extreme cold and extreme warm periods rapidly succeed each other will place more stress on old and fragile metal lines leading to failure. This would thus require increased levels of preparation. Whether this indeed applies to the situation in the Netherlands is however uncertain as current climate scenarios predict an identical increase in summer and winter temperature, hence according to the scenarios seasonal variability would then not increase.

Sea level rise in combination with storm is the climate factor to which port operations are considered to be most sensitive. Flooding of harbours causes disruptions to shipping and to operations in adjacent industrial areas. Ferry operations may be affected as well as activities of small commercial and leisure craft that are dependent on weather conditions.

Sea level rise may also affect cargo activities as the equipment used to load and unload cargo is designed to operate within the current tidal range. They will as a result cease to operate as effectively, thereby reducing the time during which operations can be undertaken (Kerr et al., 1999), but the expected sea level rise to the year 2100 stays in most studies within the range of about 100 cm.

Sea-level rise and increased risk of coastal flooding may cause structural damage to both rail and road transport infrastructure in coastal areas (Parry, 2000). This is especially relevant for the Netherlands, which has the highest density of road and rail infrastructure in the low-lying coastal zones. Increased risk on river flooding may have a negative impact especially on river traffic that may then come to a standstill.
The road network will be particularly sensitive to flooding as the capacity of drainage systems to remove excess water from the roads may be exceeded. Erosion of embankment and landslides may also be exacerbated by increased rainfall intensity.

Reduced icing and frost damage can be considered a benefit of climate change. In addition, changes in wind direction and strength will change the exposure of roads to snowdrift while the likelihood of less snow-lie at lower altitudes could reduce problems of snow-drifting (Kerr et al., 1999).

MNP (2005) reports that especially the costs of freight will change if extreme low water levels causes container ships to reduce their cargo. In the dry scenario an increase in costs by 2-4% has been predicted. The risk on extreme water levels is foremost anticipated in the dry scenario.

### 3.4.3 Adaption measures for the energy sector

A possible adaptation option to solve the problem of unstable energy supply due to cooling water discharge constraints can be solved by relaxing the law imposing a restriction of cooling water discharge. In 2004 the Commission for Integrated Water management took a first step and developed a new method to assess cooling water discharges to address the problem (CIW, 2004). The effects of a relaxation may be that ecosystem values may be affected negatively due to increased surface water temperatures, and drinking water may need additional treatments, which will lead to extra costs. Benefits of the adaptation measure include a stable supply of electricity that may be valued at avoided damage costs of a power cut.

A second option may be to reduce consumer demand for cooling and heating purposes by developing intelligent constructions on houses and buildings that provide for a constant temperature year round, without needing additional cooling or heating devices. This option would relief the pressure on cooling water used by electricity generating firms. Developing more ‘intelligent’ buildings usually require higher (investment) costs than those of conventional buildings and houses. Institutional barriers include the long planning horizon which is usually required for spatial design, development and construction. Spatial plans for this purpose may also conflict with other spatial policies, and could affect landscape (amenity) values.

A third option that may relief the pressure of demand on electricity is the use of energy-saving products like energy-saving light bulbs, rechargeable batteries, purchase of seasonal food not grown in greenhouses. The direct effect will be a decrease in demand for electricity, hence a reduced risk of power cuts and an increase in demand for more sustainable products. Benefits include avoided damage costs of power cuts. Prices of energy-saving products are likely to be higher than those of the standard products. This may have an effect on consumer expenditures for other products, which may negatively affect other sectors of the economy, but in later stages more money can be spent on non-energy items.

Adapting to increased wind speeds is possible by setting building standards as to reduce vulnerability of buildings to storms. In the Netherlands building codes have already been updated since the storm in 1990. Under these new regulations (NEN 6702, 1993) buildings should be able to withstand higher wind speeds. Depending on the measured wind speed during the 1990 storm and updated predictions since then with regard to increased wind speeds it may be necessary to set stricter standards.

A third adaptation strategy is to guarantee a stable supply of energy by enhancing the production of sustainable renewable energy systems including wind and solar energy and biofuels. Each of the options will be discussed in detail below.

***Wind energy***

The development of wind turbines off-shore will contribute to increased production of sustainable energy. This will also have a mitigating effect as Carbon emissions may be reduced (Verrips et al., 2005). A second-order, economic effect will be a decrease in demand for CO2 tradable emission permits. Benefits of wind energy could thus be valued at the avoided cost of purchasing tradable emission permits. The costs of developing wind turbines would first of all be the investment and maintenance costs. Second, there may societal costs due to decreased landscape and scenery values. These could be valued in monetary terms using non-market valuation methods. Figure 2 displays the price for wind energy, which shows a steady decline and is expected to drop to a level lower than that of conventional electricity generating costs after the year 2007. CPB (2005) calculated that wind energy will economically be beneficial after 2025.

Increased wind speeds may also require stronger wind turbines to be developed. This will require knowledge about how to develop turbines that are less prone to extreme winds and investment in stronger material.

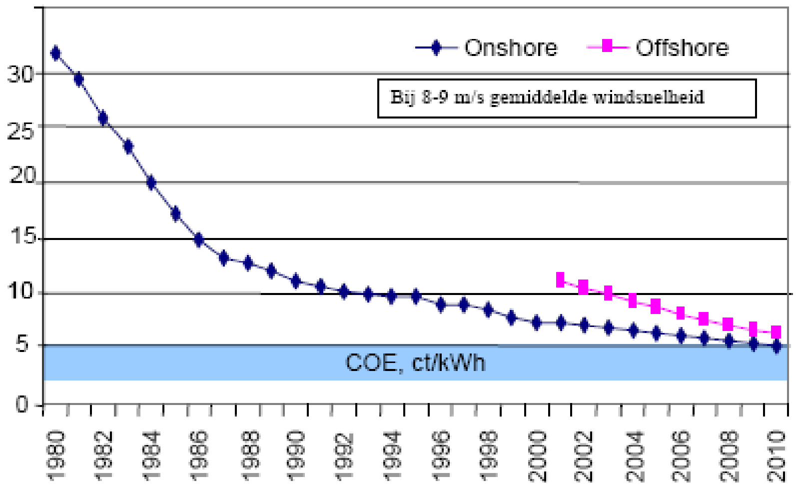


*Figure 3-4 Development of kWh-price wind energy compared to conventional electricity generating costs.*

*Source: CPB (2005)*

### *Solar energy*

Increased hours of sunshine will enhance the potential of sustainable energy production through solar energy. Analogous to wind energy, this adaptation measure will also have a mitigating aspect, as it will reduce Carbon emissions and decrease the demand for tradable permits. The costs of developing solar energy production farms include investment and maintenance costs. It is not expected that landscape and scenery values are negatively affected.

### *Biomass production*

Climate change may induce farmers to grow other crops with a shorter rotation period, including biomass crops. In addition, it may be used as a mitigation strategy to reduce carbon emissions and decrease demand for tradable permits. Considering the following biomass technologies: co-firing, combustion, waste combustion, gasification, and digestion of liquid manure, investment costs have been estimated accordingly varying from EUR 190/kW$_e$ for co-firing to EUR 4750/kW$_e$ for digestion in 2010, and EUR 190/kW$_e$ to EUR 4510/kW$_e$ in 2020. Annual operation and maintenance costs amount to 4-6.5 of investment (Van Ree, 2002). However, the actual availability of the agricultural area for energy crops will highly depend on the competition between other purposes the area may have. If other crops provide for a higher profit, the potential for energy crops will be rather small. For the Netherlands the potential of energy crops is estimated at 3 PJ/a.
In terms of electricity, improvement of overhead electricity transmission poles would be a possibility to adapt to the increased risk of windstorms. The direct benefits of this option would be avoided power cuts, and damage to infrastructure, landscape, vehicles as well as a reduced chance of (fatal) accidents due to blown over electricity poles. The actors involved include the national/regional governments and companies constructing electricity poles. The costs of building more storm-proof overhead electricity poles may be relatively modest as it does not require developing and building completely new designs but rather improving the old structures.

### 3.4.4 Adaptation options for the transport sector

Due to increased wind speeds there is a need to develop more 'intelligent' infrastructure like for example road and vehicle sensors that can serve as an early warning indicator and provide for adjustments in driving. The direct effects of such measures will be better informed and hence better prepared drivers which will lead to less road accidents. For implementing this option advanced knowledge is needed on innovative vehicle and infrastructural design. The benefits of this option are calculated as the avoided damage costs to infrastructure and decrease in number of traffic-related deaths. Important barriers include high investment costs, uncertainty with regard to future prospects of consumer perceptions which may impede the development process of new safer vehicles, i.e., producers may be hesitant as to develop the product; infrastructural design requires a long planning horizon and may be in conflict with other (sustainable) spatial planning policies.

An important aspect of increased risk of storms at sea leading to a decrease of fishing days necessitates the improvement of vessels, making them 'storm-proof'. The direct effect of this option is the avoided economic damage, calculated as the number of days the vessels can get out at sea, where otherwise they would have had to stay at home. An indirect impact will be on the supply of fish at the market for consumers. To implement this option knowledge is required about how to technically construct safer vessels. Direct benefits relate to the effects of the strategy, which is the avoided economic damage of not being able to go out at sea. Economic damage of not being able to go out at sea consists of the opportunity costs of labour, and the market price of fish. The actors involved include foremost the fishery sector, research institutes concerned with developing new 'storm-proof' vessels and companies that build ships. A possible negative effect on other sectors may be an increasing danger of over-fishing that may distort marine ecosystems.

The danger of increased flooding leading to a higher level of corrosion of vehicles, trains and infrastructure provides an opportunity to change modes of transport and develop more intelligent infrastructure. Increasing air- and over water transport would cause some relief of the high pressure on the current road network. The action needed to implement the strategy includes increased knowledge on new types of vehicle and infrastructural design and increase the load capacity of airplanes and container ships. In addition, this requires careful spatial planning in the long term that may be in conflict with other spatial planning policies. The direct benefits include avoided costs of delays, and less road accidents. Important institutional barriers to its implementation are high investment costs and conflicting interests with other long-term spatial policies that may pursue different goals. Additionally, where there are consumers involved instead of cargo, increase the reliability of public transport systems by creating new modes, less susceptible to impacts of climate change may induce an increased demand. This not only provides a relief to the congested road network, but it may also attract more tourists which will benefit the recreation and tourism sector.

Increased standards for buildings to make them more robust to increased wind speeds would be an important option to consider for the built (urban) environment. This would require up-to-date knowledge on the vulnerability of buildings to wind storms. Direct benefits of this adaptation option would include avoided damage, both in terms of material and human lives. Material damage can be valued at the market price of reconstructing buildings and infrastructure. Whether we are able to economically value human lives remains an ethical question. The most important actors involved include the national government and construction companies. The foremost important institutional aspect is the required change in building laws. The costs of implementation will therefore be relatively low.

### 3.4.5 Discussion and conclusions for the energy and transport sector

In the preceding sections we have identified several options for the energy and transport sector. This section will place the measures into a broader policy perspective. In order to be able to implement adaptation options to climate change we have to ensure that the measures are not in

conflict with policies at the European and/or global level. While this is a necessary, it is not a sufficient condition to maximize benefits that can be obtained from adaptation. Maximizing benefits in this respect would mean fulfilling multiple goals with one measure or strategy.
Important adaptation measures within the energy sector including wind energy, solar power and biomass production are in compliance with Dutch policies aimed at encouraging the use of renewable energy including Articles 36o, 36i, and 36r of the Energy tax, the Environmentally Friendly Electricity Production Programme (providing subsidies for environmentally friendly electricity generation), the Intergovernmental Wind Energy Agreement (the aim is to realize 1500 MW of onshore wind energy power capacity) and the Coal Covenant (increasing the installed capacity of biomass up to 503 MWe during the period of 2008-2012 (VROM, 2005). In fact, the Netherlands agreed to have 9% of its total electricity generation generated by sustainable energy sources. On the 17th of May 2003 the European Commission published the Directive 2003/30/EC on the stimulation of the use of biofuels and other renewable fuels in transport. The directive demands from the EU member states that a minimum proportion of biofuels and other renewable fuels is sold on their markets and, in order to achieve this the member states must set national indicative targets. This target includes a share of 5.75% (based on energy content) by December 2010 of all petrol and diesel for transport services sold on their markets.

# 4 Cross sectoral impacts and conclusions

## 4.1 Cross sectoral impacts

The adaptation options have typical cross sectoral impacts, particularly with regard to land use and water management. For instance changes in the national ecological network will affect agriculture or will reduce the space available for infrastructure and housing. Similarly many water retention options will affect the land available for other uses, such as agriculture or the growing of biomass.

At the same time climate change will ask for mitigation options that also compete for land for example in case of biomass production or the construction of wind parks.

The level and relevance of these 'competing claims' for land depend on the very detailed specification of the adaptation options that will occur at the regional level. Sofar very few detailed analyses have been made for spatial claims related to climate change. Only for the case of water management in the river areas detailed case studies have been performed, particularly in the context of retention areas and restructuring of rivers.

In order to adjust to climate change in the Netherlands in the long run it will be essential to consider a wide variety of spatial options, including decisions on where economic activity can best take place and which areas could be made less vulnerable to climate change by reducing new investments in areas that are prone to flooding.

Usually, adaptation measures are not taken for the benefit of one sector only but they aim at achieving multiple goals simultaneously. An example is the attempt to combine nature development with water management as mentioned by the Dutch government in the policy document 'Nature for People, People for Nature'.
Synergies occur also when offshore windmill parks offer another possibility to locate mussel nursery plots. The underwater foundation of offshore windmill has proven to be a suitable place to grow mussels, analogous to the pending mussel culture. This strategy offers the possibility to combine mussel production with the production of electricity.
Creating more space for water, besides increasing the water storage capacity and benefiting landscape, can also strengthen ecosystems by offering space to plant and animal species.

In the current literature only a few studies on these spatial aspects have been identified and further research results from the program Klimaat voor ruimte need to be considered before the cross sectoral impacts can be analysed in more detail.

The studies sofar indicate that sectoral impacts may be important for agriculture, recreation, nature conservation and water management. As these sectors will be strongly affected by climate change it is essential to analyse these interactions in more detail in future research in order to make the Netherlands less vulnerable to the impacts of climate change and to reduce the potential damages.

## 4.2 Conclusions

The aim of this report was to collect existing and new information on adaptation options with respect to climate change in the Netherlands. Van Ierland et al. (2001) commenced on this task in 2001 by making an inventory of vulnerability of human and natural systems to climate change, and by identifying possible adaptation options. We now review the information gathered in 2001, and make an attempt to extend the analysis by describing incremental costs and benefits of the options. To the extent that this is available, we provide quantitative estimates of these costs and benefits. The analysis was done for those sectors that in Van Ierland et al.

(2001) were identified as being most vulnerable to climate change, which included agriculture (including forestry and fisheries), nature and ecosystems, water, transport and energy. The study was explicitly restricted to these sectors.

***General observations***

The study shows that the Netherlands is particularly vulnerable to climate change in agriculture, ecosystems and the water system. The agricultural sector (including forestry and fisheries) is vulnerable to climate change and adaptation is necessary in these sectors. Detailed analysis of the various options is given below and in the chapters of the report. For the water system a wide variety of options exist and some of the adaptation options are already starting to be implemented. In addition, impacts will occur on ecosystems, but the options to adapt the management of ecosystems are limited other than considering the management of the national ecological network (NEN).

***Agricultural sector***

The choice of crop variety and genotype would be the most important adaptation strategy in the agricultural sector. Growing different crops that are more resilient to environmental pressure may also serve other purposes for example, when energy crops are being grown. Benefits of adaptation in the agricultural sector can be approximated by avoided damage due to yield losses.
In addition, water management is important. For instance, water storage on farmland in times of excess water supply is an important strategy with large spill-over effects to the water sector. While land values may decrease due to inundation, diversification of farmer’s risk, improved recreational and nature development opportunities are important potential benefits that may very well off-set the loss of land values. The costs of water storage on farmland are relatively easy to calculate, but benefits are more difficult to quantify especially those for which no market exists (e.g. nature development and recreational), or that may only appear after several years (e.g. nature development).

***Forestry sector***

Adaptation options in the forestry sector refer to species composition, spacing, thinning, and water management, including introducing new, more environmental stress resistant species; limiting timber imports to prevent the spread of pests and diseases from southern regions; and retention of winter precipitation to relieve summer drought stress are also mentioned. None of these strategies have been implemented yet, and hence costs and benefits of these strategies are unknown, and need to be explored in specific scenario studies.

***Fishery sector***

Important adaptation options for the fishery sector include adjusting fishing quota due to climate change induced decreased fish stocks; eco-labelling; reduced industrial use of freshwater preventing fish mortality; aquaculture on agricultural land, thereby increasing the economic value of otherwise inundated grassland. For adaptation options in the fishery sector benefits and costs are not known yet, and detailed studies are required to shed light on these issues.

***Nature and ecosystems***

The direct impacts on ecosystems are foremost the result of rising temperatures that lead to changes in life-cycle timing (date of flowering, ripening of fruits, leaf unfolding and species migration) which impact entire ecosystems. Indirect impacts include changes in precipitation and drought frequency, changing water levels that may result in increased risk of flooding, and extreme weather events including frost, fire and storms. The most important adaptation options include a change in design and implementation of the National Ecological Network (NEN) to make it climate proof. To date estimates of the incremental costs and benefits associated with making the NEN climate proof are unknown. In addition to the NEN, establishment and management of other protected areas that are most appropriate to develop and maintain when taking climate change into consideration is proposed. However, one should bear in mind that these options have not been designed to adapt to climate change per se but rather to prevent and mitigate damage to nature and ecosystems in general; hence it will be difficult to identify costs and benefits that are specifically attributable to making the NEN and other nature areas climate change proof.

***Water***

For the water sector important consequences of climate change are expected to result from sealevel rise; increased winter precipitation that induces flooding, or prolonged periods of drought during summer that hampers water availability, for drinking water, irrigation and process water in industry.

The adaptation options identified for the water sector all aim at improved spatial planning and design. Considering the increased anticipation on greater variability, flexibility in spatial design of water systems is key to successful adaptation to climate change.

Adaptation options for the water sector include designing areas for land retention and storage of surplus fresh water. This will however result in increased competition for land that would otherwise mainly be used for agricultural purposes and will affect some residential areas as well. Thus, farmers may need to diversify and get compensated for foregone production and possible investment costs that are needed to specialize in other functions. Benefits of this option include increased safety, enhanced recreational, real estate and nature conservation values. These benefits however to date are largely unquantified.
An adaptation option specifically related to the Dutch coast is to improve on coastal defence by developing extra sand dunes and artificial reefs. The costs of sand dunes and the construction of artificial reefs are expected to be relatively high, but exact cost estimates are at this moment not yet available.
Adaptation measures with respect to water management in the built environment include 'floating houses and industrial buildings', and re-enforcing existing dikes and dams. To date this type of floating housing and infrastructure has hardly been applied, except for some permanent and some recreational houses, hence incremental costs and benefits associated with this type of spatial design are not available yet, and they will strongly depend on local circumstances. By contrast, re-enforcement of dikes and dams are well-known and frequently applied measures. Costs for improving dikes amount to about EUR 4-8 billion. Benefits include foremost increased safety and hence reduced risk of damage and life-threatening situations, but these cannot easily be estimated in monetary terms.

***Energy***

The impacts of climate change on the energy and transport sector are expected to be of lesser importance than for example changes in consumer preferences, world oil prices and technological change. Among the important climatic impacts for energy are reduced water availability for cooling purposes, that may severely hamper a stable supply of electricity for households and the industry if no adaptation occurs. Changing climate conditions are expected to have a positive impact on several forms of renewable energy; e.g. increasing wind speeds enhance the wind energy potential by making more locations economically viable for producing wind energy; the anticipated increase in number of hours of sunshine could provide for some more solar energy; and changing growing seasons, and changes in temperature may generate favourable conditions for growing biomass crops. Adaptation options to sustain a stable supply of energy might include a policy-oriented method by relaxing the law on cooling water temperature levels. It is also possible to target at consumers energy demand for cooling and heating purposes by developing intelligent buildings and houses that provide for a constant year-round temperature by design and do not require additional heating. In addition, a large set of options for mitigation strategies exist, such as energy-saving products including for example, energy-saving light bulbs, rechargable batteries, technical devices (e.g. refrigerators, t.v.'s etc.) or to increase consumer awareness to save energy through government campaigns. Finally, production of sustainable energy systems will contribute to mitigating adverse effects of climate change.

### *Transport*

Impacts of climate change for the transport sector include physical damage (e.g. more road accidents under wet weather circumstances) and economic damage resulting from traffic (e.g. delays, congestion). Also damage may occur to electricity-, road-, train- and air traffic networks due to increased frequency and intensity of storms and increased risk of flooding with rising sea levels. In addition increased negative effects may occur in terms of corrosion of vehicles, trains and infrastructure.
On the positive side increasing temperatures will lead to less frosting days hence less roads need to be salted during winter; or more journeys will be undertaken in summer providing economic benefits.

Most notable adaptation options for the transport sector include the development of more intelligent infrastructure including road and vehicle sensors serving as early warning indicators providing for adjustments in driving, and hence a decrease in the number of road accidents.
Another option is to make existing infrastructure more robust to increased wind speeds and possibly higher frequency of storms. This option extends also to improving vessels or oil platforms at sea, making them storm-proof. This will reduce the economic damage that would otherwise occur.

### *Overall conclusions*

In order to adapt to climate change in a way that minimizes adverse environmental and economic impacts of both climate change and the adaptation options itself, a first need arises to assess the incremental costs and benefits associated with the different adaptation options. This requires consensus, at least to some extent, about the (un)certainty with which climatic impacts take place as different probabilities may lead to substantially different conclusions on what would be the best option to implement. The impacts of climate change are, even when only focussing on the Netherlands, surrounded by considerable uncertainties and its consequences are subject to debate. The report has dealt with this problem in two complementing ways. First, we have used the KNMI (2003) scenarios as a baseline4. That is we take the estimated changes on their main indicators of climate change (including temperature, precipitation, and sea-level rise) as given. Secondly, given these scenarios we proceeded by reviewing the literature and consulting experts by means of a workshop.

During the writing of the report two important observations were made. First, the literature on adaptation options for the Netherlands to date has a qualitative focus; to a very small extent costs of implementing the options have been roughly estimated, and their benefits are at best somewhat described in a qualitative way. Secondly, so far little attention has been given to spatial planning for the long run, i.e. for the period beyond 2050. This stresses the need for a more systematic research on and analysis of adaptation options, their costs and benefits, and their interactions.

A more detailed study on the costs of adaptation options was performed in the context of the Routeplanner project in the Netherlands. The results of this study are reported in E.C. van Ierland, K. de Bruin, R.B. Dellink and A. Ruijs (eds), 2006, A qualitative assessment of climate adaptation options and some estimates of adaptation costs, Environmental Economics and Natural Resources Group, Wageningen University, Wageningen, the Netherlands.

We would like to emphasize that this report is based on climate scenarios that show a gradual change of the climate. This means that unexpected events, or very rapid climate change or issues such as the slow down of the North Atlantic gulfstream are not considered in this report.

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[4] The new KNMI climate scenarios (KNMI, 2006) that were reported on 30 May 2006 were not yet available at the time of writing this report, but they do not affect the main adaptatation options as described in this report, because the differences with other scenarios are relatively small.

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# Annex I Database sheets

1. Database overview agriculture sector

| Impact | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|
| Water shortage during summer period/lack of water counter act saline intrusion. | Develop/breed new varieties | | | |
| | Invest in local water storage for irrigation (may not be efficient) | | Depends critically on who is allowed to use the stored water in case of drought. | |
| | Lower risk of failure via an increase in varieties/species. | | | |
| | Salt tolerant biofuels | | | biobased economy |
| Regional water excess-> flooding | Small scale water storage via enlargement of ditches.(is more expensive than allocating flooding areas. Excess occurs during the winter and spring period shortage during the summer is it possible to retain water long enough.) | Costs of development/construction of storage systems. (costs could be very high because land is needed.) | New storage technologies could be sold elsewhere. Waterstorage areas could be used as recreational areas. | |
| | | An estimated 4 to 7 billion euro is needed for The Netherlands (noorderkwartier calculated at: +700 milj.). Is more expensive than large scale flooding areas but relatively easy to realise. Large scale flooding is difficult because of NIMBY principle. | Need new technologies for water storage. | Technology water storage and reuse of water. |
| | water storage in urban areas | Costs of development/construction of storage systems. (costs could be very high) | | |
| Fen meadow areas with high water tables during winter period. | Livestock that can cope with wet conditions. Main problem is yield loss related to fungi and trampling of grassland. | | | |

| Impact | Strategy | Costs | Benefits | Spill over |
|---|---|---|---|---|
| Regional water excess with larger chance of flooding will result in yield reduction. | Adjust timing of operational management. Because of hired labour timing of work is difficult to manage. | | | |
| | Production levels are low; the Netherlands should focus on food crops. Land and labour are too expensive for low quality biomass production. | | | |
| | regulation of water storage and water supply | | | |
| | Different/ new varieties equipped to deal with the new situation. | | If there are no limitations the new species could provide new source of income. | Need to restructure the value chain (trade, processing industry) |
| Rise in temperature in large waterbodies will result in a different type of fishery. | Develop cooling technology or heat extraction. | | | |
| | catch new fish species. | Adjust technology (fishing gear, boats).These measure will not result in higher fish production. | | |
| Rise in temperature is not relevant for inland fishing. | | | | |
| Higher production level for grasslands related to longer growing season. | Adjust field management | | | |
| Low production levels related to shorter growing season (higher temperatures) | Reduce risk of crop failure by increasing species diversity. Organic farming may be a viable option. | | | |
| Lower mussel production in the Waddenzee, as a consequence of higher temperatures. | New species will also include new pests which could offer new opportunities for new markets. | | | |
| Reducing of production of plaice related to temperature increase. | Start fishing on new species as commercially interesting species are already overfished | | | |

| **Impact** | **Strategy** | **Costs** | **Benefits** | **Spill over** |
|---|---|---|---|---|
| Desiccation of forests. | | | | |
| Salt water intrusion reduction of production or loss of production areas. | Flood low polders and use for floating greenhouses. | | | |
| | Relocate sensitive crops (e.g. tree crops) | | | |
| | Develop salt resistant crops (also for biomass production) | | | biofuels |
| Wet/moist conditions can result in an increase in pests & diseases. | Control of (fungi etc). | | | |
| Increased vulnerability to pest and diseases in forests. | Combine forestry with waterstorage. | | | |
| | Mixed forest stands | Selective logging will increase costs. | ecological richer forest | |
| More and different pests | | | | |
| Damage to crops related to increase in extreme weather events. | Insurance | High premiums. | | |

## 2. Database overview nature sector

| Sub-sector | impacts of climate change | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding, sea level rise, extreme weather events | National Ecological Network (NEN) | Provide space for species, Decrease landscape fragmentation, Increase robustness of the ecosystem | According to the Dutch Government the network should be completed by 2018 and 12 main ecological links will be realized. Currently some initiatives (e.g. PEEN) have been taken in order to establish a wide network of ecological areas within Europe. | Maintain biodiversity, facilitate migration of species, increase robustness of ecosystem | Enhance recreation, improve air quality | 1) The benefits of defragmenting the Veluwe area by creating ecological corridors and removing a factory, were estimated at Dfl. 177 mln./yr (2001). | 1) Contingent Valuation Method and market analysis | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Establishment/ Relocation of protected areas | Provide space for species, decrease landscape fragmentation, Increase robustness of the ecosystem | The Dutch government has proposed and designated protected areas under the EU Birds and Habitats Directives. The government has announced new Habitats Directive areas. | Maintain biodiversity, increase robustness of ecosystem, support the development of the NEN | Enhance recreation, improve air quality | 2) The value of nature (contribution of nature to various public sectors) in the Netherlands is estimated at Euro 13 to 21 blllion/yr (2002). | 2) Contingent Valuation Method , Hedonic pricing and travel cost | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Agri-environmental schemes | Provide space for species, decrease landscape fragmentation, increase robustness | Agri-environmental schemes are supported by the EU (since 1992) | Maintain biodiversity, support the development of the NEN | Reduce soil pollution, improve air quality, enhance recreation | 3)The value of biodiversity is equal to EUR 17.6 mln./yr in het " Groene Hart' (2004) | 3) Contingent Valuation Method | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Artificial plant and animal translocation | Provide habitat for species | Only research activities but no concrete actions | Maintain biodiversity | Commercial use of plants and animals in new areas | 4)The recreational use benefits at " Groene Hart' (gained when nature is "kept" instead of building infrastructure) amount at Euro 848,000 per year (2004) | 4) Tavel cost | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Afforestation | Provide space for species, Decrease landscape fragmentation, Increase robustness | the government plan is to add 40.000 ha of new woodland between 2000 and 2020. New woodland will be managed in a sustainable way and will be developed also in urban areas. | Maintain biodiversity, support the development of the NEN | Enhance recreation, carbon sequestration, timber production | 5) The net benefit from changing an hectare of agricultural land into nature area were estimated at Dfl 309 (2002) | 5) Benefit transfer to estimate the consumer surplus of recreational trips | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Sustainable forest management- Switch from single stands to mixed stands | Increase robustness | According to the NFI in the last years pure conifer stands decreased of 10% in favour of mixed stands. The Dutch Government will support work to ensure that by 2010 globally binding agreements with criteria and indicators for sustainable forestry will be in effect. | Maintain biodiversity | Enhance recreation, carbon sequestration, sustainable timber production | 6) The net value of recreation as a consequence of forest expansion in urban areas was estimated at Dfl. 3,9 mln per year. The value increase of properties related to forests was estimated at Dfl. 2,5 mlm per 100 houses. (1998) | 6) Market analysis, Hedonic pricing | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Sustainable forest management- extension of the average age of trees | Increase robustness | According to the NFI the average age of broadleaf and mixed stands increasing of an average of 10 years. The Dutch Government will support work to ensure that by 2010 globally binding agreements with criteria and indicators for sustainable forestry will be in effect. | Maintain biodiversity | Enhance recreation, carbon sequestration, sustainable timber production | | | |

| Sub-sector | impacts of climate change | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| Water sector | Indirect impacts on the ecosystem due to: drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Integrated water management: Rivers (various adaptation options, see paper) | Combine water management and "nature" (e.g. more species for species) | Possibilities of integrated water management are currently being considered by the Dutch Cabinet ("Spatial Planning key decision") | Increase robustness of the riverine nature, contribute to the NEN | Improvement of the landscape, enhance recreation | 7) The non use value of nature when providing more space of natural river dynamics in the Netherlands is estimated at Euro 75 mln per year; whereas the recreational use value is estimated at Euro 30 mln. per year (2002) | 7) Market analysis, Contingent Valuation Method, Hedonic Pricing Method | |
| Water sector | Indirect impacts on the ecosystem due to: drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | EU water framework directive | Conservation and restoration of natural acquatic, wetland and terrestrial ecosystems that depend on water | In 2000 the EU Water Framework Directive (WFD) was published, obliging all European Community member states to implement effective legislations. | Maintain biodiversity, increase robustness of the ecosystem, support the development of the NEN | Enhance recreation | 8) The annual benefit of keeping natural Rhine functions, which enhance water quality, fish protection and existence value of nature (instead of human development) amount to $ 1.8 billion (2001) | 8) Market analysis and Production Function Method | |
| Water sector | Indirect impacts on the ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Coastal Management: Sand suppletion | More space for nature, enhancing the natural functions of the coastline | ? | Maintain biodiversity, increase robustness of the ecosystem, prevent and-or reduce potential ecological damages due to flooding (e.g. species protection) | Enhance recreation | 9) The natural and cultural landscape value of the Dutch coast resulted in a economic value of Dfl. 1,500 to 9,000 per ha per year (1999) | 9)Contingent valuation method, hedonic pricing, market analysis | |
| Water sector | Indirect impacts on the ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Coastal Management: Artificial reefs in sea | Reduction of the erosion of the coastline | ? | Enhance marine biodiversity prevent and-or reduce potential ecological damages due to flooding (e.g. species protection) | Avoiding investing in sand suppletion | P.M. | | |
| Social sector | All direct and indirect impacts | Monitoring nature | Detecting effects of climate change and the response from the environment | Several organizations all over the world are supporting monitoring activities (e.g. Dutch Phenological Network) | Support the selection of adaptation strategies for nature through the provision of information about the dynamics of the natural system and its reactions to climatic changes | Contributing to the daily planning of farmers, foresters, medical doctors, tourist organizations, nature lovers, photographers, etc. | P.M. | | |
| Social sector | All direct and indirect impacts | New financing mechanisms | Involving enterprises and entrepreneurs in the protection of nature, which can contribute to enhance robustness of the ecosystem | The Dutch government "Agenda for a living countryside" demands support from various stakeholders to contribute to nature development and protection | Enterprises and entrepreneurs can contribute to increase robustness of the ecosystems, maintain biodiversity, contribute to the development of the NEN | Development of a "green" market, which can provide additional benefits for the environment | P.M. | | |
| Social sector | All direct and indirect impacts | Educational programs | Increase public awareness and involving public citizens in the protection of nature, which can contribute to enhance robustness of the ecosystem | Education programs develivered in schools, institutions, or through radio, television, etc. | Citizens can contribute to maintain biodiversity, increase robustness of the ecosystems and make a sustainable use of recreation | Increase responsibility of citizens towards the environment, simplify life style and way of leaving | P.M. | | |

| Sub-sector | impacts of climate change | Adaptation Strategy | Investment costs | Unit Euro | Total investment costs Euro | Other costs | Unit Euro | Total other costs | Total costs |
|---|---|---|---|---|---|---|---|---|---|
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding, sea level rise, extreme weather events | National Ecological Network (NEN) | According to the Ministerie LNV: the costs to implement the NEN (acquisition, construction and management) are: 285 mln.Euro in 2005; 358 mln. Euro in 2006; 384 mln. Euro in 2009 etc. | | | | | | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Establishment/ Relocation of protected areas | Costs include: purchasing of land, research, design, actual implementation, management. | | | | | | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Agri-environmental schemes | Financial assistance given to farmers cover also the costs for nature conservation | | | | | | |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Artificial plant and animal translocation | Costs include: purchasing of land, research, design, actual implementation, management. | | | | | | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Afforestation | Costs include: purchasing of land, site preparation, purchasing, transportation and installation of bedding plants, form pruning and irrigation (if necessary) | | | | | | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Sustainable forest management- Switch from single stands to mixed stands | Costs due to changes in the management | euro/ha | | maintenance costs | Euro/ha | | |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding | Sustainable forest management- extension of the average age of trees | Costs due to changes in the management | | | | | | |
| Water sector | Indirect impacts on the ecosystem due to: drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Integrated water management: Rivers (various adaptation options, see paper) | Costs include: purchasing of land, research, design, actual implementation, management. Completion of a basic package of about forty projects is foreseen for 2015, with a budget of 2.2 billion. | | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Water sector | Indirect impacts on the ecosystem due to: drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | EU water framework directive | Costs for the conservation and restoration of natural acquatic, wetland and terrestrial ecosystems that depend on water | | | | | | |
| Water sector | Indirect impacts on the ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Coastal Management: Sand suppletion | In 2002 the Ministry (V&W) intensified sand supplements, its projected costs amount to Euro 45 million per year | | | | | | |
| Water sector | Indirect impacts on the ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Coastal Management: Artificial reefs in sea | Costs include: research, design, modelling, construction | | | | | | |
| Social sector | All direct and indirect impacts | Monitoring nature | The majority of monitoring organizations are relying on volunteers, therefore the costs are currently low. | | | | | | |
| Social sector | All direct and indirect impacts | New financing mechanisms | P.M. | | | | | | |
| Social sector | All direct and indirect impacts | Educational programs | The costs for delivering educational programs in schools-institutions-etc., writing articles, organizing and making Tv or radio programs, etc. | | | | | | |

| Sub-sector | impacts of climate change | Adaptation Strategy | Prioritisation | Barrier | Opportunities | Actors | Institutional aspects | Positive effects on other sectors | Negative effects on other sectors |
|---|---|---|---|---|---|---|---|---|---|
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to: drought, flooding, sea level rise, extreme weather events | National Ecological Network (NEN) | high | Lack of space, high costs of land, foregone income from alternative land use, uncertainties about the effects, scarce environmental quality within the network, high fragmentation because of motorways, railways and waterways | Protection of species not only within the Netherlands but also in connection with other European country | Env. organization, researchers, ecologists, policy makers, landowners, farmers, managers, control institutions | The government demands more involvement of the private sector (landowners and farmers) however the latter did not provide yet a relevant contribution to the implementation of the NEN. In order to increase the robustness of the NEN, actions are required at a broader, international level. | Forestry, health, insurance, recreation | (reduced space) agriculture, infrastructure, industry |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Establishment/ Relocation of protected areas | high | Lack of space, high costs of land, foregone income from alternative land use, uncertainties about the effects,the isolation of most protected areas makes migration very difficult | | Env. organization, researchers, ecologists, policy makers, landowners, managers, control institutions | There are currently several European ad national agreements: European Natura 2000 Network (EU Birds and Habitats Directives), the Flora and Fauna Act and the Nature Protection Act | Forestry, health, insurance, recreation | (reduced space) agriculture, infrastructure, industry |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Agri-environmental schemes | medium | The procedure to apply for the schemes is too complex, rigid and slow | production of environmental friendly products | EU and Dutch policy makers, farmers, landowners, control institutions | It is necessary to simplify the red tape | Forestry, health, insurance, recreation | (reduced space) agriculture |
| General | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Artificial plant and animal translocation | low | High investment costs, uncertainty about the results | trading opportunities | Researchers, environmental organizations, ecologists, policy makers, managers, control institutions | | Forestry, health, insurance, recreation | not known |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to:drought, flooding | Afforestation | medium | Lack of space, foregone income from alternative land use, risk of fire | New opportunities for timber production and recreation | Policy makers, farmers, foresters, timber industries, managers | | Forestry, health, insurance, recreation | (reduced space) agriculture, infrastructure, industry |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to:drought, flooding | Sustainable forest management- Switch from single stands to mixed stands | medium | Changes in species composition may not be welcome | New market opportunities | Policy makers, foresters, timber industries, managers | Lack of global criteria and indicators for sustainable forestry | Sustainable forestry | Intensive forest production |
| Forest sector | Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. Indirect impacts on the ecosystem due to:drought, flooding | Sustainable forest management- extension of the average age of trees | medium | Forestry income is delayed. | Production of sustainable timber | Policy makers, foresters, timber industries, managers | Lack of global criteria and indicators for sustainable forestry | Sustainable forestry | Intensive forest production |
| Water sector | Indirect impacts on the ecosystem due to:drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Integrated water management: Rivers (various adaptation options, see paper) | high | Lack of space, high investment costs, storage of extra-water may cause degradation of some ecosystems (e.g. less eutrophic semi terrestrial ecosystems) | | Policy makers, ecologists, water managers, researchers | | Safety, insurance, water management, recreation | reduced space for other sectors |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Water sector | Indirect impacts on the ecosystem due to:drought, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | EU water framework directive | high | | | Policy makers, ecologists, water managers, researchers | | Safety, insurance, water management, recreation | |
| Water sector | ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, | Coastal Management: Sand suppletion | high | Lack of space, foregone income from alternative land use | | Policy makers, ecologists, water managers, researchers | | Safety, water management, recreation | reduced space for other sectors |
| Water sector | Indirect impacts on the ecosystem due to: sea level rise, flooding, extreme weather events. Direct impacts on ecosystem due to changes in phenology, distribution, abundance of species, food availability. | Coastal Management: Artificial reefs in sea | ? | The high investment costs | | Policy makers, water managers, ecologists, researchers | | Safety, water management | |
| Social sector | All direct and indirect impacts | Monitoring nature | high | The budget available for monitoring programmes is low, It is important to secure long-term commitment and funding to allocate time and funds to carry out monitoring activities with high standard. | Involving more and more people (volunteers) in monitoring activities | Biologists, researchers, nature lovers, photographers, environmental organizations | | Forestry, health, recreation, agriculture | not known |
| Social sector | All direct and indirect impacts | New financing mechanisms | high | It is not easy to identify what types of environmental services could be financed and whether a market could be created for these services | New market opportunities | All types of stakeholders (e.g. land users, NGO's, insurance companies) that could benefit from "payment/reward for ecosystem services" | The government wants to act as a *facilitator* for the implementation of adaptation strategies, policies and programs. The responsibility of the implementation itself is given to the stakeholders (e.g. land users, managers). | Health, recreation, marketing | not known |
| Social sector | All direct and indirect impacts | Educational programs | high | Some citizens may have resistances (e.g. not believing in climate change) and may be difficult to stimulate and enroll them in the protection of the environment | New educational programs | Environmentalists, teachers, journalists, citizens, etc. | | Education | not known |

## 3. Database overview water sector

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| ***3.1 spatial concepts*** | | | | | | |
| 3.1.1 'Deal with water differently'; 'Water management 21st century' | more emphasis on spatial retention and storage of fresh water before discharge towards sea | General:<br>safe build-up of freshwater reserves during periods of excess precipitation for use during drought periods (agriculture, flushing of salinization, drinking water)<br>strategy offers options for range of economic sectors to survive (multifunctional land use with water as guiding principle)<br>spatial quality for several aims<br>reduction of inundation risks<br>reduction of damage risks<br>reduction of (potential) victims<br>enhancing of nature conservation values (wetland types)<br>enhancing value of livings<br>enhancing recreative values<br><br>Specific:<br>increment of recreative expenditure c. 7 € per daytrip (biking/hiking)<br>but dependent on scale of analysis (regional vs. local benefits), on national scale probably neutral since international tourism unlikely<br>condition: nature (water) area must be attractive for recreation<br>increment of value for livings along water c. 15% (or 2-7% other sources)<br>but dependent on what the previous land use was and on actual view on water | costs of water storage in agricultural areas: include the loss of production for all future generations (not necessarily equal to costs of investment + costs of management and maintenance) (difference between financial and economic analysis); costs water storage, water table lowering, handling of weirs, implementation inline user through radar images; enhancing pump capacities; building Decision Support Systems, financial costs water storage in agricultural land c. 250,000 €/ha; losses of space for traditional and purely terrestrial forms of land use; threat to certain types of nature, either vulnerable to inundations or to influences by foreign water | specify benefits on different levels (individual, local, regional) and different disciplines (socio-economic, societal, spatial, financial, emotional) | ministries of V&W, LNV, VROM, Water Boards, provinces, municipalities, agricultural organisations, nature managers, nature-NGOs | |
| more efficient use of existing storage and discharge capacity by improving operational management of polders; expansion of storage capacity where necessary (e.g. in polders) | lowering of risks of water-caused damages for acceptable costs | | | | | |
| disconnecting of draining ditches from main hydrological system + increase amount of ditches | less local damages | less local damages | € 0.3-0.7 billions total costs for all relevant polders | | Water Boards, municipalities, provinces | |

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| 3.1.2 better spatial policy, based on risk management, i.c. no constructions on lowest, most vulnerable parts | spatial allocation of compartments for different use intensity over territory | maintains investors-friendly conditions | | risk-analysis: risk = sum(probability*effect) | | |
| 3.1.3 widening the coastal defence area (in combination with urbanisation and nature) | | increase of safe feeling for citizens<br>decrease in stress/disquiet among people with respect to inundations<br>willingness to pay generally proves to exceed the costs necessary to provide this feeling of safety | | | | |
| 3.1.4 artificial reefs along the coastline (to reduce wave action) & development nature conservation values | | | | | | |
| ***3.2 technological (partial) solutions*** | | | | | | |
| 3.2.1 adapted forms of building and construction | floating buildings, suburbs or urbanisations;<br>constructing without cellars or crawl spaces;<br>installation of roof gardens on houses or industrial plants;<br>raising infrastructure, ports, industries and urbanisations | maintains investors-friendly conditions | | | | |

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| 3.2.2 re-enforcement of dikes and dams | lowering incidence of inundation | less damages | € 4-8 billions total costs for all relevant dikes | | national authorities, upstream countries (e.g. Belgium, Germany) | |
| 3.2.3 enhancing capacity of sluices and weirs | | | | | | |
| ***3.3 adaptations in social, political and financial attitudes*** | | | | | | |
| 3.3.1 creating public awareness | Dutch citizens become more aware of their vulnerability with respect to water-related threats; they will be more disposed to comply with adaptation strategies; they may become more creative in developing strategies | increase of safe feeling for citizens decrease in stress/disquiet among people with respect to inundations willingness to pay generally proves to exceed the costs necessary to provide this feeling of safety | | | | |
| 3.3.2 new institutional alliances: water boards - municipalities, water boards - private parties (citizens, farmers), international alliances (NL - Germany and NL -China); between municipalities, between | allow authorities and stakeholders alike to act in a more flexible and interactive way in response to climate-related | | costs of institutional transition/ flexibilisation and transactions of new alliances | | ministries, provinces, municipalities, farmers & citizens, urban regions, EU, universities | |

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| towns and countryside (multi-governance) | changes; institutional flexibility: from project management towards process management; flexible aims and targets, different recompensation schemes | | | | | |
| enhancing communication authorities - citizens - private companies | | | | | | |
| development of evacuation plans and providing information on this topic | | | | | | |
| 3.3.3 private insurances against inundations and/or drought-related damages | leveling out of remaining risks | security of households & companies; spread of costs damage reduction by loss-reducing incentives | costs of transaction/adminstration insurance system moral hazard (sensation of safety enhances risk of exposure to damages) | risk-analysis: risk = sum(probability*effect) | insurance branche, authorities | less costs for public sector; more risks for private insurance companies |
| ***3.4 drastic adaptations*** | | | | | | |
| 3.4.1 reclamation of (part of) southern North Sea | decrease of inundation risk for lowest parts near sea | increase of safety low-lying Netherlands; continuation current land use generally possible, including further options for development | long-term costs (2100 and further): 100s of billions of € short-term costs (till 2050): campaigns for public awareness and public support for drastic changes | | | |

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| 3.4.2 abandoning of the whole of low-lying Netherlands; massive migration towards higher eastern parts | strictly terrestrial forms of land use restricted to highest eastern parts; increase in safety; lowering the threat of intrusion by the sea | enhancing safety; adapting spatial use to changing hydrological conditions; opportunities for very large-scale dynamic wetland nature in low parts of Netherlands | | | | |
| ***3.5 examples of application of adaptation strategies*** | | | | | | |
| 3.5.1 Room for the Rivers, Maaswerken, etc. | lower river stretches of Rhine and Meuse are provided with more room to cope with periods of peak river discharges; design-levels for winter dikes become lower due to lower water levels at peak discharges | more safety in river areas during peak discharges, less risks for obligatory evacuations<br>enforcement of dynamic and attractive river landscape<br>opportunities for dynamic riverine nature, recreation, etc. | available budget for Room for the Rivers: € 2.2 billions until 2015<br>Maaswerken: c. € 2 billions (total amount)<br>threat to some particular habitat types (e.g. certain types of river valley grasslands and floodplain forests)<br>threat to several forms of existing floodplain land use (e.g. agriculture, urbanisations, industry)<br>total costs: € 4-6 billions | | ministries, provinces, water boards, municipalities, nature managers, users, nature-NGOs | |

| Adaptation Strategy | Effects | Benefits | Costs | Methodology to estimate monetary benefits | Actors | Spillover effects to other sectors |
|---|---|---|---|---|---|---|
| 3.5.2 enhancing discharge capacity in Afsluitdijk | current water level agreements on lake IJsselmeer can be maintained until 2050 | safety standards along lake IJsselmeer area with present shore defences maintainable until 2050; more time for adapting shore defence Friesland for water levels expected after 2050<br>opportunities for improving fish migration between lake IJsselmeer and Wadden Sea (instalment of fish passage as additional measure); opportunities for smoothening the salt-fresh water transition<br>better control of water level agreement provides better availability of sand banks, e.g. an increase in habitat for certain species | instalment costs € 250 millions<br>better control of agreed water levels results in faster vegetation succession of coastal marshlands and hence some losses of valuable habitat types and species<br>change in spatio-temporal allocation of salt and fresh water in Wadden Sea will cause a shift in spatial species composition of benthic fauna in western Wadden Sea | financial:<br>costs dike re-enforcement/ adaptation infrastructure vs. costs instalment extra discharge sluices<br>ecological:<br>expert judgement based on relationships water level - habitats and species (lake IJsselmeer) and relationships salt gradients - species (Wadden Sea) | RWS, LNV, province of Friesland, professional fishermen, nature managers | |
| 3.5.3 sand suppletions along Dutch North Sea coast | compensates for sand losses from sea defence due to increase of erosion caused by sea level rise | maintenance of legally determined safety level for coastal defence<br>compensation for soil subsidence/ sea level rise with respect to dynamic sand banks and intertidal mudflats in Wadden Sea | initial financial costs several tens of millions € for each one of at least 12 spots + an extra 10% on top of yearly budget for coastal management<br>local losses of benthic fauna due to sand suppletion<br>possible damage for recreative or professional shipping | | RWS, LNV, coastal provinces, recreation-NGOs, nature NGOs | |
| 3.5.4 re-enforcement of 'weak spots' along Dutch coastline | weakest and narrowest stretches of coastal sand dunes are re-enforced;<br>there have been eight such spots identified | lessened risk of breakthroughs from sea<br>possible opportunities for combination of small-scale nature development, e.g. salt water - freshwater transitions in sand dune area | financial costs PM<br>local losses of agricultural land use, e.g. flower bulbs | | RWS, LNV, coastal provinces, recreation-NGOs, nature managers, nature NGOs | |

## 4. Database overview energy sector

| Sub-sector | Impacts | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Insufficient water that can be used for cooling purposes | Adapt regulations such that a higher discharge temperature is allowed | There may be a negative effect on ecosystems due to higher surface water temperatures. | The CIW is currently developing a new, more flexible methodology to deal with discharge of cooling water during hot summers. | Year round stable supply of energy | | EUR 30 per non-delivered KwH (Source: ECN 2002) | Avoided damage costs of power cuts | P.M. |
| Energy | Insufficient water that can be used for cooling purposes | Sluices | | | | | | | |
| Energy | | Lowering the discountfactor for project appraisal to take predicted long-term effects of climate change into account (place a higher weight on these effects) | Future climate change effects are taken more into account when using a lower discount rate, thus projects that are generally being viewed as more sustainable in the long run, become more attractive. | The government will need to decide on a new discount rate to use for project appraisal | Projects for which benefits are not expected in the short, but in the long run, which are usually projects that take long-term projected environmental effects into account will become more attractive when using a lower discount rate | These type of projects are usually viewed as being more sustainable in the long run and put greater weight on environmental and natural concerns. | P.M. | ? | P.M. |
| Energy | Severe winds may increase the risk of damage to windturbines | Building stronger wind turbines | Adapted to avoid damage due to strong winds; generate more sustainable energy | Technical development of stronger wind turbines | Avoidance of purchasing carbon emission permits | Less need for cooling water | P.M. | Valuing at the market-price of carbon emission permits | P.M. |

| Sub-sector | Impacts | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Increased demand for airconditioning and heating | Construct buildings differently in such a way that there is less need for airconditioning/heating | There will be less need for airconditioning or heating | Spatial adjustment and technical development of these new type of buildings | Less demand for cooling/heating | | P.M. | Valuing at the market-price of providing airco and cooling systems | P.M. |
| Energy | Damage to overhead electricity transmission due to wind storms | Constructing more stable overhead electricity transmission | Avoid power cuts and damage to houses/infrastructure | Technical development of stronger overhead electricity builts | Avoided damage due to power cuts and avoided danger of electricity poles coming down during storms. | | P.M. | Avoided damage costs of power cuts and infrastructure | P.M. |
| Energy | Mitigation may affect production processes | Adapt to mitigation strategies | | | | | | | |
| Energy | Increased wind speeds | Improved opportunities for generating wind energy | Generating more sustainable energy; increased flexibility as where to place wind turbines as due to increased wind speeds more locations become profitable | Constructing new wind turbines | Contribute to sustainable energy generation, avoiding purchase of carbon permits | | P.M. | Valueing at the market-price for carbon permits | P.M. |
| Energy | Increased hours of sunshine | Improved opportunities for generating solar energy | Generating more sustainable energy | Development of solar energy farms | Contribute to sustainable energy generation, avoiding purchase of carbon permits | | P.M. | Valueing at the market-price for carbon permits | P.M. |
| Energy | Insufficient water that can be used for cooling purposes | Planting of biomass crops | Change in land use | | Contribute to sustainable energy generation, avoiding purchase of carbon permits | | P.M. | Valueing at the market-price for carbon permits | 2005: reduced $CO_2$ eq. emission of 0.4-0.54 Mton/yr 2010: reduced |

| Sub-sector | Impacts | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | $CO_2$ eq. emission of 1.3-1.7 Mton/yr |
| Energy | Insufficient water that can be used for cooling purposes | Development of cooling towers | Decrease in landscape values; increased noise nuisance, avoided damage to freshwater ecosystems | Construction of the cooling tower | Stable supply of electricity | Avoided damage to ecosystems | P.M. | Avoided damage costs of power cuts | P.M. |
| Transport | Low water levels due to hot summers | | | | | | | | |
| Transport | Increased wind speed leading to more accidents | Development of more 'intelligent' infrastructure (e.g. road and vehicle sensors) that can serve as early warning indicator | Better informed and therefore prepared drivers | Increase knowledge on new types of infrastructural and vehicle design | Less road accidents | | P.M. | Avoided damage to infrastructure and less traffic deaths | P.M. |
| Transport | Increased wind speed leading to less days of fishing at sea | Improvement of vessels | Avoid damage to the fishery sector | Technical construction of safer vessels | Economic gains for fishermen | | P.M. | Valueing at market-prices of fish | P.M. |
| Transport | Flooding leading to a higher level of corrosion of vehicles, trains and infrastructure | Change modes of transport and develop more intelligent infrastructure | Possibly more air traffic or transport over water | Increase knowledge on new types of infrastructural and vehicle design | Safer and more reliable (public) transport | Relief pressure of congested road traffic | P.M. | Avoided costs of delays | P.M. |

| Sub-sector | Impacts | Adaptation Strategy | Effects | Actions to apply the strategy | Direct Benefits | Indirect Benefits | Monetary benefits (unit) Euro | Methodology to estimate monetary benefits | Total Monetary Benefits Euro |
|---|---|---|---|---|---|---|---|---|---|
| Infrastructure | Storm damages to infrastructure | Increase standards for buildings as to make them more robust to increased wind speeds | Improved robustness to increased wind speeds | Increase knowledge on vulnerability of buildings to windstorms; development of these standards | Reduce vulnerability | | Use the model developed by Dorland et al., adjusted to current wind speed predictions and economic growth rate scenarios | see cell H17 | P.M. |

| Sub-sector | Impacts | Adaptation Strategy | Investment costs | Unit Euro | Total investment costs Euro | Other costs | Unit Euro | Total other costs | Total costs |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Insufficient water that can be used for cooling purposes | Adapt regulations such that a higher discharge temperature is allowed | P.M. | P.M. | P.M. | Damage to ecosystems (Non-market valuation) | P.M. | P.M. | P.M. |
| Energy | Insufficient water that can be used for cooling purposes | Sluices | | | | | | | |

| Sub-sector | Impacts | Adaptation Strategy | Investment costs | Unit Euro | Total investment costs Euro | Other costs | Unit Euro | Total other costs | Total costs |
|---|---|---|---|---|---|---|---|---|---|
| Energy | | Lowering the discountfactor for project appraissal to take predicted long-term effects of climate change into account (place a higher weight on these effects) | none | n.a. | none | none | | | |
| Energy | Severe winds may increase the risk of damage to windturbines | Building stronger wind turbines | P.M. | P.M. | P.M. | P.M. | | | P.M. |
| Energy | Increased demand for airconditioning and heating | Construct buildings differently in such a way that there is less need for airconditioning/heating | P.M. | P.M. | P.M. | P.M. | | | P.M. |
| Energy | Damage to overhead electricity transmission due to wind storms | Constructing more stable overhead electricity transmission | | | | | | | P.M. |
| Energy | Mitigation may affect production processes | Adapt to mitigation strategies | | | | | | | |
| Energy | Increased wind speeds | Improved opportunities for generating wind energy | Source to find information on investment costs of wind turbines is CPB (2005) | | | Decrease in landscape/scenic values | | | P.M. |
| Energy | Increased hours of sunshine | Improved opportunities for generating solar energy | | | | | | | P.M. |

| Sub-sector | Impacts | Adaptation Strategy | Investment costs | Unit Euro | Total investment costs Euro | Other costs | Unit Euro | Total other costs | Total costs |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Insufficient water that can be used for cooling purposes | Planting of biomass crops | | | | | | | P.M. |
| Energy | Insufficient water that can be used for cooling purposes | Development of cooling towers | Arcadis | | | | | | P.M. |
| Transport | Low water levels due to hot summers | | | | | | | | |
| Transport | Increased wind speed leading to more accidents | Development of more 'intelligent' infrastructure (e.g. road and vehicle sensors) that can serve as early warning indicator | | | | | | | P.M. |
| Transport | Increased wind speed leading to less days of fishing at sea | Improvement of vessels | | | | | | | P.M. |
| Transport | Flooding leading to a higher level of corrosion of vehicles, trains and infrastructure | Change modes of transport and develop more intelligent infrastructure | Innovative technological design of new infrastructure | | | | | | |
| Infrastructure | Storm damages to infrastructure | Increase standards for buildings as to make them more robust to increased wind speeds | | | | | | | |

| Sub-sector | Impacts | Adaptation Strategy | Prioritisation | Barrier | Opportunities | Actors | Institutional aspects | Positive effects on other sectors | Negative effects on other sectors |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Insufficient water that can be used for cooling purposes | Adapt regulations such that a higher discharge temperature is allowed | high | Increasing the maximum tolerable temperature of cooling water discharge would be relatively easy to implement, a possible barrier could be severe societal opposition due to the possible negative effects on ecosystems | A 'quick fix' meaning that it is a relatively easy to implement solution to deal with severe electricity supply constraints during hot periods | National government; energy generating companies; nature organisations | Regulation on cooling water discharge needs to be adjusted | The industrial, agricultural and service sector will all benefit from a stable power supply | Ecosystems may experience negative effects: species may not be able to survive in warm water; increase of algae bloom |
| Energy | Insufficient water that can be used for cooling purposes | Sluices | | | | | | | |
| Energy | | Lowering the discountfactor for project appraissal to take predicted long-term effects of climate change into account (place a higher weight on these effects) | | There is a risk that when lowering the discount factor, projects become viable that may not be warranted. There is a risk for loss of capital. | Implementation of sustainable projects | The national government; private companies that implement these projects | It may be difficult to justify using a lower discount factor when long-term future effects remain uncertain, and therefore difficult to implement | The ecosystem sector may benefit as this will enhance the chance of having more sustainable projects being approved. Landscape values may be enhanced which may also affect housing prices. | The industry may experience negative effects, for example less roads or dikes may be built |

| Sub-sector | Impacts | Adaptation Strategy | Prioritisation | Barrier | Opportunities | Actors | Institutional aspects | Positive effects on other sectors | Negative effects on other sectors |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Severe winds may increase the risk of damage to windturbines | Building stronger wind turbines | high | | Generate more sustainable energy and relieve the pressure of possible limitations in cooling water supply | The national government; electricity generating firms; private companies that construct these turbines | | | |
| Energy | Increased demand for airconditioning and heating | Construct buildings differently in such a way that there is less need for airconditioning/heating | high | Knowledge constraint on how to develop these buildings | | The national government, local governments, (Technical) Universities, Spatial Planning experts | | | |
| Energy | Damage to overhead electricity transmission due to wind storms | Constructing more stable overhead electricity transmission | high | | | The national and local governments, private companies constructing the electricity poles | | | |
| Energy | Mitigation may affect production processes | Adapt to mitigation strategies | | | | | | | |
| Energy | Increased wind speeds | Improved opportunities for generating wind energy | high to comply with policy on sustainable energy production | | | The national and local governments, private sector, nature organisations | | | It may reduce landscape/scenic values leading to economic losses of recreation areas, housing prices |

| Sub-sector | Impacts | Adaptation Strategy | Prioritisation | Barrier | Opportunities | Actors | Institutional aspects | Positive effects on other sectors | Negative effects on other sectors |
|---|---|---|---|---|---|---|---|---|---|
| Energy | Increased hours of sunshine | Improved opportunities for generating solar energy | high to comply with policy on sustainable energy production | Uncertainty about whether hours of sunshine will really increase | | National government manufacturers of solar energy, consumers | Provision of subsidies to make it more attractive to buy solar energy | | |
| Energy | Insufficient water that can be used for cooling purposes | Planting of biomass crops | high to comply with policy on sustainable energy production | Competition on land that can be used to produce other (food) crops | This adaptation strategy can complement mitigation strategies | National government, farmers, owners of biomass plants | The strategy contributes to meeting the demands of the EC biofuel Directive | Agriculture; production of biomass crops may generate higher returns than producing other crops | Due to increased land use competition food prices may rise |
| Energy | Insufficient water that can be used for cooling purposes | Development of cooling towers | high to prevent electricity shortages similar to summer 2003 | House-owners may object against the building of cooling tower in their vicinity | Generates a stable supply of electricity without compromising ecosystem values | National government, local governments, society | Cooling towers need to comply with noise regulations | Ecosystems and the (fresh) water sector | Landscape values may decrease leading to a drop in house prices and therefore to economic losses |
| Transport | Low water levels due to hot summers | | | | | | | | |
| Transport | Increased wind speed leading to more accidents | Development of more 'intelligent' infrastructure (e.g. road and vehicle sensors) that can serve as early warning indicator | high | High investment costs and a long planning horizon | Development of highly innovative and safe infrastructure | The national government, universities, spatial planning experts, private companies involved in the technical development | | | |

| Sub-sector | Impacts | Adaptation Strategy | Prioritisation | Barrier | Opportunities | Actors | Institutional aspects | Positive effects on other sectors | Negative effects on other sectors |
|---|---|---|---|---|---|---|---|---|---|
| Transport | Increased wind speed leading to less days of fishing at sea | Improvement of vessels | | | | Fishery sector, companies building vessels | | | Possible danger of over-fishing and hence a negative effect on marine ecosystems |
| Transport | Flooding leading to a higher level of corrosion of vehicles, trains and infrastructure | Change modes of transport and develop more intelligent infrastructure | | Long planning horizon and high investment costs | Relief pressure of congested road traffic | | Requires huge changes in spatial planning | More reliable public transport will have a positive effect on the tourist sector as more people will be inclined to go on a journey, leading to economic gains | |
| Infrastructure | Storm damages to infrastructure | Increase standards for buildings as to make them more robust to increased wind speeds | | | | National government, research institutes, construction companies | Requires changes in building laws | | |

# Annex II Workshop – list of participants

### List of participants Workshop 'Klimaatadaptatie in Nederland'

| Titel | Voorletter | Achternaam | Organisatie |
|---|---|---|---|
| Dhr. | J. | Aerts | Faculteit der Aard-en Levenswetenschappen Instituut voor Milieuvraagstukken |
| Dhr. | P. | Baan | WL \| Delft Hydraulics |
| Dhr. | D. | Bal | EC-LNV Directie Kennis |
| Mevr. | J. | Bessembinder | KNMI |
| Dhr. | P. | Bloemen | VROM DG Ruimte |
| Dhr. | G. | Boesjes | Provincie Friesland |
| Dhr. | T. | Bullens | Interpolis |
| Dhr. | H. | de Boois | NWO-ALW |
| Mevr. | K. | de Bruin | Wageningen Universiteit |
| Dhr. | D. | de Groot | Wageningen Universiteit |
| Dhr. | T. | de la Court | COS Nederland |
| Mevr. | F. | de Pater | Programmabureau Klimaat voor Ruimte, VU Amsterdam Climate Centre |
| Dhr. | D. | Dillingh | RIKZ |
| Dhr. | J. | Eshuis | Erasmus Universiteit Rotterdam |
| Dhr. | H. | Haanstra | LNV Directie Natuur |
| Dhr. | J. | Hagens | Bureau Buiten |
| Dhr. | O. | Hoes | TU Delft |
| Dhr. | G. | Jansen | Bosschap |
| Dhr. | A. | Jeuken | RIZA |
| Dhr. | H. | Kampf | EC-LNV Directie Kennis |
| Dhr. | E. | Koot | Bomenstichting |
| Dhr. | P. | Kuikman | Alterra |
| Dhr. | R. | Lasage | Faculteit der Aard-en Levenswetenschappen, Instituut voor Milieuvraagstukken |
| Dhr. | W. | Ligtvoet | MNP |
| Mevr. | C. | Maka | Ministerie van Verkeer en Waterstaat DG Water |
| Mevr. | E. | Nillesen | Wageningen Universiteit |
| Mevr. | I. | Oosting | Provincie Flevoland, afd. EZ |
| Dhr. | M. | Platteeuw | RIZA |
| Dhr. | P. | Rietveld | VU Amsterdam |
| Mevr. | V. | Siebering | De Kleine Aarde |
| Mevr. | M. | Soeters | VROM DG Ruimte |
| Mevr. | V. | Tassone | Wageningen Universiteit |
| Dhr. | G.J. | Ten Napel | Provincie Flevoland, afd. EZ |
| Dhr. | E. | van Ierland | Wageningen Universiteit |
| Dhr. | J. | van Minnen | MNP |
| Dhr. | J. | Verhagen | Plant Research International |
| Mevr. | A. | Weber | Waddenvereniging |
| Dhr. | P. | Wiers | The Climate Group |