GLOBAL CHANGE

Dutch National Research Programme on Global Air Pollution and Climate Change

Integrated assessment of vulnerability to climate change and adaptation options in the Netherlands

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GLOBAL CHANGE

Nationaal Onderzoek Programma Mondiale Luchtverontreiniging en Klimaatverandering (NOP)

Het Nationaal Onderzoek Programma Mondiale Luchtverontreiniging en Klimaatverandering (NOP) bevindt zich thans in de twee fase (1995-2001). De eerste fase, waarin 150 projecten zijn uitgevoerd, liep van 1990 tot 1995. Naar verwachting zullen in de tweede fase uiteindelijk circa 80 projecten worden uitgevoerd. Gezien de aard van het klimaatprobleem is een multi-disciplinaire benadering binnen het NOP noodzakelijk. Het programma is onderverdeeld in vier thema's:

I Gedrag van het klimaatsysteem als geheel en in onderdelen
II Kwetsbaarheid van natuurlijke en maatschappelijke systemen voor klimaatverandering
III Maatschappelijke oorzaken en oplossingen
IV Integratie en assessment

Het primaire doel van het NOP, als strategisch en lange termijn onderzoekprogramma, is te voorzien in de behoefte aan beleidsrelevante informatie voor de ontwikkeling van het nationale en internationale klimaatbeleid. Naast het bereiken van dit inhoudelijke doel, wordt er ook veel belang aan gehecht dat het onderzoek op de langere termijn verankerd zal blijven in de Nederlandse onderzoeksstructuur.
Door het NOP wordt twee maandelijks de (gratis) onderzoeksnieuwsbrief "CHANGE" uitgegeven. Voor meer informatie over het NOP kunt u zich richten tot:

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National Research Programme on Global Air Pollution and Climate Change (NRP)

The National Research Programme on Global Air Pollution and Climate Change (NRP) is currently in its second phase, 1995-2001. The first phase, in which 150 projects were carried out, ran from 1990 to 1995. About 80 projects are expected to be finally realised in the second phase. The nature of the climate problem warrants a multi-disciplinary approach within the NRP. The programme is categorised into four themes:

I Dynamics of the climate system and its component parts
II Vulnerability of natural and societal systems to climate change
III Societal causes and solutions
IV Integration and assessment

The primary objective of the NRP as a strategic and long-term research programme is to meet the demand for policy-relevant information for the development of national and international climate policy. Besides realising this substantive objective, a great deal of importance is attached to the long-term anchoring of the research within the Dutch research structure.
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ABSTRACT

In recent decades, it has become increasingly clear that the global climate is becoming warmer and that regional climates are changing. This report summarizes the results of an integrated assessment of vulnerability to climate change and adaptation options in the Netherlands carried out between July 2000 and July 2001 within the framework of the Dutch National Research Program on Global Air Pollution and Climate Change (NRP-2).

The project's main aims were:

- to provide an overview of scientific insights, expert judgements and stakeholders' perceptions of current and future impacts (positive and negative) of climate change for several economic sectors, human health, and natural systems in the Netherlands, considering various cross-sectoral interactions
- to develop a set of adaptation options for these sectors through a participatory process with the main stakeholders
- to perform an integrated assessment of cross-sectoral interactions of climate change impacts and adaptation options.

Climate change impacts and adaptation options have been investigated for several important economic sectors (including agriculture, forestry, fisheries, industry, energy, transport, insurance and recreation & tourism), human health and natural systems (including soils, water and biodiversity issues)

The results of this study are based on literature survey, a dialogue with experts and stakeholders. We are convinced that the report represents the most essential and relevant aspects of the impacts and adaptation options for climate change in the Netherlands, given the scenario setting of this study, the state of the art of current scientific knowledge, and today's expert and stakeholders' perceptions of the issues at stake.

Projectnummer **952274** rapport nr **410 200 088**

Executive Summary

1 Introduction

In recent decades it has become increasingly clear that the global climate is becoming warmer and that regional climates are changing. This report summarizes the results of an integrated assessment of climate change vulnerability and adaptation options in the Netherlands carried out between July 2000 and July 2001 within the framework of the Dutch National Research Program on Global Air Pollution and Climate Change (NRP-2).

The project's main aims were:

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Climate change impacts and adaptation options have been investigated for several important economic sectors (including agriculture, forestry, fisheries, industry, energy, transport, insurance and recreation & tourism), human health and natural systems (including soils, water and biodiversity issues) (see Figure 1).

For these sectors, both scientific knowledge and stakeholders' perceptions on the impacts and adaptation-options[1] were assessed in order to provide an overview of the main issues at stake, and taking into account leading opinions within sectors. Both the scientific analysis, and the dialogue with the main stakeholders, were based on generally accepted projections for future climate change, and environmental and socio-economic developments for the Netherlands, in the context of Western Europe.

Research methods included:

- *literature review* of the main impacts and adaptation options
- *dialogue* with involved stakeholders based on a *questionnaire* and a *workshop* (March 29-30, 2001)
- *integration framework* on the internet to present the main impacts and adaptation options, and their interactions.

[1] This study did not focus on mitigation policies (such as emission reduction). The NOP COOL project provides an integrated assessment in order to explore long term options for climate change policy in the Netherlands in a European and global context (see interim NOP report by M.M. Berk, L. Hordijk, M. Hisschemöller, M.T.J. Kok, D.Liefferink, R.J. Swart, W.Tuinstra on "Climate OptiOns for the Long Term (COOL) Interim Phase report".

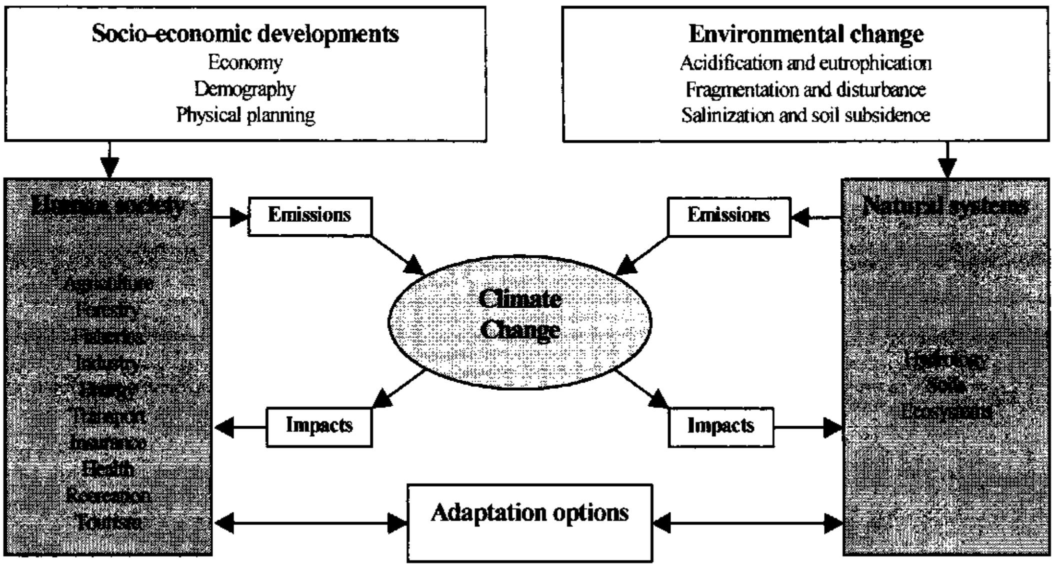

Figure 1. This diagram presents the scenarios and sectors in this study. Activities in both human society and natural systems lead to emissions and climate change. This study presents impacts of climate change on the sectors identified within Human society and Natural systems in the Netherlands and adaptation options to respond to climate change, within the context of a specific set of socio-economic, environmental and climate scenarios till the end of this century.

This Executive Summary presents in section 2 the main results of the literature review and the dialogue regarding sectoral *impacts* including scientific insights and stakeholder' views. Section 3 contains the outcome of the literature review and the dialogue on *adaptation options*, both by sector and cross-sectoral opportunities and constraints. The integration framework is available on internet http://www.dow.wau.nl/msa/nopimpact.htm. Finally, section 4 presents the results of the integration in seven *key issues* in relation to climate change vulnerability and adaptation options in the Netherlands that were identified by this study: (1) Safety, (2) Water availability and quality, (3) Biodiversity, (4) Energy, (5) Food and fiber production, (6) Human health and (7) Land use change and spatial planning.

2 Impacts and risks of climate change in the Netherlands

The impacts of climate change on various sectors were assessed by means of literature review and a dialogue with stakeholders. For each sector (see figure 1) a questionnaire was developed in order to get insight in the stakeholder perceptions on possible impacts (positive and negative) of climate change in the Netherlands. A total of 1300 questionnaires were sent out, and almost 200 were returned (15%), helping to identify the main topics to be discussed in more depth during a workshop with scientists and stakeholders. The questionnaires therefore also included questions on availability and effectiveness of possible adaptation options and cross sectoral interactions regarding impacts and adaptation options (see sections 3 and 4 in this Executive Summary).

A set of commonly used climate, socio-economic and environmental scenarios for the Netherlands, based on the latest scientific insights were presented to create a coherent and consistent starting point of assumptions about the current state of environment and society, and possible future developments. Groups of scientists, policy makers, business-representatives and interest groups were invited to participate in a workshop (March 29-30, 2001) in order to discuss further the issues described above. The main impacts are summarized for the various sectors.

2.1 Natural systems

A broad agreement exists about the sensitivity of the riverine and coastal area in the Netherlands to climate change, with many implications for safety of humans and goods (opinion of policy, experts and interest groups), as well as natural values (opinion of expert and interest groups). The impact of climate change, combined with current trends in urbanization in Europe will lead to considerable changes in biodiversity because the Netherlands is situated in a particular bio-geographical setting with many borders of distribution-ranges crossing the country. Socio-economic pressures on water availability for society (drinking water, irrigation) and natural systems (desiccation) were considered to be important pressures of climate change in general. Environmental issues, like acidification, soil pollution and eutrophication were considered to be less important than climate change in relation to soils and hydrology by actors involved within water management. Actors involved within nature conservation considered other environmental pressures of more importance than climate change. Some respondents indicated that artificial land & water management has more impact on hydrology than climate change has.

2.2 Agriculture, forestry and fisheries

Arable and animal farming are influenced by climate factors in both positive and negative ways. They are sensitive to direct (temperature, precipitation) and indirect effects (pests, water quality). Also, plant production is sensitive to the atmospheric concentration of CO_2 where mostly higher concentration will increase production (fertilisation). Arable farming and forestry will be most negatively affected by drier summers and wetter conditions in autumn and winter (expert opinion). The latter will make later harvest with heavy machinery more precarious. In the low areas, increased saline seepage may reduce productivity and reduce water quality. Agriculture and specifically biological farming may face higher pressures from pests and diseases when temperature and humidity increase. In other sectors, positive (fertilisation effect of carbon dioxide) or neutral impacts override negative effects (stakeholder opinion). Intensive pig farming and horticulture in greenhouses is regarded neutral to climate change. Other external factors such as changes in society and European agricultural policy are more important drivers of changes in the agricultural sector. Agriculture in the Netherlands in particular is expected to follow and not lead the discussion on the restructuring of the rural areas in the Netherlands (expert and stakeholder opinion).

Forest ecosystems may face changes in species composition but sustainable management of the forest resources in the Netherlands for production, recreation and nature is not jeopardized on the short term (20 years). Only if weather extremes (storm) would indeed occur more frequently, forests could face occasional damage and economic loss especially in combination with wetter winter conditions. The expansion of the Dutch forest area is not considered at risk because climate change.

There is also broad agreement that estuaries probably represent the most vulnerable aquatic ecosystem in terms of fishery-production. Higher storm frequency may damage cultures on mussel banks. No major change in the fish production in the North Sea is anticipated, unless radical changes in the North Atlantic circulation will take place simultaneously. The dialogue indicated that the additional problems that climate change may cause for the fisheries are subordinate to the existing management problems of over-exploitation.

2.3 Economic sectors

The most important impacts include (1) damages related to flooding and changes in precipitation (which may have major impact on the agricultural sector, the energy sector, transportation and industry), (2) changes in energy demand (higher energy demand for cooling and a reduction in energy demand for space heating in winter), and (3) increased demand for insurance against the damages of extreme weather events including flooding (expert & stakeholder opinion). For transportation and industry the impacts are expected to be relatively modest, if proper protection against flooding is provided.
However, it was emphasized by the stakeholders, that the impacts of climate change in the Netherlands will be much less significant for the economic sectors (excluding insurance) than the expected impacts of mitigation policies.

2.4 Health and recreation & tourism

Possible important impacts of climate change for human health in the Netherlands are more occurrences of thermal stress mortality, asthma/allergy, vector-borne diseases and water born diseases (expert opinion). Allergy effects were valued by stakeholders as an important health impact of climate change, followed by adverse health effects due to a worsening of the air quality. In general, climate change is considered to be of less importance than other developments that were mentioned by stakeholders (ageing, urbanisation, population growth, economic growth, increasing mobility, disruption of ecosystems and increasing immigration).

Beach tourism is vulnerable to sea level rise. Higher temperatures will probably not lead to more recreation but may lead to a shift in activities and concentration of recreation. Tourism trends are hard to predict and the influence of climate change on tourism is relatively small compared to other determining factors (expert and stakeholder opinion).

3 Adaptation options to climate change in the Netherlands

This section presents the outcome of the dialogue on adaptation options both by sector and their cross-sectoral opportunities and constraints; in some cases differences between scientific insights and stakeholder views are highlighted.

3.1 Natural systems

The main adaptation options identified in this study include:
- more flexible water table management and optimalisation of water retention capacity of soils and ditches (expert, policy & stakeholder opinion within water management)
- accelerated implementation of the ecological network ("more space for nature") (expert & stakeholder opinion within nature conservation)
- increase of water buffering areas/basins ("more space for water"). (policy, expert and stakeholder opinion within water management
- restoration of dynamics with the coastal zone (policy, expert and stakeholder opinion within water management and nature conservation)

3.2 Agriculture, forestry and fisheries

The main adaptation options identified in this study include:
- adjust genotype or variety of crops in agriculture and species in forestry
- crop and rotation choice in agriculture or species choice in forestry
- adjust farm (pests and diseases, soil cultivation, water) or forest (water) management
- better forecast of weather extremes to enable farmers to adjust management
- evaluate planning and location of mussel banks.

The general opinion is that most effects can be dealt with without large structural changes and are part of normal risks related to agriculture. This would be true for forestry as well, though some changes in forest species composition may just have to be accepted as species loss cannot be prevented.

3.3 Economic sectors

The main adaptation options identified in this study include:
- to adapt water management in order to prevent damage to economic sectors
- to adapt infrastructure and real estate to changed climate (e.g. extreme weather events)
- to exploit the opportunities of changed climate for sustainable energy
- to change land use (planning) to allow for water management and sustainable energy

- to improve insurance against the impact of extreme weather events in both public and private sector.

3.4 Health and recreation & tourism

The main adaptation options identified in this study include:
Health:
- long-term efforts to reduce social and economic disparities
- to provide incentives for behavioral change for health aspects (e.g. UV)
- use of technical protective devices
- 'weather-watch' warning systems
- climate-related construction and urban planning.

Recreation & tourism:
- protection of tourist facilities on the coast
- stimulation of alternative tourism and recreational developments that take the expected climatic circumstances in the Netherlands into account
- diversification of tourism.

4 Key issues: integrating vulnerabilities, opportunities and constraints

Based on literature research and expert judgement of a wide variety of stakeholders, a large number of climate change impacts and adaptation options in the Netherlands have been identified in this study (section 2 and 3). Because many elements and processes in human society and in natural systems are closely inter-linked, climate induced impacts and adaptation options in one sector have consequences (positive or negative) for other sectors. To assist decision-making on effectiveness and efficiency of adaptation options, an overview of the many linkages that exist within and between the impacts and adaptation options in different sectors is presented in figure 2. To visualize and identify the many existing interactions, a fully linked and inter-active website was created (www.dow.wau.nl/msa/nopimpact.htm). This website could form the basis for future studies and activities aiming at integration of climate change impacts and adaptation options.

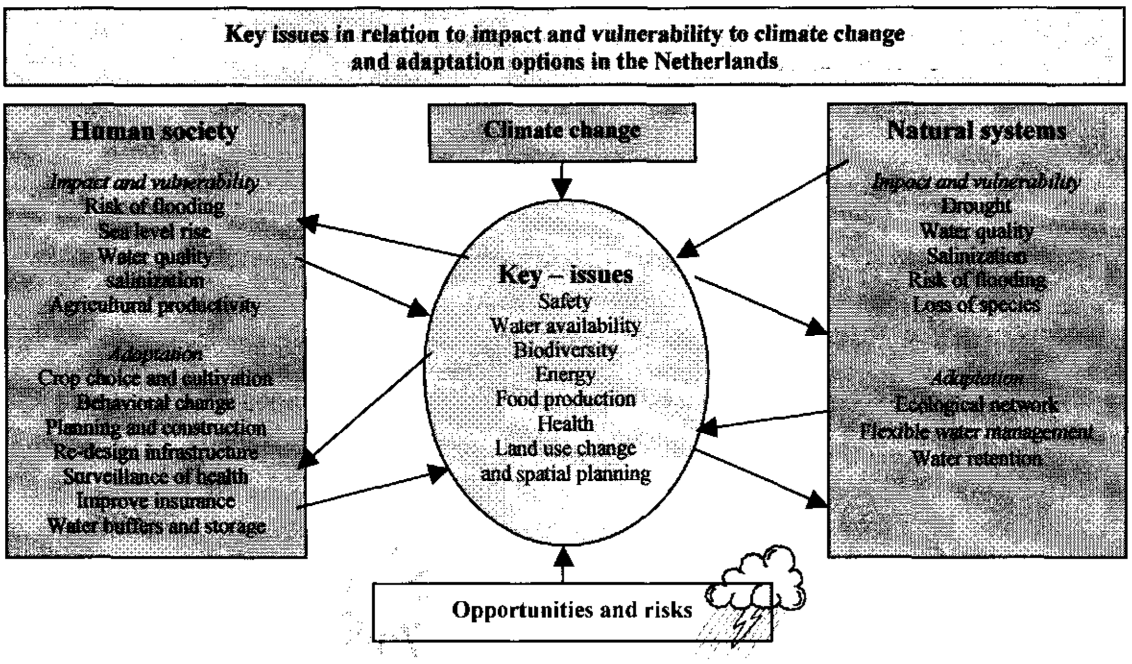

Figure 2 Key issues in relation to impacts and vulnerability to climate change and adaptation options for Human society and Natural systems in the Netherlands. This diagram illustrates some of the impacts and adaptations that were identified within 'Human society' and 'Natural systems' and how they translate into seven key issues where adaptation is considered by a forum of scientists and stakeholders. The diagram further illustrates that many interactions were identified with climate change and opportunities and risks.

To provide more detailed insight in the many interactions that occur between climate change impacts and adaptation options, the seven key-issues that were identified by this integrated assessment study are discussed below: (1) Safety, (2) Water availability and quality, (3) Biodiversity, (4) Energy, (5) Food and fiber production, (6) Human health and (7) Land use change and spatial planning.

4.1 Safety in the coastal zone and riverine areas

Riverine and coastal areas are the regions in the Netherlands most vulnerable to climate change through changes in precipitation and sea level rise. Flooding may cause casualties and economic damages. The cost of current safety and protection measures are already high and will increase in the near future. In the river valleys of the Meuse, Rhine, and Scheldt, the frequency of both high and low water will increase. Low waterflow events are relevant for various human activities such as drinking water exploitation, agricultural water use, cooling, industrial use and inland transport over water. Natural systems may benefit at the expense of agricultural activities if natural hydrological dynamics are re-established, but some negative impacts related to reduced water quality may occur.

4.2 Water availability and quality

Changes in precipitation regime (quantity and distribution) will have impact on water availability in many parts of the Netherlands. Higher areas will experience more intense and prolonged summer drought and water shortage. In the lower parts of the Netherlands, higher runoff in spring may cause problems as risks of flooding following intense rainfall are higher. Sea level rise may result in salinisation of the groundwater resources in the low lying coastal areas, with negative consequences for crop production and natural values (some stakeholders within nature conservation) assume also positive impacts: mitigation of impacts of the large engineering works for coastal defense in the 20th century.

Accumulating pressures of climate change and socio-economic water demand may induce changes in ecological processes, and affect biodiversity in coastal saltwater marshes in the lower parts of the Netherlands, and along the rivers in the higher parts of the Netherlands. This can have negative consequences for some species but also provides opportunities as water management in large areas will be less strictly regulated and natural ecosystems may develop or redevelop.

4.3 Biodiversity

Climate plays a crucial role in the distribution of plants and animals, and the expected changes in climate will have large consequences for natural ecosystems and biodiversity in the Netherlands. The main impacts are to be expected from changes in growth rate and competition, life-cycles (phenology), species migration, storm & fire damage, pests and diseases, and hydrological changes (desiccation, flooding, salinization). Although some species may benefit from climate change, others will suffer, partly because of the expected high rate of climate change, but also because other human influences such as. landscape fragmentation and eutrophication. The latter enhance the stress that climate change places on species already threatened. Adaptation measures should therefore focus on both creating conditions under which species have sufficient space to adapt, and measures aimed at reducing other threats to ecosystems (disturbance, acidification, eutrophication, introduced species or drought).

Some changes in species composition in ecosystems (i.e. forests) seem inevitable. Views among stakeholders and scientists differ with respect to whether the consequences are all negative or whether ecosystems will adapt and change gradually. All agree that the establishment of more robust structures such as an (international) ecological network may help ecosystems and species to overcome and recover from adverse effects of extreme events such as storms, floods, late frosts and droughts. However, they disagree on whether a structure such as the ecological network will enable species whose migration rate is low to follow the expected rapid climate change.

4.4 Energy

The climatic impacts on total energy consumption are likely to be less significant than the impacts of economic growth or major shifts in societal trends, e.g. individualization, aging population or globalization. In relation to temperature rise the energy required for cooling and space-heating systems is an important issue. The most important impact on the energy sector in relation to changed precipitation patterns and sea level rise is increased energy demand within coastal zone management (pumping capacity of water towards the sea) and water management on field scale (irrigation practices in agriculture), provided that sufficient protection against flooding is sustained. Adaptation to sea level rise and changed precipitation is possible at considerable cost for government and individual citizens.

Many opportunities to combine renewables with nature conservation and human health improvement were identified, such as clean biomass technologies.

4.5 Food and fiber production

It is normal agricultural practice that farmers manage their agro-ecosystems to deal with the day to day variation in weather. As such, agricultural shifts are likely as the climate changes and farmers will select new crop varieties and species that are better adapted to new climatic conditions. Farm-level adaptation strategies (planting and harvest dates, corp rotation and irrigation) are expected to be incorporated relatively easy. Necessity and cost of crop protection may increase. Dutch farmers are expected to successful in adaptation given that they have adequate technical training and financial resources. However, current scientific insight in occurrence and frequency of extreme weather events and its consequences such as droughts, floods, frosts, pests or diseases is limited. This restricts an ecological and economic assessment of damage and costs.

Agricultural production depends on the availability of sufficient quantities and good quality of water. Agricultural stakeholders view saline water intrusion, excess winter discharge and limited availability of land for buffering as a critical issues in climate change for agricultural production.Adaptation options for farmers depend on the regional availability of additional water for irrigation or flushing out saline water. Thus, farm level adaptation strategies to climate change will interact with regional issues on land and water (see 4.2) claims in other sectors and regions, such as upon relocation of entire farms and other agricultural enterprises.

Current national and European agricultural policies do strongly influence the adaptation agenda of the farmers. Climate change, shifts in crop choice and farm management options may conflict with other environmental goals, such as restricting fertilisation, irrigation, timing of soil management or leaching. To allow farmers to adapt, other policies may require to be reconsidered in the light of climate changes. The adaptation capacity is determined by financial (profitability of activities), technological (availability of adapted crop varieties) and knowledge aspects (knowing the consequences of choices and changes in management). Some of these depend on decisions by farmers themselves and financial institutions, but others depend on decisions by policy makers and industries.

4.6 Health: direct and indirect impacts of temperature change

Global climate change is likely to influence human health in various ways. Although some effects may be beneficial, most are expected to be adverse. Some impacts would occur via direct mechanisms (e.g. morbidity and mortality related to thermal stress); others would occur through indirect mechanisms (e.g. transmission of vector-borne diseases). If long-term climate change does occur, the indirect impacts would probably predominate. Different populations, with varying levels of natural, technical or social resources, would differ in their vulnerability to the health impacts. Health impacts in other parts of the world, with limited resources to react to climate change, are therefore likely to be more severe than those of the Netherlands. Nevertheless, the Dutch population will also experience the effects of climatic change. An increased mortality due to increasing numbers of heatwaves is to be expected. Mortality associated with cold spells, particularly hypothermia in the elderly, is likely to decrease with climate change. Furthermore, climate change is likely to change the seasonality of pollen-related disorders such as hayfever, and increase the risk of outbreaks of certain infectious diseases.

4.7 Land use change and spatial planning: competition for space

Socio-economic growth (welfare, population numbers) is the primary pressure on the availability and utilisation of space in the Netherlands. There was a broad agreement within the dialogue that climate change will further increase the pressure on land (and water), since many of the adaptation options require additional space. This, however, does not only cause problems but also offers opportunities for a more sustainable and multi-functional spatial planning.

The areas of the Netherlands most exposed to impacts of climate change are the coastal zone and river-valleys, and most of the space claims related to climate change adaptation in the Netherlands are related to water management. This implies that some activities that have to give way for additional measures in water management may require relocation and so interfere with other local or regional land use.

Adaptation to climate change through physical planning, water management, infrastructure development and land use may facilitate policies to mitigate the impacts of climate change. For example, the further development of ecological networks is not only an opportunity for adaptation of species and ecosystems, but also may enhance mitigation measures to climate change by increasing the carbon-sink function of natural areas.

As a result of changes in the climate in the Netherlands, more recreational facilities may be needed, requiring more space. Farmers may benefit economically as more recreation and tourism occurs in the countryside in the future.

During the last decade admirable achievements have been made with integrated water management and physical planning in the Netherlands. The link between climate change and physical planning asks for a further integration between spatial planning policies (agricultural land use, infrastructure & urban development), water and nature management policies and policies in relation to the climate change mitigation and air quality issues.

5 Conclusions

Within these key-issues many of the identified impacts and adaptation options for the Netherlands are related to water and either water shortage, excess water discharge or rainfall or water quality e.g. salinization. The Netherlands is a low area situated in a delta and relative to sea level low area, is particularly vulnerable to changes in precipitation and sea level rise. Both water, land and biodiversity are identified as the crucial factors in adapting to climate change in the Netherlands in the 21^{st} century. Many effective adaptation options are available and recognized by stakeholders in the Netherlands. Though some may be easy to achieve, others will be expensive and/or require additional space in a highly competitive market with high prices for land, e.g. measures to increase water storage or water retention and combat increased drainage and salinization. It is therefore essential to anticipate climate change and to introduce adaptive measures in an early stage in order to avoid excessive damages or increased implementation cost of adaptation in case of late responses. This may be difficult to achieve as it may be necessary to take adaptive measures well before stakeholders or civilians will recognize risks or actually experience damage. It is crucial to develop early warning systems based on clear indicators of climate change or its effects.

6. Concluding remarks

This report dealt with the main impacts of climate change and adaptation options for the Netherlands. For the interpretation of the results it is essential to consider that the impacts and adaptations options have been based on a specific set of scenarios for economic development and climate change till the end of this century. The results of the study are only valid within the context of these scenarios, and its is important to note that the impacts may be completely different, if the pattern of climate change turns out to be less gradual and more hectic or more substantial than assumed in the climate scenario of this study.

The results of this study are based on literature survey and a dialogue with experts and stakeholders. We are convinced that the report represents the most essential and relevant aspects of the impacts and adaptation options for climate change in the Netherlands, given the scenario setting of this study, the state of the art of current scientific knowledge, and today's expert and stakeholders' perceptions of the issues at stake.

Samenvatting

1 Inleiding

Ons klimaat verandert en de mens beïnvloed die verandering. Het *Intergovenmental Panel on Climate Change* (IPCC) stelt, in haar meest recente rapportage[2], dat de *mondiale* temperatuurstijging zal doorgaan en tussen de 1,4 en 5,8 °C zal liggen aan het einde van deze eeuw. Voor de gematigde en noordelijke streken van het noordelijk halfrond wordt ook een toename in de neerslag verwacht. De zeespiegel stijgt en de frequentie van weersextremen verandert. Omdat klimaatverandering zich niet overal op dezelfde manier zal uiten is het zinvol antwoord te krijgen op vragen zoals: welke systemen zijn het meest kwetsbaar voor klimaatverandering, welke groepen of regio's zullen het zwaarst getroffen worden en wat zijn de aanpassingsmogelijkheden van deze systemen en groepen?

Verschillende landen maar ook op Europees niveau hebben studies gedaan om de mogelijke gevolgen van klimaatverandering in te schatten. Ook in Nederland is een dergelijke studie uitgevoerd en dit is een samenvatting van het rapport van die "*Integrale analyse van kwetsbaarheid voor klimaat verandering en aanpassingsmogelijkheden aan klimaatverandering in Nederland*" uitgevoerd in het kader van het Nationaal Onderzoek Programma Klimaatverandering en Luchtverontreiniging (NOP 2). Het ging hierbij niet enkel om een wetenschappelijke overzicht maar betrof ook de percepties van belanghebbende.

De doelen van het project waren:

- Een overzicht geven van de wetenschappelijke inzichten, meningen van deskundigen en inzichten en perceptie bij belanghebbenden van huidige en toekomstige positieve en negatieve effecten van klimaatverandering voor economische sectoren, gezondheid en natuurlijke systemen in Nederland (zie figuur 1)
- Een lijst van mogelijkheden voor aanpassing in deze sectoren ontwikkelen in een participatief proces met de belangrijkste belanghebbenden en rekening houdend met interacties tussen sectoren
- Een integrale analyse uitvoeren van interacties tussen sectoren voor effecten van klimaatverandering en aanpassingsmogelijkheden

Voor deze sectoren is zowel wetenschappelijke inzicht als inzicht en perceptie van belanghebbenden en de leidende meningen over effect en aanpassingsmogelijkheden[3] beoordeeld en in een overzicht van de belangrijkste

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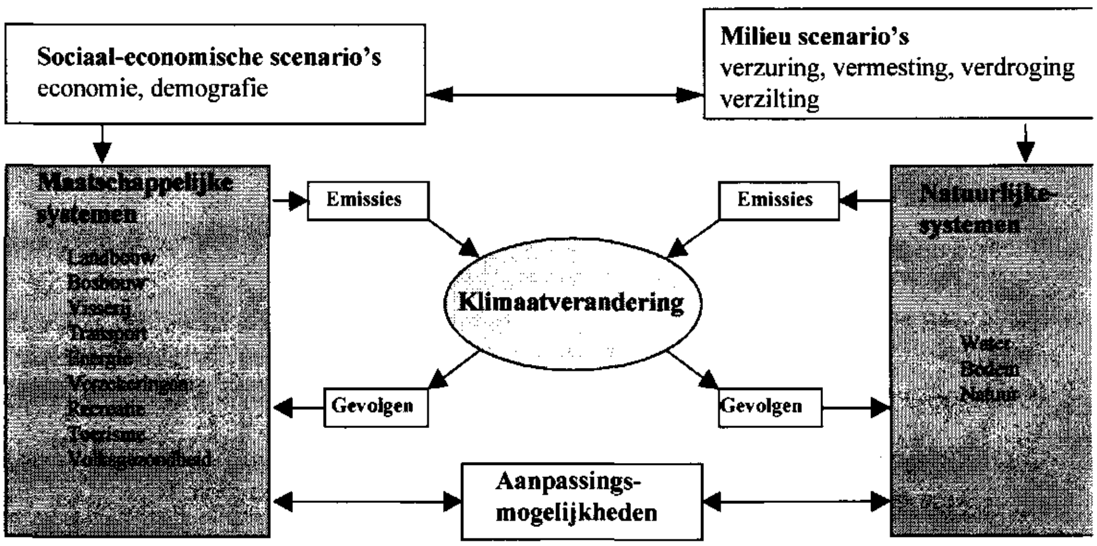
[2] IPCC Climate Change 2001: The Scientific Basis

[3] Dit project onderzocht effect van en aanpassing aan klimaatverandering en niet beleid gericht op voorkomen (mitigatie) van klimaatverandering. Het NOP project COOL (Climate OptiOns for the Long term) heeft een integrale analyse van de mogelijkheden voor klimaatbeleid gericht op voorkomen van klimaatverandering op de lange termijn in Nederlandse, Europese en mondiale context gemaakt (zie NOP rapport van Berk et al., 2000, Climate Options for the Long Term (COOL), Interim Phase Report

onderwerpen geplaatst. Bij de wetenschappelijke analyse en in de dialoog met belanghebbenden is uitgegaan van aanvaarde beelden van de toekomstige klimaatverandering en van de economische en milieuontwikkelingen voor Nederland. Het klimaatscenario voor Nederland dat in beginsel voor alle NOP projecten is gebruikt is gebaseerd op data van het Hadley Centre in Engeland. Op basis van deze gegevens wordt een temperatuurverhoging van circa 2,5°C voorspeld en kleine verschillen in de totale hoeveelheid jaarlijkse neerslag in Nederland waarbij zomers droger en winters natter worden. Er wordt een zeespiegelstijging van 0,2 – 0,9 meter verwacht in deze eeuw.



Figuur. 1. De relaties tussen scenario's, klimaatverandering en maatschappelijke en natuurlijke systemen met de onderscheiden sectoren in deze studie

De onderzoekmethode omvatte:

- *Literatuuronderzoek* van de belangrijkste effecten van klimaatverandering en aanpassingsmogelijkheden
- *Dialoog* met belanghebbenden op basis van een vragenlijst en enquête en een workshop
- *Integratie raamwerk* op het internet om inzicht in de belangrijkste effecten en aanpassingsmogelijkheden en hun interacties te geven

Deze samenvatting gaat achtereenvolgens in op de resultaten van het literatuuronderzoek en de dialoog over effecten van klimaatverandering en meningen van wetenschap en belanghebbenden (sectie 2), op de resultaten van literatuuronderzoek en de dialoog over aanpassingmogelijkheden (sectie 3) en op de resultaten van de integratie waarbij een aantal sleutelonderwerpen worden besproken (sectie 4). Het integratie kader is beschikbaar via internet (http://www.dow.wau.nl/msa/nopimpact.htm).

2 Effecten en risico's van klimaatverandering in Nederland

In de analyse van effecten van klimaatverandering op verschillende onderdelen van de Nederlandse economie, gezondheid en natuurlijke systemen werd gebruik gemaakt van wetenschappelijke literatuur en inzichten van deskundigen en van een dialoog met belanghebbenden. Inzichten over positieve en negatieve effecten van klimaatverandering en over perceptie daarvan bij belanghebbenden werden verkregen via een enquête en via een workshop. Er zijn 1300 enquêtes verstuurd waarvan er 200 zijn ingeleverd (15%). Uit de antwoorden zijn onderwerpen geselecteerd die in discussie zijn gebracht op een workshop waaraan wetenschappers en belanghebbenden hebben deelgenomen. Voor de enquête en workshop is een set van scenario's over ontwikkelingen op economisch, milieu en klimaat gebied ontwikkeld om een gemeenschappelijk en coherent startpunt voor de discussie te creëren.

2.1 Natuurlijke systemen

Er is grote overeenstemming dat kust en rivieren in Nederland kwetsbaar zijn bij klimaatverandering en er gevolgen zullen zijn voor veiligheid van mensen en goederen en voor natuurlijke systemen en waarden. Er worden aanzienlijke veranderingen in biodiversiteit voorzien ook in Nederland. Vanuit de samenleving wordt belangrijke druk uitgeoefend op waterbeschikbaarheid (drinkwater en beregening) en natuur (anti-verdroging) die wordt beïnvloed door klimaatverandering. Milieuaspecten zoals verzuring, bodemverontreiniging en vermesting worden als minder belangrijk beoordeeld dan klimaatverandering voor bodem en waterhuishouding door belanghebbenden in waterbeheer. Natuurbeheerders beoordelen overige milieuaspecten als belangrijker dan klimaatverandering. Een aantal deelnemers is van mening van de menselijke invloed op land en waterbeheer een grotere invloed heeft op de hydrologie in Nederland dan klimaatverandering.

2.2 Landbouw, bosbouw en visserij

Landbouw heeft een directe relatie met weer en klimaat en in de landbouw worden zowel positieve als negatieve effecten verwacht. De voornaamste effecten worden verwacht in akkerbouw en veehouderij. Drogere zomers kunnen leiden tot oogstderving en een natter voorjaar en herfst hebben een nadelig effect op de grondbewerking en op de oogstbaarheid van gewassen. Een toename van de verzilting in laag Nederland leidt tot lagere productie. Met name de biologische landbouw zal een grotere ziekten- en plagendruk ondervinden bij toename van temperatuur en vochtigheid. In gesloten teelten en intensieve veehouderij worden geen of positieve effecten verwacht. Bosbouw zal schade ondervinden als gevolg van drogere zomers en bij hogere frequentie van stormen in combinatie met nattere winters. De soortensamenstelling in het bos kan op termijn veranderen. Op korte termijn wordt geen nadelig effect voorzien op duurzaam beheer van Nederlands bos en bosuitbreiding in Nederland is goed mogelijk. In de visserij is algemeen erkend dat de estuaria het meest kwetsbaar zijn voor klimaatverandering en mogelijk schade ondervinden in visproductie. De mosselbanken zijn kwetsbaar bij hogere stormfrequentie. Er wordt geen schade aan de visproductie in de Noordzee voorzien.

2.3 Economische sectoren

De belangrijkste effecten zijn: (1) economische schade als gevolg van overstroming en veranderingen in neerslag met invloed op landbouwproductie, energie, transport en industrie, (2) veranderingen in de vraag naar energie (meer energie voor koeling en minder voor verwarming) en (3) toename van de vraag naar verzekeringsmogelijkheden van schade als gevolg van extreme weers-omstandigheden zoals overstromingen. In transport en industrie zijn de effecten relatief gering mits voldoende bescherming tegen overstroming wordt geboden. Belanghebbenden brachten verder naar voren dat de effecten van klimaatverandering voor economische sectoren en activiteiten kleiner zijn dan de gevolgen van klimaatbeleid dat is gericht op voorkomen van klimaatverandering.

2.4 Gezondheid en recreatie & toerisme

De mogelijke gevolgen van klimaatverandering voor de gezondheid van mensen in Nederland aldus deskundigen zijn: toename van sterfte als gevolg van warmtestress, van astma en allergie, vector gebonden ziekten en water gerelateerde ziekten. Door belanghebbenden werden allergieën als belangrijkste effect van klimaatverandering beoordeeld, gevolgd door effecten op gezondheid als gevolg van slechtere luchtkwaliteit. Over het algemeen beoordelen belanghebbenden de effecten van klimaatverandering als minder belangrijk dan gevolgen van ontwikkelingen zoals vergrijzing, verstedelijking, bevolkingsgroei, economische groei, mobiliteits-toename en verstoring van ecosystemen en toename van migratie.

Strandtoerisme is kwetsbaar voor stijging van de zeespiegel. Hogere temperaturen leiden waarschijnlijk niet tot meer recreatie maar wel tot verschuivingen van activiteiten en patronen van recreëren. Trends in toerisme zijn moeilijk te voorspellen en de invloed van klimaatverandering is relatief klein ten opzicht van het effect van andere factoren aldus belanghebbenden.

3 Aanpassingsmogelijkheden aan klimaatverandering in Nederland

3.1 Natuurlijke systemen

De belangrijkste aanpassingsmogelijkheden die werden geïdentificeerd in deze studie zijn:

- Flexibeler beheer van grondwaterpeil en optimalisering van de capaciteit van om water vast te houden van bodems en sloten (deskundigen, beleidsmakers en belanghebbenden in waterbeheer)
- Versnellen van de aanleg van de Ecologische Hoofd Structuur (meer ruimte voor natuur) (deskundigen en belanghebbenden in natuurbeheer)
- Toename van de opslagcapaciteit van water in bekkens en gebieden (meer ruimte voor water) (deskundigen, belanghebbenden en beleidsmakers in waterbeheer)
- Herstel van de dynamiek in de kustgebieden (beleidsmakers, deskundigen en belanghebbenden in waterbeheer en natuurbeheer)

3.2 Landbouw, bosbouw en visserij

De belangrijkste aanpassingsmogelijkheden die werden geïdentificeerd zijn:

- Aanpassen van de keuze van gewas of rotatie in de landbouw of van soorten in bosbouw
- Wijzigen van bedrijfsvoering op landbouwbedrijven (ziekten en plagen, bodembewerking, water) en bosbeheer (water)
- Betere en tijdige voorspelling van het optreden van extreme weersomstandigheden om boeren in de gelegenheid te stellen de bedrijfsvoering aan te passen
- Heroverwegen van de plannen en locatie van mosselbanken

De overheersende mening bij deskundigen en belanghebbenden is dat de meeste effecten kunnen worden ondervangen zonder omvangrijke structurele maatregelen op landbouwbedrijven en dat de noodzakelijke aanpassingen onderdeel zijn van de normale risico's die samenhangen met het bedrijven van landbouw. Dit gaat in feit ook op voor bosbouw, hoewel sommige veranderingen in de soortensamenstelling van bossen moeten worden geaccepteerd omdat zij niet kunnen worden voorkomen.

3.3 Economische sectoren

De belangrijkste aanpassingsmogelijkheden die werden geïdentificeerd zijn:

- Aanpassen van het waterbeheer om schade aan economische activiteiten te voorkomen
- Aanpassen van infrastructuur en gebouwen aan veranderingen van klimaat en extreme weersomstandigheden
- Uitbuiten van mogelijkheden die veranderingen in het klimaat bieden voor duurzame energie
- Veranderen van de planning van het landgebruik om waterbeheer en duurzame energie mogelijk te maken
- Verbeteren van de verzekeringsmogelijkheden tegen schade van extreme weersomstandigheden in publieke en private sector

3.4 Gezondheid en recreatie & toerisme

De belangrijkste aanpassingsmogelijkheden die werden geïdentificeerd zijn:

- Verkleinen van sociale en economische ongelijkheid
- Gedragsverandering stimuleren in relatie tot gezondheid (UV straling)
- Toepassing van technische maatregelen ter bescherming (dijken)
- Waarschuwingssystemen voor weersextremen
- Klimaatgericht bouwen en plannen van steden
- Bescherming van toeristische attracties aan de kust
- Stimuleren van alternatieven voor toerisme en recreatie die inspelen op veranderingen van klimaat in Nederland
- Diversificatie van toerisme

Een overzicht van de gevolgen en effecten van klimaatverandering (sectie 2) en de aanpassingsmogelijkheden (sectie 3) zijn in tabel 1 samengevat voor de onderscheiden sectoren in Nederland (tabel 1).

Tabel 1 Gevolgen van klimaatverandering met mogelijke aanpassingsmogelijkheden voor Nederland.

	Gevolgen van klimaatverandering	Aanpassingsmogelijkheden
Natuurlijke systemen (water, bodem, natuur)	Droge periodes.	Flexibel waterpeilbeheer en optimaliseren van waterretentie in de stroomgebieden.
	Toename hoogwater in rivieren.	Aanleg waterbekkens, ruimte voor water. Dijkverzwaring.
	Zeespiegelstijging	Kustverdediging via harde en zachte structuren.
	Omgeving ongeschikt voor huidige natuur.	Versnelde invoering EHS, ruimte voor natuur. Natuurbeeld aanpassen.
Landbouw	Droge periodes	Aanpassing van de beschikbare rassen en variëteiten is gewenst (droogte tolerantie, grotere stressbestendigheid).
	Nattere periodes	Aanpassen plant- en oogstdata. Verplaatsen van bedrijven.
	Verzilting.	Verplaatsing van bedrijvigheid bij zoutschade in laag Nederland. Aanpassing van de beschikbare rassen en variëteiten is gewenst (zouttolerantie, grotere stressbestendigheid).
	Schade aan gebouwen en gewassen.	Afsluiten van verzekeringen.
Bosbouw	Stormschade	Risicospreiding en verhogen van de veerkracht door verhogen van genetische- en soortendiversiteit van het bos.
	Omgeving ongeschikt voor huidige boomsoorten.	Acceptatie van zekere veranderingen in soortensamenstelling en waardering voor 'nieuwe' natuurwaarden.
Visserij	Verstoring zoet-zout gradiënt	Spuiregimes aanpassen.
Transport, Energie en Verzekering	Toename aantal zonne-uren tijdens de zomer maanden.	Faciliteren en zonne-energie.
	Hoogwater in rivieren.	Aanpassingen aan waterbeheer. (ruimte voor water)
	Schade aan infrastructuur	Aanpassingen aan de infrastructuur, dijken, wegen en spoor.
	Toenemende vraag naar verzekeringen	Aanpassen polissen en verzekeringswezen
Volksgezondheid	Toename in hitte-gerelateerde sterfte en allergieën	Waarschuwingssystemen. Adequate gezondheidszorg.
Recreatie	Zonniger zomers met korte periodes van intensieve neerslag.	Diversificatie in aanbod.

4 Sleutelonderwerpen en integratie van kwetsbaarheid, kansen en mogelijkheden

Op basis van literatuuronderzoek en meningen en perceptie van deskundigen en van belanghebbenden is een overzicht gepresenteerd van effecten, kwetsbare onderdelen en ongewenste verstoringen van natuurlijke en maatschappelijke systemen in Nederland. Effectieve en reële aanpassingsmogelijkheden zijn geïdentificeerd voor verschillende sectoren. Effecten en aanpassingsmogelijkheden zijn soms sectorgebonden maar vaak zullen effecten en aanpassingsmogelijkheden in een sector ook invloed hebben op andere sectoren. Deze interacties hebben soms een negatief en soms een positief karakter. Deze studie maakt duidelijk dat met name de sectoren natuur, water en landbouw kwetsbaar zijn en als eerste de gevolgen zullen ondervinden. Maar ook in transport en gezondheid worden effecten verwacht en verder neemt de vraag naar verzekeringen toe. Niets doen is voor de meeste sectoren dan geen optie. Om inzicht, afweging en besluitvorming over effectiviteit van aanpassingen in verschillende sectoren te vergroten en te ondersteunen is een interactieve internet pagina (www.dow.wau.nl/msa/nopimpact.htm) met een overzicht van effecten en aanpassingsmogelijkheden gemaakt. Hier worden ook de vele interacties en zichtbaar gemaakt. Deze internet pagina kan worden gebruikt als basis voor het definiëren van toekomstige studies en activiteiten die zijn gericht op de integratie van effecten van en aanpassingsmogelijkheden aan klimaatverandering.

De belangrijkste knelpunten waar kwetsbaarheden zichtbaar worden en de belangen van verschillende sectoren samenkomen zijn voor Nederland niet moeilijk te duiden. In deze studie zijn 7 sleutelonderwerpen geïdentificeerd uit de vele invloeden en interacties die het gevolg zijn van klimaatverandering in Nederland (tabel 2).

Tabel 2. Sleutelonderwerpen (v) en interacties(+) voor zeven hoofdpunten zoals naar voren gekomen uit de interactie met de belanghebbenden.

	Sector			
Sleutelonderwerpen	**Natuurlijke systemen**	**Landbouw, bosbouw & visserij**	**Transport, energie en verzekeringen**	**Gezondheid, recreatie en toerisme**
Veiligheid	V	+	V	V
Waterbeschikbaarheid en –kwaliteit	V	V	V	+
Biodiversiteit	V	+	+	+
Energie	+	+	V	
Voedselproductie en grondstoffen	+	V	+	+
Gezondheid		+	+	V
Competitie voor ruimte	+	V	V	V

Veiligheid en water zijn hier de bepalende factoren. Deze rode draad is, voor Nederland, niet nieuw. Andere punten zoals volksgezondheid, biodiversiteit en voedselproductie zijn gekoppeld en zeker niet onbelangrijk. De verschillende aspecten van de problematiek en oplossingsrichtingen komen samen in de ruimtelijke ordening. Door deze verwevenheid zullen ingrepen in een sector direct gevolgen hebben voor een andere sector. Van belang is nu deze interacties te identificeren (zie tabel 2) en waar mogelijk positieve terugkoppeling te stimuleren en negatieve effecten te neutraliseren.

5 Conclusies en slotopmerkingen

De meeste effecten en aanpassingsmogelijkheden voor Nederland die in de 7 sleutelonderwerpen zijn belicht zijn nauw verbonden met water en watergebrek, (te) hoge waterafvoer, overmatige regenval of met waterkwaliteit en verzilting van grondwater. Nederland is laaggelegen in een delta van 3 rivieren en ligt gedeeltelijk beneden de zeespiegel en is daardoor bijzonder kwetsbaar voor veranderingen in neerslag en van het niveau van de zeespiegel. Zowel water, land en biodiversiteit zijn herkend als sleutelfactoren in de aanpassing aan klimaatverandering in Nederland in de 21ste eeuw.

Er zijn vele effectieve aanpassingmogelijkheden beschikbaar en herkend door belanghebbenden in Nederland. Een aantal van deze aanpassingen zijn gemakkelijk te realiseren maar andere zijn ongetwijfeld minder gemakkelijk en kostbaar of leggen een claim op ruimte waar ruimte in Nederland nu al een schaars en kostbaar goed is. Tot deze laatste behoren maatregelen wateropvang bij overmatige afvoer laten toenemen en maatregelen die verzilting in laag Nederland tegen gaan maar ook maatregelend die het watervasthoudend vermogen van bodem en sloten verhogen om verdroging tegen te gaan. Het is daarom essentieel om vooruit te lopen op een verandering van ons klimaat en (vroeg)tijdig aanpassingsmaatregelen te implementeren en zo omvangrijke schade en relatief hoge kosten van late aanpassing te voorkomen. Dit is waarschijnlijk moeilijk om te realiseren omdat het nodig is aanpassingen te doen en te implementeren voordat belanghebbenden en burgers de risico's herkennen en daadwerkelijk schade ondervinden. Daarbij is het van het grootste belang om een systeem van indicatoren op te zetten waarmee vroegtijdig effecten van klimaatverandering zichtbaar kunnen worden gemaakt.

Het is voor een juiste interpretatie van de resultaten van het grootste belang te weten dat de effecten en aanpassingsmogelijkheden zijn gebaseerd op een specifieke serie scenario's of toekomstbeelden over economische ontwikkeling, milieuaspecten en klimaatverandering voor Nederland in de 21ste eeuw. De resultaten van deze studie zijn dan ook alleen van toepassing binnen de context van deze scenario's Indien de klimaatverandering minder geleidelijk zou verlopen of er meer extreme situaties zich voordoen of klimaatverandering sterker is, zullen de effecten ook anders zijn.

De resultaten van deze studie zijn gebaseerd op literatuurstudie en een dialoog met deskundigen en belanghebbenden. De auteurs zijn er van overtuigd dat in dit rapport de meest essentiële en relevante aspecten van effecten van en aanpassing aan klimaatverandering aan bod komen tegen de achtergrond van de gepresenteerde scenario's, de stand van zaken op terrein van wetenschappelijke kennis en de huidige inzichten en perceptie van aspecten van klimaatverandering bij deskundigen en belanghebbenden in Nederland.

Acknowledgements

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Table of contents

1 Introduction

In recent decades, evidence is increasing that the global and regional climate is changing. *"The balance of evidence suggests a discernible human influence on climate"*. In the IPCC Second Assessment Report, the human impact was uncertain because the human influence was still small, insight into natural variations had not been developed and magnitude and pattern of climate change was uncertain (IPCC, 1992, 1996). In August 2001, IPCC published its 'Third Assessment Report on Climate Change' and here scientists come to the conclusion that observed change in climate is unlike to have a natural cause and can only be explained by a human induced greenhouse gas effect. Three recent years (1995, 1997 and 1998) are the warmest within the Netherlands since 1860 and probably in the last 1000 years.

To reduce human impact on the climate system, a protocol was drafted at the 3rd Conference of Parties of the Framework Convention on Climate Change in Kyoto (1997). Consensus has been achieved about the Kyoto-protocol (July 2001, Bonn). However, such a protocol and reduction would only be a start as emission reduction targets from the Kyoto protocol are insufficient to mitigate climate changes as expected to occur over the next 50 years. It would therefore be very wise for society to prepare for climate change and to identify options to adapt in the near future.

This project aims to assess the vulnerability and adaptive capacity of natural and human systems to climate change in the Netherlands, in propagation of similar worldwide (IPCC, 2001) and National or European assessment studies (e.g. Parry, 2000; Environment Canada, 2000). Although climate change can only be dealt with properly through international agreements, individual countries will also have to take their share in reductions of emission of greenhouse gases. Especially adaptation measures will be regionally specific and differ at national scales. For example, the vulnerability of the Netherlands for climate change differs from other countries in Northern Europe because large parts of the Netherlands are situated below sea level. Furthermore, the climate in the Netherlands will change in a different direction compared to the climate in areas that are located further away from the ocean and seas.

1.1 Objectives

The objective of this so-called "NOP-Impact" project was to make an integrated assessment of these impacts (positive and negative) and vulnerabilities to climate change and adaptations options in the Netherlands.

The aim of this project is to carry out an integrated assessment in order:

- to provide an overview of current scientific- and stakeholder-insights and perceptions of impacts and vulnerabilities (positive and negative) of climate change for economic sectors, health, and natural systems based on given climate and socio-economic scenarios, taking account of the cross-sectoral interactions

- to explore possible future impacts and vulnerabilities[4] (positive and negative) for each sector, taking account of the cross-sectoral interactions
- develop a set of (sectoral and cross-sectoral) adaptation[5] possibilities, and identify the main actors involved, through a participatory process with the main stakeholders
- make an integrated assessment of cross-sectoral interactions of climate change impacts and adaptation options (figure 1.1).

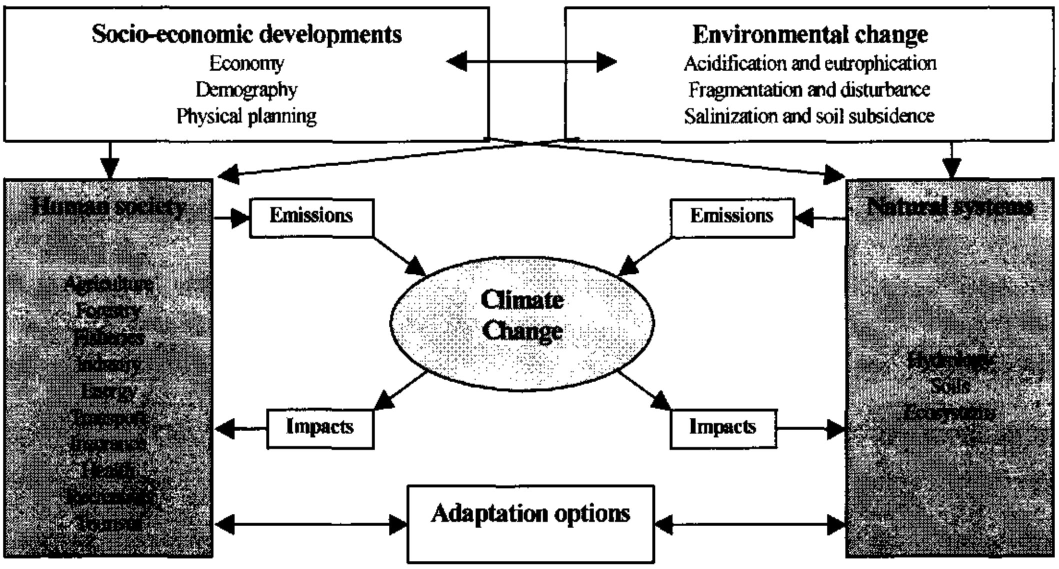

Figure 1.1 This diagram presents the scenarios and sectors identified in this study. Activities in both human society and natural systems lead to emissions and climate change. This study identifies impacts of climate change on the sectors identified within Human society and Natural systems in the Netherlands and adaptation options to respond to climate change, within the context of a specific set of socio-economic, environmental and climate scenarios till the end of this century.

This project considered the main economic sectors (including energy, transportation, tourism, agriculture, fishery, and forestry), natural ecosystems (including resources such as ecosystems, water and biodiversity) and human

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[4] *Vulnerability* is the degree to which a system is susceptible to, or to cope with, adverse effects of climate change, including climate variability and extremes. Vulknerability is a function of the character, magnitude and rate of climate change and variation to which a systems is exposed, its sensitivity and its adaptive capacity. *Senssitivity* is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass all the elements of climate change, including mean climate variability, and the frequency and magnitude of extremes. The effect may be direct or indirect (IPCC, 2001).

[5] *Adaptive capacity* is the ability of a system to adjust to climate change, including climate variability and extremes to moderate potential damages, to take advantage of opportunities, or to cope with consequences (IPCC, 2001).

health aspects (see table 1.1). Impacts and adaptation options were assessed and evaluated in a dialogue with the main stakeholders, based on projections for future climate change and socio-economic developments in the context of Western Europe.

Table 1.1 Sectors included in this study in 4 groups.

Group 1: *Natural systems*	**Group 3:** *Economic ectors*
• **Ecosystems** (flora, fauna, landscapes) • **Soil** (erosion, shrinkage, salinisation) • **Hydrology** (hydrology, water quality)	• **Energy** (energy demand and supply) • **Insurance** (domestic property, companies) • **Transportation** (road, water, air and rail)
Group 2: *Land use and fisheries* • **Agriculture** (productivity, crop selection) • **Fisheries** (productivity, recreation, diversity) • **Forestry** (productivity, recreation, diversity)	**Group 4:** *Human health and recreation* • **Human health** (Lyme disease, air pollution) • **Recreation and Tourism** (national and international)

1.2 Methodology

The methods of the study include A) an overview of the impacts and adaptation options based on the literature B) a dialogue with involved stakeholders based on a questionnaire and C) a dialogue with involved stakeholders in a workshop. Finally, the project provides D) an integration module on the internet to present important impact and adaptation options and their interactions.

A) Current state of the art of science in relation to impacts and adaptation options

An inventory has been made of the current insights of science (mainly based on results of the NRP-research programme) and stakeholders (mainly based on policy publications) about possible impacts of climate change and available adaptation options (Van Ierland *et al.*, 2000; Martens, 1996; Fresco *et al.*, 1996). The survey focused on Dutch literature. The results were presented in discussion sheets that were used in the dialogue with stakeholders and are available on the internet (see http://www.dow.wau.nl/msa/nopimpact.htm). To facilitate the dialogue between experts and stakeholders, a project website was developed. (figure 1.2).

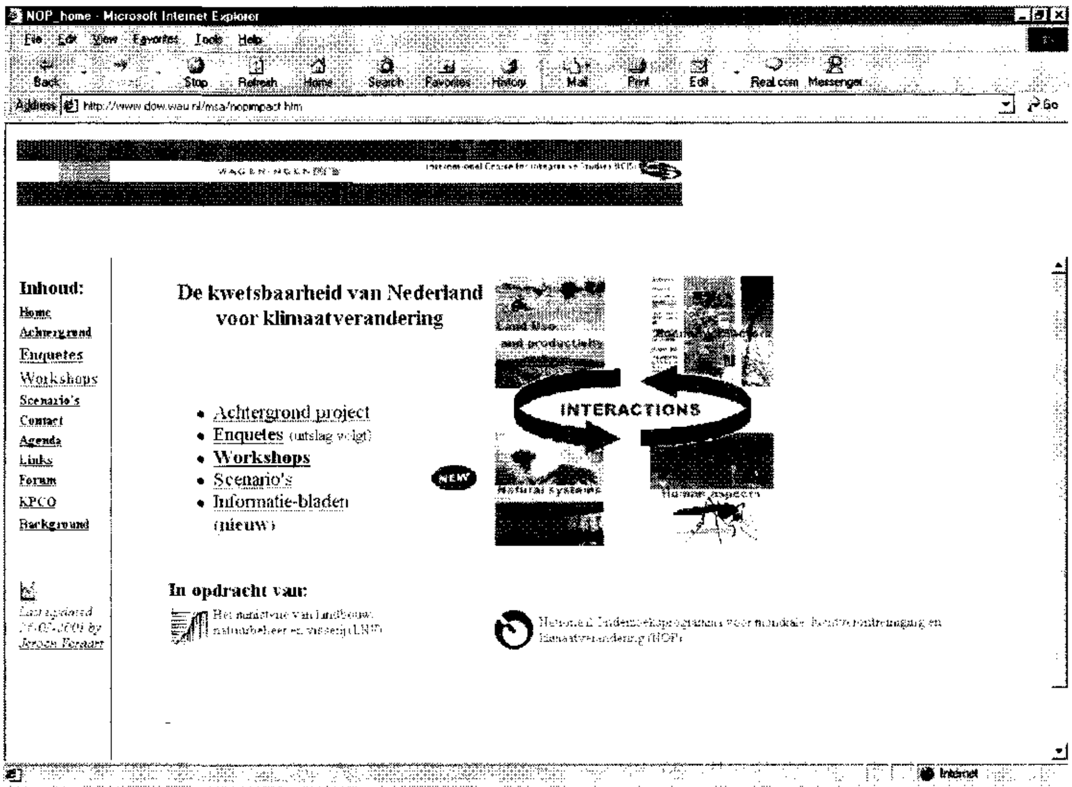

Figure 1.2 Picture of Project website (Source: http:// www.dow.wau.nl/msa/nopimpact.htm).

B) Dialogue with involved stakeholders: questionnaires

Questionnaires for each sector were developed in order to get insight in:

- the perceived vulnerability (positive and negative) to climate change in each sector (table 1.1) for different forms of impact (e.g. temperature rise, increased flooding risk)
- availability, identification and effectiveness of possible adaptation options
- the most important cross sectoral interactions.

The questionnaires were designed to identify discussion topics that could be used during the workshop with stakeholders (see C.).

A set of commonly accepted scenarios for the Netherlands, based on the latest scientific insights (CPB, 1998), RIVM (De Milieuverkenning 5, RIVM &CBS, 2000) and Hadley Centre for Climate Prediction and Research (Viner and Hulme, 1998; Verweij and Viner, 2001) and KNMI (Können *et al.* 1997; Kors *et al.*, 2000a,b) were used to create a coherent and consistent starting point of assumptions about the current state of environment and society, and possible future developments.

Three types of scenarios were used:
(i) climate scenarios
(ii) socio-economic scenarios
(iii) environmental scenarios.
If possible, several scenarios (e.g. 'high – medium – low') were used. The target years for the scenarios were 2020, 2050 and, if appropriate, also 2100.

In February 2001, approximately 1300 copies of 11 different questionnaires were sent out to stakeholders: 300 copies to Group 1, 500 copies to Group 2 and 250 to Groups 3 and 4 (see table 1.1). Each stakeholder received one questionnaire; a climate change scenario, and a factsheet on the issues at stake. The 11 questionnaires and other materials were also available at internet in order to give stakeholders the opportunity to complete questionnaires for other sectors. An important selection criterion for the mailing was to create a sampling group in which scientists, policy makers and society were distributed evenly, but it has never been the aim to design a representative sample. The questionnaire has just been used to provide an opportunity to a wide variety of stakeholders to indicate important opinions on important impacts and adaptation options.

C) Dialogue with involved stakeholders: workshop

Climate change is just one of the driving forces in relation to environmental change in the Netherlands. During the workshop it was assumed that climate change will happen according to the available scenarios (chapter 2). Mitigation measures (like emission reductions) are not discussed as this is the focus of the COOL project (Berk *et al.*, 1999; Hordijk *et al.*, in prep.), another climate change dialogue project financed by the National Programme on Transboundary Air Pollution and Climate Change (NOP).

The selection of the workshop participants was done in order to assess the general perceptions in relation to vulnerability to climate change and expected effectiveness of adaptation options in the Netherlands, as perceived by stakeholders. This required:
- Balance between scientists, policy makers, business and interest groups
- Representatives from main stakeholders in the Netherlands
- Representatives for each sector (see table 1) should be present.

For each of the 4 workshops 15 participants were invited (Appendix I). Within each group of 15 participants, 3 'Key persons' were selected who attended the workshop at both days and participate in various sessions.

D) Integration module on Internet

After the analysis of the outcome of the dialogue, the project website was extended with an integration module which provides an overview of the many linkages that exist within and between the impacts and adaptation options in different sectors (see http://www.dow.wau.nl/msa/nopimpact.htm) (figure 1.3).

<table>
<tr><td colspan="4">Frame 1:
Header which also includes links to other parts of the website</td></tr>
<tr><td rowspan="4">Frame 2:
Section with causes of change

Issue 1

Several rows with a description of the impact (same as the description text in frame 3).
This is at the same time a link to a full description of the factor. By clicking it will be loaded in Frame 3.

Issue 2

Other issues are covered in a similar way</td><td colspan="2">Frame 3:
Title of the impact

Description
Several rows with a description of the impact</td><td rowspan="4">Frame 4:
Section with consequences of change

Issue 1

Several rows with a description of the impact (same as the description text in frame 3).
This is at the same time a link to a full description of the factor. By clicking it will be loaded in Frame 3.

Issue 2

Other issues are covered in a similar way</td></tr>
<tr><td>Causes
List of links to issues that influence the impact described above. By clicking on a link the issue will be displayed in Frame 2.</td><td>Consequences
List of links to issues that are influenced by a change of the impact as described above. By clicking on a link the issue will be displayed in Frame 4.</td></tr>
<tr><td colspan="2">Expected impact of climate change
Description of the expected impact under a change in climate.</td></tr>
<tr><td colspan="2">Adaptation options
Overview of potential adaptation options related to this impact</td></tr>
</table>

Figure 1.3 Main structure of the integration section of the website on integration.

1.3 Outline of the report

Chapter 2 of the report provides the scenarios used in the project. Chapter 3 presents the impacts and adaptation options based on a review of the literature for each of the sectors. Next, in chapter 4, the results are given of the questionnaires and the discussions with the stakeholders in the workshop. Finally, chapter 5 summarises the key issues, their interactions and the implications for adaptations in various sectors.

2 The Netherlands in the 21st century: scenarios

2.1 Introduction

The aim of this chapter is to introduce the recent trends and plausible future scenarios for three aspects: (1) climate change, (2) socio-economic trends, and (3) the environment for shorter and longer terms. This facilitates the dialogue about the vulnerability of the Netherlands to climate change. Scenarios are capable of serving multiple roles in climate change assessment but until now they have tended to be used as an aid to understanding future emission profiles (e.g. IPCC, 1996, CPB 1997). Socio-economic and climate change scenarios are applied for an integrated assessment to investigate climate change impacts, vulnerabilities and adaptive responses (Feenstra *et al.*, 1998; CPB, 1999a; IPCC, 2001; Lorenzoni *et al.*, 2000a; 2000b).

The scenarios are providing plausible descriptions of how the future could develop, based on coherent and internally consistent set of assumptions ('scenario logic') about key relationships and driving forces (e.g. economic growth, population, energy consumption and emission of greenhouse gases) (IPCC, 2000). It differs from a forecast in that a scenario is a 'plausible future' whereas a forecast is the 'most likely future'. A scenario is part of a set of scenarios, which together span the range of likely future developments. Scenarios also differ from projections since they are 'a plausible future of a suite of interrelated variables', whereas a projection often is 'a simple extrapolation of current trend', and often concerns a single variable (Tol, 1998).

Using scenario analysis as a tool for predicting future trends for both long and short-term analysis has its advantages and disadvantages. The longer the time period is, the more uncertainties are involved in the analysis. The main drivers of the impacts are (1) change in population, (2) resource use, and (3) technology. All drivers contain uncertainties, but technological development in particular. The advantage of short-term modelling is that it is easier to deal with uncertainties. Climate change is a slow process, and the socio-economic response (adaptation) to climate change impacts will happen gradually in a long-term time horizon. Ideally, an integrated assessment study of the vulnerability of the Netherlands to climate change should thus take into account long-term developments. In this study, we introduce both short-term and long-term scenarios, which could differ in terms of reliability.

2.2 Climate change in the Netherlands in the 21th century

In this chapter, climate scenarios for the Netherlands in the 21st century are presented. These scenarios are based on information from IPCC reports (IPCC, 2001), KNMI reports (Können *et al.* 1997) and calculations on the basis of data provided to NRP by the Hadley Centre in England (see appendix III).

2.2.1 Climate change and human activities

The final years of the 20th century were very warm both in the Netherlands and globally (table 2.1). These deviations from long term averages bring forward uncertainties and questions about the climate in the 21st century. The concentration of greenhouse gases in the atmosphere has been rising ever since 1750 (carbon dioxide or CO_2 with 30%, methane or CH_4 with 150%, nitrous oxide or N_2O with 15% and CFCs have been introduced by humans). This increase will continue in the 21st century (section 2.4). Greenhouse gases keep our globe warm and more greenhouse gases reinforce that warming effect.

"Human activities such as the emission of greenhouse gases and deforestation are a major cause of global warming since the middle of the 20th century. The scientific evidence for this is stronger now than 5 years ago at times of the publication of the previous IPCC (Intergovernmental Panel on Climate Change of the United Nations) assessment report (IPCC, 1996). The chemical composition of the atmosphere will continue to change in the 21st century as a result of human activities. The average global temperature and the sea level will continue to rise. Also, other aspects of our climate such as precipitation and the frequency of extreme weather events will change. This is the conclusion of the International Panel on Climate Change (IPCC) at the closure of its meeting in Shanghai in January 2001 during a meeting where the first part of the Third Assessment Report on climate change was accepted[6].

Table 2.1 Climate in de world in 1990 compared to the climate 100 years ago on the basis of the IPCC Third Assessment Report (IPCC, 2001).

Parameter	Change
Temperature	Increase since 1860 by 0.6 °C
Precipitation	Increase of 0.5 – 1 % per 10 year in the 20th century in the Northern hemisphere
Seasonality	Increase in precipitation mainly in the winter period
Sea level	Sea level rise of 0.1 – 0.2 meter in the 20th century

[6] The main conclusions in the IPCC Third Assessment Report part I and background information on IPCC and climate change can be found at: http://www.knmi.nl; the Third Assessment Report will be published in the course of 2001; the previous full analyses by IPCC was published in 1996.

2.2.2 Global climate change

Changes in climate are very difficult to predict and are still based on a large number of assumptions. The global climate system is very complex and changes in Western Europe and the Netherlands could be very different from the changes that may occur on a global scale. At the global level, scientists under supervision of the IPCC assess climate changes by analysing results from scientific research. The expectation of IPCC that our climate will change is based on a continued increase of the concentration of greenhouse gases in the atmosphere[7] and the absence of effective climate policies and measures.

IPCC in its most recent report indicates a rise in global temperature between 1.4 and 5.8 degrees Celsius and a higher precipitation in the temperate and northern parts of the northern hemisphere. The rise in temperature leads to melting of snow and glaciers and results in an average sea level rise in the range of 0.1 to 0.9 meter by the end of the 21st century (table 2.2).

Table 2.2 The global climate in 2050 on the basis of the IPCC Third Assessment Report as compared to 1990.

Parameter	Change
Temperature	Increase by 1.4 – 5.8 °C
Precipitation	Increase in the Northern Hemisphere
Sea level	Rise of 0.1 – 0.9 meter in the 21st century

2.2.3 Climate change in the Netherlands

To develop scenarios for regional climate changes, i.e. for western Europe or the Netherlands, on the basis of global climate changes, it is necessary to know how regional climate responds to global climate. Many scientists hold the opinion that we have insufficient insights to do so. The international climate centers such as KNMI or Hadley therefore do not speak in terms of climate predictions but use *scenarios* with reference to a possible future climate.

The uncertainty in sketching developments in regional climate are still rather large. Within these uncertainties, models predict changes in temperature better than changes in precipitation. This may result in different outputs between different models. In this section, climate changes as calculated by two models are presented, i.e. the KNMI model (the Netherlands) and the Hadley Centre model (UK). Both models have generated data that represent the geographical area of the Netherlands.

7 Greenhouse gases concerned are: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorinated fluor carbonates CFC's. The data for this study assume an increase in concentration of greenhouse gases of 1% per year. The concentration of the main greenhouse gas 2020 will in 2020 be 450 ppm, in 2050 600 ppm and in 2100 between 600 and 900 ppm. These changes are based on assumptions on developments of population growth, industry and energy-use.

Climate changes for the Netherlands prepared by KNMI logically follow the IPCC prognoses and are in line with the measured and documented changes of the climate in the Netherlands during the 20[th] century (see also Können *et al.*, 1997). KNMI give a temperature rise for the period 2020 – 2050 of 2 °C and an increase in precipitation up to 6% as compared to 1990 (see table 2.3).

Table 2.3 The climate in the Netherlands in 2050 on the basis of data by KNMI as compared to the climate in 1990 (Können et al., 1997).

Parameter	**Change**
Temperature	Increase of 1 – 2 °C in 2050 and a maximum increase of 4 °C in 2100
Precipitation	Increase by 3 – 6% in 2050 and 6 – 12% in 2100
Seasonality	Wetter winters (6 – 12% increase and at the most 25% increase of precipitation by 2050 and 2100, respectively; 1-3% more precipitation in summer, mostly as heavy showers and longer dry periods in summers; temperature rise will be stronger in winter than in summer
Extreme precipitation	In the winter, increase of 10 – 20% in 2050 en 40% at the most in 2100 en in the summer, increase of 1 – 2% in 2050 4% at the most in 2100 especially in local and heavy showers (10-20% higher intensity in 2050 and up to 40% in 2100 as compared to 1990)

Table 2.4 Consequences of climate change in the Netherlands on the basis of KNMI data.

Parameter	**Consequence**
Water discharge	Increase of precipitation in winter will result in higher discharge of water and more problems following heavy showers
Winters	Severe winters will be more rare and shorter.
Extremes in temperature and precipitation	Extremes in temperature and precipitation possibly increase, character of summer precipitation will change to showers
Storms	Chances on storms and the severity of storms increase but are relatively uncertain
Sea level rise	Sea level rise is locally enhanced by a drop in the level of land and could amount to 25 cm in 2050 and 60 cm in 2100

For this NRP project, climate change scenarios have been made at Alterra[8] on the bases of data from the Hadley Centre GCM (General Circulation Model) in England for the period 1980 – 2100. These data were provided to NRP and used in many projects within the Dutch Climate Change Research Program (see appendix A for further explanation) (Viner and Hulme, 1998; Verweij and Viner, 2001). A useful scenario for the central and eastern part of the Netherlands was made on the basis of data for a specific area with its center 50 km east of

[8] Data from Hadley Centre provided to NRP (National Research Program on Climate Change) have been re-arranged to represent climate in the Netherlands by P.E.V. van Walsum (Alterra); these Hadley Centre data have been used throughout projects of the NRP (Dutch National Research Program on Climate Change).

Winterwijk (see figure 2.1: the cell directly east of the darkest cell that covers the larger part of the Netherlands but also a relatively large fraction of sea). These data have been named HadleyNL (see appendix). This area is entirely over land and this will exclude that the sea has a moderating effect on the climate data. Next, these calculated climate data from Hadley have been compared to actual climate data for the period 1980-1998 and then calibrated (HadleyNLcalibration – light grey bar in figure 2.2). Finally, precipitation data has been manipulated on the basis of the assumption that precipitation will proportionally increase with an increase in temperature (HadleyNLwet – dark grey bar in figure 2.2). This latter operation fits the usual practice in climate research.

The Hadley based scenario predicts relatively minor changes in precipitation (see HadleyNL and HadleyNLcalibrated); higher precipitation both in summer and winter only shows if the assumption of higher precipitation as a consequence of higher temperatures is followed (HadleyNLwet as in the KNMI scenario)[9].
The temperature change varies in the 3 approaches but in all cases gives an increase of 1.5 to 2.5 degrees °C between 2050 and 2100.

The annual precipitation and the distribution between winter and summer strongly depends on the approach taken. Here, we have chosen to calibrate the Hadley cell data for Dutch conditions on the basis of predicted weather and actual weather for the period 1980-1998 (see appendix III for methodology). After this calibration (HadleyNLcalibrated) there is no change in winter precipitation and drier summer conditions (figure 2.2, light grey). Coupling of precipitation to changes in temperature give for the Netherlands a wetter winter and minor changes in summer precipitation (HadleyNLwet, figure 2.2, dark grey). In this latter case, the scenario on the basis of Hadley data diverges from that on the basis of KNMI data.

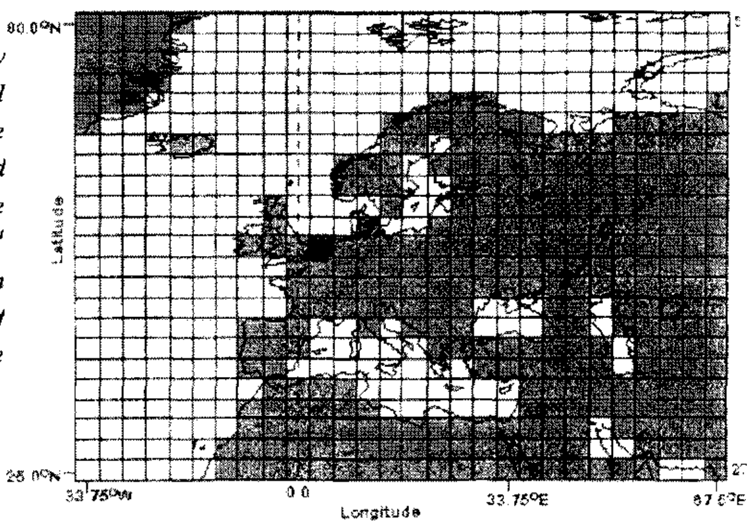

Figure 2.1 Grid of Hadley General Circulation Model (GCM) for Europe. The Netherlands is largely located in the dark grey cell; for the climate scenario for the 21st century for the Netherlands in this project, the cell due east of the dark grey cell was used (see text for explanation).

[9] This is based on the assumption that each 1°C increase in temperature will yield 1% more summer precipitation and 6% more winter precipitation.

Table 2.5 Climate in the Netherlands in the period 2020 – 2100 on the basis of data provided by the Hadley Centre.

Parameter	Consequence
Temperature	Increase of 0.5 °C in 2020 to 1.5 °C in 2050 and 2.5 °C in 2100
Precipitation	Decrease of precipitation with less than 40 mm per year up to 2100 in the HadleyNLcalibrated scenario (5% change) or increase of precipitation with 40-80 mm per year (5-10% change) for 2050 – 2100 in the HadleyNLwet scenario
Seasonality	Changes in precipitation in the winter period are larger than the changes in precipitation in the summer period: winter will be wetter (between 20 and 40-80 mm per year in 2050 and thereafter) and summer will be either drier (-40 mm or 5% per year less to no change)
Extreme precipitation	Minor change on the basis of frequency distribution of precipitation events in winter and summer

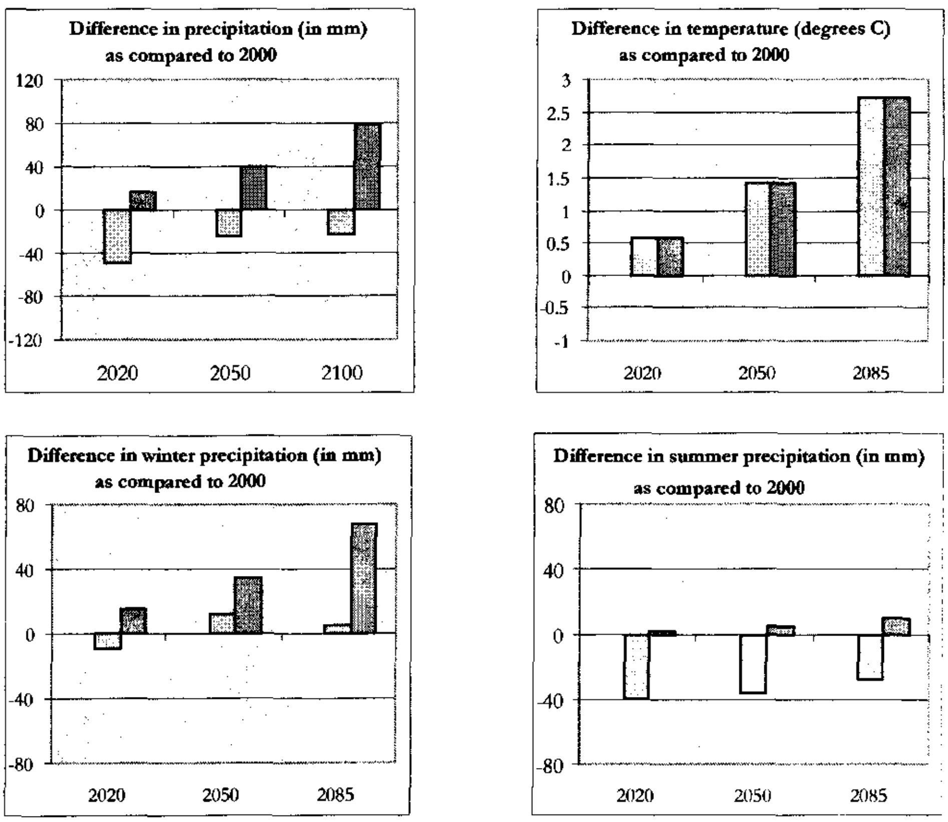

Figure 2.2 Changes in precipication and temperature between 2000 and 2020, 2050 and 2085, respectively (light grey bar – Hadley data calibrated for the Netherlands in HadleyNLcalibrated; dark grey bar – coupling of precipitation to temperature in HadleyNLwet).

2.3 Socio-economic scenarios

2.3.1 CPB (1990-2020)

The Central Planning Bureau (CPB) scenarios for the period 1990-2020 (CPB, 1997) provide baseline estimates for the Netherlands in three scenarios: Divided Europe (DE), European Co-ordination (EC), and Global Competition (GC). The analysis of physical variables is structured around four themes: energy, land requirement, transport and the natural environment. Assumptions for the scenarios differ with respect to global economic development, Western European economic and political development, demographic and socio-cultural development, and development in technology. These 'short-term' scenarios are suitable to measure the emission profiles of the country (and used as a baseline for mitigation policy) (Berkhout and Hertin, 2000).
The CPB scenarios show that in the absence of specific government intervention other than under already agreed policies, the pressure on the physical environment will develop during the period up to 2020. The three background scenarios: Divided Europe (DE), European Co-ordination (EC) and Global Competition (GC) mainly differ in projected integration policies, environmental policies, and economic growth. The EC scenario shows realistic picture of the current policy in the Netherlands. Therefore, in the analysis the EC scenario is chosen for baseline, GC draws a high-growth and DE represents a low-growth scenario. The GDP growth is shown on figure 2.3. For the full description of the three scenarios see table 2.6 (CPB, 1997).

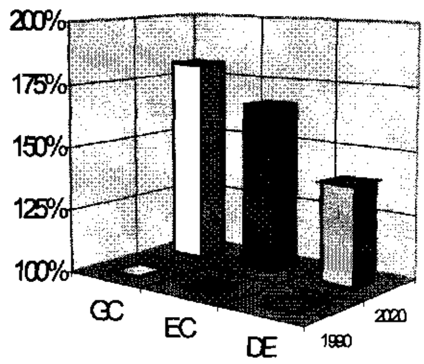

Figure 2.3 Level of GDP in 2020 in the Netherlands in % of year 1990 (CPB, 1997).

In Divided Europe, the Netherlands will record only a modest GDP growth rate (1,5% annually). The integration of the EU slowly proceeds and neither the market mechanism, nor the co-ordination mechanism will function well. There is sluggish growth in knowledge potential and technological development. The population growth is slow as a result of low immigration and relatively low fertility and life expectancy.

In European Co-ordination there is a relatively strong GDP growth rate (2.7% annually). Co-ordination plays a major role in policy planning, and there is more emphasis on intra- and inter-generational equity. There is strong growth in knowledge potential. The technological development is focused more on societal needs. The consumption patterns and lifestyles more oriented on non-material and environmental friendly aspects. The population growth is higher owing to higher immigration rate and higher fertility and increasing life expectancy (figure 2.4).

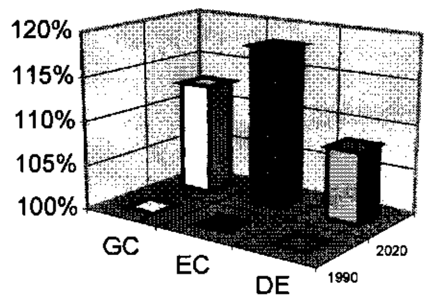

Figure 2.4 Population in the Netherlands in 2020 in % of 1990 (CPB, 1997).

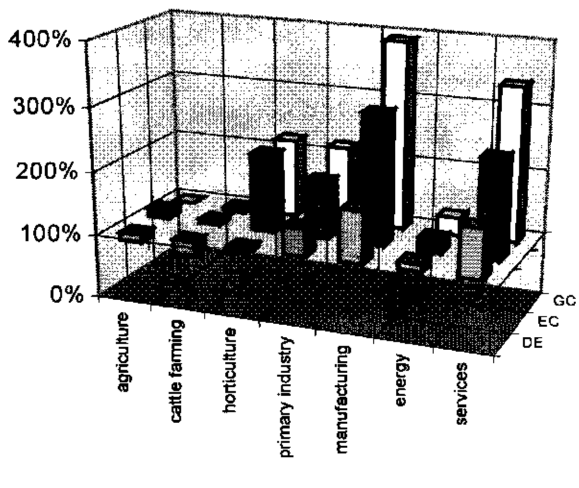

Figure 2.5 Production growth of the economic sectors in 2020 in the Netherlands (base year 1995 = 100%) (CPB, 1997).

In Global Competition there is strong GDP growth worldwide. The Dutch GDP growth is around 3.3% annually, with strong market oriented co-ordination mechanism. There is also strong growth of knowledge potential, and the technological developments are strongly market oriented. The population growth is lower than in the EC scenario owing to the lower immigration balance and moderate fertility and life expectancy.

The core differences in economic growth, population dynamics and co-ordination policy results in different trends on energy supply and demand, transport patterns and the level of greenhouse gasses (figure 2.6).

The economic sectors are booming in the GC scenario. In EC the strict co-ordination for sustainable development and social equity results in emission standards which could have an impact on the economic performance (figure 2.5). In DE scenario strong nationalist feelings are predominant, which significantly reduce the value of foreign trading. Amongst the land intensive economic sectors only horticulture shows significant increase in the EC and the GC scenarios. During 25 years the production of the primary industry will almost double in GC, while the secondary industry (in particularly metal industry and chemistry will be almost four times than the level in 1995. This increase will have significant impact on the changes in greenhouse gases (CO_2, NO_X). The energy supply is predicted more or less stabile, energy efficiency will compensate the higher energy use. Services will grow together with the economic growth. Trade, transportation and communication, tourism and other services are included in this category.

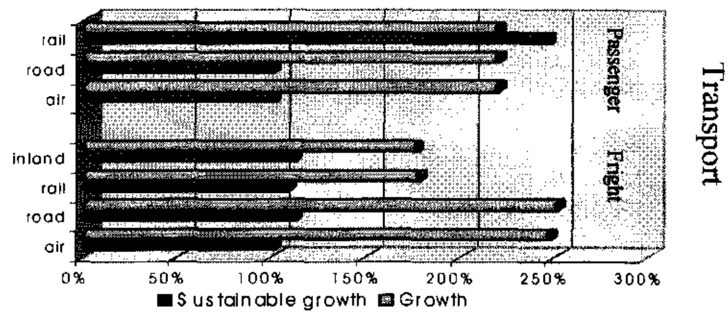

Figure 2.6 Comparison of Growth and Sustainable Growth Scenarios 1995-2020 for transport for Randstad area in the Netherlands (Ubbels et al., 2000).

Economic development will enhance the growth of transport, so transport continues booming in EC and GC scenarios. A study in the Netherlands (Ubbels *et al.*, 2000) compares growth and sustainable growth scenarios for the period 1995-2020. Figure 2.6 shows the growth of transport in the Randstad area (industrial area, which includes Amsterdam, Rotterdam, The Hague and Utrecht) for passenger and for freight transport. The results clearly show that the growth intensity is highly above the sustainable level. The passenger transport will double in 2020 compared to the level in 1995. According to the sustainable passenger scenario road and air transport should not exceed the level of 1995, meanwhile a shift in transport modes towards rail is desirable. The inland and rail fright transport is predicted 50% higher than the sustainable level. The rapidly growing road and air fright transport is expected to reach the 2.5 times the sustainable level in 1995.

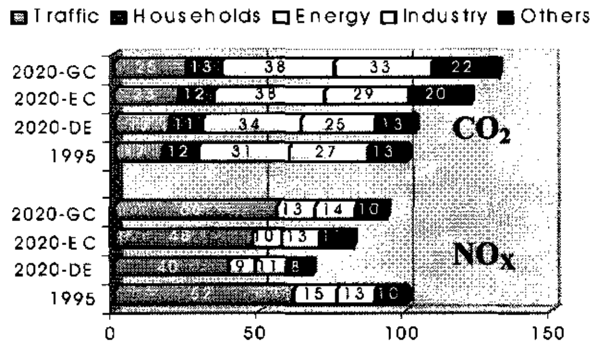

Figure 2.7 CO_2 and NO_x emissions in three scenarios in percentage of the year 1995.

The increasing industrial production and growing traffic enhance the accumulation of greenhouse gases. The CO_2 emission in 1995 shows the relative share (percentage) of the contribution to carbon dioxide pollution from the different sources, such as traffic, households, energy sector, industries and others (figure 2.7).
The three scenarios show the relative increase. The total amount of carbon dioxide is predicted to increase by 2% in DE, 20% in EC (which is far above the Kyoto level) and 30% in GC scenario. The total NO_x emission is expected to decline with 33% in DE, 18% in EC and 7% in GC scenarios. Though NO_x emissions are increasing in freight transport with 20% in EC and almost 50% in GC, this is compensated by emission reduction from other sources. Significant reduction will be achieved in the energy sector and personal transport.

2.3.2 IMAGE-WorldSCAN integrated assessment scenarios (1990-2100)

The IMAGE WorldSCAN model is presented with four scenarios to extrapolate data for 100 years interval (Geurts *et al.*, 1997). The model captures the interactions of the economic sectors and the environment, such as the feedback impacts on the economy. The IMAGE-WorldScan model framework provides scenarios, which became part of the SRES emission scenarios family (IPCC, 2000). All models used four base scenarios: A1, B1, A2, and B2. The scenarios differ in terms of participation in international trade and focus on economic or environmental sustainable growth. The classification of the groups is fairly similar to the CPB scenarios (figure 2.8). Scenario A1 with some additional assumptions could be equivalent with the Global Competition (high-growth), scenario B1 might be equivalent with the European Coordination (middle growth). Scenario A2 and B2 has the basic assumption of resticted international trade such as in the Divided Europe (low-growth) within the CPB scenarios. Scenario A2 represents a situation of restricted trade concentrating resources on economic growth, scenario B2 represents a sustainable growth option (figure 2.8).

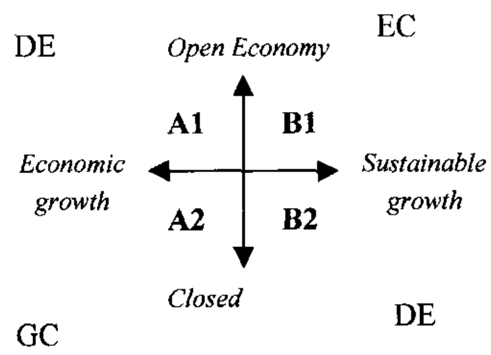

Figure 2.8 Possible Socio-economic directions of development combined with scenarios from Worldscan and CPB.

IMAGE stands for an Integrated Model to Assess the Greenhouse Effect. The model was developed to provide a comprehensive overview of some key global change issues and to assist policy makers in the development and evaluation of future scenarios to mitigate the negative effects of global change (Leemans and Kreileman, 1999). The integrated assessment model analyses the impacts of economic, demographic and technological changes on the energy-industry system and the terrestrial environmental system. The model shows the impacts of industrial/energy and landuse emission on and atmosphere/ocean system, on greenhouse gas emission. The model applies a climate feedback on agriculture and land use.

WorldSCAN stands for a model of the WORLD economy for Scenario Analysis. The computable general equilibrium model was developed to extrapolate future economic development scenarios based on neoclassical growth theories of economic growth and international trade. The pace of exogenous, labour augmenting technological progress and the rate of population growth determines the growth rate of production and income. The core model is extended to add realism to scenarios in order to bridge the gap between scientific and policy discussions (CPB, 1999b) (see table 2.6 for characteristics of CPB scenarios).

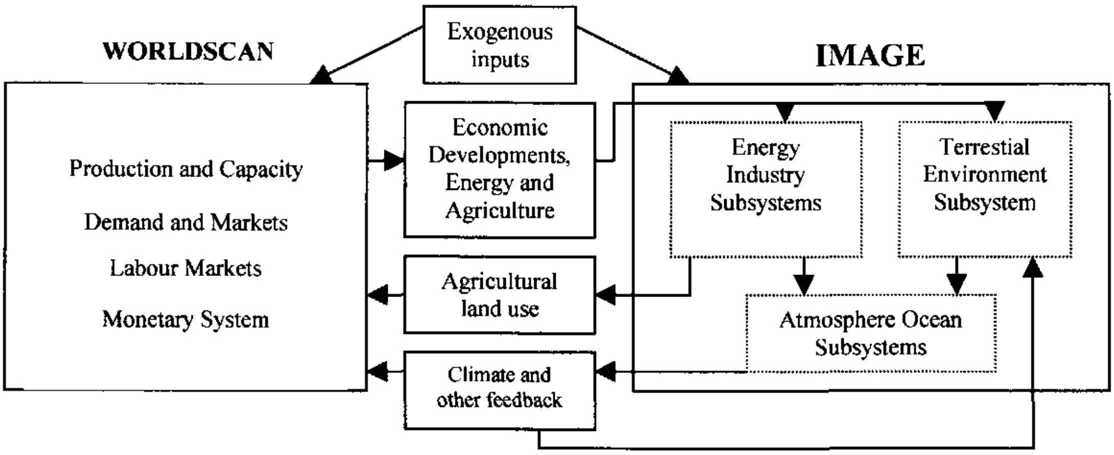

Figure 2.9 Overview of WorldScan and IMAGE.

The necessary linkages between WorldScan and Image models are presented in figure 2.9. Energy is integrated fully in the model structure in Worldscan. IMAGE's energy system has been adjusted so as to make use of WorldScan outputs.

The model results are aggregated for the OECD region. In our analysis all charts will present the relative change in the variables compared with 1990 level. We can assume (though many uncertainties are involved) that the Dutch socio-economic development on the long term (1990-2100) will not differ much from the predicted OECD average. In figure 2.10 three scenarios are presented.

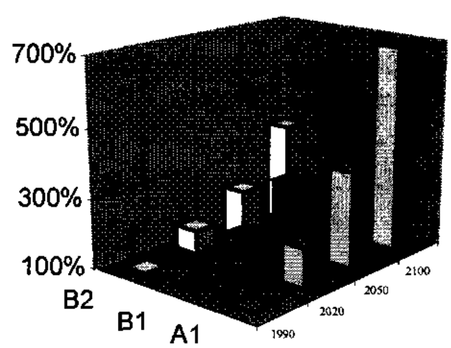

Figure 2.10 Economic growth (GDP) scenarios for OECD for the period 1990-2100 (% of year 1990) (IPCC, 2000).

The economic growth is highest in scenario A1 (Worldscan) and more optimistic than the CPB scenarios. By 2020 the GDP is expected to double, by 2050 it reaches almost four times and by 2100 almost seven times the current level of GDP. The GDP/capita increases to 5.38 times the current level by 2100. In the two approaches different discount rates have been applied. In the EC scenario the economic growth is slower, but still high. By 2100 the GDP is expected to reach 5 times the level of current GDP. The economic growth is the lowest in the DE scenario. The population growth is modest in each scenario with a change of 26-30% by 2100.

Energy scenarios are important indicators of the climate change policies. The share of primary energy sources in the baseline (1990) is shown in figure 2.11. Above the changes in energy use are indicated in three scenarios (A1,B1, and B2) in 2020, 2050 and 2100. In A1 (Global Competition) scenario the total energy use will increase with 50% in the period 1990-2020. After 2020 there is no significant change in total energy use, but we can monitor changes in the contribution of different energy sources. The use of fossil fuel is increasing till 2020, after 2020 renewable energies will substitute some of the fossil fuel supply. Scenario B1 (European Coordination) assumes strong sustainable development, including changes in consumer awareness. The energy consumption will increase till 2020. After 2020 energy consumption will drop significantly until 2100 to 60% of the level of 1990.

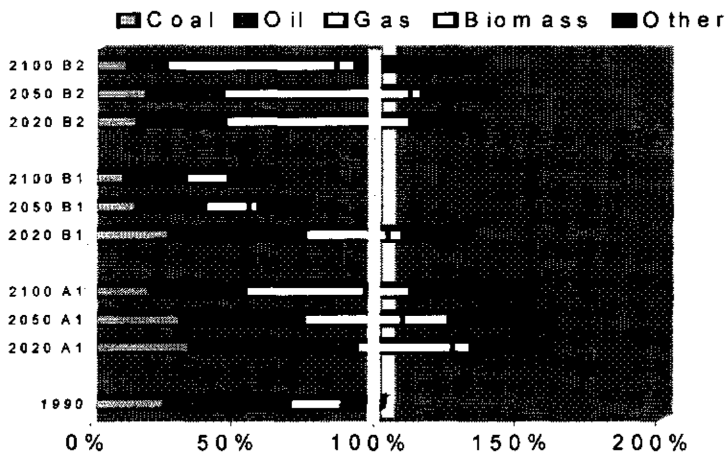

Figure 2.11 Long term energy scenarios for OECD average (1990-2100).

In scenario B2 (DE) the total energy consumption will increase till 2020, and it keeps this level till 2100. There is no intention to enhance environmental policy by international cooperation.

Table 2.6 Characteristics of CPB scenarios (1990-2020).

DIVIDED EUROPE	EUROPEAN COORDINATION	GLOBAL COMPETITION
1. INTERNATIONAL ECONOMIC AND POLITICAL DEVELOPMENT		
- market mechanism and regulation do not work well - EU: slow further integration	- coordination plays a greater role than in GC - more emphasis on 'equity'	- market mechanism dominant: fierce international and policy competition - emphasis on 'efficiency'
2. TECHNOLOGICAL DEVELOPMENTS		
- sluggish growth in knowledge potential - little knowledge diffusion - more traditional focus on technological development	- strong growth in knowledge potential - inefficient knowledge diffusion - technological developments focused more on social needs	- strong growth in knowledge potential - strong knowledge diffusion - market oriented technological development
3. SOCIAL AND CULTURAL DEVELOPMENTS		
- nationalist feeling predominant - little additional scope for quality consumption	- Sense of being 'European' or 'regional' citizen - Greater sense of community, solidarity - Consumption patterns and lifestyles more oriented on non-material and environmental friendly aspects	- Sense of being 'world' citizen - Strong individualism - Large degree of product differentiation and strong materialistic/hedonistic culture
4. DEMOGRAPHY		
- Immigration balance lowest - Fertility and life expectancy relatively low	- Immigration balance higher owing to solidarity - Fertility and life expectancy higher	- Immigration balance relatively low owing to policy competition - Fertility and life expectancy moderate
5. ECONOMY		
- Strong GDP growth in North America and Asia, Europe lagging behind - Dutch GDP growth: 1,5% per year - Sluggish private consumption growth - Relatively few changes to production structure - Relatively high unemployment	- Relatively strong GDP growth in Europe and Asia; North America lagging behind - Dutch GDP growth: 2,75% per year - Relatively strong consumption growth - Social and environmental aware - Less intense international competition - More international environmental policy - More public services - Falling unemployment, less dynamism	- Strong GDP growth worldwide - Dutch GDP growth 3,25% per year - Strong private consumption growth - Strong private consumption growth, very high degree of product differentiation - Highly dynamic production structure; emphasis on comparative advantages; on high-value activities - Low unemployment, great job security

2.4 Environmental scenarios for the Netherlands until 2050

In this chapter, environmental scenarios for the Netherlands in the short (2020) and long term (2050) are provided for use in the NOP impact project on the basis of the Dutch 5th National Environmental Assessment. The Dutch National Environmental Assessment 5 (RIVM, 2000). ("*Milieuverkenning 5*") provides an assessment of the anticipated environmental pressures and environmental quality in the Netherlands for the period 2000-2030 on the basis of developments on European and Global scale. The different descriptions of the future in MV5 have been developed on the basis of two long term scenarios of the Central Planning Bureau (CPB), i.e. European Co-ordination (EC) and Global Competition (GC)[10]. The Dutch 5th National Environmental Assessment ("Milieuverkenning 5") has been set up to prepare for the 4th National Environmental Policy Plan ("Vierde Nationaal Milieubeleidsplan - NMP4") which appeared only recently (June 2001). Among the different environmental issues, the anticipated climate change is expected to be the most important development. In this chapter other environmental issues that are affected by climate change or that by themselves may or will impact climate change such as greenhouse gases, acidification, eutrofication and drought and hydrology are discussed.

2.4.1 Greenhouse gases

Climate change policy in the Netherlands is considering all greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and several halogenated compounds (i.e. HFCs). To compare these greenhouse gases with one another, they are expressed in CO_2-equivalents[11].
The total emission of greenhouse gases in 2020 will increase by approximately 10% (EC-scenario) or 20% (GC-scenario) compared to the total emissions in 1990[12] (figure 2.12). To achieve the commitments that the Netherlands agreed to under the Kyoto Protocol, it needs to reduce emissions by 50 billion kg CO_2-equivalents in the period 2008-2012 as compared to 1990. At least 50% of this reduction (25 billion kg CO_2-equivalents) should be realised within the Netherlands; the remaining reduction may have to be achieved through emission trading or in other countries by other mechanisms under the Kyoto Protocol. The CO_2-emission as a result of the use of fossil fuels and energy use in industrial production will increase between 1995 and 2020 by 10 – 30% and depends on economic developments (figure 2.12).

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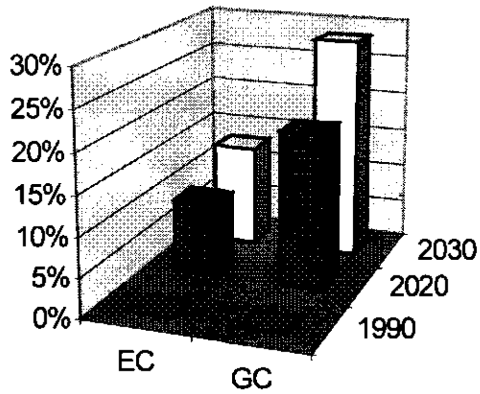
[10] See also the chapter on economic scenarios. The Divided Europe (DE) scenario has not been used in MV5 or the last 5 years due to international European developments.

[11] Nitrous Oxide (N_2O) has a global warming potential (GWP) of 310 (GWP for 100 years) and is a 310 times more powerful greenhouse gas than CO_2 is; for methane a GWP factor of 21 is used.

[12] Within current policies, the emissions of greenhouse gases in the Netherlands in the period 2000-2030 are expected to increase by 15-50 billion kg CO_2-equivalents and rise to 250-285 billion kg CO_2-equivalents in 2030. This is an increase of 5 to 20% as compared to 1995 emissions.



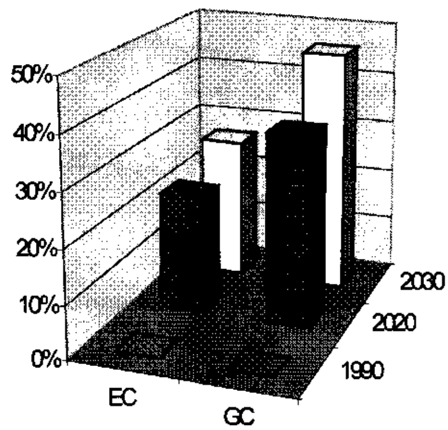


Figure 2.12 Scenarios for emissions of greenhouse gases with carbondioxide (CO_2) emission (top) and CO_2-equivalents in the EC- en GC-scenario (bottom) in % in relation to 1990 (MV5, 2000).

The CO_2-emission as a result of traffic and transport will increase between 1995 and 2030 by 60 – 90 % and is relatively stronger in the road transport of goods (see Nederveen *et al.*, 1999). The CO_2-emission as a result of the production of electricity will stabilize between 1995 and 2010, but will increase again in the years following 2010. The available emission reduction options are not sufficient to compensate for higher demand for electricity after 2010.

Agriculture is a main source of nitrous oxide and methane. The emissions of these greenhouse gases is anticipated to decrease as the number of cattle and other animals will go down (methane) and as the available manure will decrease as a result of the implementation of the policy measures in that restrict the use of animal manure and chemical fertilizers (nitrous oxide).

2.4.2 Acidification and air pollution

The deposition of air pollutants that change the soil quality and direct exposure to air pollutants influence the quality of nature and natural ecosystems in the Netherlands. The emissions of acidifying compounds such as NO_x, SO_2, NH_3 and

VOS will continue to decrease at the current rate as a result of ongoing policies (figure 2.13). In the years to follow 2010, emissions will increase again though slightly. The levels of acid deposition and nitrogen deposition in 2030 are expected to be 60% above the targeted level of 2010. The foreign contribution to the atmospheric concentrations of these compounds (except for ammonia NH_3) is large and significant.

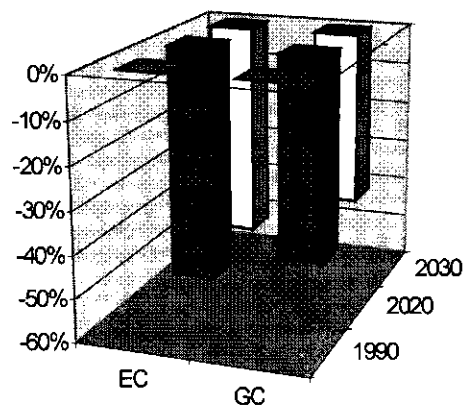


Figure 2.3, Emission of nitrogen oxides (NO_x) in the EC and GC scenario in % in relation to 1990 (MV5, 2000).

2.4.3 Sulphur dioxide emissions (SO_2)

Sulphurdioxide emissions result from the use of sulphur containing fuels (oils, gasoline and coals) in industry, transport, production of electricity and oil refining industry. These emissions in 2020 will be approximately 60% less (EC-scenario) to 70% less (GC-scenario) than the emissions in 1990. Future changes in the mix of fuels used may further reduce emissions and mainly due to replacing oil by natural gas in refining processes and in production of electricity and less due to changing the sulphur content of fuels.

2.4.4 Nitrous oxide emissions (NO_x)

Traffic and transport is thought to be responsible for 60% of the total Dutch emissions of nitrous oxides in 2020. Major heating industries and powerplants for energy generation are responsible for another 25% and other sources for the remaining 15%. The total emissions of nitrous oxides in 2020 has decreased by 55% (EC scenario) and 48% (GC-scenario) as compared to 1990. The nitrous oxide emission by road transport will decrease between 1990 and 2030 despite more use of motorcars for private transportation and for goods and is a result of further tightening of allowed emission rates. In the total emissions of NO_x and SO_2 from traffic, the contribution of transport over water will increase. The environmental policies and restrictions for the emissions in river- and seatransportation are less severe that those for road transportation.

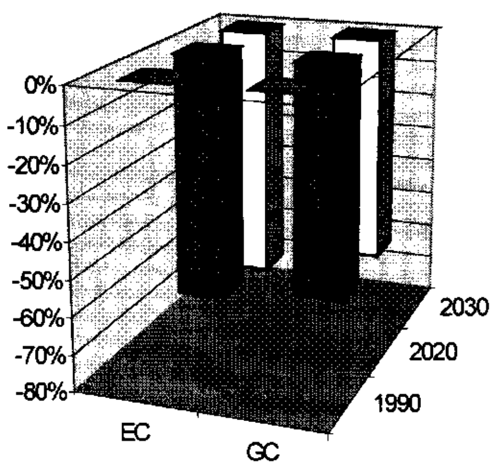


Figure 2.14 Emission of sulphur dioxides (SO2) in the EC and GC scenarios in % in relation to 1990 (MV5, 2000).

2.4.5 Ammonia emissions (NH_3)

Agriculture in 2000 produces more than 90% of all ammonia emissions. The emission of ammonia in 2020 is expected to decrease by 35 to 45% as compared to 1990 (figure 2.15). The main cause is a reduction in the number of animals and manures. The results depend on the level of acceptation for application of animal manures to replace chemical fertilizers by arable farmers. The future ammonia emission strongly depends on the level of success for the current manure and fertilizer policies.

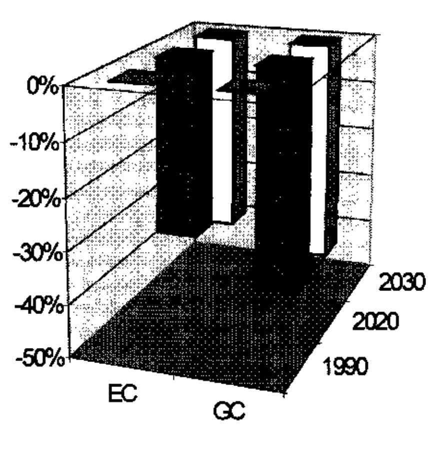


Figure 2.15 Emission of Ammonioa in the EC and GC scenarios in % in relation to 1990 (MV5, 2000).

2.4.6 Eutrofication

Excessive application of nutrients to crops, i.e. nitrogen and phosphorus, interferes with ecological processes in water and soils. This process is called eutrofication ("vermesting"). The primary sector responsible for the loading of water and soils with nutrients is agriculture[13]; fertilization contributes to the loading of freshwater with nutrients through surface run off to streams and lakes and through leaching to groundwater. The policy objectives for prevention of eutrofication have been defined in terms of criteria for the amount of nitrogen (N) and phosphorus (P_2O_5) that may be lost per hectare of agricultural land into the environment, criteria for the N from animal manures (EU nitrate directive) and objectives for quality of groundwater and surface waters.

2.4.7 Nitrogen

In the period 1986 – 2000, an average of 900 billion kg of nitrogen was applied to Dutch soils through chemical fertilizers and animal manures (subtracting losses through ammonia volatilization). As a result of intended policies, the average load of nitrogen to soils will in the period 1986 – 2000 decrease with 40% as a result of the intended policies. As a consequence, the leaching of nitrogen into groundwater will decrease by 50% and the run-off of nitrogen to surface waters will decrease with 35%. Also, the emission of nitrous oxide (N_2O) is expected to decrease by 30%.
The policies on manuring and manure handling will have little impact on the total area in which in the period 2016 – 2030 the runoff water will meet the quality criterion for surface water of 2.2. mg N per litre. However, on sandy soils, this quality criterion will be met on a larger area. Despite this, down stream areas and its natural ecosystems will still be exposed to nitrogen doses too high as a result of runoff from upstream agricultural land. The nitrogen emission to soils via runoff and leaching will be reduced by 70% as compared to 1990 under the VAC- and WAC-scenario[14]) in 2020 (figure 2.16).

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[13] With respect to eutrofication the MV5 takes into account the initiated manure policies on Integrated Manuring Approach including the additional policies with respect to nitrogen, Ministry of Agriculture, Nature Management and Fisheries, 1999)

[14] The VAC- and the WAC-scenario are based on the EC-scenario and the new intended manure policies. In the VAC scenario is assumed that arable farmers are willing to conclude contracts on application of manure with cattle farmers. In the WAC scenario is assumed that only few such contracts on application of manure by arable farmers will be concluded and is the number of cattle that will remain lower. The effect of less manure production in the WAC scenario is compensated for by a higher chemical fertilizer application. The emission of nitrogen in both VAC and WAC scenario is thus similar. This effect does not hold for phosphorus as this compensation mechanism does not hold because phosphorus is not (yet) regulated under the nutrient book keeping system (MINAS).

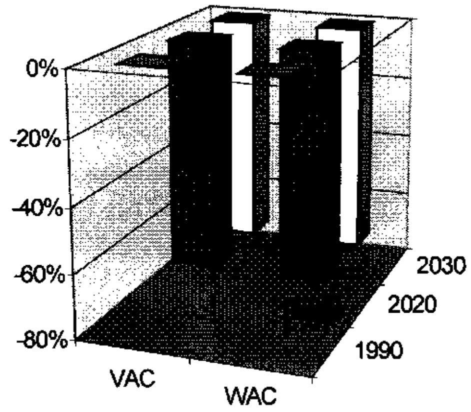


Figure 2.16 Emission of Nitrogen in the VAC- and WAC scenarios in % in relation to 1990 (MV5, 2000).

The acceptable nitrate concentration in the upper groundwater of 50 mg NO_3 per litre is currently exceeded in virtually all agricultural land on sandy soils. As a result of implementation of new manuring policies, the level of exceeding this nitrate level will strongly decrease. The nitrate concentration in the upper groundwater for all agricultural land will decrease by an average of 35% and for sandy soils by 45% as compared to the current situation. Despite this, the quality criterion for nitrate in groundwater will not be met on several 10^{th} of percentages of the total agricultural land on sandy soils.

2.4.8 Phosphorus

In the period 1986-2000, the average application of phosphorus through chemical fertilizers and animal manures was approximately 120 kg P per year for the total Dutch agricultural area. As a result of intended policies, the average input of phosphorus will decrease by 30% in the period 2016-2030. The rate of accumulation of phosphorus in soils will decrease with 75%. Despite this, the loading of soils with phosphorus will continue though at a lower rate. Runoff of phosphorus to surface water is determined primarily by the P stock in soil and will hardly decrease. As a consequence of the full sequestration of excessive phosphorus in soils, the phosphorus saturation will continue in the future despite a lower fertilization pressure. The area of phosphorus saturated soils (saturation level > 50%) in 2016 – 2030 will almost double to 55% as compared to the period of 1986 – 2000.

The emission of phosphorus to soils will decrease by 60% in the VAC-scenario and by 70% in the WAC-scenario in 2020 as compared to the emission in 1990. The runoff of phosphorus will hardly decrease due to the high degree of saturation of soils with phosphorus and the continuing loading of soils. The phosphorus concentration in the runoff water until 2030 will hardly decrease and may even increase a little in some regions.

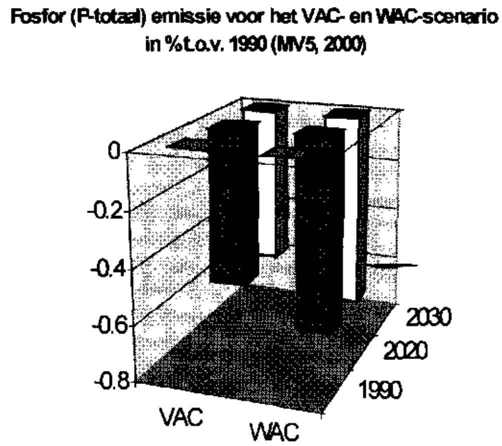


Figure 2.17 Emission of phosphorus in the VAC- and WAC scenarios in % in relation to 1990 (MV5, 2000).

2.4.9 Dessication

A relative desiccation ("verdroging") occurs in natural ecosystems or in areas with both agricultural and natural functions as a result of insufficient groundwater or surface water of good quality. Approximately 60% of this desiccation are the result of intensification of drainage to facilitate agriculture and the consequently lowering of the groundwater table. The application of groundwater for several purposes, among which is irrigation in agriculture, is responsible for 30% of this additional desiccation. The consequences of retrieving groundwater are lowering the groundwater table and reduced (upward seepage) of groundwater elsewhere. The remaining 10% of the desiccation have other causes such as more infrastructures and stoned surfaces and mining of sand.

The national objective for the control of desiccation is to reduce the area of desiccation by 40% as compared to the reference year 1985 and an area of 6000 km^2. The policies to achieve these objectives include the following components (4^{th} Report on Water, Ministry of Traffic and Water Management, 1998):

- Combine projects to restore nature with the possibility to conserve and store water
- Terminate the national increase in use of groundwater (2000)
- Re-allocate winning of groundwater
- Define desired groundwater tables for the medium and long term (2025) and
- Incorporate controls of desiccation into plans for regional development

In 2030, the water- and humidity condition of at most 40% of the area that is currently too dry (1998) will be improved or restored. Between today and 2030, measures to control or counteract desiccation will be taken in an additional 3000 m^2 of nature area. The raise of the groundwater table that is desired for desiccated natural areas is usually between +10 and +40 cm. This exact level will depend on the regionally specific targets for the development of natural conditions and ecosystems and the local regimes for groundwater and surface water.

Anti-desiccation measures and the intended developments in retrieving groundwater in approximately 4000 km^2 of the rural area will lead to a change in the regional water relations that will result in more runoff of nitrogen and phosphorus to surface water. Desiccation is most prominent on the higher sandy soils and in relatively vulnerable areas such as lowland peat areas and dune valleys. In these areas, the impact of anticipated future drier summers will be most pronounced.

3 The vulnerability of the Netherlands for climate change: Impacts and adaptation options

This chapter gives a summary of the (scientific) literature review and expert judgements obtained through direct interviews or written input on the observed and future impacts and adaptation options on Natural systems, Land use and fisheries, Economic sectors and Human health.

Based on this analysis of current scientific insights, 11 discussion sheets have been written as background material for the stakeholder-dialogue (see chapter 4). Much information has been taken from previous NRP-studies, but also additional literature has been consulted dealing with Dutch and European climate impact assessment studies (eg. Parry *et al.*, 2000). In the 1990s several studies have provided elements of the possible impacts of climate change in the Netherlands (Baan *et al.*, 1993; Zwerver *et al.*, 1995; projectgroep klimaatverandering en bodemdaling NW4, 1997; Kok en Zwerver, 1999; Kabat *et al.*, 2000; van Ierland *et al.*, 2000).

3.1 Natural systems

In this section impacts (A) and adaptation options (B) are discussed for hydrology (3.1.1), soils (3.1.2) and ecosystems (3.1.3), respectively. These are based on literature review.

3.1.1 Hydrology

A) Impacts on hydrology

The riverine and coastal areas of the Netherlands are most at risk in the Netherlands in relation to sea level rise and changed discharges of the rivers due to climate change. Impacts of climate change on the hydrological systems will most likely affect the safety of people and socio-economic capital, freshwater availability (drinking water and irrigation) and biodiversity conservation. In this section these impacts are presented together with currently discussed adaptation policies in Dutch water management (Commissie Waterbeheer 21e eeuw, 2000a,b). Theoretical opportunities and constraints of impacts and adaptation options are evaluated for the riverine regions, the lakes, the coastal zone and regional water systems.

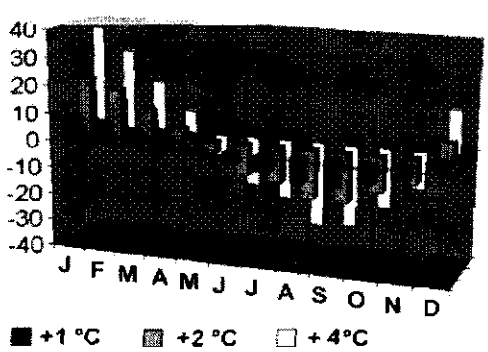
Impacts on Dutch rivers

Mean annual discharge of rivers in the Netherlands (Rhine, Meuse, Scheldt) will hardly change, but increasing temperature and winter precipitation will lead to increased winter discharge, while summer discharge will be lower, sediment transport wil change (Asselman *et al.*, 2000; Parmet *et al.*, 1995 in Zwerver *et al.*, 1995; van Deursen *et al.*, 1998; Dijk and Kwaad, 1998). The river Rhine, currently a combined rainfall-snow-melt fed river will change in an almost completely rainfall fed river (van de Geijn *et al.*, 1998). In future, the Netherlands will face larger differences between winter (peak floods) and (low) summer discharge (figure 3.1). Assessing the implications of future climate for current water management in the catchments of the rivers should include also developments which are independend from climate such as soil subsidence (in particular for the Netherlands), land use changes, economic growth, population growth or institutional changes. The vulnerability of the Rhine catchment to climate change (flooding risks and water availability) will increase in future due to these autonomous pressures (Asselman *et al.*, 2000; Middelkoop *et al.*, 2000). Impacts of climate change on water quality are considered to be of minor importance in the river Meuse because the current new policy of the districts Brussels and Wallonië in Belgium to construct waste water treatment plants will have a higher positive impact on water quality then the negative impact from climate change (Warmerdam *et al.*, in prep.) In the Meuse catchment autonomous water exploitation will increase in future, as a result the water resources within the catchment becomes more vulnerable to climate change (more frequently dry summers) (Warmerdam *et al.*, in prep.).

The increasing winter peak floods require measures to ensure safety. During the summer period water availability for agriculture, drinking water and industry (use of cooling water) will be more limited. Inland navigation could face problems with large ships in summer due to low water levels.

The changed river dynamics are not a-priori negative for biodiversity: The increased dynamics may result in a higher habitat diversity (Projectteam klimaatverandering NW4, 1997). Changed river dynamics (sediment transport, water quality) in combination with temperature rise may, however, have consequences for the aquatic ecosystem. It is expected that in the deep polders in the Western part of the Netherlands, saltwater intrusion will increase due to sea level rise. This will have consequences for agriculture and biodiversity.

(a)



(b)

	Rhine (m^3/s)	Meuse (m^3/s)
Current (2000)	16000	3800
Low scenario 2100	16800	4180
Medium scenario	17600	4560
High scenario	18000	5320

Figure 3.1 (a) Scenarios for the montly discharge of the River Rhine in 2100 (change in %), based on 3 climate scenarios) (b) Peak discharges of the Rhine and Meuse in 2000 en 2100 on which constructions of dikes are based. Source: WIN (2000) and Commissie Waterbeheer 21e Eeuw (2000a,b).

Impacts for the lakes (lake IJssel region)

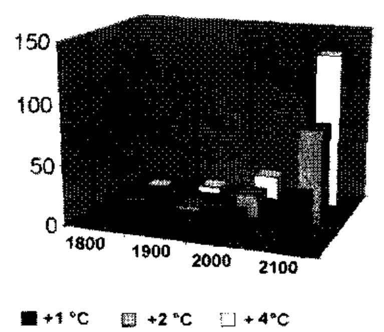
Scenario studies (WIN, 2000) assume that the water levels will rise (some decimetres) in lake IJssel, lake Marker and the 'Randmeren' in winter. A small water level increase (some centimetres) is assumed during the summer.

These rising water levels are mainly due to increased problems to drain water towards the Wadden sea (figuur 3.2). Because of sea level rise it will become more difficult to drain water towards the sea and pumping will become necessary. The areas around the lakes are more at risk for flooding because of the rising water tables. The seasonal water level fluctuations will however become more natural (higher in winter than in summer) because they will follow the regime of the river IJssel. (Currently water levels are higher in summer than in winter due to water management). In relation to water availability the conditions seem to improve as a result of climate change (higher water tables in winter and summer). The increase is, however, relatively small. Extreme dry years will occur more frequently resulting in water shortages.

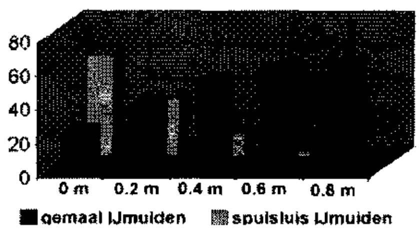
Impacts on the coastal zone

Sea level rise, possible changes in wind patterns and sea-currents may influence sedimentation and erosion processes near the coast. As a result, flooding risk will increase. The coastal line, including its beaches and dunes protects almost 9 million people, living in the lower part of the Netherlands. In addition to the possible human toll, economics costs are already high and may increase. Currently approximately 60% of the Dutch national product is produced in the lower parts of the Netherlands (CPB, 2000), the most vulnerable area to climate change. Economic and population growth will probably continue in the 21st century in the Netherlands (section 2), especially in the lower part of the Netherlands.

(a) *Scenarios for relative sea level rise (cm)*



(b) *Development of necessary pump- and drainage capacity (in m^3/s) in the North Sea canal as a function of sea level rise.*



Explanation (b): *By rising sea levels it will become more difficult to drain water towards the sea, pumping will be come necessary. However, pumps use a lot of energy and there are high construction costs.*

Figure 3.2 Scenarios for the relative sea level rise (cm) (a) and ratio between pump and drain capacity (m^3/s) in the North Sea canal as a result of sea level rise (b) (WIN, 2000).

A preliminary conclusion from the NRP studies in relation to the Wadden Sea (Wolff, 1995) is that the Wadden Sea tidal flats and salt marshes may survive an increased rate of sea level rise if erosion processes can be controlled. Sediment supply and accretion rates seem to be sufficient to compensate for higher rates of increase of sea level and soil subsidence than at present. This conclusion is in line with a recent study on the possible effects of soil subsidence due to gas extraction on Wadden Sea saltmarshes (Oost *et al.*, 1998). The flooding period may, however, become longer (Brinkman, 1995; Oost *et al.* 1998), which may result into less feeding time for shore birds. Changed water temperature (milder winters) may have consequences for reproduction raties of bentic fauna (box 3.1). Bentic fauna has no physical options for adaptation. It is expected that climate change will result in changes in species composition in the Wadden sea but no important changes in ecosystem functioning are assumed (see also section 3.1.3).

Box 3.1 The relationship between water temperature and productivity/ food availability within the food web in the ecosystem of the tidal flats (After Wolff, 1995)

Winter temperature appears to be a factor in determining the reproductive success of shellfish (Proven by experimental results with *Mytilus edulis*, *Macoma balthica* and *Cerastoderma edule,* Wolff, 1995) on the tidal flats. After mild winters with a mean water temperature in the period January-March of about 6°C, the recruitment was lower than after cold winters with a mean temperature of about 1°C. Two hypothese may be formulated to account for this diminished recruitment:

1) The first hypothesis assumes increased predation of just-settled larvae of these bivalves by brown shrimps *(Crangon crangon)* and shorecrabs (*Carcinus maenas*). More predators survive in mild winters.
2) The second hypothesis states that the metabolic rate of adult bivalves is on a higher level in mild winters due to higher temperatures. Since food is scarce in this period, this higher metabolic rate is achieved at the expense of stored reserves. As a consequence, less energy is available for reproduction.

Impacts for regional (agricultural) hydrological systems

A changed precipitation pattern, rising temperatures in combination with soil subsidence and sea level rise may have considerable impacts on the regional hydrological systems of the Netherlands. Regional hydrological systems in the coastal zone are more sensitive to climate change compared to regional water systems in the higher part of the Netherlands. Regional water systems in the coastal zone are exposed to sea level rise, soil subsidence and changed precipitation patterns (section 2.2). Increased precipitation in winter will result in a more than proportional increase of the surface water levels in the spring in the lower parts of the Netherlands, while this increase is proportional in the higher parts of the Netherlands (Projectteam klimaatverandering NW4, 1997). A scenario study explore the impact of climate change and soil subsidence on groundwater and surface water tables in spring by the year 2050 (Project team klimaat-verandering, 1997). It was concluded that soil subsidence had a minor impact on groundwater tables in the higher part of the Netherlands. Only the peat bogs in the lowland catchments of brooks in the province of Drenthe seems to be more sensitive in this area. The impact of climate change combined with soil subsidence showed the following trends in the central scenario for 2050: Increased spring ground water tables (>5cm) will occur in 20% of the Dutch surface area. In the higher parts of the Netherlands the absolute increase of the spring groundwater tables is generally higher (5-10cm) than in the coastal zone because groundwater tables are in this part of the Netherlands more explained by precipitation than by surface water tables. A decline (>5cm) of the spring groundwater tables will occur in about 5% of the Dutch surface area, mainly in the coastal zone and riverine region. However, current trends in freshwater exploitation for agriculture and drinking water production may have more impact on groundwater tables (a decline) than the potential increase due to climate change in the Netherlands (derived from WIN, 2000; IUCN, 2000).

The projectteam klimaatverandering NW4 (1997) concluded that the general increased spring groundwater tables will have a positive impact on natural values, because the water table rise due to climate change will mitigate the impact of dessication (declining groundwater tables) as a result of water exploitation.

Other scientific stakeholders (chapter 4), however, point out that climate change (dry summers, higher rain intensity, higher peak discharges in streams), despite increased groundwater tables, will result in a decline of the natural values in the Netherlands.

Seepage patterns will change throughout the country as a result of changed precipitation patterns, sea level rise and soil subsidence. The central scenario for 2050 (Projectteam klimaatverandering NW4, 1997) showed an increase in the reclaimed Flevopolders and the south of the province of Friesland (0 -0.25 mm day^{-1} and locally some increase in the riverine regions. The central scenario showed that in the other areas of the Netherlands seepage declined with 0-10 mm day^{-1}.

Impacts for regional (urban) hydrological systems

Changes in the frequency and intensity of short precipitation events is of concern for urban water management. Frequency and intensity of short precipitation events in summer are likely to increase as a result of climate change. This may result into more frequent urban point discharges from the sewage infrastructure into the surface waters. Increased discharges from sewage infrastructure may have negative consequences for water quality.

B) Adaptation options for hydrology

Dutch water management policies aim to adapt the current hydrological system in an integrative way in which implications for all stakeholders are considered.

Three general concepts are used in water management in order to asses sustainable water management (Commissie waterbeheer 21e eeuw, 2000a,b), in order of importance:

- retention of water upstream, in the soil, ditches and small streams
- increase the discharge and retention capacity of the rivers
- discharge water into the sea.

Adaptation options for rivers

These concepts led to more concrete strategies for the Dutch rivers in which all three concepts are combined:

'Space for the river': Restriction of human activities in the watershed by development of hydrological criteria within physical planning (In Dutch: Water als ordenend principe, Watertoets) in order to create more space for the river (for opinions of stakeholders see box 3.2). Increase of the water retention capacity of the rivers by moving the dikes or by deepening the floodplains. Divertion of water from the main stream by creation of branches in areas outside the floodplains (Commissie Waterbeheer 21^{e} Eeuw, 2000; Rijkswaterstaat directie Oost-Nederland, 1999; Rijkswaterstaat, 2000).

Agricultural water management: Optimise water retention in agricultural areas before the water reaches the river. Controlled flooding at graslands in the floodplains may used as an adaptation technique in an early stage of a calamity (Boland *et al.*, 2000).

Changed discharge distribution between the Waal, the IJssel and the Nederrijn-Lek: Safety risks are minimised and chances for nature development are maximised in the river catchments if relatively more water is drained by the Waal and less by the IJssel and the Nederrijn-Lek (Rijkswaterstaat directie Oost-Nederland, 1999; Rijkswaterstaat, 2000).

Box 3.2 Considerations of stak holders in relation to multifunctional land use in the riverine region.

Allocation of space for the river in the floodplains in order to increase the safety of people and economic goods could be achieved in combination with the re-establishment of natural values, recreation focussed on natural values, exploitation of clay and grind and re-establishment of landscape and cultural values (Rijkswaterstaat directie Oost-Nederland, 1999). This could be done by implementing the floodplains within the ecological main structure of the Netherlands/Europe (section 3.1.3). From a scientific point a view more space should be allocated to the river in order to maintain the safety for people and goods and the effectiveness of nature development projects. Some Dutch environmental interest groups point out that more frequent (controlled) inundation of the riverine floodplains may have also negative consequences for nature conservation within the floodplains, if water quality is not improved. The landscape of the floodplains will become attractive for recreation. Public support for water management measures to adapt to climate change may increase as a result of increased attractiveness of the riverine regions for tourism. However, agriculture will loose fertile productive areas. Furthermore, in general Dutch rural communities fear an increase of recreational potential of the rural area. They are afraid that the rural area will become the garden for the urban area (Van Tatenhove, 1996).

Adaptation options for the lake IJssel area

The policy objectives for future water management for the lakes are to guarantee the safety, to minimise inconvenience caused by water flooding and to achieve optimal conditions for the regional water availability. To achieve these objectives 3 adaptation scenarios were developed which are evaluated using criteria like robustness, flexibility, space requirements and economic costs (WIN, 2000).

- *Water drainage to the sea:* water management is optimised to ensure current water levels in the lakes by drainage of water to the sea.
- *Higher water tables in the lakes:* Higher water tables in the lakes are accepted as a consequence dikes and dams should be strengthened. Extra pump capacity is necessary in the regional hydrological systems to discharge water in lake IJssel.
- *Space for water:* Rural areas around the lakes (and river catchments) are used to store surplus of water. This strategy will also create opportunities for a more natural water table management and increase of the freshwater availability (during the dry summer period). However, dams and dikes should also be strengthened.

Finally, the Dutch ministry of Transport, Public Works and Water Management in the Netherlands has a preference for a combination of these management strategies, named: *'Growing with the sea'*. Extension of the drain capacity in combination with rising water tables in the lakes have the provisional preference (WIN, 2000).

Also WWF (Helmer *et al.*, 1996) has developed a strategy for water management in the 21st century also named *' Growing with the sea'*. This strategy, however, differs from the Dutch government's postition at some points:

- *Nature development in the lakes:* Water management adapted to climate change should also consider the habitat and regulation functions (De Groot, 1992) of the lakes in the Netherlands. Desiccation of shallow banks in dry summers (more frequently due to climate change) is potentially beneficial for development of wetlands. Wetlands in and around the lakes are not only important habitats for flora and fauna but have also an important 'purification'-function (sedimentation of suspended solids and nutrient uptake by vegetation). More natural water table fluctuations in lake IJssel have disadvantages for agriculture in the bordering peat areas. In dry summers these areas will face water shortages, while in periods with much precipitation it will become more difficult to discharge water into lake IJssel (Helmer *et al.*, 1996). A solution might be to increase the water retention capacity in the regional hydrological systems.

Others consider land reclamation as an adaptation option (Anonymous, 2000b):

- *Land reclamation in the Marker lake:* Although it seems paradoxically, some stakeholders suggest to reclaim land in lake Marker in order to create space for water to adapt to climate change. In this reclaimed land area physical planning could allocate large areas for wetlands, which provide space for water and nature. The potential water retention capacity of these wetlands is comparable with the current water retention capacity of lake Marker and the natural values are higher (Anonymous, 2000b). It is easier to allocate space for water in newly reclaimed land than allocation of space for water in the 'old parts' of the Netherlands.

Adaptation options for the coastal zone

The main objective of current Dutch coastal zone management in order to adapt to the impacts of sea level rise and soil subsidence is to maintain the 1990 coastline in such a way that natural dynamics are not counteracted (Rijkswaterstaat, 2001). The coast line may fluctuate between margins based on the geographical location of the basis of the dunes and low tide border. In practice this strategy results in the following measures (Rijkswaterstaat, 2001):

- *Maintenance of the coastline by sand suppletion*: this measure is important for the maintenance of the recreational and natural functions of the coastline
- *Re-establishment of the natural dynamics of the dunes*: to create more space for natural dune development
- Compensation of sand losses in the deeper water: Sand suppletion under water
- *Development of engineering construction works into the sea*: For example, barrages into the sea were constructed at the Northern coast of Texel (Island situated in the Wadden Sea) in order to promote sedimentation processes. As a result less sand suppletion at the beach is needed. WWF confirms as well that artificial constructions may improve the robustness of the coast. It should, however, be examined that these construction do not disturb natural erosion and sedimentation processes (Helmer *et al.*, 1996).

WWF mentions (Helmer *et al.*, 1996) also other adaptation options for the coastal zone:

- *Improvement of ecological regulation functions of nature*: Natural areas (like dunes, coastal salt marshes, peatlands and other wetlands) can function like a sink for sediment (mitigation to soil subsidence) and increase also the water retention capacity of the coastal zone (adaptation to reduced freshwater availability as a result of saltwater intrusion caused by sea level rise)
- *Re-establishment of the connection between the riverine estuaries and the sea*: The Rhine-Meusse estuary could be broadened and sluices could be constructed within the present dams in order to create connections with the sea in order to mitigate the impact on natural values of increased freshwater seepage in spring due to climate change (precipitation patterns). This impact is a perception of stakeholders (chapter 4), not a scientific point a view. Coastal salt marshes may start to develop as a result of this adaptation. Channels in this part of the estuary will deepened by erosion because the tidal fluctuations will increase. The sand from this erosion process can be used for development of outside delta's and coastal dunes. The salt-freshwater gradient will be restored. This salt-freshwater gradient is of high ecological importance.

Adaptation options for regional water systems:

- *Minimise the impact of soil subsidence:* The decreased groundwater tables in the peat areas in the lower part of the Netherlands should be gradually increased in order to mitigate the impact of drainage on soil subsidence. Agricultural and natural areas should be hydrological separated from each other through the development of buffering zones (Projectteam Klimaatverandering NW4, 1997)
- *Hydrological measures*: plantation of forests, development of wetlands, changed drainage and irrigation infrastructure on field scale. These measures make variable water table management possible and minimise the risk of floodings
- *Renaturalisation of the morphological structure of brooks*: The retention capacity of canalised brooks and streams could be improved by renaturalisation of the streambeds and by creation of retention reservoirs. More frequent floodings due to climate change are in this way mitigated
- *Development of (rain)water buffering reservoirs):* In urban areas this measure could be an effective adaptation to increased frequency of intense precipitation events in summer in combination with the reduction of asphalt paving
- *Flush system with freshwater from the retention reservoirs (lake IJssel, etc)*: Flushing the regional water system with water from another system might be an effective measure to reduce impacts of salinisation due to sea level rise on crop yields. Agricultural systems may also structurally adapt to salinisation via selection of salt tolerant crop types or water management measures on field scale(see section 3.1.2 and 3.2).

3.1.2 Soils

Soil and water are our most vital natural resources. Soils perform a number of essential functions including the principal medium for plant growth, a substrate for fauna and flora, a filter controlling water quality and flow rate, a source and sink for pollutants, and a foundation for buildings. Soils are therefore of major importance for the stability of global processes and provide one of the major buffers against man-induced climate change.

Many soil processes will be influenced by climate change: chemical reactions in solution, diffusion-controlled reactions, and dissolution of solid and gaseous phases. Although some processes take centuries or more to make a distinct imprint, there are some important ones which operate over a 1-10 year time scale and will certainly be affected by the changes in climate projected between now and 2050 (UK Climate Change Impacts Review Group, 1991; Parry, 2000).
Although climate change will enhance certain ongoing soil-quality and quantity problems, the overall effect of climate change compared to the impact of land use and (air) pollution is small. Below, an overview of the main impacts and adaptation options is given, based on scientific literature.

A) Impacts of climate change on soil structure and processes

Soil formation/organic matter content

As temperature increases, the rate of soil forming processes *can be expected to increase*, in particular if this is combined with an increase in rainfall. However, the effect depends on the type of ecosystem and latitude. For example, elevated CO_2 alone does not cause extra peat formation in Dutch peat soils (Hoosbeek, 1999). Model studies show that under predicted evapotranspiration for 2050, based on a 3°C (= comparable with the "central scenario" of this study) temperature increase and a 10% rainfall increase, enhanced losses of organic matter will occur (UK Climate Change Impacts Review Group, 1991).

Soil quality, especially nutrient contents

Evidence for the impact of climate change on decomposition processes in the soil is conflicting and still subject to much debate (Gorissen, Kuikman & Whitmore, 1998). Below, a few findings on effects of climate change on mineralisation are summarised. In agricultural land the effects of climate change on the soil nutrient status is probably negligible, and with a deposition of 50 kg N ha^{-1} the effects on natural ecosystems in the Netherlands will also be limited (box 3.3).

Box 3.3 Scientific considerations in relation to Soil quality, especially nutrient contents.

- It is likely that total *soil nitrogen content will diminish* under a warmer and drier climate (Parry, 2000).
- "Increased microbial activity [due to climate change] would lead to *elevated rates of N-fixation, N-immobilisation and denitrification*, increased importance of mycorrhizal associations and enhanced production of soil aggregates and enhanced rates of acidification and weathering" (Parry, ed., 2000). According to (Bradbury and Powlson, 1994), *soil organic nitrogen contents would be maintained*"
- "Potentially, greater mineralisation could cause an *increase in nitrogen losses* from the soil profile, as illustrated by experiments based on soil warming (Lukewille and Wright, 1997; Kolb and Rehfuess, 1997).
- Several studies show decreased degradability of leaf material and roots grown under elevated CO_2 and this decreased degradabilty does not always correlate with C-to-N ratio, possibly because elevated CO_2 induces other changes in tissue quality or in the relation to relative allocation to (root) tissue fractions (Arp, Kuikman & Gorissen, 1997)

Soil biota and microbial activity

There is great uncertainty surrounding the response of soil organisms and thus, soil biodiversity, to climate change and the potential effects of these responses at the ecosystem level. Most soil biota have relatively large temperature optima which suggests they are *unlikely to be adversely affected* by climate change, (Tinker and Ineson, 1990), although some evidence exists to support changes in the major functional groups of the soil biota" (Parry *et al.*, 2000).

Soil organisms may be affected by elevated atmospheric CO_2 concentrations because of changes in litter supply to, and fine roots in, soils as well as by changes in the soil moisture regime (Rounsevell *et al.*, 1996 in Parry, 2000), and through changes in C:N ratios of plant residues (Mosier, 1998). However, other scientists (A. Gorissen, P.J. Kuikman and A.P. Whitmore, pers. com.) argue that increasing atmospheric CO_2 induces changes in the quality of plant litter, these changes reduce litter decomposibility and so increase carbon storage in soil. The authors do admit that elevated CO_2 induces changes in litter quality, i.e. C-to-N ratio but in most experiments, so the argument goes, these changes have not resulted in differences in decomposability. Carbon storage in soils will therefore mainly result from increased plant productivity and increased physical protection of labile substrates.

Soil-atmosphere interactions

In general, higher soil temperature, mean higher microbial reaction rates in the soil, which will influence the soil-atmosphere exchange of CO_2, CH_4 and N_2O (Mosier, 1998). Below, a few possible effects are briefly summarised in box 3.4.

Box 3.4 Scientific considerations in relation to Soil-atmosphere interactions.

- *CO_2-flux*: Soil organic matter represents the largest pool of both C and N in the terrestrial biosphere. (Parry, 2000). Changing temperature and rainfall patterns will have a major impact on carbon fluxes: as precipitation increases the potential carbon sink capacity may increase caused by decreased mineralisation (Insam, 1990, in: Parry, ed., 2000). Also changes in C:N ratios in the soil may influence the uptake of CO_2 by soils, which will *increase the CO_2-sink function* (Holland *et al.*, 1997, in: Mosier, 1998). However, changes in the source-sink balance for CO_2 seems to depend on the type of ecosystem: v.Breemen & Verburg (1995), for example, found an increase in CO_2-emission in coniferous ecosystems under higher temperatures. As the C and N cycles are closely linked, they should be addressed in combination, in both science and policy-making.
- *Methane:* Most aerobic mineral soils are methane sinks, although the addition of nitrogen fertilisers reduces the sink capacity (Mosier *et al.*, 1991, in: Parry, 2000).
- *Nitrous Oxide:* The higher temperatures and accelerated turnover of organic matter arising from climate change are likely to enhance losses of N_2O by nitrification. Most soils in the Netherlands are cultivated, and here emissions depend strongly on the rate and timing of the fertiliser application. (Parry, 2000; Boland *et al.*, 2000).

Erosion and land degradation

On a global level land degradation processes, such as salinization and soil erosion are likely to increase in the future. However, the magnitude of any change will vary greatly between geographic locations, and will depend strongly on changes in rainfall distributions and intensity, as well as changes in land use (Parry, 2000). Loss of organic matter and a decrease of soil biological diversity would reduce the stability of soil structure, resulting in increased vulnerability to land degradation, both from water- and wind erosion (UK Climate Change Impacts Review Group, 1991). Salinisation of soils occur in regions where there is a high precipitation deficit, or in coastal zones with sea level rise with low precipitation (Kabat *et al.*, 2000).

It can be concluded from the climate scenarios (chapter 2) and the geographical location of the Netherlands, that the Netherlands are much less sensitive to salinisation and soil-erosion compared to southern Europe. Only the Dutch coastal zone could become vulnerable in case precipitation patterns change but also here, major impacts of erosion are not likely.

Shrinkage/swelling
In case summers become drier and warmer, many soils would shrink more extensively than hitherto, and in winter under wetter conditions, would swell again, with major economic consequences (e.g. on agriculture and buildings, see section 3.2 and 3.3). The areas most affected would be clay soils with a large shrink-swell potential, which can be found in the riverine regions and the coastal zone of the Netherlands (Projectteam Klimaatverandering NW4, 1997). Peat soils, situated in the provinces of South & North Holland and Utrecht show some properties analogous to these shrinking clay soils and on drying can become hydrophobic. Re-wetting of peat soils is slower than drying and may be irreversible (UK Climate Change Impacts Review Group, 1991).

Groundwater quantity and water holding capacity
In springtime, an increase in the groundwater-table of between 0-20 cm is expected, with the highest changes occurring in the higher parts of the Netherlands (Projectteam Klimaatverandering NW4, 1997). In summer, groundwater tables will probably be lower. Some effects of changing groundwater levels are briefly listed below (see also chapter 3.1.1 for a more detailed discussion).

- Changes in groundwater-level will influence mineralisation processes
- The water holding capacity is likely to decrease (UK Climate Impacts Review Group, 1991)
- Changes in the water retention properties of soils arising from, for example, loss of Soil Organic Matter or changes in soil structure, are likely to affect hydrological processes at the catchment scale. The magnitude of this effect, however, is difficult to estimate but most likely negligible (Parry, 2000). Optimalisation of the water retention properties of the soil is seen as an adaptation strategy to climate change for water management (see section 3.1.1).

Groundwater quality/leaking of nutrients and pollutants
Potentially, denitrification might be stimulated in spring, mainly in the high parts of the Netherlands (with intensive agriculture) caused by increased groundwater tables (section 3.1.1). As a result less nitrate will leach into the groundwater and surface water (a beneficial impact for the water systems). However, the phosphate binding capacity will decrease as a result of increased groundwater tables in

spring, i.e. more phosphates will leach into the ground and surface waters (a negative impact on water quality) (Boland *et al.*, 2000), despite measures of fertilisation restrictions(see section 2.4.8). Higher groundwater tables, leading to increased anaerobic conditions in spring, combined with salinisation might result in desorption of heavy metals (derived from Salomons and Stigliani, 1995). However, current trends in freshwater exploitation for agriculture and drinking water production may have more impact on groundwater tables (a decline) than the potential increase due to climate change in the Netherlands (derived from WIN, 2000; IUCN, 2000). Some statements on this topic from other European studies are listed in box 3.5.

Box 3.5 Scientific considerations in relation toground water quality.

- "The role of soil as a filter controlling water quality and flow rate will change" (UK Climate Change Impacts Review Group, 1991). Bypass flow arising from soil shrinkage and swelling could increase the rate of movement of polluting chemicals (Rounsevell *et al.*, 1999)
- "Warmer climates can result in reduced organic matter levels and in the release of formerly adsorbed chemicals" (Parry, 2000)
- In coastal regions, contact with brackish water provide ideal conditions for the formation of potential acid sulphate soils. When such soils are drained later, extreme acid conditions would result" (UK Climate Change Impacts Review Group, 1991). If acidification occurs depends on the buffer capacity of soils (calcium carbonate concentration). In the Oosterschelde this is currently an issue, although on a limited scale (Zwolsman pers. comm. In: Veraart, 1998).

B) Adaptation options for soils

Adaptation to climate change through soil management remains a complex issue given the multiplicity of factors affecting land use decision-making (including policy and economics) together with the unknowns of technological change (including engineering and biotechnology) (Parry, 2000).

A summary of appropriate techniques and their relationships to the soil functions and properties discussed in part A is given in table 3.1 (based on Parry, 2000 and other sources.

Adaptation options listed in table 3.1 mainly relate to cultivation activities and occur primarily at three spatial scales (Rounsevell, 1999):

1) field scale: for example by changing machinery, or the timing of operations, the use of different crops, introducing or adjusting irrigation
2) farm scale: through socio-economic changes affecting, for example, farm sizes or diversification to non-agricultural land uses

3) regional and/or national scale: eg. through environmental regulation, such as the recognition of soils as a non-renewable natural resource.

Table 3.1 Adaptation options and their relationships to the impact of climate change on soils.

Impact of Climate change:	**Adaptation options**							
	1. Adjust manure appli-cation	2. "Preci-sion-farming"*	3. Better water-management **	4. Reduce tillage and better tech-niques*	5. Adjust crop rotation*	6. Adjust crop selection	7. Genetic engineering	8. Land use change
1 Soil formation/ org. matter content	x	x		x				
2 Soil quality (esp. nutrients)	x				x	x		
3. Soil biota and microbial activity								x
4. Soil-atmospheric interactions	x		x					
5. Erosion and land degradation		x		x				
6. Shrinkage/ swelling			x					
7. Groundwater quantity + holding capacity	x		x					
8. Groundwater quality/leaking	x	x	x		x	x	X	

x = Effective adaptation option to mitigate impact, * see section 3.2.1, ** see section 3.1.1

3.1.3 Ecosystems

Biodiversity (i.e. the diversity of genes, species and ecosystems), is measured by the number of genotypes, species and ecosystem types and their spatial and temporal distribution. A large number of biotic and abiotic environmental variables influence biodiversity by determining the success of the organisms' productivity and reproduction. Climate plays an important part in this:

- Climate variables (like temperature and precipitation) **directly** determine a large number of life processes like photosynthesis, respiration, reproduction, growth, start and length of the growing season, and moment of bird migration. Species have adapted to climatic conditions during their evolution.
- Climate also has many **indirect** effects on organisms and thus biodiversity via for example, fires, water balance, soil erosion, and soil, water and air quality.
- Because of these direct and indirect relations, climate also influences species-species interactions through which changes occur in competition and predator prey relations, the frequency, nature and intensity of pests and diseases, as well as pollination.

A schematic overview of the many direct and indirect impacts of climate and the biotic and abiotic interactions is given in figure 3.3.

The complex and important role of climate variables in biospheric processes makes clear that the expected changes in climate can have large consequences for natural ecosystems and biodiversity. To determine the possible impacts in any detail, it is required to know how climate is going to change, preferably on a regional scale, and how ecosystems and species will respond. It is very difficult to find an answer to both of these questions. Current climate change scenarios are still too "global" and knowledge regarding interactions between climate parameters (such as temperature and water-balance) and biotic and abiotic components of ecosystems is still limited. Information on the possible impacts of climate change on biodiversity is usually only available per ecosystem and sometimes per species group and an integrated overview is still lacking.

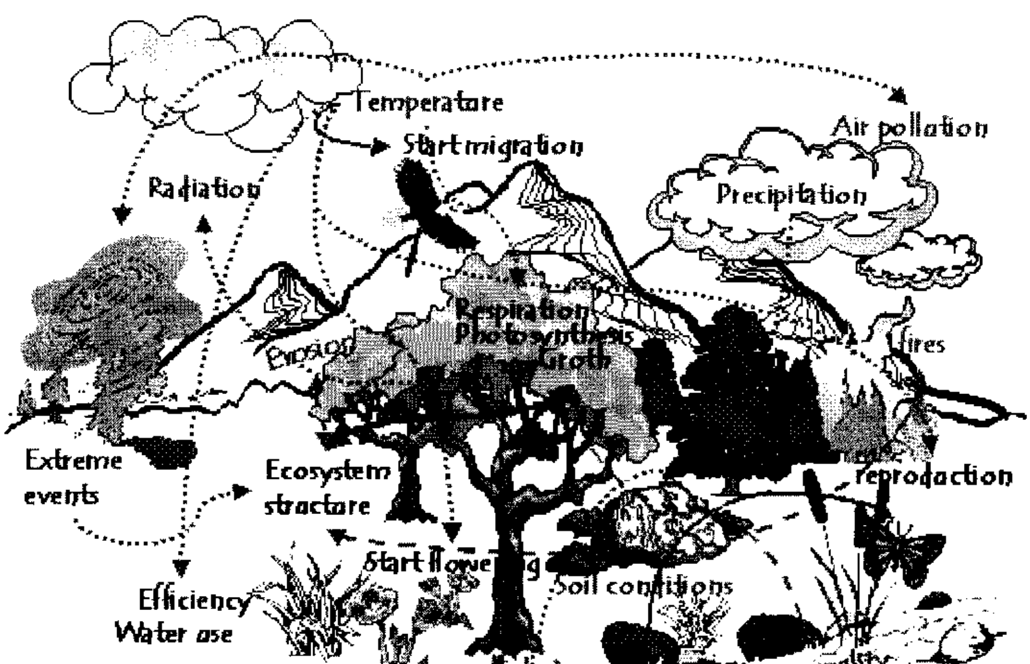


Figure 3.3 Interactions between climate and the biosphere (source: van Vliet and De Groot, 2000).

The next section synthesises both information on different ecosystem types and the effects on species groups. The paper discusses changes that already have occurred as well as potential future changes. In addition to direct climate impacts, a large part of the observed decline in number of species has been caused by human interference in the Dutch landscape such as lower groundwater tables, eutrophication, and landscape fragmentation (e.g. Roos and Vintges, 1992; section 2.4). Since many of these changes can amplify the climate change impacts on natural ecosystems and biodiversity, they are taken into account in the below discussion when necessary.

A) Impacts on ecosystems

In this section, a synthesis is given of possible impacts of climate change on five main types of Dutch ecosystems: 1) forests, 2) heathland & peat moors, 3) freshwater wetlands and brooks, 4) coastal systems (esp. the Wadden Sea), and 5) the North Sea (table 3.2). Being the delta of three large European rivers, river ecosystems influence a considerable part of the Dutch landscape and are therefore discussed in a separate section (3.1.1).

Table 3.2 Impact of climate change on different ecosystems in the Netherlands.

Ecosystems: Main impacts:	Forests	Heathland & peat moors	Freshwater wetlands	Coastal systems	North Sea
Growth and phenology	++	0	++	0	
Species distribution	++	0	0	++	++
Storm damage & fire (+erosion)	++			++	
Pests and diseases	++				
Hydrological changes (dessication,flooding, salinization)	++	++	++	0	
CO_2-effect	0	++	++	0	

++ = main impact discussed in this chapter 0 = possible impact, not discussed

After the discussion of these 5 ecosystem types, a synthesis is given of observed and possible impacts of climate change on 3 species groups: birds, mammals, and insects.

A1 Effects of climate change on forests

Growth and phenology

It is generally assumed that growth and reproduction of many tree species will change because of climate change, causing a change in the functioning and species composition of forests. Net Primary Productivity (NPP) will potentially increase with an increase of the atmospheric CO_2 concentration and the temperature (and the resulting increase of nitrogen mineralisation speed). According to Lankreijer (Lankreijer, 1994), the reaction of trees depends on species and nutrient environment with the possibility of the tree to develop sinks for the extra carbon. With limited nutrients, which is the case for many forests on sandy soils, the increase of biomass will be concentrated in the roots. Satellite observations clearly show that the NPP increased in the last decades at the northern hemisphere (Myneni *et al.*, 1997). Part of this increase is caused by the observed increase in growing season length. More and more publications show that phenological processes like start of leaf unfolding and leaf fall strongly depend on climate (Van Vliet and De Groot, 2001; Beaubien and Freeland, 2000; Crick and Sparks, 1999; Zwart, 2000; Hughes, 2000). Menzel and Fabian (1999)

e.g., showed that the growing season length in Europe increased with 10.8 days on average since the early 1960s).
There are also a number of processes, which prevent the increase in NPP. High temperature, e.g. demands a higher evapotranspiration and if the precipitation does not increase or even decrease, drought stress occurs. It is still unclear to which extent this is compensated by the increased water use efficiency because of the increase in CO_2 concentration (Nabuurs *et al.*, 1997). In addition, a higher frequency of the occurrence of pests and diseases or forest fires and storms can give a negative feedback. Model results show that climate change can cause widespread tree mortality within several decades (Nabuurs *et al.*, 1997).

Species distribution
Species are adapted to the local environmental conditions. With a change in climate, the location of the (climatic) most favourable locations will change. Consequently, several stages of the life cycle cannot be completed anymore which reduce the possibilities for survival. the Netherlands is located on a special geographical position, providing the southern border for boreal species and the northern border for Mediterranean species, the eastern border for maritime and the western border for continental species. On this crossroad of many different species groups, large changes on national scale can occur. That changes already take place is concluded by a large NRP-study of Oene *et al.* (1999; 2001). In this study Tamis *et al.* (2001) analysed long-term data sets on plant species distribution and found significant relations between temperature and changes in plant occurrences in the 20th century. Historic information on changes in distribution ranges shows a marked increase of warmer species in the last decades. Temperature explained about 55% of the explained variation in the changes in occurrence of plant species in this period that could not be explained by other indicators of global change.

In addition to these monitoring data, a large number of models have been developed to assess potential changes in geographic distribution of species. The Euromove model shows that under a Baseline A scenario on average, only 68% of the European plant species depict a stable behaviour and will remain present in a grid cell; thus on average 32% of the plant species will disappear from each grid cell. Macro-scale ecosystems will generally shift northwards and further into the continent. In many cases, suitable areas for macro-scale ecosystems will move over large distances. For individual plant species the potential shifts in climatically suitable areas will mainly be from Southwest to Northeast Europe (Oene *et al.*, 1999). However, scientific results are not always in agreement. According to model studies of Sykes and Prentice (1995) on changes in distribution ranges, *Quercus petrea*, *Fagus sylvatica*, *Tilia cordata*, and *Fraxinus excelsior* will retreat from the Netherlands to the Northeast. This change in distribution is mainly based on insufficient winter chilling of these species (high temperatures during winter). However, Kramer (1996) concludes (based on studies on studies of trees with Dutch origins) that chilling requirements of especially *Quercus petrea* and *Fagus sylvatica* will be met, even with a temperature increase of four degrees Celsius. Based on these results a drastic change in distribution area is not likely. From the NOP-Impact questionnaires it was stated that pine forests in the Netherlands might suffer from climate change if moisture levels increase.

The observed migration speed of species is significantly lower than the speed which is required to keep up with the expected future changes in climate. According to Nabuurs *et al.* (1997) it is likely that most of the tree species will be able to maintain themselves in the Netherlands with a change in climate as their southern distribution range is outside the Netherlands. Several species have their northern distribution limit just south of the Netherlands. These species might expand their distribution to the Netherlands. Species that might improve their competitive power are e.g. *Juglans regia*, *Castanea sativa*, *Robinia pseudoacasia*, *Aesculus hippocastanum*, *Acer pseudoplatanus*, *Platanus hispanica*, *Quercus cerris*, and *Tilia Platyphylos* (Nabuurs *et al.*, 1997).

Extreme events

It is still highly uncertain whether there will be a change in the occurrence of fires and storms under a change in climate (Albritton *et al.*, 2001) but there is a chance that they will occur more often. In case of large scale events there will be a major impact on species composition and ecosystem structure of forests. The large-scale storm damage in France is a good example of this. The rejuvenation of forests resulting from these events can also have positive impacts on the species composition and ecosystem structure but it is highly likely that many plant and animal species have difficulties to recover because of fragmentation and isolation of ecosystems in the Netherlands and in Europe.

Pests and diseases

It is likely that small changes in climate will influence the frequency and intensity of outbreaks of insects and fungi infestations as these species often have the ability to quickly adapt to new environmental conditions and often can easily migrate. Furthermore, climate influences the hibernation, the number of generations per year but also the food quality. In the Netherlands a number of examples can be given of increases in number of pests. An example is the recent increase of *Lymantria dispar*. The caterpillars of this species mainly feed on the Oak. This species has played on an unprecedented scale in Central Europe and Northern America in the 1990's. Most of the pests in the Netherlands started in 'de Peel' which is the warmest part of the Netherlands. It is known that dry and warm periods are beneficial for larval growth of *Lymantria dispar* (Nabuurs *et al.*, 1997).

An increase in winter temperature can also have negative impacts on pests. There is e.g. a small chance for a pest of the Winter moth after warm winters caused by a lack of synchronisation between the hedging of the eggs and the leaf unfolding of oak is (Moraal, 1996). The opposite is probably the case for the Oak Procession Moth (*Thaumetopoea processionea*). The first outbreak was reported

in 1978 and from 1991 to 1996 the species spreaded over a large part of Noord-Brabant, Midden Limburg and the Rijk van Nijmegen.
From a research to the vitality of the Dutch forests which is being carried out since 1984 in the Netherlands it appears that *Picea abies*, Douglas and the *Pinus nigra* var. *maritima* show a negative trend. Furthermore, clear fluctuations have been observed in the vitality of Oak and Beech. Causes for the development and fluctuations are believed to be: drought, many fruits (Beech), insect and fungi infestations (Oak and Japanese Larix), infestations of the Bark beetle (Beech), *Xerula radicata* (Douglas) and infestation of Sphaeropsis (pines) ((Hilgen 1995) as cited in (Nabuurs *et al.*, 1997)). Sphaeropsis thrives well under moist conditions in spring. Therefore, an increase in precipitation might have negative impacts.

Hydrology
Drought poses a large threat to the Dutch forests. Of the moist deciduous forests 50% suffers from moderate to severe drought. This mainly concerns forests on sandy soils in the southern and eastern part of the country. An increase in winter precipitation might improve the situation. However, dry summers can affect both flora and fauna in many ways. Drought causes levelling off of the vegetation and a reduction in biodiversity. Trees suffer more severe from drought. Especially Beech and Birch are sensitive while Oaks have difficulties with changing water tables. Kramer (1996) found that Beech would be able to better compete with Oak and Birch in the Netherlands (under the assumption of sufficient moisture). Small changes in soil moisture and sunlight can change survival possibilities of seedlings and the seed production. Both plants and mushroom flora which are characteristic for moist places/conditions in forests are threatened (Wood anemone, Wood sorrel). Plants as e.g. Bracken (*Pteridium aquilinum*) that grow on less moist places benefit from this. In general, drought results in the disappearance of plants and animals that prefer a high water table or seepage water (Roos and Vintges, 1992). It is highly likely that this will occur in the Netherlands because of changes in precipitation but certainly also in water management.

A2 Effects of climate change on heathland and peat moors

Groundwater table and water availability
The lowering of the ground water table caused by human activities resulted in drought in 90% of the wet heathlands and peat moors and 50% of the grasslands with low productivity and few nutrients. Dry heathlands do not suffer from this problem as they depend only on precipitation. Changes in precipitation and temperature might however improve or worsen the situation and should be taken into account in the ecological management plans of these areas.

A small lowering of the groundwater table already has large consequences for grasslands with low productivity and few nutrients, moist heathlands and peat moors via changes in physiology, chemistry and biological activity. The flexibility and resilience of these systems decreases under drought conditions. Too long dry period can do irretrievable damage to peats. The changes become visible in the vegetation. Molinea (*Molinia caerulea*) is expanding at the cost of Bog-cotton (*Eriophorum vaginatum*). At wet places Cotton grass will be replaced by Common rush (*Juncus effusus*) which indicates a larger availability of nutrients like nitrogen. Finally, trees like Birch (*Betula pubescens*), Willow (*Salix aurita*) and Buckthorn (*Rhamnus cathartica*) will enter the system. In wet heathlands heather will be replaced by Molinea. Drought also aggravate the impacts of eutrophication and acidification and the ecosystem will slowly turn into dry heatlands – and grasslands with low productivity and few nutrients. Plants like Sundew (*Drosera rotundifolia*), Gentian (*Gentiana pneumonanthe*), Bog rosemary (*Andromeda polifolia*), Grass of Parnassus (*Parnassia palustris*), Rhynchospora (*Rhynchospora alba*), Cranberry (*Oxycoccus palustris*) will disappear (Roos en Vintges, 1992).

Animals are as well as plants also directly or indirectly dependent on water availability. All animals that are characteristic of a humid environment are currently under threat like dragonflies (White-faced darter, Small Red Damselfly), *Phryganea grandis*, and several butterfly species. Other invertebrate species like snails, *Eucumulus fulvus* and *Columella aspera* increase in peat moors that suffer from drought. Birds like Bluethroat, Water Rail, Common snipe, Spotted Crake, Common Redshank and other meadow birds like Marsh harrier, Hobby, Yellowhammer and the migrating Common crane are threatened. Bluethroat, Water rail and Common snipe will become threatened because of closing shores and a reduction in food availability. Forests that grow thick and are closing open areas also reduce the amount of habitat for a number of bird species like e.g. the Marsh harrier and the Yellowhammer (Roos *et al.*, 2000)

CO_2-effect

In addition to drought, other factors, like changes in CO_2 concentration, cause changes in species composition. Analysis by models demonstrate that heather will increase its competitive strength to Deschampsia (*Deschampsia flexuosa*) under an increase in CO_2 concentration and nitrogen deposition (Kovel and Wilms, 1995).

A3 Effects of climate change on freshwater wetlands, swamps and brooks

Physiology and growth

Precipitation, temperature, and the temporal variation play an important role in wet ecosystems like wetlands and swamps. Temperature determines, just like in terrestrial ecosystems, many ecological and physiological functions (primary productivity, microbiological activity, nutrient cycles and habitats). The physiological and chemical characteristics of plants determine largely the insect, birds, fishes and mammals that depend on wetlands. In addition, higher water temperatures increase the growth of water plants, algae bloom and the growth of animal species. Therefore, temperature is likely to influence the composition of aquatic macrophyte-communities also because of fundamental differences in its influence on the life cycle of different species. Many aquatic species hibernate by means of vegetative propagules. A change in temperature (and quality and quantity of light) may influence production, ripening, sprouting, and dormancy-breaking of these vegetative propagules and stimulate earlier onset of growth and germination. A change in distribution of these species may also occur.

Hydrological cycles and drought

Precipitation regulates the direct input of water in the wetlands. In addition, temperature also influences evapotranspiration speeds, which have implications for the hydrological cycle in wetlands. Many wetlands have large spatial and temporal variation in plant communities because of climatic variations, seasonal flooding and variations in micro-topography. Often, an increase in the length of flooding will lead to mortality of trees and to a replacement of these trees by herbal vegetation. A long-lasting lowering of the water table might increase the number of trees.

Human activities also interact with climate change effects. Because of dehydration and sprinkling of agricultural fields, lowering of the water level in brooks, and canalisation, the seepage to brook valleys decreases causing drought. In 80 to 90% of the natural systems the seepage (which contains large amounts of calcium) has been lowered to sometimes far beneath the rooting zone. These areas are thus highly susceptible to a decrease in precipitation and increases in temperature during summer. Brooks and pools might suffer from low water tables or even completely dry up. It is unclear how far old wells will be able to discharge water under a change in precipitation patterns. Negative impacts will mainly occur in case of long periods of drought, when the distance between remaining pools become larger, when there is no contact between pools via groundwater, when the pools are too small to have sufficient differentiation of habitats, and when the pools dry up seasonally and irregularly. The effects of drying up on organisms remain visible untill many years after the event and long after the complete hydrological restoration (Dolman *et al.*, 2000).

Human induced changes in the water management have also caused drought in brook accompanying forests (Alder forests on sandy soils) which have resulted in the decrease in characteristic species that prefer moist conditions. When precipitation is able to better penetrate the soil because of drought, indicators for acidification appear like Yorkshire fog and on wet locations *Carex rostrata*, and Violet (*viola palustris*). In Alder-Ash forests, nitrogen preferring species expand after drought and eutrofication (e.g., Bishop's weed, Robin-run-the-hedge, and Ground ivy) which impacts the characteristic spring flora of these forests like e.g. Primula's (Roos *et al.*, 2000).

In brook accompanying grasslands drought causes a strong decline of species like *Carex dioica*, *Carex pulicaris*, and *Carex hostiana*. Also orchid species like the Butterfly orchid, *Dactylorhiza majalis*, and Grass of Parnassus are sensitive for drought. The Marsh, which is dependent on Devil's bit, has completely disappeared from the Dutch brook valleys. Grasses like Yorkshire fog and *Calamagrostis canescens* and several nitrogen preferring species like Ribwort and Sorrel expand. Drought and eutrofication in King-cup haylands results in the expansion of grasses like Yorkshire fog, *Calamagrostis canescens*, *Glyceria maxima* and herbal species like Nettle, Creeping thistle, Chickweed, and Cow-parsley (Roos and Vintges, 1992).

A reduction in sedge-swamps can change the mesotrophe environment in an oligotrophe environment (nutrient poor and acid) as a result of the large impact of precipitation. Because of this, typical mesotrophe species like Bogbean, *Carex lasiocarpa*, Greater spearwort, and Marsh cinquefoil disappear. Because of acidification we will observe an increase in species that prefer acid environments like *Carex curta*, *Carex nigra*, Violet (*viola palustris*), and Cotton grass. A further drought and eutrophication growth of trees and bushes increases with mainly Alder, Elder, Buckthorn, and Rowan.

Changes in precipitation will have large impacts on the hydrology and ecology within brooks. Changes in the discharge will change the force of the currents that changes the distribution of substrate. As the differences in discharge will become more extreme, less species will find their required niche. The current condition of the brooks in the Netherlands already can be compared with this situation. It is caused by canalisation, normalisation and the fastened discharge via drainage and the disappearance of swamps. Climate change will strengthen these effects.

Carbon cycle

There are still many uncertainties regarding how an increase in CO_2 concentration in the atmosphere will affect wetland ecosystems. It is however highly likely that the carbon cycle will change. An increase will have a direct fertilisation effect leading to a higher productivity. It also can change stress tolerance of plants (against high or low temperatures, and droughts). However, species rich ecosystems can respond in complex ways to the increases. An increase in the CO2 concentration might change the evapotranspiration of plants that will affect the water balance as the vegetation plays an important role in the transport of water from soil to atmosphere. Several wetlands that currently function as a carbon sink will change in carbon sources because of a decrease in the groundwater table or an increase in temperature. In the arctic areas this is already happening. If climate change results in a change in saturation and flooding of wetlands, this have also have consequences for the methane emissions, another greenhouse gas. Drought will increase to a decrease in methane emissions.

A4 Effects of climate change on coastal wetlands & dunes

According to Dolman *et al.* (2000) climate change has two main impacts on coastal ecosystems: an increase of mean temperature and sea level rise. It is still unclear which factor will be most important in the coastal zone.

Another effect of climate change in the coastal zone might be the sudden discharge of fresh water in case of extreme runoff, which can cause considerable damage to species richness which only slowly recovers. Salt-water marshes can quickly turn into fresh water systems if the connection with saline seepage disappears. Finally, a change in climate can lead to an increase of dune erosion and a change in the dynamics of sea currents.

Two main effects are discussed in some detail below: changes in erosion (and sedimentation) and changes in species composition

Erosion
Sea level rise will cause increased coastal erosion along the mainland as well as the Wadden Islands, influencing both the dune-landscape and salt marshes. For example, part of the loss in salt marsh area in the Wadden Sea in the period 1976 and 1983 might be due to an heightening of the level of mean high water with 4,4 mm/yr from 1961 to 1983 (Terwindt, 1995). A sea level rise of 3 to 6 millimetres per year can be compensated by growth of the vegetated salt marshes which can retain three times more sand than salt marshes with no vegetation. Differences between the vegetated low salt marsh and the un-vegetated pioneer zone become more apparent which may lead to cliff formation. These cliffs, even as small as a few centimetres, will form the locus from where erosion of the marsh area starts during a rise in the mean high water level (Terwindt, 1995).

Another effect is that an increase in storm frequency will lead to a higher degree of turbulence in the pioneer zone which becomes more dynamic and will lead to an increase in seed loss up to 99%, and worsen the ability of the settlement of the pioneer vegetation.

Species diversity
A change in temperature will cause a change in species distribution. Many responses of species are however influenced by more than one factor. Brinkman (1995) e.g. demonstrated that a change in temperature in combination with changes in sea level influence the diversity of algae. Diatomes are extremely sensitive to temperature. They grow better under lower temperature opposed to the non-diatomes. An increase in temperature, thus leads to an increase of non-diatomes. A sea level rise of 20cm will lead to a decrease in algae concentration because of light limitations.

An increase in the force of water currents, because of sea level rise, will increase the amount of sediment in the water which decrease the use of the estuary for a nursery area. It is also likely that the period of stand-clear of the water will decrease (in case sedimentation is not sufficient). In this case, the bentos production on the plates will decrease which in turn negatively influences the food availability of many birds. This increases competition between birds which need to find their food in shorter periods. Inexperienced birds will die which can have dramatic impacts on the population structure.

Seals require sand banks for resting and reproduction. The population of seals is currently increasing but the disappearance or the shorter availability of the banks might negatively affect this positive development.

Changes in diversity have also been observed in the Zeeuwse delta. It is however, unclear what the contribution of the increase in temperature has been. The # also reports increases in populations of Sole. This fish species prefers warm sea floors. Its northern distribution is on the North Sea but it is moving further to the North. In 1994/1995 five Trigger-fishes where caught which normally only occur in warmer waters. Other warm water fish species that have been observed are the Red mullet and the Opah (which normally does not live in the North Sea) (http://www.waddenzee.nl/dutch/ecomare/NED0362.HTM).

A5 Effects of climate change on the North Sea

The consequences of climate change for the North Sea ecosystem are largely unclear. Lack of knowledge on the processes that occur in the system are the main cause. Probably the main effect of higher temperatures and changes in sea-currents will be on the species diversity.

According to the VOFF (1997), many southern species have recently increased in the North Sea, while several northern species have decreased in numbers. Especially in the period 1990 to 1995, several crustaceans with an originally southern distribution have increased substantially. Examples are Small hermit crab, Helmet crab, Pennant's swimming crab, Arch-fronted swimming crab, Marbeled swimming crab, and Smooth swimcrab. Especially in this period, the increase in species seems to be associated with warm winters and warm summers. Of the sixteen species that showed a continuous decline over the period 1980 to 1995, the *Tubularia indivisa*, Lion's Mane and the Great spider crab can be seen as northern species.

A6 Consequences of climate change for some species groups

Birds

Discussions on climate change impacts on birds often focus on the impacts on *migratory birds* (eg Meekes and Geelhoed, 1990). Migratory birds are extra sensitive to climate change because climate-induced changes in the timing and pattern of their migration place additional stress on their physiology. Bird species that depend on wetlands for part of their life cycle are threatened the most as their young are precocious, i.e. leave the nest shortly after they hatch (e.g. ducks, swans and geese). These young birds might suffer from heat stress or an increase in precipitation. In addition, wetlands might flood or dry up which causes a change or even loss of habitat (e.g. vegetation structure) and food supply.

Another important threat to birds in wetlands is botulism. This disease is strongly connected to high water temperatures. An increase in temperature will increase the distribution and frequency of occurrence of these bacteria.

Whole populations of many wetland species often depend on only a limited number of areas which makes them very vulnerable for changes (e.g. a change in the availability of food by changes in the timing of insect appearance).

In addition to migratory birds, Dutch *breeding birds* will also face impacts (see for example Van der Jeugd (1992) for a good overview), mainly related to temperature stress, food-availability and habitat change.

Direct temperature-effects

Those species of which their northern distribution limit is determined by temperature (below a certain, species-specific level, the survival of young is strongly reduced) will be able to expand their distribution range to the north with an increase in temperature. The southern border of a species distribution range is sometimes also determined by temperature. There is a tendency that the basal metabolism towards the Poles increases. This means that the amount of generated warmth increases. If the temperature rises above a certain level, young individuals will produce too much heat that cause them to die. With an increase in annual temperature several species with their southern border in the Netherlands will be faced with this problem. Their population will decrease or they might even disappear. For a number of species it is known that their theoretical southern border (based on thermo-regulation) can't be reached because the southern replacer out-competes the other one. In this case, the southern species will increase at the cost of the northern species.

For many sedentary species the survival is dependent on the occurrence of low temperatures (via effects on thermo-regulation and food availability which, in turn is determined by ice and snow-cover). Higher temperature decreases the occurrence of cold winters. Species that will be influenced are all migratory fish eating species and small, non-migrating singing birds

Food availability and breeding success
The moment of insect appearance during spring depends in many cases on temperature. In cold springs the food availability is insufficient to raise the young birds. Higher temperatures reduces the chance for a spring that is too cold and will increase the breeding success of insect feeding birds and birds of which the young depend on insects. This effect will mainly be visible with fowl, Common swifts and Swallows.

Stevenson and Bryant (2000) also observed that fine-scale patterns of climate change could be critical to the reproduction of some species and underlies previously unexplained variation in the breeding success of some temperate birds. Changes in temperatures furthermore change phenological processes like arrival, breeding, and departure date of birds and their food-species (especially insects). This might positively and negatively affect food availability and nesting success. From a number of studies it has become clear that changes are becoming increasinlgy visible since the 1980's which goes together with an increase in temperature (Pilzecker *et al.*, 1998; Crick and Sparks, 1999).

These changes will influence many species-species interactions (e.g. Visser *et al.*, 1998; Both and Visser, 2001) leading to enhanced competition for food.

Drought leading to habitat change
In addition to the impacts of temperature, birds are also sensitive to drought as it causes an impoverishment of habitats like forests, wet dune valleys, peat moors and other natural areas. Acute threatened ecosystems are the many small peat moors and fens in the higher parts of the Netherlands. Many of these pools will dry up more often in years with warm and dry summers. Breeding areas of the Black-necked Grebe, Little Grebe, and Common Teal will be directly threatened by these events. In general, there will be a continuous reduction of the amount of

wet biotopes (swamps and reed-beds). Especially bird species depending on reed-beds will be threatened (Savi's Warbler, Great Reed Warbler, Bearded Tit). Drought also reduces the species richness in grasslands which then negatively affects the food availability for meadow birds.

Mammals

A study of Ovaa *et al.* (1993) concluded that 34% of mammal species in the Netherlands will benefit from an increase in temperature, drier summers and wetter winters. About 21% of the species will be negatively affected. For drought, the percentages are respectively 24% and 31%. The type of response varies strongly for different species, and it has become clear that a large number of other factors play a significant role. Below several possible impacts are presented, mainly taken from a study of Zoon (1993).

An increase in growing season length will increase the winter survival of the hedgehog, which currently causes the largest natural mortality of 50% (Corbet, 1988). The Common forest shrew is a species, which tries to avoid drought and warm conditions. However, the impact of an increase of precipitation during winter and an increase in temperature is difficult to assess. An increase in moistness is, on the other hand, beneficial for the Dwarf shrew as this species mainly lives above ground in dense vegetation of open areas. An increase of temperature and drought during summer has negative impacts.

Insects

The presence of insects is influenced strongly by climate. Although insects play an important role in ecosystems, still relatively little information is available on the impact of climate change.

Butterflies are insects of which the sensitivity for climate is relatively well-studied. Van Swaay (1990) divides the climate change impacts on butterflies in physiological impacts and a change in the abiotic and biotic conditions. A small rise in temperature can cause a significant increase of the growing season length of butterflies. Temperature changes in the past have shown that species respond strongly and quickly (e.g., by changing their geographical distribution) (Parmesan *et al.*, 1999). The life cycle of butterflies is strongly adapted to the local climate and under favourable conditions, a number of butterflies might be able to produce an extra generation per year. On the other hand, plant-insect relations can become disrupted which can reduce food availability during essential periods of the year. For example, early flowering can reduce food-availability to adult butterflies or changed food quality (nutrient-content) of leaves can force caterpillars to eat more plant tissue to gather the required amount of nutrients.

A case-study of Van Swaay (1990) indicated that of the 65 buttefly species that have been examined, 30 species were correlated with one of the climate variables. Many species have the edge of their geographical distribution in the Netherlands which makes them extra sensitive to changes in climate. Especially, the weather during springtime seems to be very important for many species (Van Swaay, 1991).

In addition to impacts to butterflies, many other insects will be affected too. Studies of Ellis (Ellis et al, 1997a; Ellis et al, 1997b) on changes in distribution and phenology of Microlepidoptera showed that during the period 1975 – 1994 the flight peak has become on average 11.6 days earlier. This shift is primarily associated with a rise in spring temperatures. Fifty percent of the species have undergone a significant change in distribution in the last few decades. Generally, the pattern of changes shows a NW/SE opposition, matching the major trend in climatic isolines. A large survey of changes in the abundance of Lepidoptera species in the Netherlands based on existing long-term databases by Ellis *et al.* (2001) concluded that "the strongest effects of climate change are seen in the decreased abundances of those species that hibernate as adults. This effect is probably caused by the present moist and mild winters that negatively affect winter survival and/or reactivation in spring of such species. Further, weak effects of increased temperature could be observed in the increases of Lepidoptera species that have host plants with a high temperature preference."

Wasscher and Van Tol (1993) studied changes in dragonfly populations in the Netherlands. They have observed that several species are expanding their distribution to the north. At least a part of the changes can be linked to the observed recent changes in climate. At the conference "Fingerprints" of Climate Change; Adapted behaviour and shifting species' ranges a paper was presented on the expansion of dragonflies in Germany and Europe. A clear trend of expansion towards the north, the increase of population sizes and the colonisation of biotopes at higher altitudes as also several biological and behavioural adaptations were observed (Juergen, in press).

Discussion

The large number of ecological impacts of climate change that have been described in the previous sections illustrates the extent and complexity of the problem. The required knowledge for making a thorough analysis of observed changes and to extrapolate the results to potential future changes is however often lacking, especially when the changes are caused by indirect impacts. In many cases it is only possible to consider the impacts of an increase in temperature on a specific species without taking into account other impacts or the causes of changes in species-species interactions.

Environmental problems that are closely related or linked to the climate change issue (like drought and eutrofication) are often not taken into account. Since these other environmental impacts can significantly increase the vulnerability of species and ecosystems for climate change impacts, an integrated approach is essential.

Modelling results of Kovel (1995) and Oene *et al.* (1999) e.g. show that there are strong interactions between the impacts of climate change and the nutrient and water availability in the ecosystem. Climate change has important effects on ecosystem functioning and thereby possibly on plant diversity (Oene *et al.*, 2001).

Leemans and Hootmans (2000) acknowledged that: "ecosystems play a major role in global biogeochemical cycles. Changes in ecosystems can change this role and surprises in their response and functioning cannot be ruled out, all leading to pronounced effects on current biomes, landscapes, communities and biodiversity. Many of these effects are judged as being irreversible."

Despite all uncertainties we can conclude that climate induced impacts on Dutch ecosystems are already taking place and future changes will be considerable

B) Adaptation options of ecosystems

The previous sections clearly demonstrated that climate change will have a large number of impacts on ecosystems and biodiversity in the Netherlands.

Before discussing some adaptation measures, we should realise that changes in climate are, basically, natural processes with which ecosystems have been confronted as long as they exist and that there always will be "winners and losers". However, the current situation is exceptional for a number of reasons:

- The changes in climate are very large, and rapid, and will become even larger and more rapid in the future, according to climate change scenarios.
- Humans contribute significantly to climate change (Albritton *et al.*, 2001) and thus have the responsibility to address this problem.
- Ecosystems are exposed to a large number of other human induced threats that have increased the vulnerability to climate change.
- Climate change can enhance the effect of acidification, eutrofication and drought.

Adaptation measures for ecosystems can be separated in the following measures:

- Measures aimed at creating conditions under which species have sufficient space adapt (i.e. measures targeted at maintaining the "quantity" of ecosystems)
- Measures aimed at reducing other threats to ecosystems (disturbance, acidification, eutrofication, introduced species, drought). These measures are targeted at improving ecosystem quality.

A number of generic adaptation measures can be taken which reduce the vulnerability of most ecosystems in the Netherlands (table 3.3). At the workshop it was noted, however, that the measures mentioned will only be effective under moderate changes in climate (between 1 to 2°C in 100 years) but that they are not effective anymore under larger and/or more rapid changes.

Construction of an ecological network (Ecological Main Structure)

The so-called "Ecological Main Structure" (EMS) is an ecological network and aims to decrease the landscape fragmentation and increase the connectivity of natural areas to better enable species to migrate. It also provides room for more individuals within a population and thus makes populations (and species) more genetically more viable.

Together with the enlargement of existing natural areas, and creation of new ones, the EMS is considered to be one of the most important adaptation measures to counteract climate change impacts on ecosystems and species. It is also seen as a robust solution which can be operational for the long term.

There are, however, a number of problems related to the construction of the EMS. The lack of space in the Netherlands makes physical realisation difficult and costly. Furthermore, if the EMS is to be successful, it should be developed in a European context. There are also uncertainties about the effectiveness of the EMS. The current connections between natural areas are not functioning well, which is mainly caused by a lack of knowledge on the ecology but also on the use of an EMS at the local level. Finally we have to change our definition and management of exotic species: if southern species, which are currently exotic for the Netherlands, move "naturally" into the Netherlands in the future they should become accepted, and managed as native species.

Table 3.3 Adaptation options and their relationships to the impact of climate change on ecosystems.

Adaptation Options: / **Main impacts:**	EHS/EMS (more space for nature)	Multi-functional land use/ planning	More natural management	Water-quality improvement	Monitoring (eg. species, forest fires)	Recreation management + education
Growth and phenology					+	
Species distribution	++				++	
Storm damage & fire (+erosion)			++		++	+?
Pests and diseases	++				++	+?
Hydrol. Changes			++		+	
CO_2-effect						

Spatial planning/multi-functional land use

Under unstable climatic conditions combining different land use activities (eg agriculture, recreation and living) with nature conservation will result in an increased diversity, and thus "adaptability" of species and ecosystems.

Other issues to be considered in spatial planning in relation to climate change are fire control measures in forests and other (semi-natural) ecosystems

More natural management (of forests, wetland and the coastal zone)

Forest management

To prevent large scale wind throw in forests mixing species is an effective management measure. A trend to a more natural forest management can already be observed in Europe which will result in more distributed and more local wind throw events, which are less harmful to forest ecosystems (Dolman *et al.*, 2000).

This type of management (mixing species) will also increase the species richness in some forests.

Water management
More natural fluctuation of the groundwater table can counteract drought. This however might not be effective on the larger scale or on dry soils for certain ecosystems. The soil may become too wet for tree species, which makes them more vulnerable to wind throw or they might not have the time to adapt. In addition, this measure might have negative consequences for the washing away of pollutants (thereby affecting soil water and fresh water supply).

Coastal management
The impacts of a sea level rise can, in some cases, be best counteracted by, withdrawing the coastal defence and creating more natural dynamics and more elasticity to the system. Other measures that can be taken are to stimulate natural re-growth of dunes, restoration of brackish water zones, the establishment of hydrological buffer zones, and the creation of nutrition banks at –5meters NAP. Some of these issues are discussed in more detail in the hydrological section of this report (section 3.1.1).

Water quality improvement
For inland waters, the most important adaptive measure was considered to be the reduction of the level of eutrophication, because a poor water quality in combination with high temperature may enhance anoxic conditions. Regarding large rivers, solutions might be found in a reduction in the use of cooling-water in power plants and other industries, because effects of climate change would be superimposed on rises in temperature that have already taken place.

Monitoring
a) Species distribution
Monitoring species occurrence and population size is extremely important. A large number of organisations is already involved in this but the support by the government is not sufficient and should be improved. Climate change impacts should be one of the issues taken into account when data are being analysed. Preferably, a selection of climate change indicators are selected in advance. The most important indicators are changes in geographical distribution and the phenology of species as these processes are often closely linked to climate and quickly respond to climate changes (e.g. earlier start of the growing season or the appearance of new species from the south).

b) Pests and diseases
Monitoring of changes in the occurrence, intensity, and frequency of pests and diseases is required to be able to take the required countermeasures. It is also advisable to stay in contact with foresters in surrounding countries as a sort of early warning measure.

c) Forest fires (and other damages, eg storms and floods)
The number of forest fires will increase with warmer and dryer summers. Forest monitoring during the critical periods have to increase. We will have to determine whether the available tools and manpower is sufficiently available to fight the fires if needed. Also other environmental hazards such as storm and water damage can be used as indicators and should be monitored.

Education and recreational measures
Education and information of the general public on the dangers is also one of the possible measures.

- Manage recreational activities to prevent disturbance and pollution.
- Increase the amount of (wet) ecosystems can at the same time satisfy the increase in demand for nature for recreation. To prevent harm to natural systems a proper phasing of recreation is important.
- Inform the public on possibilities to prevent disturbance.

Nature policy
Current, and future, nature policy formulation and implementation should take better account of climate change. Many nature development projects are executed and evaluated based on the so-called "target species". Climate (change) sensitivity should be considered more often in selection of these target species. If a species lives close to its southern distribution in the Netherlands (e.g. the Northern vole, *Microtus oeconomus*) than it is likely that an increase in temperature will negatively impact the populations. Thus, a decrease of the population size does not say anything about the effect of policy or management. At the workshop, it was suggested that we might even abandon the target species or target ecosystem types that we try to restore. This, however, might reduce the ambition to protect and preserve certain species.
Nature policy should not take additional measures to preserve species which are located at their southern or western border of the distribution if the expected climate change leads to a decreasing survival change of the species. In this case the money is better spent to preserve other species. Policy recommendations of Parry (2000) stress that policies need to be based on detailed regional assessments, since impacts are regionally different due to climatic and land use gradients, as well as due to the spatially variable signal from climate change.
The enquiries of our study also highlighted that the problems can not be solved in a generic way but only by looking at the specific conditions from location to location. An even more important question which we have to answer is what we consider to be "ideal or wanted natural systems" in a specific area in relation to certain policy goals. For example Parry (2000) states that many European ecosystems are likely to have higher net primary productivity due to higher temperatures, higher CO_2 concentrations and atmospheric nutrient pollution. He stresses however that environmental policy should not assume that this necessarily implies increased benefits from ecosystem services, since disruptions in the present ecological balance are likely to follow. Because soil respiration will

increase with higher temperatures, the higher net productivity does not imply increase in carbon storage. It can therefore not be expected that climate change will contribute to an easier fulfilment of Kyoto commitments.

3.2 Land use and fisheries

In the Netherlands, 60% of the total area is currently in use for agriculture, 15% for surface water, 8% for production forest, 4% as natural zones and 13% for urban areas, infrastructure and other space use (CBS, 1999).

The functioning of rural areas will be affected by climate change. The effects of climate change are difficult to quantify but could be substantial. Early detection of adaptation strategies by actors, government and society is essential. Because climate change will not be the single driver of change these adaptation strategies need to be identified and defined in relation to other developments that effect the rural areas.

3.2.1 Agriculture

In the last decade a number of impact studies at various scales were made. Working group II of the Intergovernmental Panel on Climate Change (IPCC) focussed on the impact, vulnerability and adaptation to climate change for human and natural systems. It concluded (IPCC, 2001) that agricultural production in the temperate zones may benefit from an increase in temperature of a few degrees, at higher temperatures the effects are expected to be negative. In 1995 the Environmental Change Unit at the University of Oxford presented a report on Climate Change and Agriculture in Europe (Harrisson *et al.*, 1995). They concluded, based on modelling studies, a increase of wheat production across most of the continent, and a decrease in sunflower yield for most scenarios, the impacts tend to positive for the northern part and negative for the southern part of Europe.

The Europe Acacia Project (Assessment of potential effects and adaptations for climate change in Europe) presented its results in 2000 (Parry, 2000), and provided the base for the European chapter for the IPCC third assessment report. For agriculture the conclusions in Parry (2000) were in line with previous studies and reported predominant negative effects for southern Europe.

In the Netherlands the Dutch National Research Programme on Global Air Pollution and Climate Change (NRP) financed several impact studies including a model study on the impacts of climate change on agriculture in the Netherlands (Schapendonk *et al.*, 1998).

The impact of climate change is a function of the direction, magnitude, rate of change and geographic distribution of the exposure. For example changes in precipitation regime and intensity will effect peak drainage in especially the river Maas. This will not only effect land use and land use planning in the river valleys but in combination with sea level rise will claim larger areas for water buffering and storage in the coastal areas. Moreover polders with limited storage capacity will experience extreme high water situations more often. In coastal areas saltwater intrusion will increase as result of sealevel rise. In the drought sensitive sandy areas changes in rainfall dynamics will directly influence production levels. In general groundwater dynamics will increase with increasing rainfall dynamics. Workability and traficability in early spring (planting/sowing) and autumn (harvest for late crops and soil management) will, depending on soil type, be directly influenced by changes in rainfall patterns. In the erosion sensitive löss areas, e.g. South Limburg, erosion will amplify as result of increased rainfall intensity and changes in rainfall dynamics.

This chapter will address the expected effects of climate change on the agricultural production functions of the rural area. Three agricultural sectors are discussed:
1. *Arable farming*
2. *Animal husbandry and grassland*
3. *Greenhouse production.*

Feedback mechanisms between these functions and the climate system are not taken into consideration in this study. For the direction and magnitude of the expected climate change in the Netherlands, see climate scenarios in chapter 2.2.

1) Arable farming

Primary crop production is directly effected via climate parameters such as: CO_2, temperature and precipitation. The nature and character of these effects and reactions are crop specific and are strongly interrelated.

Warming is expected to increase the season in which crop production can take place but will also reduce the growing period for e.g. cereals whereas potato and sugar beet will be able to exploit the longer growing season. Increased CO_2 concentrations will directly enhance crop productivity and increase water use efficiency (Schapendonk *et al.*, 1998). In 1998, arable land use was 810100 ha (CBS, 1999). Schapendonk *et al.* (1998) reported an area of 720900 ha for 1995 with a total production value of 3503 millions NLG (table 3.4).

Table 3.4 Area and production value in 1995 for different crop groups (Schapendonk et al., 1998).

Crop	Area (ha)	Production value (x 10^6 NLG)
Cereals	193700	444
Seed potato	37800	532
Consumption potato	80200	643
Starch potato	61300	314
Sugarbeet	117700	846
Total	720900	3503

Based on model calculations Schapendonk *et al.* (1998) estimated the relative changes related to the 1990 levels in crop production for two scenarios and 2020 and 2050 (table 3.5).

Table 3.5 Relative changes in crop production per ha in the Netherlands (percent in 2020 en 2050) (Schapendonk et al., 1998).

Crop	2020		2050	
	Low(1)	High(1)	low	High
Winter wheat	103.7	104.3	105.1	107.6
Seed potato	108.9	111.2	121.8	129.1
Consumption Potato	107.4	109.7	115.7	121.6
Starch potato	109.8	112.0	124.8	132.0
Sugar beet	116.2	118.1	129.0	135.1

(1) Low and high refer are based on studies by Alcamo *et al.* (1996).

General conclusions based on the study by Schapendonk *et al.* 1998, are:

- A doubling of CO_2 concentrations can, under optimal conditions, depending on crop and weather conditions lead to a production increase of 15-50 %. As result of increased temperature the positive CO_2 effect will be reduces to 10-30%. Simulation and experimental studies show that a temperature increases results in early maturing of crops. The processes of early maturing and faster ageing of leaves compensate the higher spring growth
- Water use is expected to remain at comparable levels. The positive reduction in water use related to the higher CO_2 concentrations are neutralised by the increased transpiration and temperatures
- Changes in frequency and dynamics of climate parameters will have a direct effect on the risk of crop failure and loss of quality of the end product.

Apart from the direct effects of climate change on primary production indirect effects are expected to have impact on agricultural production. Especially higher temperatures during the winter period are expected to have large effects on the survival rates of larvae of harmful insects. Increased temperature will increase development and insects are expected to mature earlier, in combination with longer growing seasons will allow a completion of more lifecycles (Rosenzweig & Hillel, 1998).

Costs of crop protection measures are expected to increase as the combination of higher temperatures and wetter winter and spring periods will enhance pressure of existing fungi and introduce new fungi and diseases. Moreover, changes in wind direction and speed may alter the spread of wind born pests.

Climate change impacts on tree crops and fruit trees could include more frequent frost related damage in spring. Sensitive stages in the life cycle of most tree species - including pollination, flower production, and seed germination - could be upset by climate change.

The relative high sandy areas of the Netherlands will experience water shortages during the dryer summer period. Low-lying areas are expected to suffer from excessive rain during the winter/spring and autumn periods. Trafficability will be negatively affected during planting/sowing and harvest periods. Especially harvesting root crop (potato, sugar beets) will become more precarious and counteract the positive effects expected from a longer growing period. Sea level rise will enhance the effects in the coastal zones. For the low-lying coastal areas sea level rise resulting in salt-water intrusion will pose additional difficulties for agriculture in these areas.
In general, organic agriculture, which does not depend on agro-chemicals such as, herbicides and pesticides, is sensitive to changes in external factors, such as temperature and humidity, which also influence pressures of pests and diseases. Ecologically based farming systems will follow the natural dynamic more closely; climate change will have a direct impact on the production levels in such systems.

Adaptation
Agricultural systems have adapted to changes in environmental conditions via crop choice, changes in crop rotation, water management, reclamation of land, research programs, and organisation structure. Some farm-level adaptation strategies, such as changes in planting and harvesting dates, crop rotation, selection of crop variety, and irrigation can be incorporated without large changes in the farm management practices.

Other more structural changes in organisation and research needs, such as research on drought and salt tolerant crop types, extension services and regional water management, will need longer planning and implementation periods. Examples of climate changes related changes in agriculture are incorporation of woody crops in wetter areas, water "production" in agriculture, fodder production for dairy farming (NRLO, 1998).

Government and EU policies have been a major driving force in agricultural development, this is not likely to change in the near future. Research, education, water management, export and farm subsidies (e.g. fuels) are areas in which the local and European policy makers influence the short and long term adaptation agenda of the farmer.

In general, agriculture can adapt to gradual climate change. Extreme events, (floods sea level rise) or large changes (>2-3°C cf. IPCC, 2001) require other strategies which are not part of the current portfolio of adaptation strategies. Adaptations to extreme events or large changes require timely action and long term capital investments.

2) Animal husbandry and grassland.
Indirect energy use, via supply of fodder and fertiliser, in this sector is relatively high. Growth in this sector will increase the demand for energy, also the implementation of environmental friendly measures related to manure storage and processing will also add to the energy demand.

Animal fodder production depends heavily on production systems (e.g. citrus and soya) located in other agro-ecological zones. The impacts of climate change on the production in the supplying regions are not clear, but could have a significant impact on the cost effectiveness of animal husbandry in the Netherlands.

In what way temperature increase and changes in wind patterns will effect occurrence of diseases is unclear. At larger temperature increases climate control in stables will become necessary and increase energy demand.
The area of grassland is >50% of the rural area and either grazed or used for fodder production. Direct effects of climate change are comparable with arable farming.
Higher groundwater levels, associated with increased precipitation and higer sealevels, will reduce the grazing potential. Dairy farming accounted for 1278700 ha with a total production value of 3761 millions NLG in 1995 (table 3.6).

Table 3.6 Area and production value in 1995 for grassland and silage maize (Schapendonk et al., 1998).

Crop	Area (ha)	Production value (x 10^6 NLG)
Grassland	1048500	3037
Silage maize	230200	724
Total	1278700	3761

The intensive dairy systems in the Netherlands are possible because of supply of nutrients and animal feed from different regions in the world. Locally produced roughage (grass, silage maize and alfalfa) will become more important as self-sufficiency and vulnerability issues become more important (table 3.7).

River flood hazards related too higher peak drains will increase (IPCC, 2001). The need for water buffering and storage areas will put a claim on grassland areas.

Table 3.7 Relative changes in production of fodder maize and grass per ha in the Netherlands (percent in 2020 en 2050) (Schapendonk et al., 1998).

Crop	2020		2050	
	Low[(1)]	High[(1)]	Low	High
Fodder Maize	93.1	92.2	84.0	83.8
Grass	118.2	120.6	139.6	149.1

[(1)] Low and high refer are based on studies by Alcamo *et al.* (1996).

Adaptation
Most adaptation strategies for maize and grassland production are comparable to those as defined in the section on arable farming. Major issues for the (near) future are self-sufficiency and reduction of vulnerability.
In some areas where water related problems require the need for water buffers it is likely to effect grassland more than arable land, as the compensation costs per hectare are lower.

3) Production in greenhouses
The total area of greenhouses increased over the last decade, expansion mainly took place in the provinces South Holland and North Brabant. This sector is not expected to claim more space in the near future as economicgrowth will mainly focus on specialised quality products (Brouwer *et al.*, 2001, in preparation).
Effects of climate change on this sector are expected to be relatively small. Energy demand for climate control and illumination will most likely change. Wetter springs bring more cloud cover during this period and reduce incoming radiation and negatively influence primary production. Higher winter temperatures, however, will reduce the energy demand for heating during spring and autumn.

Adaptation
Adaptations in the production process are technical, cost effectiveness of the required measures will largely determine the decisions made by the farmers.
In the low-lying western coastal areas problems related to salt intrusion from sea may force the use of tap water for irrigation purposes and increase the cost of production. In extreme cases of groundwater level rise in the low-lying coastal areas may result in closing of greenhouse complexes and a necessity to relocate them.

3.2.2 Forestry

Forests, according to FAO guidelines (UN-ECE/FAO forest resource assessment, 1992) are land areas that are covered with natural or man-made populations of woody species that can grow taller than 7m and with a crown cover of at least 20%. According to this definition of a forest, there are 341.000 ha in the Netherlands. Roughly 75% is multi-functional (production, recreation, nature) and 25% is natural forest in which production and recreation are secondary to the nature values of the forest. Little over half of the forest area is coniferous (species) and the remaining is either mixed or deciduous forest (species). The forest area in the Netherlands will likely increase in the near future.

Aims of Dutch forest policy for the period 1994 – 2020 include:
- sustainable maintenance of forest area with characteristic forest ecosystems
- optimal fulfilment of forest functions: timber production,recreation, nature (table 3.8)
- expansion of forest area (from 340 kha to 360 kha).

All Dutch forests have a management history, *i.e.* there is no forest in the Netherlands that is not affected by man in some way. Moreover, the Dutch forest is a relatively young forest, which has been planted or allowed to recover from overexploitation since around the mid-nineteenth century. The annual production in forests in the Netherlands is approximately 2.2 Mm^3 to the standing wood of 52 Mm^3 whereas the harvest is 1.4 Mm^3 per year.

Forests are likely to be sensitive to climate change. This is due to the longevity of individual trees and the magnitude of the expected climate change within their life span. The vulnerability of the forest will depend on the species sensitivity and the species composition of the forest. On the other hand, forests are also resistant to large variability of the climate they experience during their life span (Kuikman *et al.*, 1999).
The questions addressed here are: 1) does the anticipated climate change provoke a significant change in the forest ecosystem; 2) is it likely that the forests adapt to climate change and if so how; and 3) is human intervention required to adapt to the changes that are considered undesirable and exploit new opportunities as a result of climate change?

Table 3.8 Overview of forest functions, criteria for these funcions, and how thesecriteria are evaluated.

Function	Criterium	Evaluation
Production	Yield, wood quality	Financial
Recreation	Variation within and between stands	Variation in speciescomposition and (spatial) structure of the forest
Nature	Naturalness, characteristic, diversity	Biodiversity; indicators of natural development; match with natural reference

In the following an overview is presented on the likely effects of climate change on forests. Possible adaptation measurements will be discussed to counteract adverse effects. This will be done with special focus of the relevance of these effects to meet the aims of the Dutch forest policy. The overview is based on both available literature and scoping studies performed by others.

Impacts
The productivity of forests is very likely to be affected by climate change. Both positive and negative impacts can be expected.
Growth of trees is anticipated to increase by 10-30% due to increasing the atmospheric CO_2 concentration, an extension of the growing season, higher temperatures and increasing amount of precipitation. The actual increase depends on tree species, site and management.
The IPCC Working Group II Third Assessment Report reports that "Vegetation modelling studies continue to show the potential for significant disruption of ecosystems under climate change. Migration of ecosystems or biomes as discrete units is unlikely to occur; instead at a given site, species composition and

dominance will change. The results of these changes will lag behind the changes in climate by years to centuries". Both conclusions are given the judgement high confidence.

The increase in growth will result an increasing harvest level, and attributes positively to the Dutch policy of a higher degree of self-sufficiency in wood production in the Netherlands. Forest companies may also increase their income if the sequestration of CO_2 in forest will be subsidised. The Dutch forest has a net annual growth of ca. 2.2 Mm^3 annually. This is an increase in value by fl 42 million annually for the total Dutch forest area. However, currently the forest manager does not benefit economically of the carbon sequestration function of forest.

These opportunities may partly or fully be counteracted by the vulnerability of forest for some of the anticipated changes in the climate. If extensive summer droughts will occur more frequently (see section 2.2) then growth will be hampered by lacking water availability, especially forests on dry and sandy sites that are most susceptible to this effect. Extensive summer droughts will furthermore deteriorate germination and establishment, and increase the risk of forest fires. In nature-following forest management, i.e. use of natural regeneration processes, resulting in more vertically structured forests, the probability of crown fires in coniferous forest may also increase. Storm damage is likely to increase if winters become more wet, even with an unaltered storm frequency. The combination of storms and wet trees leads to higher risk of damage. The scientific information currently available is insufficient to assess the impact of climate change on the occurrence of outbreaks of insects or fungi.

Based on several scoping studies of different regions in the UK Climate Impacts Programme (2000) it was concluded that "Forestry should benefit from increased growth rate and yields, although the possibility of worse wind storms would lead to more windthrow and limitation of tree height. Expansion of this industry can also play a significant role in the national policy to reduce carbon dioxide emissions" Depending on site conditions and location, "there could be problems .... of stress due to drought and diseases, and more forest fires".

On the global scale the IPCC WG2 TAR mentions that " global timber market studies that include adaptations through land and product management, even without forestry projects that increase the capture and storage of carbon, suggest that a small amount of climate change would increase global timber supply and enhance existing market trends towards rising market share on developing countries (medium confidence). Consumers may benefit from lower timber prices while producers may gain or lose depending on regional changes in timber productivity and potential die back effects"

Considering the carbon sequestration function of forests, the IPCC reports (SAR, 1995 and TAR, 2001) mention: "Terrestrial ecosystems appear to be storing increasing amounts of carbon. At the time of the Second Assessment Report, this was largely attributed to increasing plant productivity because of the interaction between elevated CO_2 concentration, increasing temperatures, and soil moisture changes. Recent results (TAR, 2001) confirm that productivity gains are occurring but suggest that they are smaller under field conditions than indicated by plant-pot experiments (medium confidence). Hence the terrestrial uptake may be due more to change in uses and management of land than to the direct effects of CO_2 and climate. The degree to which terrestrial ecosystems continue to be net sinks for carbon is uncertain due to the complex interactions...". (See Nabuurs *et al.* (1997); Kuikman et al (1999); Kramer & Mohren 2001 for more extensive discussions on the above mentioned topics).

Considering the effects of climate change on plant species diversity Van Oene et al (1999) conclude for a given scenario that 68% of plant species remain in a grid cell whilst 32% are anticipated to disappear. The study predicts that in European lowland areas such as the Benelux 70-80% of the plant species is retained. However, this study does not differentiate between forest and non-forest plant species. The estimate of retained plant species under climate change can be considered an upper value for forest plants as forest plant species have very limited dispersal capacities.

Adaptations

Adjustment of forest management to counteract undesirable effects of climate change on forest could include:

- aiming at mixed forest with high biodiversity and a broad range of species to spread the risk of possible negative effects
- introduction of southern provenances of species already occurring in the Netherlands thus maintaining sufficient genetic variation in the forest
- introduction of new species for the Netherlands that have their geographical distribution south of the Netherlands
- limited planting of drought sensitive species
- reduce nitrogen deposition, as this may enhance the effects of drought especially on well-drained sandy soils
- retain winter precipitation in the forest to counteract the adverse effects of summer drought, rather than draining the water from the forest efficiently.

Care should be taken that the latter enactment does not increase the vulnerability of the forest to storm damage. Nabuurs, Kramer & Mohren (1997) discuss these possible adaptation measures in more detail.

The IPCC Working Group II Third Assessment Report indicates on this subject that "Possible adaptation methods to reduce risks to species could include the establishment of refuges, parks, and reserves with corridors to allow migration of species". These considerations are in line with the Dusch policy to attain an ecological network or "Ecological Main-Structure" (EMS). This network contains large natural areas that have nature and recreation as the main function and limited production goals. These areas are connected with corridors through which species may migrate between the large natural areas. There is general agreement that large natural areas will be beneficial to adapt to negative climate change impacts. However, much discussion remains if the corridors are efficient as a means to counteract negative effects. Typically the dispersal rates of trees are very slow compared to given the anticipated rate of climate change. Corridors may be interesting for animals and plants living in forests, as not all individual species can be transferred. For the introduction of new provenances or new tree species human transfer will be required.

Interactions with other sectors of society
Two main interactions between adaptive measurements required for forestry and other sectors of society can be identified: land use and water management. Expansion of the forested area and more rapid implementation of the ecological main structure in the Netherlands will be at the expense of other land use. This will usually be the agricultural sector. A change in water management, such as the retainment of winter precipitation may also negatively affect yield of adjacent agricultural area's.

Conclusions on forestry
General conclusions of the impacts of climate change to realise these aims are:
sustainable maintenance of forest area as such will not be treathened by climate change. However, forest ecosystems that are currently characteristic for a certain forest type may undergo changes as their species composition changes over time as a results of north bound change of climate zones.

The optimal fulfilment of forest functions will not be jeopardised on the short term (20 years) if a climate change induced increase extreme events is not to be expected. Changes in management, and changes in other environmental condition than global change (*e.g.* pollution, N-deposition) may have stronger effects on forests. However, on the mid-term (20-50) years important effects of climate change can be expected (see below)

Expansion of forest area and implementation of the ecological main structure as an adaptive measure is not jeopardised by climate change. The decision process could in fact be accelerated.

There is currently a lack of information on where in the Netherlands the impacts, adaptive measures and interactions are relevant, e.g. how much of the forest area is likely affected by drought, which adaptive measures can be taken to counteract it for specific locations, and how does this interact with the local agricultural activities? A nation wide inventory would be very helpful to determine the relevance of likely impacts, adaptive measures and interactions.

Furthermore, information is lacking on the frequency of future climate change disturbances and their effects on the forest functions. The impacts of climate change evaluated in the literature thus far assume that a gradual increase of atmospheric CO_2 results in a gradual rise in temperature and a gradual change in precipitation. These future projections can be completely wrong if *e.g.* the frequency of wind storms increases. A scenario analysis on the effects of disturbances on forest production, carbon sequestration, biodiversity and recreational values is required to gain more insight on the impacts of climate change on forest, and the best adaptive measures taken.

3.2.3 Fisheries and fish production

At the macro economic level, marine fish production is a minor activity in most countries of western Europe, including the Netherlands (Parry *et al.*, 2000). Nevertheless, it is an important industry that provides employment to a large number of people. To evaluate potential impacts of climate change, differences in ecosystems exploited by Dutch fisheries have to be distinguished: the open North Sea, the coastal zone and estuaries, and the inland waters. Many of the North Sea fish stocks are overexploited and some of these suffer severe decreases. Although climate change may enhance the problem, the primary concern is that too much fish is taken out of the system. The most important fisheries in the coastal zone are those that exploit bivalves. The commercial inland fisheries have gradually become less important, but sport fishing is an important recreational activity. Fish culture is largely restricted to closed systems that are not directly affected by climate change, except perhaps by a reduction in heating costs.

North Sea

Climate change encompasses an interplay of factors that influence individual species (e.g. distribution) as well as ecosystem processes (e.g. production). Temperature, rainfall and wind conditions and, in the coastal area, changes in sea level are important factors affecting human use of terrestrial ecosystems. In contrast, hydrographic conditions as affected by large-scale circulation and current systems are more important determinants of productivity in the marine environment than local weather conditions (OSPAR, 2000). The available simulation models for calculating the effects of global warming on oceanic circulation are still in their infancy, and the uncertainty about the possible impacts of for instance a decrease in Arctic ice volume on North Atlantic Gulf Stream strength make it difficult to make predictions of the effects of climate change on fish production and fisheries.

Still, the long-term effects of climate change may easily be masked by the immediate effects that are caused by the present level of overfishing. Within an ecosystem as strongly influenced by human activities as the North Sea is today, it seems unlikely that gradual changes might be detected and isolated from the effects of current fishing practices (Daan, 1994). A relatively small change in temperature in the order of 1°C per 50 years will only shift isotherms northward a little, while the buffering capacity of large water bodies do not make the seas sensitive to short-term weather extremes. For instance, seasonal average bottom temperatures vary only within 1°C over large parts of the central and northern North Sea.

Furthermore, if changes would occur in the productivity as a consequence of climate change, there seems to be no other option than to accept these changes and adapt the fishing industry because the marine environment does not qualify for large-scale adaptation measures.

Coastal zone and estuaries

The situation for the coastal zone and estuaries is different. This area is a highly dynamic environment where erosion and deposition are important processes (CWSS, 1993). Even today, our coastline is maintained only with large-scale and costly measures such as sand suppletion and dyke reinforcement. The sediment dynamics in the Wadden Sea are such that the anticipated drop in bottom level of 18 cm in 10 years caused by extraction of natural gas is expected to be balanced by increased deposition (Oost *et al.*, 1998). Similarly, a sea level rise of 1 cm per year might largely be balanced. although one should prepare for more extreme forms of erosion than today. A recent study points out that conditions for sedimentation and erosion may change in the 22nd century (TNO, 2001).

Not only may severe storms occur more frequently, but also deeper and larger water masses arrive with the tides and pass the Channel to arrive into the North Sea suggesting increased impacts. This may locally lead to rearrangement of the pattern of flats and gullies. Because of exposure to higher storm frequency and changes in bottom topography, re-allocation of licence plots may prove necessary. The anticipated level of temperature change is expected to have only minor effects. Although some species that are found in more southerly waters today may extend their distribution northward and others may disappear because of a northward shift, major changes in species composition are not anticipated. This is related to the marine habitat having less well developed boundaries than we observe in terrestrial ecosystems. Even today species composition may change temporarily in response to annual variations in weather conditions and temperatures. A possible adverse effect may be caused by more frequent occurrence of anaerobic conditions as result of the combination of eutrofication and high temperatures. This could be prevented by measures that reduce excessive use of nutrients in terrestrial ecosystems and consequently the nutrient load of rivers. Although major progress has been made on reducing run-off of phosphates, attention should focus on nitrates.

Coastal and tidal zone

The transition zone between freshwater and seawater presents a special problem. Sea level rise on the one hand, with the associated tendency of farm lands in the coastal area turning more brackish, and higher discharge rate of rivers in winter on the other hand may require reconsideration of the present defence dams and water discharge regimes. Extending dams and increasing their height to improve protection against danger of flooding will reduce the options for diadromous fish (such as eel, salmon and twaite shad) to find their way to the rivers. Further, brief periods of excessive discharges of freshwater into the estuaries may cause death of the local fauna, including mussels. These aspects may have to be addressed in policy development.

Freshwater

Commercial fishing in the freshwater systems in the Netherlands is a minor activity, with the exception of "IJsselmeer"; most freshwater fishing is recreational. Higher temperatures generally will positively affect the production of cold-blooded organisms such as fish. Yet, higher temperatures in eutrophic waters may promote anaerobic conditions and cause fish kills. In this case, eutrophication owing to nutrient runoff resulting from agricultural practices rather than the increase in temperature appears the more imminent problem. Also, many rivers and lakes experience considerably increased temperatures that result from using freshwater for cooling in power plants and other industries. A further increase in temperature owing to climate change may cause some species to go extinct and render current policy ("Salmon to return to the Rhine") ineffective of unachievable. Though natural watersheds limit the exchange of species between rivers, canals to connect rivers have released these natural restrictions to colonisation to a large extent. This is for instance exemplified by the settlement of typical Donau species such as asp in the Rhine.

A major impact on rivers is anticipated from changes in amount and pattern of rainfall and subsequent runoff: higher in winter and lower in summer. A higher frequency of flooding might be seen as recovery of the natural dynamics of rivers following a period in which management has been directed towards regulation of the discharge. However, extended periods of drought during summer would diminish the positive effect on the characteristic river fauna expected from planned and already creat side channels, as these waterbodies would be dry for larger parts of the year. Changes in rainfall pattern may impact fish communities and other components in other freshwater ecosystems if they lead to large differences in water level. While spring floods would generally enhance conditions for spawning and development of larvae, subsequent droughts would reduce available nursery areas. Development of specific buffering areas for excess water may reduce the negative impacts of both wetter conditions (flooding) and dryer conditions (water reserves), though other problems may come with creation of water reservoirs.

Conclusions fisheries and fish production (see table 3.9)

- No major change in the fish production in the North Sea is anticipated as a result of the predicted rise in temperature over the next 50 years, unless radical changes in the North Atlantic circulation will take place simultaneously. Even if this would occur, options for development of adequate policy measures for management appear to be extremely limited.
- The anticipated higher storm frequency will impact the mussel culture. Within the existing management policy, consideration could be given to reallocation of the licence plots for the activities within this sector. More dramatic changes in the production may be expected if as a result of safety precaution measures, estuaries will be more protected against storm surges, such as has been the case in the province of Zeeland. Further reduction in the nutrient load of the river discharges reduces the risk on anaerobic conditions in coastal waters.
- The anticipated sea level rise as a result of climate change may necessitate reconsideration of the management policies relating to the existing facilities (and their use) in the transition areas from freshwater to seawater conditions in the Delta area in the south–western part of the Netherlands and along the northern dam ("Afsluitdijk") enclosing the "IJsselmeer".

Table 3.9 Summary of impacts and adaptation options for the section of fisheries.

Environment	Main impact factor	Impact	Adaptative measures
Open sea	*Temperature*	No change in fish production; species composition may change	Fishing industry will have to adapt its strategy and tactics.
	Oceanic circulation	May have dramatic effects, but at present unpredictable	No obvious measures available: acceptation
Coastal zone and estuaries	*Storm frequency*	Damage to present licence plots and redistribution of flats and gullies	Re-allocation of plots
	Sea level rise	No major direct impact; potentially secondary ones because of mitigation measures to threats of human safety	
	Temperature	More frequent anaerobic conditions	Reduce runoff of nutrients (particularly nitrates) derived from agricultural use
	Rainfall	Death caused by higher and more concentrated discharges of freshwater during winter	Adapt discharge strategy used in sluice mangement
Freshwater	*Temperature*	No change in production, species composition may shift. More frequent anaerobic conditions	Reduce industrial use of surface water for cooling
	Rainfall	Positive effect of winter floods and negative effects of summer droughts on riverine fish fauna.	Creation of wider river beds and depper waterbodies for water storage

- The anticipated raise in temperature of the freshwater basins and rivers in the Netherlands might largely be compensated for by reducing the current industrial use of freshwater for cooling. The higher risks of anaerobic conditions as a result of higher temperature and lower water quality may be mitigated by reducing the nutrient load from agricultural land (runoff and groundwater). Rivers will face more variation in runoff between summer and winter; this will contribute to more natural and ecological conditions and may also urge for a policy to establish wider riverbeds and create more side channels. However, during extended periods of drought, the latter policy may be less effective. Reconsideration of the policies on creation of buffering streams may require further study.

3.3 Economic sectors

Climate change will affect society and ecosystems in many ways (Van Ierland *et al.*, 1996). In general, the sensitivity of the energy, industry and transportation sectors is expected to be relatively low compared to that of agricultural or natural ecosystems, and the capacity for adaptation through management and normal replacement of capital is high. However, construction and infrastructure in these sectors would be vulnerable to increased frequency or intensity of extreme weather events (IPCC, 1996). Extreme weather events could hit particularly the insurance sector, since the financial interest of the insurance sector is weather dependent.

Combating against climate change requires global international Cupertino. As the results of the 6th Conference of Parties in 2000 at The Hague show, it will take a long time till global co-operation will result in coherent action against global warming. International and national climate change policies have largely concentrated so far on mitigation strategies. Since global warming already is on the edge, adaptation is at least as important as mitigation policies. More attention is now given to how society could adapt to the gradually unfolding impacts of climate change.

Box 3.6 Some facts on weather and climate change in the Netherlands (KNMI, 1999).

- The average temperature in The Netherlands was 0.7°C higher in the last twenty years (1978-1998) than it was between 1900-1920. The increase in temperature has been particularly pronounced since 1988.
- There was more precipitation in the second half of the century, and all winters with more than 500 mm of precipitation were after 1960.
- In spite of the increase in winter precipitation, the average discharge from the rivers Rhine and Maas do not reveal any specific trends.
- The risk of unusually high tides has increased due to an average 20 cm sea level rise per century along the coastline.
- The wind activity in the century reveals no trend (KNMI, 1999): the chance of storms has remained unchanged. However, Tol (2000) reports 2% increase of the intensity of storms (windgust) in 25 years and 6% increase in 75 years in The Netherlands.

3.3.1 Energy

The energy sector is influenced by a wide range of climate variables like temperature change, precipitation, cloud cover, wind speed, and the occurrence of extreme weather events. These have impacts on both primary and final energy sources (electricity, heating, oil) by extraction, distribution, power generation and fuel storage, and in particular on existing and potential renewable energy sources. Extreme weather can have severe impact on human activities and energy infrastructure, whereas a slow temperature rise will likely modify energy consumption pattern, such as demand for heating and cooling. Figure 3.4 shows the model structure of the energy and material system. The analysis is divided in two parts: the impacts on energy consumption (residential, industrial, and transport demand) and on energy supply. The graph shows the interactions amongst the economic sectors, changes in industrial and transport demand will have direct impact on energy demand.

Impacts of climate change on energy consumption

Economic development and increased standard of living are likely to occur in the coming decades, resulting in increased energy and electricity demand. Over the last decade, the residential electricity consumption in the Netherlands has increased rapidly. In the period 1982-1998 the total final energy demand has grown with 25% (Uyterlinde *et al.*, 2000). The increase in electricity consumption is the highest of all energy demand, while the consumption of gas remained more or less stable. An important matter should be addressed: the 'additionality' of climate change impact (or net climate impact) to the current energy consumption trends. According to the IPCC energy scenarios energy consumption will continue to increase with 30-60% till 2020 (depending on the scenario).

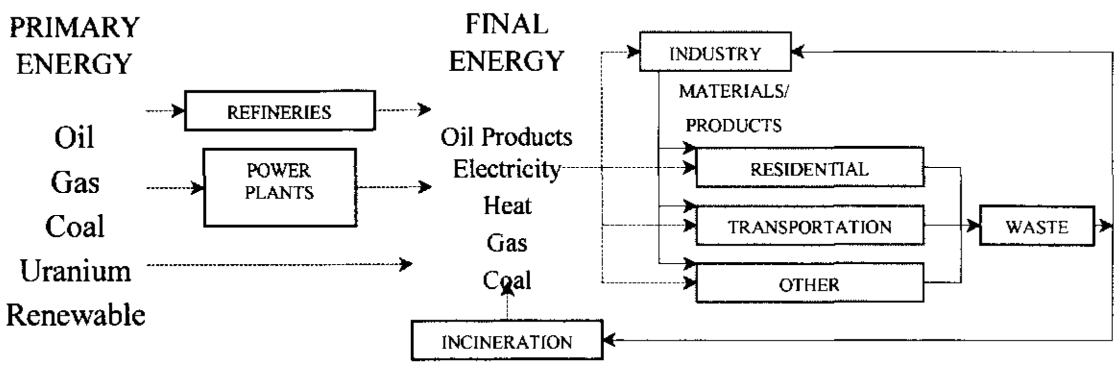


Figure 3.4 Energy and material system model structure (Gielen, 1997).

The climatic impacts on the increase of total energy consumption are likely less significant than the impacts of economic growth or major shifts in societal trends, individualisation, ageing population and globalisation. (Slob and Van Hoorn, 1999). Meanwhile, climatic impacts hit some sectors more than others (e.g.

farmers, small insurance companies) and social groups will be confronted with the fact that on-going processes of economic globalization are modifying or exacerbating existing vulnerabilities (O'Brien and Leichenko, 2000).

The most significant impacts of climate change on energy consumption in the Netherlands are likely to be the effects of higher temperature on the use of electricity and on direct use of fossil fuels for heating. Climate change affects space heating, higher temperature will decrease energy demand (Feenstra *et al.*, 1998). To some extent, the use of air-conditioning will also be affected. In the Netherlands, air conditioning is not as significant as in the low latitude countries, which generally have warmer climate. Refrigeration and water-heating equipment are often located in conditioned spaces (spaces that are heated or cooled at a constant level) and not affected by outdoor temperature (Feenstra *et al.*, 1998). Electricity demand for greenhouses may decrease in agriculture, however the total energy demand in horticulture is likely increasing (CPB, 1997). Irrigation may require some additional energy to pump up the water, if the climate becomes warmer but not wetter. In the Netherlands the winter climate is expected to become wetter (KNMI, 1999). Generally speaking, the magnitude of the impacts on the various energy demand categories depends on the electricity usage patterns.

A Dutch study from the Energy Research Center (Uyterlinde *et al.*, 2000) shows the shares of sectors in final energy consumption in the Netherlands in 1998 compared with year 1982. In this period, total final demand has increased with 27% from 39.3 Mtoe to 50.1 Mtoe (excluding non-energy uses). This increase was a result of growth of the energy consumption in all sectors. The shares in total energy consumption are: 20% residential consumption, 8% agriculture, 30% industry, 28% transport, 14% tertiary and others. The industry and transport demand is mostly independent of climate. Impacts will, however, occur in agriculture. Some impacts can be measured on space heating of residential and commercial services.

Households behaviour has significant impact on total energy consumption. Direct impacts occur on demand for electricity, natural gas and fuels for transportation. Typical OECD values on residential energy consumption range from 15 to 20% of the total energy consumption (figure 3.5). However, households also use energy in an indirect way by purchasing goods and services delivered by the production sectors (Biesiot and Noorman, 1999).

Data for 1996 (Uyterlinde *et al.*, 2000) shows that for an average household in the Netherlands the home energy use contains 57% for heating and cooling, 31% for lighting, cooking and other electrical appliances and 12% for water heating. Household expenditures on heating and cooling are the most sensitive to weather change and will show parallel and seasonal fluctuation with the weather pattern.

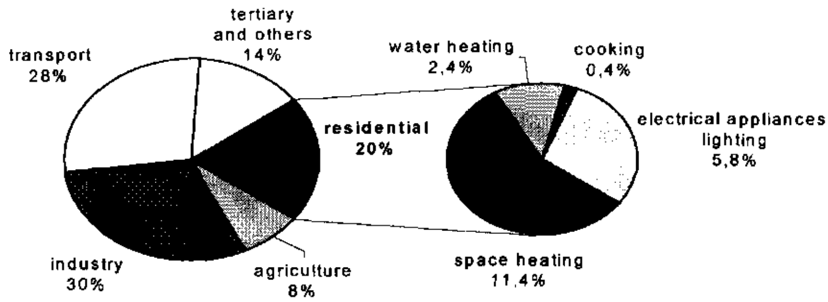


Figure 3.5 Energy consumption data for the Netherlands in 1998. The residential energy consumption ratios are based on year 1995 (from Uyterlinde et al., 2000).

Energy consumption by industries and transportation and part of the residential energy consumption such as electrical appliances, lighting and cooking are not significantly influenced by temperature rise. Other end-uses are slightly influenced by a slow global warming. Some case studies review the impacts on specific end use factors.

A study from Tol (2000) examines the impacts of weather variability of Dutch winters on energy consumption using time series data. The analysis of annual, national data indicates that electricity use is not significantly influenced by temperature, as air conditioning and electric heating are not widespread in the Netherlands. Gas use is more sensitive to weather change: it goes up in cold winters, and the year after a warm summer. The study reports that 1°C increase in the average temperature shall lead to a decrease of 3.8% for domestic gas, and 0.85% for industrial gas use and 3.2.% for total gas use. This is equal to savings on total gas use of NLG 611 million per year.

A similar study in the U.K. (Palutikof *et al.,* 1997)) shows that savings in the mild winter of 1994/95 amounted to £220 million in domestic gas consumption and £95 million for the public administration, commerce and agriculture sectors. In the hot summer of 1995 there was an added cost of £34 million to domestic electricity customers but a saving of £74 million on domestic gas consumption. The net savings to the consumer as a result of the anomalous weather of 1994/95 are estimated at £355 million. The shift from electricity to gas for domestic heating in the last twenty years means that gas consumption has become more sensitive to anomalous weather. The same phenomena can be seen also in the Netherlands, where the electricity production is dominated by gas. From the 1995 data, it seems that electricity consumption is increasing in hot summers, presumably, due to increased use of refrigeration and air cooling, but this result is tentative (Palutikof *et al.*, 1997).

The extent of change in heating demand can be estimated from the change in the number of heating degree days per year. Degree days statistics provide a measure of the length of time and the extent to which temperatures fall below (heating degree days-HDD) a given threshold temperature. Table 3.10 shows the predicted change in HDDs in the Netherlands (Carter, 1991). Mild winters in the European Union resulted in HDDs more than 10% below the 30 year average and caused more than 2% reduction of energy demand (Parry, 2000). The cooling degree days (CDDs) indicator is less reliable in forecasting energy demand, due to the mild summers in the Netherlands.

Table 3.10 Estimated change in heating degree days and energy demand in the Netherlands.

	HDD (Carter, 1991)	**Household's energy demand (Parry, 2000)**
1990-2025	10-15% reduction	2-3% reduction
1990-2055	25-30% reduction	5-6% reduction
1990-2085	> 35% reduction	> 7% reduction

The climate change trend favours the air conditioner industry in the Netherlands. Recently indoor climate control was available to only a few, but it is rapidly expanding. The main target groups are hotels, bars, restaurants, banks, entertainment businesses, commercial and shopping complexes. In general the air-conditioner industry is operating in a robust market, which is significantly concerned for energy and the environment. The rate of change of the industry will be exponential, if warmer temperature enhance the central air-conditioning in homes. Milbank (1989) estimated that for Northern Europe a 4.5°C temperature rise would more than double the electricity consumption of air conditioning systems.

Climate change and mitigation policies will have impact on the consumer price index (Miller *et al.*, 2000). Most studies suggest that prices due to climate change are likely to rise across all sectors, but particularly in agriculture and the energy sector, although the increases are likely to be slight. Consumers would find that the dollar buys less than it does today (Fankhauser and Tol, 1996). The most significant increases in prices would derive from increased costs of electricity generation, due to increased energy demand for air conditioning and irrigation. Increased cost in agriculture is expected, due to changing and unpredictable growing conditions and electricity usage for greenhouses; and the effects of sea level rise (for example, increased costs of insurance and infrastructure). As consumers get less for their money, their real household consumption decreases. Since low-income households spend proportionally more of their income on food and energy, their decline in real consumption from the impacts of climate change will probably be greater than that of wealthier households. Forced to spend more for basic necessities, low-income households will have even less potential to purchase less-essential goods. Therefore one of the socio-economic impact of climate change will be the increasing gap between the rich and the poor.

Adaptation options from demand side

Miller *et al.* (2000) review three strategies to adapt higher cost of electricity. Consumers can (1) simply pay more for their energy bills; (2) reduce their usage of electric appliances, cooling, or heating (for example, wear a sweater inside); or (3) invest in energy-efficiency improvements to get the same amount of heating, cooling, and appliance for less energy. Compensation policies could help low- or fixed-income households to pay more, actually undermining the environmental benefit that society is seeking—to reduce fossil fuel use. Investments in efficiency improvement combined with reduced (sustainable) energy use are the best adaptation consumers can make. They reduce energy use—the social goal—and they reduce the financial burden of paying higher energy bills. Most people will, however, not invest in energy efficiency unless it saves more money than its costs within a relatively short period. A thoughtful climate policy package could enhance these private investments in all societal groups.

Energy efficiency and technological improvement plays significant role in adaptation and mitigation to climate change. More efficient appliances contribute to relatively less energy use. A case study of the Netherlands on energy requirements of household consumption (Biesiot and Noorman, 1999) claims that the implementation of the full technical energy conservation potential in all production and consumption strata could result in 50% reduction of (direct and indirect) household energy consumption in the year 2015 in comparison to the year 1990. Developments over longer periods cannot be studied in the same way as no reliable datasets concerning conservation potentials and technology options are available. Therefore, the study suggests that an increase in energy consumption in some cases will be compensated by increasing energy efficiency from improved technology, and the overall net impacts could be reverse.

One of the most important adaptation options to climate change could be exploiting the potential of the unpreventable global warming in a sustainable way. This may imply making use of temperature rise by using less energy to dry and heat. Using more air-conditioning and cooling would be another option for adaptation, but it would result in more energy consumption and would increase emissions of greenhouse gases, if non-sustainable energy were used.

Impacts of climate change on energy supply

Many components of conventional energy supply systems that involve fossil and nuclear energy are largely independent of climate. Many renewable energy sources (such as hydropower, solar, wind, and biomass) are strongly affected by climate in positive or negative ways (IPCC, 1998). Economic sectors may, however, become more dependent on renewable energy in the future, and hence

more vulnerable to climate change, especially if greenhouse gas controls constrain the use of fossil fuels and current barriers to nuclear growth continue.
Significant impact of climate change could be on offshore extraction of oil and gas because of the increasing frequency of extreme events. Long periods of extreme weather (eg. winter storm) could hold up the extraction of energy sources, and also strong wind can cause big damages to offshore and inland infrastructure. A big windstorm in 1998 caused high damages to the electricity cables in Northern France and left the inhabitants without electricity for several days in a cold winter.

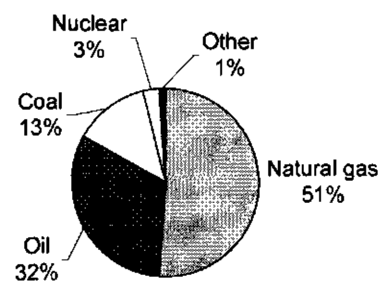


Figure 3.6 Netherlands Total Primary Energy Demand for 1996 (CBS, 1996)

The total primary energy demand is dominated by natural gas, because of its vast reserves (figure 3.6). Natural gas is used extensively in the residential, industrial, and commercial sectors. Oil is mainly used in transport, refineries, and the petrochemical industry. Coal is mainly used in the iron and steel industry and in electricity production.

There is currently one nuclear power plant in the Netherlands. The Borssele energy plant (450MW) was opened in 1973, and was expected to last 30 years. The future of the nuclear plant is under discussion. The nuclear power plants in general are susceptible to hydrological and water resource constraints that affect their cooling water supply, but this is not expected to be relevant for Borselle. Power plant output may be restricted because of reduced water availability or thermal pollution of rivers with a reduced flow of water. Generally speaking under more extreme temperature conditions, some nuclear plants might shut down to comply with safety regulations (Miller *et al.*, 1992). Future power plants are less likely to depend on once-through cooling and may be designed to deal with anticipated shortages of cooling water supplies. It is though not likely that new nuclear power plant will be built in the Netherlands in the coming years.

The Dutch Climate Policy Implementation Plan targets a significant increase in renewable energy sources (table 3.11). Currently domestic (53%) and industrial waste (23%) incineration is the main source for electricity from renewable energy sources. These are not likely to be effected by climate change. The remaining energy sources are wind energy (12%), biomass (8%) and others (2%), including landfill gas (methane) and a very small quantity of hydroelectricity.

Table 3.11 Projected Renewable Energy Usage (PJ) in the Netherlands.

Values in PJ	**2000**	**2007**	**2020**
Wind energy	16	33	45
Photovoltaic energy	1	2	10
Thermal solar energy	2	5	10
Geothermal energy	-	-	2
Storage of heat and cold in aquifers	2	8	15
Heat pumps	7	50	65
Hydroelectric power	1	3	3
Energy from waste and biomass	54	85	120
Imported Norwegian hydroelectric power	-	18	18
Total (including export)	**83**	**204**	**288**

Source: Ministry of Economic Affairs, 1995.

Adaptation options from supply side

> *"...first of all, stop this unsustainable economic growth. It doesn't only cause climate change but also costs a lot on the medical and health care side of our society. We are already living above our standard and shifting the problems to other generations and to less developed countries which are socially weak and vulnerable."*
>
> /Stakeholders' view/

Amongst the available adaptation options politicians, scientists and stakeholders of the business sector could enhance the sustainable adaptation possibilities. The supply-side mitigation options are broadly discussed in climate change mitigation studies. Mitigation options are available to prevent further climate change by using less energy and generating it with renewable sources. Attention should, however, also be given to adaptation measures to anticipate on uncertain future events in order to reduce possible future damage.

We will analyse how the potential impacts of climate change (temperature rise, increased precipitation) could enhance renewable energy sources. In 1997 biomass provided 8% of the total electricity generated from renewable energy in the Netherlands (Scheepers, 2000). In order to reduce negative impacts of climate change on future biofuel production, energy farms should be intensively managed and have short crop rotation; therefore, they would be better able to adapt to changing conditions through choices of crops and management techniques (IPCC, 1998).

Wind activity in the past century reveals no trend according to Dutch Meteorology Institute (KNMI,1999). In this case it has likely no significant impact on offshore wind generation. If extreme weather occurs, or strong windgust and windstorm become more frequent, however, some damages can occur in the energy generating and transmitting equipment. Increased windgust (Tol, 1996) could, however, enhance further expansion of energy generation from the coastal to inland areas.

Solar energy is highly dependent on cloud cover, which may increase with the expected intensification of the hydrological cycle. Many of the newly constructed buildings are benefiting from solar energy, but the contribution of solar energy to the total energy production is low. Climate change could have a positive impact on solar energy generation. If the average sunshine increases it enhances the use of solar energy.

Hydroelectricity, which supplies only 2-3% of the renewable energy in the Netherlands (Scheepers, 2000), depends on the quantity and seasonal distribution of precipitation. Greater annual precipitation is projected in the Netherlands, with the greatest increases in winter and spring. Climate projections suggest greater seasonal variation.

Impacts on manufacturing industries and construction

Generally speaking the climate change impacts on industries are relatively low compared to the impacts of climate change mitigation policies, but it could change in the future with increasing vulnerability from the rate of impacts. Several studies reviewed the impacts of mitigation options on the Dutch industry, e.g. Beer and Blok (1995) on the long term efficiency improvement; and Gielen and van Drill (1997) on the prospects of energy intensive industries such as petrochemical and basic metal industries.

The sensitivity of industries to climate change depends on the rapidity of climate change and the rate of replacement of equipment and infrastructure. Lifetimes of assets in the energy, industry, and transportation sectors are short compared to the time-scales for change projected using climate change models (IPCC, 1996). Short life assets (up to 15 years) such as consumer goods, motor vehicles, and space heating/cooling system will be replaced several times, offering considerable opportunities for adaptation. Medium-life assets such as industrial plants, oil and gas pipelines, and conventional power stations are also likely to be replaced over 30 years. More difficulties could arise with long-life assets such as certain residential buildings and infrastructure. Along the climate change, these buildings and infrastructure and their potential risks must be must be monitored, and in certain circumstances decisions have to be made for re-investment.

Sea level rise without proper adaptation would have harsh impact on the country. According to IPCC (1998) one meter sea level rise would cause 6% loss of total land in the Netherlands, if no adaptation would take place, and the value of capital loss would reach 186000 Million US$ (69% of current GNP) and 67% of the total population would be affected.

The construction industry is exposed to climate change since it involves work in outdoor activities exposed the weather. In general, the key climatic risks in relation to constructions are: high wind and turbulence; snow load; driven rain; thermal expansion; excessive rates of weathering; thawing of permafrost; drought frequencies; and sea level rise (IPCC, 1996). However, climate change adaptation policy opens new market opportunities to the sector by enhancing public and private investments in more energy efficient buildings and infrastructure (e.g. changes in design criteria and in the choice of materials used in construction) and other investment for adaptation (e.g. increasing dikes, relocation of industrial areas).

Adaptation options from industries

The construction industry has an important role in adaptation. Adaptation of the construction process occurs in three areas: structural safety during extreme weather events, energy conservation, and minimisation of life cycle costs of buildings and structures. Changes in the construction sector in the Netherlands also affects the real estate market through price changes, and the stock supply (Romijn, 2000).

Research and development (RandD) also benefits from the climate change trend, by receiving support to improve the efficiency and effectiveness of adaptation and mitigation options. RandD expenditure is likely to be booming in the information society. Especially computer based technological developments will take significant part in adaptation options. The climate change related research could produce new technologies for adaptation and mitigation options. These new technologies may induce the booming of some and the decline of other industries. For example, developing an air conditioning system with low environmental impacts could enhance the demand for cooling equipment.

It is likely that sea-level rise will be under control in the Netherlands, by increasing and strengthening the coastal defence. However, industries should also adjust buildings against storm damages and protect their infrastructure against flooding. In addition it may be necessary to consider delays in supply of materials and semi-products as a result of delays in transportation due to climate change. Options are to insure the risk of climate related catastrophes.

3.3.2 Transport

While the transport sector significantly contributes to global warming, the effect of climate change on transportation is expected to be relatively small. Climate change does not have significant impact on the demand and supply of transport modes. Transport demand mainly depends on population size, demographic characteristics, economic growth, available infrastructure, and relative prices of energy. However, climate change affects tourism demand. It therefore indirectly has an impact on transport demand.

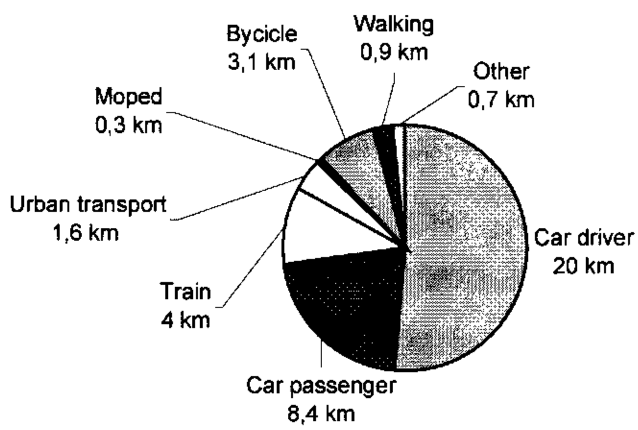


Figure 3.7 The mobility of the Dutch population in 1998 - distance travelled per km per person per day

The Dutch mobility was rapidly growing in the last decade: 15 percent increase in the total mobility (distance travelled per km per person per day) of the Dutch population between 1986 and 1998, is mainly explained by the increase in number of cars, and increase in car driver's kilometres (figure 3.7). The average car passenger kilometres are not increasing, which is explained by the fact, that the number of individual drivers is increasing.

Impacts of climate change on transportation

Transport is, in general, expected to be less vulnerable to climate change than other sectors. Though transport has significant impact on the environment. Most of the transport equipment (with short and middle life-time) show the technological capacity to adapt to climate change. However some extreme weather may cause accident and casualties.

In the Netherlands 2,400 kms of dikes shield the low, flat land - almost half of which lies below sea level - from invasion by the North Sea (National Geographic Atlas of the World, 1995). Reclamation of the Zuider Zee has created 165,000 hectares of arable land - a precious commodity in this densely populated nation. A big flood in 1953 cost 1,800 lives and stimulated a new approach to flood protection. New estimates of water levels were made and in consequence new dikes, buildings and underground stations were built. Measures to protect the coast from erosion have been based on an estimated 16 cm rise in sea water level; a 20 cm rise is now being contemplated. Methods are evolving of linking costs and risks (Grundy, 1998). Sea-level rise will have enormous impacts on ports. If the current infrastructure is to be protected, extremely high costs are to be expected. Increase in runoff and precipitation will lead to a higher sediment load of rivers. Need for dredging operations increases, which leads to an increase in costs in ports.

Without proper adaptation policy in the long run all types of coastal transport infrastructure would be directly affected by sea level rise. Approximately 67% of the total population could be affected. Protecting the Netherlands from 50 cm in sea level rise could cost US$3.5 trillion according to the Panos Media (1996). However, without proper adaptation policy, the country would loose a large part of its territory, including densely populated areas, and expensive infrastructure. It is, however, most likely that there will be proper adaptation actions against sea level-rise.

If the frequency and intensity of tropical storms and cyclones increases, tropical routes become more dangerous and higher losses can be expected. It may affect the Dutch trading activities by companies based in the Netherlands. The rising public awareness of the greenhouse effect and the implementation of mitigation policies have a positive side effect on sea-born transports. Internalisation of external costs into freight rates will favour ships, vis-à-vis other modes of transportation, as the most environmentally sound long distance transport mode.

Inland transport is sensitive to extreme weather, some of which may become more frequent as a result of climate change. Parry (2000) collected the main impacts of severe local storm on surface transportation (table 3.12).

Table 3.12 Severe local storms and surface transportation

Storm attribute	Impact	Adaptation/Mitigation
Tornadic winds	Structure and vehicle damage/ displacement power loss	Evasion, diversion, closure
Other strong winds	Structure damage, debris damage, vehicle instability, visibility reduction, power loss	Design, advisories, caution
Heavy rain	Flooding (closure, impedance, entrapment, transport). visibility reduction	Design, advisories, caution, diversion, closure, flood control
Heavy snow/sleet	Closure, impedance, entrapment, visibility reduction	Advisories, caution, diversion, closure, plowing
Hail	Vehicle damage, impedance	Advisories, caution, seek shelter
Lightning	Structure and circuit damage, power loss, distraction	Design, back-up, caution, advisories

Source: Parry, 2000

Inland shipping along River Rhine and Meuse is affected by the increased precipitation and runoff, but also by periods of drought, particularly in summer. The winter service is likely to be longer, due to milder winter. Extreme events like flooding or droughts may cause temporary cancellation of shipping services. On land, railway is vulnerable to extreme weather, and several delays are reported due to weather impacts.

Weather as a factor of road accidents in the UK has been analysed by Edwards (1996). In many Northern European countries local fog turns out to be the most dangerous weather hazard that drivers fear most. Traffic flow is seriously affected when visibility drops below 150 m.

Air transport is expected to be affected directly by extreme weather and indirectly by the changes in tourism and trade patterns.

Adaptation options for transport

"The best adaptation option in the long term is mitigation".
/A stakeholder's view/

A report on Environmentally Sustainable Transport (EST) (RIVM, 2000) identifies the action to achieve sustainable transport in the following strategies: 1) change of transport technology and behaviour, 2) change of market supply, 3) change of transport market demand, 4) changes in affected markets, 5) changes in the aggregate economic indicators and 6) changes in environmental indicators. Implementation of EST would have significant macro-economic impacts. Yearly GDP growth would be some tenth of percent points lower than the business as usual scenario, and the total Dutch employment level would be also some points lower in 2030. The total loss of material welfare can largely be compensated by non-material welfare (e.g. reductions of external cost). There are some other demand-side conservation options related to transport, such as reduced distances for holiday transport and switching to train instead of planes or cars, as well as sharing cars.

Main adaptation options for transportation sector are the protection of coastal and harbour infrastructure, improved water management in river systems, and stronger infrastructure for railways. The adaptations will make the transportation sector less vulnerable for the negative impacts of climate change.

Transport is, in general, expected to be less vulnerable to climate change than other sectors. Though transport has significant impact on the environment. Most of the transport equipment (with short and middle lifetime) have the technological capacity to adapt to climate change. Some extreme weather may, however, cause accidents and casualties.

3.3.3 Insurance

The insurance industry's financial interest is inter-dependent with climate and weather. The risk of natural extreme events, is one of the factors driving the demand for insurance coverage. If insurance companies do not allocate well their insurance portfolio packages they can be over-exposed in high-risk areas. Most insurance coverage is based upon historical data, which is then extrapolated using adjustments for inflation and other economic factors. Climate variability will most likely change the previous trends involving higher uncertainty in the future in the dimensions, location, or timing of extreme weather events. Insurance companies can no longer calculate risks based on historical data, but should look to the future in calculating and mitigating risk.

Impacts of climate change on the insurance companies

Climate change is a global phenomenon and insurance is a global, as well as a local, market service. The insurance sector consists of three main players: policyholder (the insured), primary insurers, and re-insurers. Primary insurers are actually providing insurance and being insured by re-insurance companies at the same time. Therefore they spread the risk of large damages. Local insurance companies will partly be affected by climate change impacts within the region, but also climate catastrophe all over the world, which will result in changes to their reinsurance rates and availability. climate impact on the insurance

The main re-insurance companies do the major research on climate change. Munich Reinsurance Company reports, that the number of natural catastrophes in this decade is four times greater than in 1960's; economic losses are eight times greater, and insured losses are 15 times greater, even adjusting for inflation.

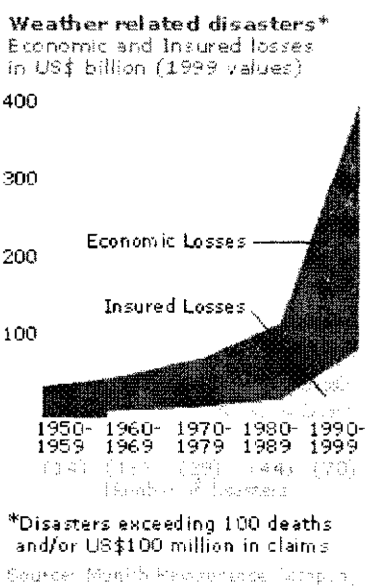


Figure 3.8 Weather related disasters - Economic and Insured Losses in US$ billion (1999 values) Disasters exceeding 100 deaths and/or US$100 million in claims are considered.

There are several factors behind the dramatic rise in catastrophe losses (Nutter, 1999):

- Population growth and increasing concentration of population in high risk areas
- High increases in insured values
- Expansions of coverage by insurance companies
- Insecurity of building structures
- Climate change and the incidence of more frequent extreme event.

In the Netherlands there were no billions US $ valued weather related large-scale catastrophes reported, but the damage of weather related property losses are significantly high in Europe. Strong wind caused big damages in electricity infrastructure, property loss and disturbance in transportation in January 1998 when a winter storm moved through the UK, France, Belgium, the Netherlands, Germany, Switzerland, Austria, and Poland. The economic losses reached US$ 500 million, and the insured losses reached the amount of US$ 350 million. In September 1998 a flooding caused more than US$ 530 million damages in the Netherlands and Belgium. In this case the values of insured losses were as 'small' as US$ 2 million. Almost one month later a winter storm hit the UK, the Netherlands, Germany and Switzerland and caused almost 500 million US$ damages. Almost half of these damages were insured (Munich Re, 2000). Some experts say that 1998 has been an extreme year, exposed to natural disasters, and causing some profit loss for the insurance companies. Others think, that the climate change is responsible for the more frequently occurring extreme whether events, and they urge global action against climate change.

On the long term the Netherlands is considered one of the high risk areas (table 3.13). Almost 70% of property is at risk because vast areas lie below sea-level or can be flooded by the Rhine or the Maas Rivers (Swiss Re, 1998). Flood protection on the coast line is very good, but along the rivers protection is still inadequate in some cases. At the moment insurance companies are not worried about the consequences of flood damages. In view of the enormous loss potential the Dutch insurers concluded a market agreement in 1965 to exclude flood cover as it is not represent an insurable risk. This resolution remains in force today with a few exceptions of major risks mainly for industrial property. There is no state insurance either, but disaster relief for ad-hoc compensation of disaster damages. According to the climate change scenario, even more average precipitation is expected in the coming decades. The river floods in 1993 and 1995 (Tol and Langen, 2000) set again a new debate on the lack of insurance protection. Technical improvements - for example in flood protection measures - and new insurance instruments may render the risk of flooding insurable in the future.

Table 3.13 Large scale economic losses related to flood hazard in the Netherlands.

Date	Disaster	Losses
September 1998	Heavy rainfall in south western Holland	Several hundred million USD economic loss. Many crop losses. Partial compensation from the government.
January 1995	River flooding on Rhine and Maas	USD 1.2 billion economic loss. USD 250 million compensation from the government
December 1993	River flooding	USD 150 economic loss.
February 1953	Storm surge disaster	1835 fatalities. 1650 km^2 of land under water. NFL 2 to 2.5 billion economic losses. 3000 houses destroyed, 43000 damaged.

Source (Swiss Re, 1998)

Table 3.14 Most significant historical storm events with insured losses in Europe.

Date	Countries	Insured loss (USD billions)	Return period (years)
October 1987	UK, F, NL	4.3	5
January 1990	Europe (mainly F, D, UK)	5.8	8-10
February 1990	F, D	1.1	< 5
February 1990	UK, F, NL, B, D	3.4	< 5
February 1990	D, CH, A	1	< 5
January 1995	Northern Europe	1	< 5
December 1999	DK, D, UK, SW	1.5	< 5
December 1999	F, D, CH	5.8	8-10
December 1999	F, CH	2.4	< 5

Source (Swiss Re, 2000).

Storm activity, however, is covered with property insurance, and is one of the main climatic hazards, that causes large scale damages in the Netherlands and across Europe (table 3.14). Reinsurance companies apply risk assessment model to determine the insurance premium and their long term strategy. The key factors integrated in the model are: the actual hazard (storm path, storm frequency and intensity), vulnerability (loss experience specific to buildings, to the utility of structures and to countries), the geographical distribution of all insured values, and the existing insurance covers with their specific treaty conditions. The traditional approach of historical time-series analysis was replaced with probabilistic models, which provide more information on the expected return period (or frequency). Probabilistic models are used to determine the relationship between loss frequency and intensity. (Swiss Re, 2000).

Adaptation options

A study of Leggett (1996) reviews three strategies to climate change. The first strategy is a status quo or business-as-usual scenario, where insurers hope that the rise of large-scale losses from storms and other weather related disasters is temporary. The second strategy is an adaptation option: globalisation of insurance industry and capital accumulation in order to allocate the liabilities in more global way. In case of large-scale catastrophes there is enough coverage from other insurance portfolios. Similarly a well-structured re-insurance net could be built up, to cover large scale damages, without threatening the viability of the insurers. One of the adaptation options is to slowly going out from highly exposed markets, first with sharply increasing premium, then in a later stage leave the market. In case of a non-adaptation policy, the insurance industry would cancel the coverage on the most vulnerable coastal areas in the long term. The third strategy involves actions for mitigation options. At one hand lobbying governments to act to reduce CO2 emissions, at the other hand promoting shifting investment away from fossil fuels and towards non-carbon based energy sources with premium differentiation. Insurance companies can also follow green investment strategies by investing their funds in new, less carbon-intensive technologies (forming a kind of climate venture fund). Finally, insurance companies could spur the development of less threatening energy system (Flavin, 1994).

3.4 Human health, tourism and recreation

One hears a great deal about the ominous consequences of global warming—melting icecaps, rising sea levels, torrential floods, devastating droughts and severe harvest failures—but one scarcely hears a word about the potential effects of climate change on public health, tourism and recreation. Such changes to the earth's surface will surely affect human life, but how? The answer is not a simple one, and there may be as much good in the forecast as there is bad. For the moment, we do not know exactly where the balance lies.

Part of the reason the question has received so little attention is that it is so difficult to answer. The problem arises from the fact that climate change will affect health and patterns of tourism in various parts of the globe in very different ways. For example, the incidence of natural disasters—droughts, floods and heat waves—may increase, but how severe will they be and where and when will they occur? And then how do we quantify the consequences for human life? Does an extra foot of water correspond to a certain number of deaths or a decrease in recreational opportunities? What may be manageable for one region may be overwhelming for another. And not all of the changes will be for the worse. A general warming may actually be beneficial for human life in certain parts of the world, but where?

In the sections that follow we will sketch the main impacts of climate change on human health, tourism and recreation, and discuss the adaptive mechanisms available reduce these impacts. Although we will look specifically to the Dutch situation, our view will be broader in the sense that impacts for other regions are discussed as well.

3.4.1 Human health

The link between weather and disease is illustrated by the seasonality of many diseases. Until the first decades of the 20th century, 'summer diarrhoea' was a major cause of childhood deaths in Europe. Although the current seasonal variation in many infections is well described, the reasons behind the rise in infections at certain times of the year are less well understood. There are many seasonal mechanisms that are not related to climate, or are only indirectly related to climate, for example, changes in diet, food preparation behaviour and travel.

Climate change impacts on population health will reflect the conditions of the ecological and social environments in which humans live. Our health is profoundly affected by various natural systems such as the ecology of pests and pathogens, food supplies, water supplies, and weather patterns. In addition, climate change will affect human health simultaneously with other ecological and demographic changes. Countries and populations do not exist in isolation. The vulnerability of certain groups is likely to affect the well-being of more advantaged members of the same population, for example, infectious diseases can spread from primary foci in poor populations to the wider population. What applies within populations may apply also between countries. Therefore, the assessment below addresses the impacts of climatic changes on human health within a European context (see also Kovats and Martens, 2000).

Climate change and health: storms and floods
Major impacts of climate change on human health are likely to occur via changes in the magnitude and frequency of extreme precipitation events and associated flooding. The changes in risk of coastal flooding are significant if no adaptive measures are taken. The majority of deaths and injuries caused by major flooding occur within a few hours of the event starting. The main cause of death is drowning. The small fraction of deaths that occur later are primarily deaths resulting from initial injuries, typically crush injuries to the chest and limbs. In the aftermath of a flood disaster, physical injuries may also occur as residents return to dwellings to clean up damage and debris (Menne *et al.*, 1999).

During and following both catastrophic and non-catastrophic flooding, there is a risk to health if the floodwaters become contaminated with human or animal waste. Floods may disrupt water purification and sewage disposal systems. "Foul flooding" occurs when sewage is flushed out of the drainage system onto the surface. There is also danger that toxic waste sites, storage tanks and chemical stores will be flooded, so that floodwaters may become contaminated with chemicals.

Much of the effect of flooding upon mortality and ill health may be attributable to the distress and the psychological effects of the event (Green, 1988; Green, 1989). Following flooding in Bristol, UK, for example, primary care attendance rose by 53% and referrals and admissions to hospitals more than doubled (Bennet, 1970).

Similar psychological effects were found following floods in Brisbane in 1974 (Abrahams *et al.*, 1976). An increase in psychological symptoms and post-traumatic stress disorder, including 50 flood-linked suicides, were reported in the two months following the major floods in Poland in 1997 (IFRC, 1998).

In the Netherlands, disease risks from flooding are greatly reduced by a well-maintained sanitation infrastructure, and by a decreased risk of flooding due to better dikes. In addition, public health measures undertaken during a flood have been successful in preventing outbreaks. Such measures include monitoring and surveillance activities to detect and control outbreaks of infectious disease.

Climate change and health: temperature extremes
Global climate change will be accompanied by an increase in the frequency of heatwaves (daily temperature extremes), as well as warmer summers and milder winters. Even with no change in climate variability, an increase in mean temperatures would increase the number of summer heatwaves (as currently defined) and reduce the number of cold spells in winter, for any given location.

Episode or time-series analyses have been used to determine the "acute" effects of hot weather on populations. Daily mortality from all causes has been shown to increase during heatwaves. A heatwave in July-August 1995 in London, United Kingdom (immediately following the severe Chicago heatwave of that July) was associated with a 15% increase in total mortality over the 5-day period (Rooney *et al.*, 1998). A heat wave in July 1976 in London, United Kingdom, was also associated with a 15% increase in total mortality, approximately 520 excess deaths (McMichael and Kovats, 1998). A heatwave in 1994 in Belgium was associated with a 13.2% increase in mortality among the elderly (Sartor *et al.*, 1995). Much of the excess mortality attributable to heatwaves is attributable to increases in deaths from cardiovascular, cerebrovascular and respiratory disease.

It is likely that a proportion of the observed excess deaths during a heatwave is brought forward by a few days. A deficit in mortality can sometimes be seen following the peak (e.g. Sartor *et al.*, 1995). This phenomenon is called "early harvesting" when a proportion of deaths that occur during a heatwave occur in susceptible persons - the frail or sick - who were likely to have died in the near future. Furthermore, many questions about the interaction between high temperature and high concentration of air pollutants need to be resolved.

Extremes of temperature cause physiological disturbance and ill health. It is therefore likely that, during hot weather, persons with chronic diseases experience additional health problems. Several studies have observed that the elderly are particularly vulnerable to heat-related illness. Many countries in Europe (including the Netherlands), and elsewhere, have an ageing population. Therefore, the population vulnerable to thermal stress will increase and climate change will represent an additional burden on this population.

Autonomous adaptation (both physiological and behavioural) will mitigate some of the impacts of future increases in the frequency or intensity of heatwaves. Physiological acclimatisation to hot environments can occur over a few days, but complete acclimatisation to an unfamiliar thermal environment may take several years. There is some evidence of acclimatisation to hot weather at the population level. The impact of the first heatwave on mortality is often greater than the impact of subsequent heatwaves in a single summer. This effect can also be explained in part by the accumulating deaths of susceptible individuals i.e. towards the end of the summer there are fewer susceptible people alive to die in a heatwave.

In cold and temperate locations, daily death rates increase as daily wintertime temperature decreases. A direct increase in mean summer and winter temperatures associated with global climate change would mean fewer cold spells. Mortality associated with cold spells, particularly hypothermia in the elderly, would be expected to decrease with climate change.

Many countries with a high proportion of deaths in winter are likely to experience a reduction in excess winter mortality from milder winters under climate change. Langford and Bentham (Langford and Bentham, 1995) estimated that 9000 wintertime deaths per year could be avoided by the year 2025 in England and Wales under a 2.5°C increase in average winter temperature. A meta-analysis by Martens (Martens, 1997) estimated that an increase in global temperature of a few degrees could result in a reduction in winter cardiovascular mortality in Europe. However, these analyses may overestimate the role of temperature in its contribution to the excess mortality. Therefore, the potential reduction in deaths may be an overestimate. Socio-economic changes (e.g. improvements in housing stock) will also have a significant impact on winter mortality.

Health and temperature extremes in the Netherlands

A study by Huynen *et al.* (Huynen *et al.*, 2001) estimated the relation between temperature and mortality rates due to a variety of causes in the Netherlands during the period 1979-1997. Their findings support the idea that the relation between cold and warm weather and mortality is largely attributable to the exposure to ambient air temperatures. For cold-related effects, they found that only a proportion of the cold-related mortality was attributable to the increased incidence of influenza. Mortality from respiratory disease appeared to be most sensitive to the effects of cold. Important mechanisms may be an increased incidence of minor respiratory diseases due to impaired immunological defence and contraction of the trachea upon inhalation of cold air (the latter being of particular importance for patients with chronic obstructive lung diseases).

Huynen *et al.* found a V-like relationship between mortality and temperature (Figure 3.9), with an optimum temperature value (e.g. average temperature with lowest mortality rate) of 16.5 °C for total mortality, cardiovascular mortality, respiratory mortality and mortality among those aged 65 and over, while for mortality due to malignant neoplasms and mortality in the youngest age group it was 15.5 °C and 14.5 °C respectively. For temperatures above the optimum, mortality increased by 0.47, 1.86, 12.82 and 2.72 percent for respectively malignant neoplasms, cardiovascular disease, respiratory diseases and total mortality for each degree Celsius increase above the optimum in the preceding month. For temperatures below the optimum, mortality increased respectively, 0.22, 1.69, 5.15 and 1.37 percent for each degree Celsius decrease below the optimum in the preceding month. Mortality increased significantly during all of the heat waves studied, and the elderly were most effected by extreme heat. The heat waves led to increases in mortality due to all of the selected causes, especially respiratory mortality. Average total excess mortality during the heat waves studied was 12.1 per cent or 39.8 deaths per heat wave day. The average excess mortality during the cold spells was 12.8 per cent or 46.6 deaths per cold spell day, which was mostly attributable to the increase in cardiovascular mortality and mortality among the elderly. The results concerning the forward displacement of deaths due to heat waves were not conclusive. We found no cold-induced forward displacement of deaths.

The results from another study show how future changes in mortality related to the global warming may take place, according to several climate models (Martens and Huynen, 2001). Although global climate change is likely to be accompanied by an increase in the frequency and intensity of heat waves, winters will likely be milder as well. Therefore, although the overall balance would also depend on adaptive responses (e.g. air-conditioning, improved housing) and future health levels, it is likely that in many temperate or cold regions, including the Netherlands, a continuing decreasing trend in winter mortality would tip the scales to the increasing excess summer mortality rate increases in heat related mortality.

Aeroallergens

The production of many aeroallergens in the air, particularly pollen, depends on the season of the year. The onset of the pollen season is dependent on the weather in the spring and early summer. For example, the start of the grass pollen season in the United Kingdom can differ by about 32 days. Weather conditions during pollination can affect the amount of pollen produced and distributed in a specific year. Thus, the farther north you go, the later the pollinating period and the later the allergy season. Trends in pollen abundance over the last few decades are more strongly attributable to land use change and farming practices than observed climate warming.

Consultations for allergic rhinitis (hay fever) consultations coincide with the onset and duration of pollen season. Climate change is likely to change the seasonality of pollen-related disorders such as hayfever. However it is not yet known whether this would entail a season of longer duration in addition to an earlier onset. There are local and national differences in sensitivity to different pollens and this makes forecasting future health impacts difficult.

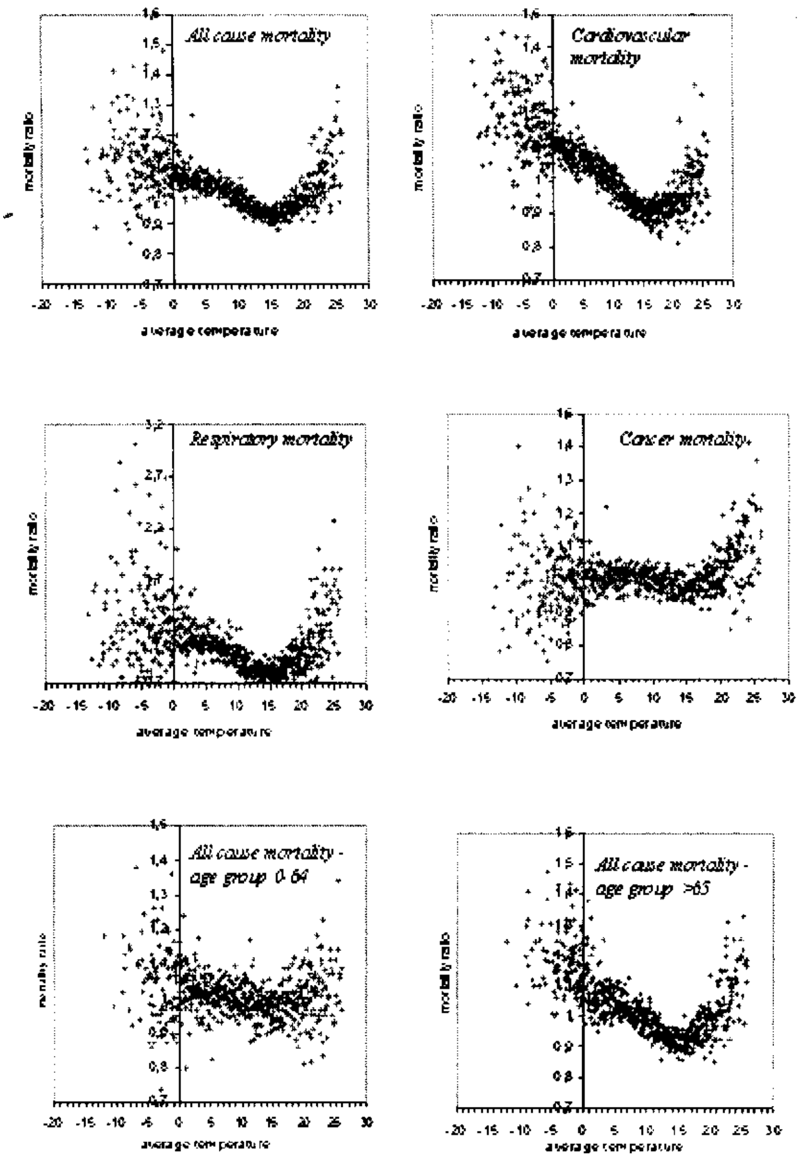


Figure 3.9 The association between mortality and temperature, the Netherlands, 1979-1997. Source: Huynen et al., (2001).

Health in the Netherlands: aeroallergens
As with many atopic diseases, prevalence of hay fever is rising in the Netherlands for reasons that are not clear. Small changes in seasonality may affect a large number of people with hay fever.

The seasonality of asthma is complex and not well understood. Only a small proportion of asthma mortality or morbidity is estimated to be related to pollen allergens (Anderson *et al.*, 1998). However, changes in temperature and humidity could lead to an increase in the concentration of biotic allergens (e.g. pollen or house dust mites): mites require an environment that has a stable and high relative humidity of between 65% and 85%. If relative winter humidity increases with climate change, we may see a further increase in house dust mite densities and a corresponding rise in the incidence of asthma.

Water-related diseases
Diseases associated with water are varied and cover multiple environmental pathways. Some important diseases are caused by pathogenic organisms (water-based diseases) that spend part of their life cycle in aquatic organisms and often are associated with standing water. In Europe, an example of such a disease would be cercarial dermatitis ("swimmer's itch") for which the intermediate host is the water snail (de Gentile *et al.*, 1995). Other helminth (fluke) infections in Europe include *Fasciola* spp., which can be transmitted thorough drinking water, and tapeworm.

Many countries in Europe have high quality drinking water supplies, compared to poorer regions of the world. However, microbiological contamination of the public supply in Europe is still an important problem (EEA/WHO, 1999). In Nordic countries, approximately 100 outbreaks of water-borne disease were reported in community systems and 40 in non-community systems between 1975 and 1991. Since the early 1980s, several new waterborne pathogens have been identified in outbreaks in the European region - *Campylobacter, Norwalks agent, Giardia* and *Cryptosporidium.* However, in around 60% of water-related outbreaks the etiological agent is not identified.

The most significant water-borne disease associated with the public water supply in Western Europe is cryptosporidiosis. *Cryptosporidium* is an intracellular parasite of the gastrointestinal and respiratory tracts of numerous animals. Cryptosporidium oocysts can survive several months in water at 48C and are among the most chlorine-resistant pathogens. When contamination occurs, it has the potential to infect very large numbers of people. This is illustrated by an outbreak of cryptosporidiosis in Milwaukee, USA, which affected more than 400,000 persons in 1993. Some notable outbreaks of cryptosporidiosis have been associated with heavy rainfall events. At present, there is insufficient evidence to estimate whether climate change would have an impact on this disease.

Some important water-related diseases (cholera and typhoid) have become rare in Western Europe. The vast majority of reported cases are acquired abroad on holiday. The impact of climate change beyond Europe may lead to an increase in imported cases of these diseases.

The contamination of shellfish with marine biotoxins occurs seasonally in many coastal regions of Europe. Such contamination often occurs in the absence of an algal bloom. The various environmental factors that influence the occurrence of marine biotoxins are poorly understood. Biotoxins that are associated with temperate waters cause paralytic shellfish poisoning (PSP) and diarrhoeic shellfish poisoning (DSP). The production of these biotoxins is temperature-sensitive and may be expected to increase at higher sea surface temperatures that are projected with climate change (Tester, 1994). Many countries in Europe, such as the UK, monitor marine shellfish for biotoxins as a food safety issue. It is important that such monitoring systems are maintained or expanded.

Water related diseases in the Netherlands
Thanks to modern sanitation, epidemics of infectious diseases, which spread via drinking water, are hardly seen any longer in the Netherlands. The last outbreak, recognised as such, occurred in 1981 in the Scheepvaart district of Rotterdam and was caused by wastewater discharged from a French naval vessel (Huisman and Nobel, 1981). In the Netherlands 99.9% of the households are connected to central drinking water supplies – one of the highest percentages in Western Europe. The disappearance of a typical water-borne disease like typhoid fever is closely associated with the increase in such connections.

In the Netherlands a warmer spring, summer and autumn may increase leisure time associated with bathing in coastal waters. This would increase the contact between humans and water, increasing the risk of infection.

Vector-borne diseases
Several important diseases are transmitted by blood-feeding vectors such as mosquitoes or ticks. The distribution of such vector-borne diseases is restricted by the climatic tolerance limits of their vectors. Furthermore, biological characteristics that limit the survival of the infective agent in the vector population also determine the geographical limits to disease transmission. Human activities play a major role in restricting disease transmission both directly (reducing vector populations by spraying, removing pathogens by treating cases) and indirectly (introducing agricultural practices unfavourable to the local vector species).

Climate plays a role in determining the distribution, seasonality, and abundance of insect and tick species, either directly or indirectly through its effects on host plants and animals. Therefore, it is anticipated that climate change will have a significant effect on the geographical range and seasonal activity of many vector species. This sensitivity is reduced, however, if the vector is adapted to an urban or domestic environment. In addition, land use change is also likely to be the major factor in future changes in vector distribution and abundance in Europe. The life-cycle stages of the infecting parasite within the vector are temperature dependent. The minimum temperature for completion of the extrinsic incubation period is a limiting factor for transmission in temperate areas where both vector and pathogen are present. These limits will expand north with climate change.

Table 3.15 Necessary conditions for the transmission of malaria in Western Europe.*

Condition	Present under current climate	Likely to be affected by climate change	Significant non-climate factors
Presence of vector	Yes	Yes - but only at very northern limits	Changes in land-use, changes in vector control programmes.
Presence of parasite	No	No	Increases in international travel and population movements, lack of health care.
Minimum temperature for parasite development in mosquito	Yes - in some areas	Yes – more often and in more areas.	Not applicable

* these are *not sufficient* conditions. To re-established endemicity, the vectors, parasites and humans must be present in sufficient numbers to maintain transmission in the population. In practice, the parasites will be removed as cases are treated.

Malaria

Malaria was successfully eradicated from most of Europe during the 1950s and the 60s (Bruce-Chwatt and Zulueta, 1980). Last century, malaria was found up to the southern UK and southern Sweden. The mosquito vectors were never eradicated in Europe (figure 3.10). It is therefore possible for local or autochthonous transmission of malaria to occur under particular circumstances (table 3.15).

The six major vectors of malaria in Europe (*Anopheles atroparvus*, *An. labranchiae*, *An. maculipennis*, *An. messae*, *An. sacharovi* and *An. superpictus*) are distributed throughout the continent. High densities of *An. sacharovi*, *An. labranchiae* and *An. atroparvus* sufficient for malaria transmission have been reported from Greece, Italy, Spain and Portugal. The population of *An. labranchiae* has recently increased in Italy from large-scale rice cultivation. However, *An. Atroparvus* is not able to transmit the tropical type of malaria *Plasmodium falciparum* (Jetten and Takken, 1994).

The resurgence of malaria in Eastern Europe is now a major cause for concern. The disease is currently endemic in Azerbaijan, Tajikistan and Turkey. There have been recent reports of local transmission in Turkmenistan, Uzbekistan and the Urals, which is thought to originate from imported cases from nearby Afghanistan, Tajikistan or Azerbaijan.

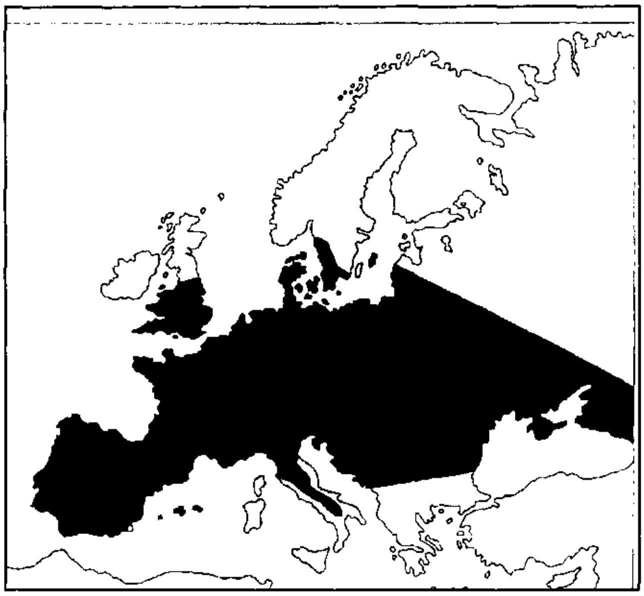


Figure 3.10 Distribution of A. atroparvus in Europe.

Concomitant with increases in the volume of international travel, all countries in Europe have seen a steady increase in the number of imported cases of malaria (i.e. cases where the infection was acquired abroad). It has been estimated that, in the period 1985-1989, 16,000 European travellers were infected with malaria but this number is likely to be an underestimate (WHO, 1997a). A few of these cases are fatal, primarily due to late diagnosis. The majority of imported cases originated in Africa., and in recent years, the proportion of *P. falciparum* (the more lethal parasite) has increased.

Airport malaria occurs when vectors that have arrived on aircraft infect people. People who work and live in or near airports are most at risk. Since 1969, approximately 100 cases of airport malaria have been reported in Western Europe and most were caused by *P. falciparum*. Consequently, aircrafts there are now sprayed regularly with residual pyrethroids.

Tick-borne diseases

Ticks transmit several bacterial, rickettsial and viral pathogens to humans. Ticks are ectoparasites and their geographical distribution depends upon the availability of suitable habitat vegetation and host species, usually rodents, large mammals, such as deer and birds. The distribution and population density of ticks is also limited by climatic factors. Tick vectors are long-lived and are active in the spring-summer-autumn months. Temperature must be sufficiently high for completion of the tick's life cycle during the warmer part of the year (i.e. above 5-8°C), and high enough in winter to suspend the life cycle. Humidity must be sufficient to prevent both eggs and ticks from drying out. Higher temperatures enhance proliferation of the infectious agent within the ticks, although temperatures above the optimum range reduce the survival rate of both ticks and parasites.

Ixodid ticks such as *Ixodes ricinus* and *I. persulcatus*, which are widely distributed in temperate regions, transmit tick-borne diseases in Europe. People most at risk of infection are those who spend time in the countryside or come into contact with the ticks in vegetation in periurban areas. People have also been infected in city parks. Tick populations are difficult to control directly using pesticides. It is also difficult to control the host animal populations due to the diversity of species that can provide ticks with a blood meal. Tick populations may be controlled indirectly by modifying the local vegetation type but this can only be done on a small scale. Currently, the most effective public health measure is to raise public awareness about tick-borne diseases and how to avoid infection.

Lyme Borreliosis or Lyme Disease is prevalent over much of Europe. The disease agent was described in 1975 after an outbreak in the US and the disease is therefore considered as an emerging infection. It is now the most prevalent arthropod-borne disease in temperate climate zones. There is some evidence that the northern limit of the distribution of ticks in Sweden has changed between 1980 and 1994. In regions where ticks were prevalent in 1980s, population density has increased between the early 1980s and mid 1990s.

An increase in incidence has been report in Sweden due to both an increase in public awareness of the disease and due to a serologically confirmed increase in cases in the last decade (Berglund *et al.*, 1995). Some other European countries also show increased numbers of cases (e.g. Finland, Slovenia, the Russian Federation, Germany and Scotland) however, this may partly be due to increased reporting rather than a real trend. Transmission occurs during the spring-summer-autumn months when the ticks are active. Climate warming is likely to lengthen this transmission period.

TBE (tick-borne encephalitis) is present in southern Scandinavia, northern, central and Eastern Europe. There are at least two distinct types: the central European form of TBE which was first identified in the 1930s; and the Russian spring-summer encephalitis subtype which encompasses several diseases world-wide including Omsk haemorrhagic fever in Siberia. The virus has been shown to infect humans via unpasteurised goat milk as well, which has lead to some rare localised outbreaks in Eastern Europe. A study of TBE during nearly 4 decades in a highly-endemic region in Sweden found that TBE incidence increased after milder winters (i.e. less days with temperatures below -7°C) in combination with extended spring and autumn seasons during two successive years (Lindgren, 1998). It is therefore likely that climate change could extend the length of the transmission season for tick-borne diseases in central, eastern and northern Europe and facilitate the spread of the disease to higher latitudes and altitudes.

Climate change and health: vector-borne diseases

In the coastal areas of the Netherlands, northern Germany and Denmark, a very characteristic type of malaria occurred, caused by *P. vivax*. It was recorded that the British invasion of the Dutch province of Zeeland in 1806, failed to drive French troops out of the Netherlands because most of the British soldiers contracted malaria. As late as 1945, malaria caused havoc in the Dutch provinces of North Holland and Zeeland, where thousands of people contracted the disease each summer. *P. vivax* is not usually fatal, but it causes high fever and creates complications if accompanied by another disease. Malaria was eventually eradicated from the Netherlands by a combined use of insecticides and the anti-malaria drug chloroquine, and the last endemic case was recorded in the early sixties.

Around 1980 a new parasitic disease called Lyme disease, caused by the spirochaete *Borrelia burgdorferi* and transmitted by the sheep tick *Ixodes ricinus*, was discovered and shown to be highly prevalent in much of Europe, including the Netherlands. The disease has a wide array of symptoms, and can cause cardiac arrest several years after infection. The most often recorded symptom is severe arthritis. The natural reservoir is believed to be wild rodents, from where it is transmitted to humans through *Ixodes* ticks. Early infections can be treated with antibiotics, but it is not known whether established infections can also be cured. The prevalence of Lyme disease may increase in the Netherlands, especially if the local ticks can be active for a much greater period of the year due to increased temperatures. Thus, while at present transmission only occurs during the summer months, when the ticks are active, transmission could expand over a much greater period of the year (Piesman, 1987).

Vector-borne diseases in the Netherlands

the Netherlands enjoys an excellent health care system, with compulsory reporting of vector-borne diseases. In 1995 >300 malaria cases were reported, which represents probably about half of all recorded cases (J. Lelijveld, pers. comm.). These cases were all imported from areas in which malaria is endemic. However, the large water surface and the presence of the malaria vectors *An. atroparvus* and *An. measseae* allow for local transmission of at least *P. vivax* during the summer months. It is believed that the local vectors are refractory to *P. falciparum*, but this has not been investigated in recent years. Around Schiphol airport a few cases of *P. falciparum* cases have occurred, which must have been transmitted by infectious mosquitoes that arrived with incoming aircraft (Delemarre-van de Waal and De Waal, 1981). The predicted increase in mosquito generations due to climate change (Jetten *et al.*, 1996), suggests that in the future the risk of local *P. vivax* epidemics will increase, as has occurred in New York city in 1993 (Laytone *et al.*, 1995), and occasional summer epidemics may occur in the Netherlands. It is also possible that the Mediterranean vector *An. labranchiae* may expand into central and Western Europe, presenting a potential for *P. falciparum* infections. However, the chances of the return of an endemic malaria situation in the Netherlands remain very low (Takken *et al.*, 1999).

Several new diseases have emerged in the last few years, and it is not unlikely that arbo-viral diseases, which are vector-borne, may appear in areas where they have so far been absent: if the climate becomes favourable for vectors that have hitherto not been present, the diseases that these vectors transmit may arrive as well. An example of this is already occurring: in 1989 a new vector, *Aedes albopictus*, was detected in Albania and northern Italy. *Ae. albopictus* is the vector of dengue haemorrhagic fever, as well as of a host of other viral diseases. It has rapidly spread across Italy and the Balkans, and is expected to migrate further north, as it has done in the USA. There, for the first time, it has been associated with local epidemics of dengue (Gubler and Clark, 1996) and more outbreaks could be expected in the future.

Climate change and health in the Netherlands: summary

Global climate change is likely to influence human health in various ways (table 3.16). Although some effects may be beneficial, most are expected to be adverse. Some impacts would occur via direct mechanisms (e.g. morbidity and mortality related to thermal stress); others would occur through indirect mechanisms (e.g. transmission of vector-borne diseases). If long-term climate change does occur, the indirect impacts would probably predominate. Different populations, with varying levels of natural, technical and social resources, would differ in their vulnerability to the health impacts. Health impacts in other parts of the world, with limited resources to react to climate change, are therefore likely to be more severe than those of the Netherlands. Nevertheless, the Dutch population will also experience the effects of climatic change such as, for example, increased mortality due to increasing numbers of heatwaves and increased risk of outbreaks of certain infectious diseases.

Table 3.16 Summary of the potential health impacts of climate change.

Health impact	Effect[a]		Certainty of estimate[b]
	Global	the Netherlands	
Thermal stress			
mortality	++	++	+
asthma/allergy	+	+	+
Vector-borne diseases	++	+	-
Water-borne diseases	++	+	-

a: Expected effect: -: none; +: small effect; ++: large effect.
b: -: low; +: reasonable

Main adaptive options available

Adaptation strategies span a wide spectrum, from long-term efforts to reduce social and economic disparities, to the more immediate provision of local information, incentives to behavioural change, and the use of technical protective devices. A simple example is that of reducing the extra deaths and episodes of serious illness experienced by urban populations during extremes of heat. Adaptations could include 'weather-watch' warning systems, better housing design, climate-related urban planning (to reduce the 'heat island effect'), and greater access to emergency medical care. As far as possible, such interventions should be undertaken on the basis of evidence that demonstrates their effectiveness.

The success of these strategies will rely on the involvement of local and national communities in the decision-making process, which in turn is dependent on an effective programme of information sharing and dissemination. the Netherlands should be able to adapt to some of the health impacts of climate change, either through maintaining existing health and other services, or through new policy measures. Little is known about the biological or passive adaptation of humans to climate change. Most assessments of the health impacts of climate change have not addressed adaptation explicitly.

Public health programmes should anticipate the health impacts of climate change. Improvement of monitoring and surveillance systems is discussed below. Health sector response may also include vaccination programmes and vector control, and drugs for prophylaxis and treatment could be stockpiled. Irrespective of climate change, breakdowns in public health measures have been responsible for many recent outbreaks of disease. It is therefore important to stress that climate change presents an additional burden on health that must be addressed.

Monitoring and Surveillance
Monitoring of the potential impacts of climate change on health is important for a number of reasons. The provision of epidemiological data is needed to inform policy-makers about the magnitude of effects. As a part of surveillance systems, data can help to determine the requirements for and the effectiveness of preventive actions.

A number of infectious diseases are likely to be affected by climate change. Monitoring networks exist for some of these diseases in Europe: *Salmonella* infections are monitored through the Enter-net network and *Legionella* infections by the European Working Group on Legionella Infection (EWGLI). WHO European Regional Office is currently developing a more standardised monitoring system for the Region but there are still significant differences between countries in the diseases that are reported and how they are reported.

Infections imported to Europe and the Netherlands, such as cholera or malaria, may also prove important in monitoring the effects of climate change outside Europe and the implications for travellers. The effect of extreme weather events such as heatwaves and floods need to be included in the enhanced surveillance for the assessment of future impacts. There is also a need to link health activities with global monitoring systems that are being developed for the climate, oceans, and earth's surface.

Main Policy Implications

There are two strategies for preventing or minimising the human health impacts of climate change:

- slow down or halt environmental change processes by cutting down gaseous emissions;
- implement adaptation strategies that reduce the health impacts of those environmental changes.

The former requires co-ordinated international action. The latter could be tackled on a local or national level. Although mitigation measures will not be discussed in this chapter, it is important to note that there might be opportunities to improve population health in the ongoing negotiations to reduce greenhouse gas emissions. There can be substantial near-term health benefits of many mitigation policies and technologies in Europe (Combustion, 1997).

Population health status is an important integrating outcome that reflects a range of other environmental impacts. Therefore, awareness of the potential health impacts of climate change should have substantive implications for policy-making in the various "upstream" sectors (environment, industry, public water supplies, construction, agriculture, etc.) that would mediate some of the effects of climate change. High standards of water quality are dependent on the comprehensive surveillance for water contaminants and pollutants, as well as intersectoral and international co-ordination (Stanwell-Smith, 1998). However, a recent review of water borne disease suggested that many countries have no national monitoring and recording system for water-borne outbreaks.

A barrier to the understanding of health impacts assessments by policy makers is the lack of a common currency in health outcomes. In order to measure the burden of disease, one must aggregate quality of life and years lived across various health states. Methods such as DALYs (Murray and Lopez, 1997) which quantify morbidity impacts in a single unit of disability-adjusted years of life lost, may make health impacts assessment more acceptable to policy makers. Further, many policy-makers are naturally far more concerned with current pressing health problems. Policies which address climate change will therefore be more acceptable if they improve public health in the near-term.

3.4.2 Tourism and recreation

Tourism is a world wide phenomenon and its importance in the world economy is increasing. According to the World Travel and Tourism Council (WTTC) in 1999 tourism was responsible for 11 percent of global income and 8 percent of global employment (WTTC, 2000). Although the reliability of these statistics is sometimes questioned, it is clear that tourism is one of the largest and fastest growing industries in the world. Important driving forces of tourism, like technological developments and globalisation take place on a world scale; global developments however create the context in which lower scale developments take place and can be researched.

More than half the volume of international tourism, both in tourist numbers as in revenues, takes place in Europe (WTTC, 2000). Most of the international tourists come from Northwest Europe and the Alpine countries. In absolute numbers Germany and Great Britain are leading. The most important tourist destinations are located in the south of Europe; particularly France, Spain and Italy are popular.

Differences in climate between the regions are an important factor when explaining the large flocks of tourists travelling from cold and wet Northern Europe to sunny southern Europe. Climate change can, therefore, have major consequences on tourism in Europe. On the other hand, tourism also has a rapidly growing impact on climate change.

In 1999 almost 10 million foreign tourists visited the Netherlands; predominantly from Germany, Great Britain and North-America. Particularly the larger cities, the beach and the water sports areas are (Marktplan Adviesgroep BV 1996). Foreign tourists altogether spend 15 billion guilders, that is almost one third of the annual turn over of 50 billion guilders of the sector Tourism and Recreation. This sector in 1999 employed 320.000 people, divided over 45.000 companies (NBT 1999).

The possible effects of climate change on tourism and recreation are discussed. These effects are clustered in five groups: change of temperature, storms and floods, weather extremes, change in precipitation pattern, and a slower recovery of the ozon layer. First of all the effects on tourism in general will be dealt with, after which we focus on the Netherlands.

In order to provide more insight into the analysis the broad concept of 'tourism and recreation' will be subdivided alongin several dimensions. First, there is a difference between day recreation and tourism: a tourist at least spends one night away from his/her normal living environment. A day tourist, however, fulfils his/her recreational needs within the course of one day. Tourism will be subdivided into domestic and international tourism, while recreation will be split up into outdoor and indoor recreation.

After discussing the effects of climate change on tourism and recreation, a few lines will be dedicated to the opposite relationship. The section continues by zooming into possible adaptation options and the impacts on other sectors.

Change of temperature
Temperature and precipitation are factors that have a lot of influence on the attraction of a certain area on tourists, especially for outdoor activities like beach tourism and open air recreation. Areas that are too cold are not attractive, but the same holds for too hot and too wet areas. Research by Lise *et al.* (2000) shows that Dutch tourists choose a destination with a climate that meet their wishes. According to a recent study countries around the Mediterranean Sea will become too hot in future summers, but their attraction may increase during the season period (Parry , 2000). Calculations from the year 1992 prove that more that 95%

of the Spanish, Italian and Greek territory will become too hot for tourism during the summer due to climate change (Anonymous, 1992).

According to Parry (2000), climate change in Northern Europe will have a positive effect on tourism. He draws upon research by (Carter, 1991) that indicates that an average temperature increase of 4 degrees Celcius will shift the zone of ideal summer climate strongly to the north, regardless of changes in the precipitation pattern.

In winter tourism, the effects of climate change become already visible. In the Alpine countries the guarantee of snow is decreasing and glaciers are retreating. According to calculations by Viner and Agnew (1999) the amount of snow may have declined by 30% in 2020 and by more than 50% in 2050. According to rough estimates, a temperature change of one degree in the Alps can shift the snow line up by 100 to 200 metres (Schär *et al.,* 1998). On the other hand, climatic circumstances for winter tourism are getting better in the Scandinavian countries, because of higher temperatures.

Tourism is a fashion related industry: trends and preferences can change in a relatively short time. That is why estimations are hard to make on how large the relative effect of temperature change on tourism will be. For recreation this seems easier to determine. A more pleasant temperature, especially a larger number of warm and sunny days, will undoubtedly lead to more outdoor day recreation, because people go out to enjoy the weather.

Change of temperature and consequences for the Netherlands

According to climate scenarios of the KNMI (Royal Dutch Meteorological Institute) during the summers, temperatures in the Netherlands will mainly increase in the coming years. Higher temperatures will make the Netherlands more attractive as a holiday destination, not only for foreign guests but also for the Dutch people themselves. Lise *et al.* (2000) found a correlation between the summer temperature and the behaviour of Dutch tourists: an increase of the summer temperature with one degree Celsius leads to a 4,7% increase of domestic tourism.

Bad weather automatically leads to a larger exodus of tourists (for research in Great Britain, see Parry (2000)). It is expected that a lower frequency of bad summers will lead to more domestic tourism, especially when taking the decreasing attractiveness of the Mediterranean Sea into account.

Day recreation is very important in the Netherlands. In summer, higher temperatures will cause larger numbers of people to go to recreation areas, like the Veluwe, inland water and the beaches. During the winter, the lack of cold weather can have implication for the traditional winter recreation on ice. People may go to alternative indoor ice rinks or may go abroad in search for the right winter weather. According to Lise *et al.* (2000) climate is an important factor in the decision making of tourists during the winter, while in the summer it is not as important. In summer people adjust their destination choice, while in winter people accept climatic conditions and adjust their behaviour.

Sea level rise and floods

The sea level rise that results from climate change will have serious consequences for the coastal areas. Particularly islands are vulnerable. The AOSIS (the Alliance Of Small Island States), of which 36 island states are a member, has been founded as a result of a shared vulnerability to climate change. There is a risk that many of these islands will disappear or become partly uninhabitable. Also, the warming of the oceans has an harmful effect on coral reefs, that function as a tourist attraction for many tropical islands.

Coastal areas are very important for tourism since many tourists are drawn to the beaches. Many of the AOSIS-member states in the Caribean, like the Bahamas and Jamaica, are well-known holiday destinations. Also, in Europe beach tourism is very important; one can think about for example the Spanish and Greek beach destinations.

Particularly the combination of sea level rise and the higher chance of storms is threatening coastal areas. Beaches may be washed away and tourist facilities are endangered. It is obvious that rich countries are better capable of protecting themselves for these risks than poor countries, for example by raising beaches and constructing dikes.

Sea level rise and floods and consequences for the Netherlands

The Dutch coastal areas are an important tourist attraction, both for domestic tourists as for foreign visitors. Particularly Belgians and Germans draw to the Dutch Northsea coast and West Frisian Islands (Marktplan Adviesgroep BV, 1996). Possible damage to beaches and islands in the Netherlands may have serious impacts on tourist industry. Because of available financial resources and knowledge, a lot of the damage can be avoided through preventive measures.

Weather extremes

According to current insights, climate change will lead to a higher frequency of extreme weather events, such as heat waves, excessive rainfall and storms. This will undoubtedly have an influence on tourism. Temperature extremes can reinforce the effects of the increasing average temperature. Particularly in countries that have hot and dry climates already, like the Mediterranean countries, this can have a negative influence on the attraction of the climate. But also in the temperate zones heat- and cold waves may have negative impacts on outdoor recreation.

Temporary abundant rainfall can cause serious damage to tourist facilities. Besides that, it has a direct influence on day recreation. Storms are also expected to cause damage to facilities and day recreation. Water sports enthusiasts can be surprised by a sudden rise of the wind. The effects of excessive rainfall and storms are probably limited in the case of tourism. They do not seem to be factors that play any role of importance in peoples' selection of holiday destinations.

Weather extremes and consequences for the Netherlands
Because of its temperate climate it is not probable that larger temperature fluctuations will have an important effect on the attraction of the Netherlands as a tourist destination. Particularly the recreation sector in the Netherlands will notice the impacts of weather extremes. Heat waves and larger amounts of precipitation are of direct influence on the recreational behaviour of people. People swith to indoor entertainment or stay at home. Sudden storms can become a threat to water sports enthusiasts and they form an important group when it comes to recreation and tourism in the Netherlands. The main determinants of the significance of weather extremes for tourism and recreation are their frequency and intensity.

Change in precipitation pattern
Together with the temperature, the amount and spread of precipitation are important for the attractiveness of a tourist destination and thus for tourist demand. For many tourist activities, dry weather is a pleasant circumstance. The supply side is concerned with sufficient precipitation to guarantee the water supply. The tourism sector in general uses a lot of water, not only for drinking water but also for example to fill swimming pools and to maintain golf courses. In dry areas this may lead to water shortages whereby tourism competes with other water consumers like arable farming and households. If climate change in those areas leads to less precipitation, then the vulnerability for human water extraction increases. At a certain moment it may become necessary to put limits on tourist water consumption and even on tourism itself. Water shortage is a topical problem in the Mediterranean area; in Northern Europe water issues are mainly of a qualitative nature.

Changes in the precipitation pattern and consequences for the Netherlands
Climate scenarios of the KNMI show that the Netherlands are expected to become wetter, especially in winter. Changes in the amount of precipitation during the summer are limited. As tourism and recreation in the Netherlands predominantly take place during the summer months, changes in precipitation do not have much influence then.

Changing precipitation patterns in other regions of Europe may have consequences for outbound tourism during winter. Because of decreasing snowfall in the Alpine countries, tourists could move to other mountainous areas, for example in Scandinavia.

Slower recovery of the ozon layer
Climate change appears to have a slowing effect on the recovery of the ozon layer. The risk of skin cancer as a result of too much exposure to harmful UV

radiation therefor remains large. In tourist and recreational activities the exposure to UV radiation is relatively big, since these activities often take place outside. For example, a long lasting stay on the beach can be dangerous.

Dependent on the perception of the risks by the population the ozon problem can become an important theme for tourism and recreation. For now this feeling of discomfort is still offset by the desire for sun, but this could change in the future. Just like sea level rise and high temperatures, the fear for skin cancer could change the dominant position of beach tourism and stimulate the development of alternative form of tourism.

Slower recovery of the ozon layer and consequences for the Netherlands
A possibly greater fear for skin cancer may also affect the position of tourism and recreation in the Netherlands. Outdoor activities, like beach tourism, water sports and recreation in wood- and heath land may become less popular, possibly in the favour of city tours. Because of the influence of lifestyles and perceptions it seems hard to predict in what way the ozon problem will affect tourism and recreation in the Netherlands.

The contribution of tourism to climate change
The largest contribution that tourism makes is through mobility. On the short and middle range distances usually the car is used, on the longer distances the aeroplane. *"It is hard to say what the exact contribution is of tourist transportation to the greenhouse effect. However, it is clear that this contribution is in the order of billions of tons CO_2"* (Egmond, 1999, translation by author), that is more that 10% of total emissions by human activity. Especially the contribution of air traffic has grown enormously. Since 1960, air traffic, in terms of passenger-kilometres has grown at an average of nine percent per year. Between 1990 and 2015 an average growth of five percent per year is expected (Penner *et al.*, 1999). In the IPCC reference the contribution of the air traffic in changing the radiation balance increases from 3.5% in 1992 to 5% in 2050 (Penner *et al.*, 1999). The Dutch contribution to the growth of air traffic for tourism purposes is substantial. There is a trend towards travelling more often and to more remote areas.

Climate change and tourism in the Netherlands: summary

Climate change will probably not be an important factor for the development of tourism. Economic, social, cultural and technological developments are undoubtedly more important (Parry, 2000). Nevertheless, climate change can play a role in the spread of tourism across the world, since it will surely change the relative attraction of destinations.
Also in the Netherlands tourism and recreation are expected to change under influence of climate change. An estimation of the consequences contains many uncertainties, but in general one can estimate that climate change will lead to more tourist and recreational activity in the Netherlands. Because of a temperature rise, the Netherlands will become more attractive for foreign tourists; the urge of the Dutch to spend a holiday abroad will also decrease. For the tourist sector in

the Dutch coastal zone, climate change is not just a blessing. The sea level rise and the higher frequency of storms lead to an increased risk of damage to tourism infrastructure, facilities and the beaches.

In the rest of the Netherlands the higher temperatures during the summer will enhance tourist and recreational activity, predominantly outdoors. Higher temperatures in this way can stimulate the current trend of more active holidays. The threat of the ozone problem, the increasing amounts of precipitation and the higher frequency of weather systems may, however, stimulate the demand for indoor tourism.

Adaptive strategies
Adaptation to the consequences of climate change is possible on several levels. On the short term one can try to fight the symptoms of climate change, for example by protecting tourist facilities on the coast against the sea level rise and storms. On a higher strategic level one can stimulate alternative tourist and recreational developments that take the expected climatic circumstances in the Netherlands into account. For example, certain areas can be expanded or further developed in order to anticipate the estimated growth as a result of climate change. Such considerations can play a role in discussions about spatial planning.

The short and medium term aim may be to prevent damage on tourist facilities as much as possible. In the construction of new tourism infrastructures a safe distance can be taken into account from the coast and near the major rivers. This however might not correspond with the business interest to locate facilities as close to the sea or water as possible.

In the long term, climate change will influence the relative competitiveness of different tourist activities and destinations. All those involved have an interest in anticipating this, for example by striving for a greater diversification in the supply of tourist products. This does not only hold for the range of tourist and recreational products that is offered but also for the length of the tourist season. Because of the uncertainties related to the local outcome of climate change, specialisation involves large risks in the long term.

In order to gain insight into the relation between climate change and tourist patterns it is of great importance to monitor developments and collect statistics. In this way more knowledge will be available on the consequences of climate change for tourism and recreation. Impacts and trends are more easily identified, which allows for timely adjustments of tourism strategy.

The tourist industry in the Netherlands is already very diverse: cultural, historical and beach tourism are examples of well developed segments. Still more events could be organised off season. The NBT, the Dutch Bureau for Tourism, clearly aims for diversification in its product development (NBT, 1999). The attention of the NBT is focused on city tourism, the development of the coast, the rural areas and the stimulation of culture and event based tourism and recreation. Besides that, the growing market segment of senior tourists spreads tourism demand more equally over the year. Stimulating alternative forms of tourism, like nature- and cultural tourism and active holidays seems feasible, given the current trends in that direction.

Interactions with other sectors

Climate change will have influence on the Dutch society and natural environment in many ways. It is important to look for synergies in policy making to make sure that policies have positive outcomes in as many sector as possible. Adaptation to climate change for tourism and recreation in the Netherlands will have consequences in other areas, like traffic, health and nature. Several possible consequences will be highlighted below.

Effects on health

Warmer weather in the Netherlands during the summer can lead to more heat stress. Apart from that, the exposure to harmful UV radiation may increase because of growing importandce of outdoor activities. In the Mediterranean area there is a rising chance on heat waves. Tourists from northern areas, who are not used to high temperatures, may become the victims of this. Furthermore, in dry areas the access to sufficient clean drinking water for local residents may become a problem because of a combination of climate change and tourism growth.

Effects on insurance

Sea level rise and weather extremes will increase the risks for the tourism and recreation sector. Especially the tourist facilities along the coast and the major rivers may suffer from coastal erosion and floods. Probably insurance companies could come up with products to cover those risks. This would be favourable for the tourism sector, despite the associated increase of the total social security contributions.

Effects on transport

Due to the improved competitiveness of the Netherlands on the tourist market, the Dutch will probably make less foreign holidays (compared to the situation without climate change). At the same time the mobility within the country will strongly grow because of the increasing number of domestic holidays and the larger numbers of foreign tourists. Therefore, congestion on the Dutch roads could increase.

Effects on nature and biodiversity
The trend towards more tourism in the Netherlands and the growing demand of leisure activities will lead to larger pressure on recreation areas. These include not only the coastal and water sports areas, but also for example wood and heath lands and the Frisian islands. The tourism and recreation sector will put a growing claim on space in the Netherlands. This trend will probably be mainly attributable to the growing amounts of income and leisure, but is likely to be accelerated by the temperature rise as a result of climate change.

Effects on agriculture
The growing demand for recreation areas urges expansion of these areas. Areas that are currently still being used for agricultural purposes will probably be targeted first. The recent trend of disappearing agricultural areas in favour of more natural areas may get extra momentum due to the growing demand for tourism. Multi-functional land use, however, is also an option whereby nature, farming and recreation go hand in hand in the same area.

4 Dialogue with stakeholders: which impacts are serious and which adaptation options are effective?

4.1 Introduction

In this chapter the results are presented from the questionnaires and the workshops (29-30 March, 2001). Results are discussed for Natural systems (4.2), Land use (4.3), Economic sectors (4.4), and Human health & tourism (4.5). In figure 4.1 the response to the questionnaires and the background of the respondents is summarised.

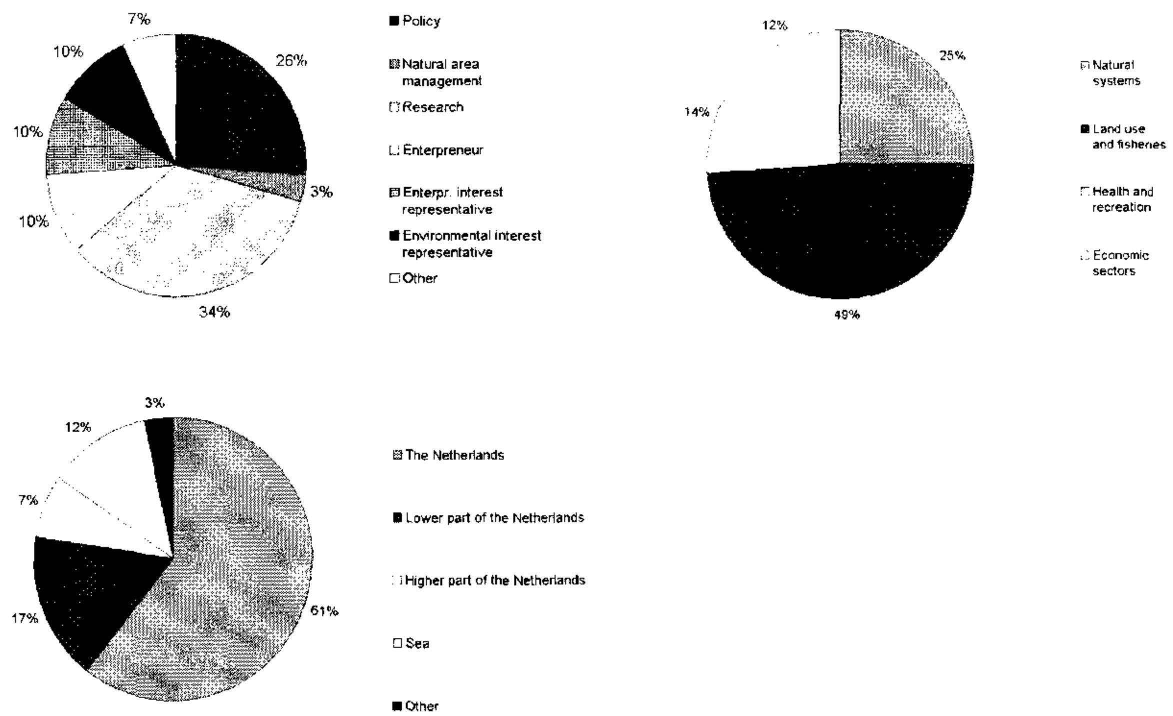


Figure 4.1 Top left: background of people who responded to the questionnaire (n=177, response=15%); top right: relative distribution of the response over the sectors "natural systems", "land use", "economic sectors" and "human health and tourism"; bottom left: discussed regions by the respondents

In total ca 1300 questionnaires were sent out of which about 15% were returned; this is a fair rate compared with a similar mail-survey (Tol, 2000). Response was relatively evenly distributed over policy makers (26%), scientists (34%) and representatives from interest-groups (e.g. NGOs, entrepreneurs) (40%). Of the total of 177 questionnaires returned, 25% were on Natural Systems (ecosystems, hydrology, soils), 49% on Land use, forestry and fisheries, 14% on Human aspects (health and recreation) and 12% on Economic sectors (transport, insurance, energy) (figure 4.1).

4.2 Natural systems

This chapter is divided into 3 main sections. First the outcome of the questionnaire is discussed (4.2.1). Next, the outcome of the workshop-sessions is presented (4.2.2). In section 4.2.3 an overview is given of the most important impacts and adaptation options for natural systems, based on the outcome of the questionnaire, workshops and literature review.

4.2.1 Outcome of questionnaire

Approximately 300 questionnaires were sent out: 125 on ecosystems, 125 on water systems and 50 on soil. 17 replies were received on the ecosystem questionnaire (13.6%), 24 on the water system questionnaire (19.2%) and 1 on the soil questionnaire (2%). The very low reply rate to the soil questionnaire (n=1) is explained by the fact that the stakeholders for soils are mostly people who are active in agriculture, forestry or nature conservation. This group identified itself probably more with the questionnaires on agriculture, forestry or ecosystems. Also, in the water-questionnaire issues regarding groundwater were included.
Figure 4.2 shows the background of the respondents of the ecosystem, soil and water questionnaire. Fifteen stakeholders were invited to discuss vulnerability and adaptation options during the workshop organised 29 and 30th of March 2001 (section 4.2.2).

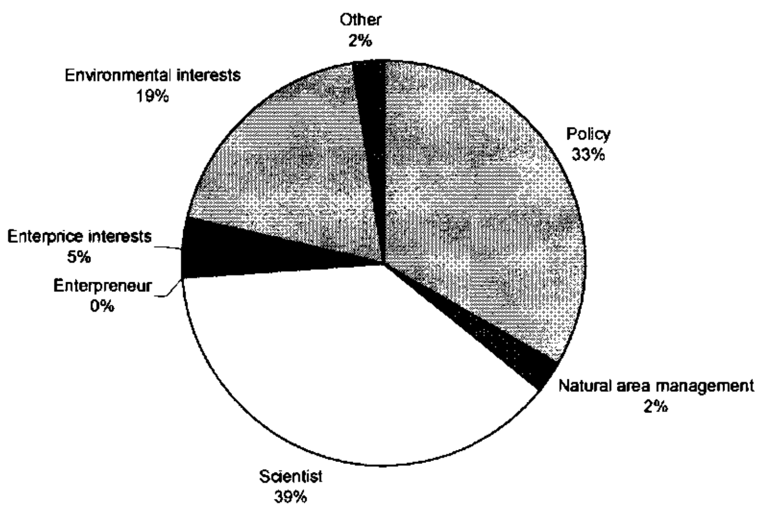


Figure 4.2 Background of respondents of the soils, water and ecosystem questionnaire (send out = 300, reply rate =14% (on average).

The results of the questionnaire are presented as follows: a discussion of Impacts (part A), suggested adaptation options (part B) and interactions (part C) as a result of the implementation of the adaptation options with other sectors and other possible future societal and environmental trends. Finally, some perspectives for natural systems in the 21th century (box 4.5) are given.

A) Perceived impacts of climate change on natural systems

Here, the results of the questionnaire on hydrology and soil (figure 4.3) and ecosystems (figure 4.4) in relation to the perception of vulnerability to climate change are presented. The soil and water questionnaires were integrated because of the low response rate to the soil questionnaire. The most important impacts based on the inventory of the ecosystem and hydrology questionnaire are:

1. flooding and safety risks
2. impacts on water quality and aquatic ecology
3. declining groundwater tables/desiccation
4. salinisation and
5. biodiversity loss.

The outcome of perceived regional differences in climate change vulnerability (6) is also briefly discussed.

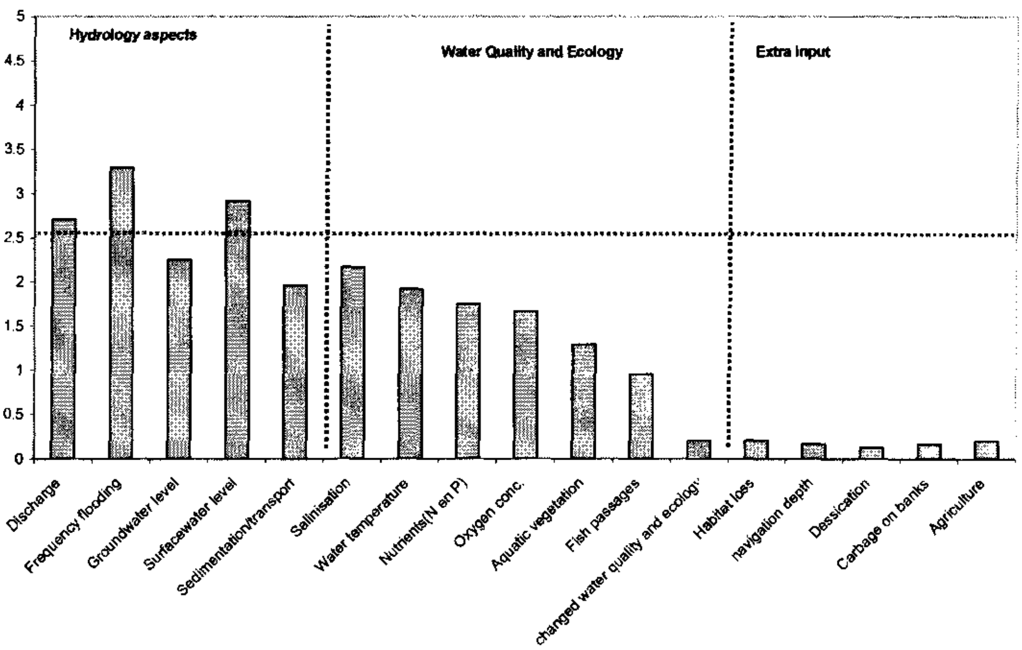


Figure 4.3 Perceived vulnerability for different possible impacts of climate change on hydrological and soil systems (n=24), rating on scale of 0 (small impact) to 5 (large impact). Extra input = items added to the list by respondents.

1) Flooding and safety risks

The questionnaire-results indicate that actors involved with water management (figure 4.3) perceive increasing flooding (economic damage) and safety risks as the key impact in relation to climate change. In a comparable perception study on regional level (Stichting Reinwater, 2000) it was also concluded that increased risk of flooding combined with impacts for physical planning was assumed to be the key impact of climate change for the national hydrological systems.

The answers of the respondents of the Hydrology questionnaire show that they are aware of the presented climate scenarios for sea level rise (Können *et al.*, 1997) and changing river discharge fluctuations (Kwadijk, 1995; Kwadijk *et al.*, 1998). These climate change scenarios were also the basis for the vision of Dutch water management the 21th century (Commissie Waterbeheer in de 21^{e} Eeuw, 2000).

2) Impacts of climate change on water quality and aquatic ecology

Several respondents with a background in water management did not see climate change as a serious threat to water quality and aquatic ecology. An exception was the perception of the seriousness of salinisation due to sea level rise in the lower part of the Netherlands (see point 4). In particular the stakeholders with environmental protection interests (Stichting Reinwater, WWF) assume serious impacts of climate change on water quality and aquatic ecology. They often refer to the indirect impacts resulting from the proposed adaptation options in the "vision for Dutch water management in the 21st century". In the policy arena there are still few climate change impact studies dealing with water quality and aquatic ecology (except impact studies in relation to the Wadden Sea, (Wolff *et al.*, 1995). As a result the assumptions in relation to possible impacts of climate change on water quality and aquatic ecology are more speculative compared to perceptions in relation to the possible impacts on hydrology.

3) Declining groundwater tables and desiccation of natural areas

The results of the questionnaire show that perceptions about both the seriousness and probability of declining groundwater tables is very different. Some of the respondents assume that natural areas will have to deal with more environmental pressure due to prolonged desiccation in summer as a result of climate change. Other respondents doubt whether this impact will be significant compared to other driving forces that may induce changes in groundwater tables, like autonomous increasing pressures on water resources (increasing population, changes in land use and irrigation). In general three different views in relation to the seriousness and probability exist:

- The Project team NW4-klimaatverandering (1997) concluded that natural values may profit from increased groundwater tables in spring (which is the most crucial period for groundwater bound vegetation). These increased water tables are a result of the changed precipitation patron (i.e. more rain in winter and less in summer).

- Other scientists/ecologists think that this potential positive impact on natural values is insignificant compared to the negative impacts of drier summers and more intense precipitation events.
- Some hydrology experts state that the impact of climate change on groundwater tables is not important. Water management, agricultural activities and drinking water exploitation determine groundwater tables. However, several hydrologist stress that adaptation options to reduce increasing flood risks due to climate change (see also discussion adaptation options) will interfere negatively with adaptation options to mitigate declining groundwater tables.

4) Salinisation and seepage
Salinisation of ground- and surface water is perceived as a very most important impact of climate change on water quality (figure 4.3). In general, respondents assume that salinisation will increase due to sea level rise in the lower part of the Netherlands. Some respondents assume that freshwater seepage as a result of changed precipitation patterns will have a larger impact than salinisation due to sealevel rise. From a science point of view this assumed impact of freshwater seepage seems to be very small. The scenarios for salinisation in 2050 (Projectteam klimaatverandering, 1997) indicate that increasing saltwater seepage is dominant in the lower parts of the Netherlands. Only, very locally ground- and freshwater seepage will increase. The scenarios do not indicate increased salinisation in the higher parts of the Netherlands.

Perceptions, however, differ in relation to the seriousness of salinisation. Agricultural interest groups and some regional water boards are very conscious about the negative impacts on crop yields in the lower parts of the Netherlands. In the province of North Holland some agricultural interest groups assume that several places (for example, the reclaimed land in lake Wieringen) will become useless for agriculture within 30 years. However, some other respondents state that agriculture is not vulnerable for increased saline seepage because adaptation options are available, like inlet of freshwater from lake IJssel or another regional water system. However, these adaptations, will mean that environmental problems are shifted to other regional water systems. Desiccation of nature and increased salinisation will increase in surrounding regional water systems.

Different perceptions exist amongst ecologists regarding the seriousness of the impact of salinisation on natural values. Several respondents assume a loss of (freshwater) species due to salinisation. Other respondents prospect a positive impact on natural values of climate-induced increased saline seepage. The same respondents perceive negative impacts from increased freshwater seepage, because it is a pressure for already rare of salt marshes in the estuaria of the river Rhine and Meuse (Zeeuwse delta) and in the region around lake IJssel.

The (regionally explicit) different perceptions in relation to the impact of salinisation due to climate change on natural values could be explained as follows:

- *Respondents might have a different focus in relation to the concept of biodiversity (see also point 5).* The perception of the impact of salinisation on biodiversity depends on which level (species or ecosystem) it is discussed. Saline habitats are usually species poor (Wolff, 1995; Bloemendaal and Roelofs, 1988; Santamaria and Amezaga, 1999). However, saline habitats represent important and characteristic habitats, which is often overlooked by policy makers dealing with water and nature management, because their focus is usually on freshwater habitats.
- *Climate change impacts are compared with the impacts of coastal defense* The closure of lake IJssel through the construction of the 'Afsluitdijk' in 1932 and the taken coastal defense measures in the Rhine-Meuse estuary between 1953 and 1986 (Deltawerken) have changed the ecosystems in these areas considerably. The dynamic estuarine habitat, was in both cases replaced by a more static freshwater habitat, with artificial hydrological dynamics. For example, in the regions around lake IJssel increased freshwater seepage resulted in loss of characteristic salt marshes. Some respondents stated that increased saltwater seepage due to sea level rise may restore such habitats that have disappeared due to the Deltawerken.

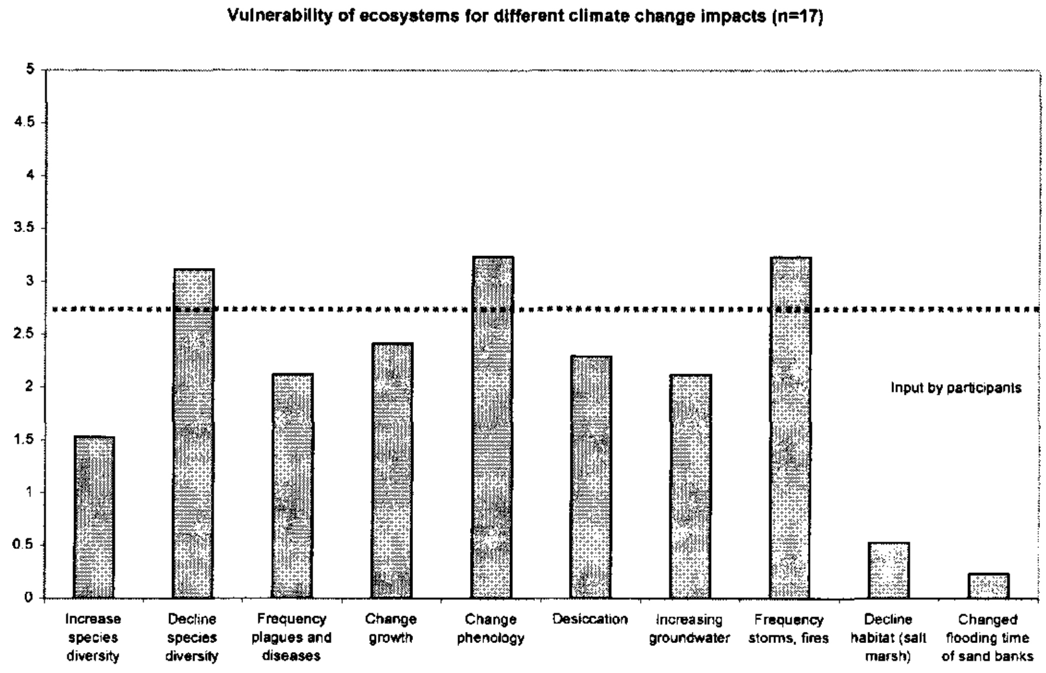


Figure 4.4 Perceived vulnerability of ecosystems for different climate change impact , rating on scale of 0 (small impact) to 5 (large impact). Extra input = items added to the list by respondents

5) Biodiversity

Figure 4.3 illustrates that respondents to the ecosystem questionnaire consider a decline in species diversity, changed phenology and changed frequency of storm and fires as relatively serious impacts. The given explanations indicate that almost none of the respondents have doubts about the probability of these impacts. However, opinions differ in relation to the seriousness compared to other environmental pressures. Most of the respondents state that the direct impacts of climate induced changed phenology and frequency of storm and fires are not serious because most of the Dutch ecosystems are influenced by society. The respondents also agree that these changes become very serious impacts combined with other environmental pressures (like dessication, forestry and water management, survival chance of exotic species and eutrophication). One respondent stated that direct impacts of climate change can only be significant in closed ecosystems, in which species are very depended on each other. For example, in isolated shallow lakes changes may occur in species composition of the algae flora.

Some respondents stated that changes in phenology are a natural way of species to adapt to environmental change. Other respondents argue that changes in phenology of a certain species is not serious for the species itself but it may have consequences for the survival of other species. Secondly, some respondents explain that the seriousness of impacts on species diversity and phenology depends on the rate of change of temperature. An absolute threshold value of an increase of 2°C by the year 2100 was mentioned at the workshop. Some of the temperature change rates of the climate scenarios used in this assessment are lower than this threshold value. The temperature change of the new IPCC climate scenarios (IPCC, 2001) are, however, higher.

6) Regional differences in relation to the vulnerability of natural systems to climate change in the Netherlands

Vulnerability of the lower part of the Netherlands

Water managers of the lower part of the Netherlands who responded to the questionnaire perceive this area particularly vulnerable because:

a) It is threatened from two sides (sea level rise from the west and changed river discharges (higher discharges in winter) from the east. The lower part of the Netherlands is at the end of three major European rivers (Scheldt, Meuse and Rhine).

b) Water management problems upstream related with land use strategies (for example deforestation) and urban developments are shifted to the lower parts of the Netherlands.

c) It is the economic centre of the Netherlands, implying high potential economic damage to buildings. Moreover, the major part of the Dutch population lives there, implying serious safety risks.

Urban areas

' The increase of paved surface as a result of urbanisation combined with changes in frequency and intensity of short precipitation events may result into more frequent discharges from the sewage infrastructure into the surface water, with negative consequences for [illegible]

Regional differences in vulnerability of natural systems in relation to climate change (sited quotes)

Low part of the Netherlands:

' Increasing groundwater tables in the reclaimed areas in the west will result in increased damage for nature and society. Damage already exists and will become higher due to climate change. Grassland birds are endangered (if water tables exceed surface level). Higher groudwater tables will mean economic damage for agriculture and urban areas. However, groundwater hydrology is a complex issue, so it is difficult to estimate the possible impact of a climate change.'

High parts of the Netherlands:

' Natural brook valleys with their characteristic community are already rare in the Netherlands. A further loss of their unique ecological integrity and loss of characteristic species may occur if the hydrological characteristics of these brooks will result into 'the ecology of a ditch' due to climate change.'

Figure 4.5 The lower part of the Netherlands (white) and the higher part of the Netherlands (blue). The lower part of the Netherlands is below sea level.

Vulnerability of the higher parts of the Netherlands

The response rate for the higher parts of the Netherlands was lower for the water system questionnaire and agricultural questionnaires than for the lower part of the Netherlands. This seems indicative of the difference in perception of the seriousness of climate change, which seems to raise less concern in the higher parts of the Netherlands. However, some respondents indicated that the brook valleys in the east and the middle of the Netherlands are particularly vulnerable for climate change (higher discharges in winter and desiccation in summer). These catchments are particularly vulnerable because of their current morphology (often canalised) and urbanisation-pressure.

Differences in vulnerability within systems

The respondents to the ecosystem questionnaire (mainly nature conservationists) indicate often that particularly the Dutch Wadden Sea is vulnerable because of its high natural value which is of international importance. Some respondents indicate that the Wadden Sea is more vulnerable to climate change because of fisheries. They consider reduction of fisheries as an adaptation option to climate change (see also section on fisheries).

Some respondents indicate that forests are in particular vulnerable. Yhe distribution of pine forests may reduce at the expense of broad leaved forests (with lower age differentiation and species diversity compared with currently).

B) ***Suggested adaptation options***

In this section, the main adaptation options for ecosystems (incl. biodiversity) and water-management that were put forward by the respondents are briefly discussed, as well as the implications of the adaptation-options for natural systems for the other sectors included in this study.

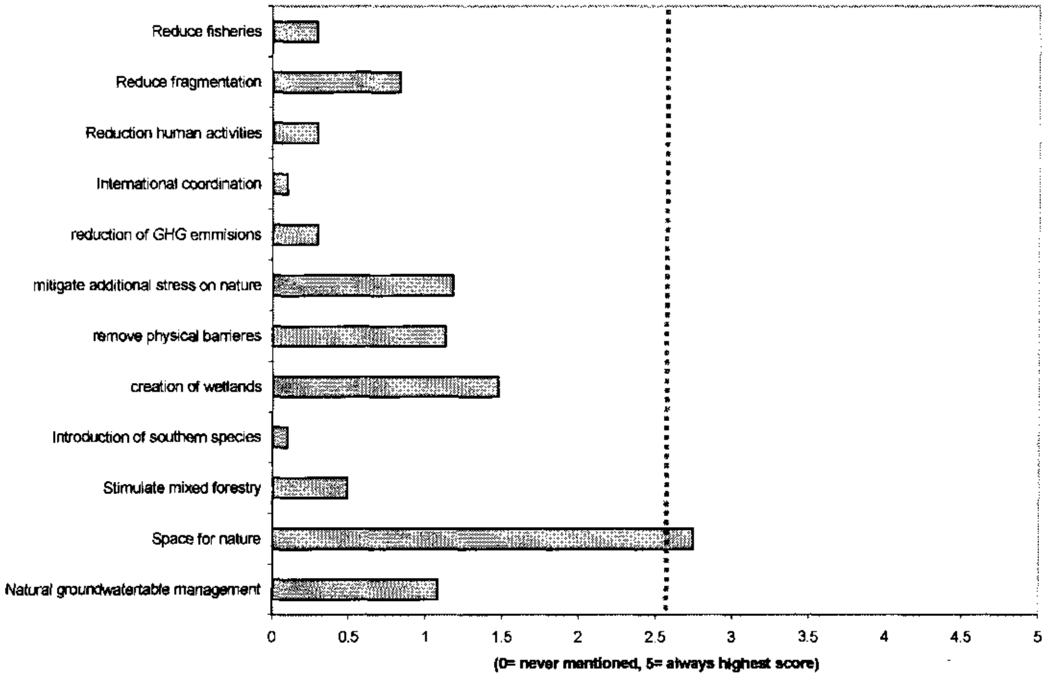


Figure 4.6 Adaptation options to climate change for ecosystems, rating on scale of 0 (never mentioned) to 5 (always mentioned). Extra input = items added to the list by respondents.

Adaptation options for ecosystems

Three main types of adaptation strategies for ecosystems can be distilled from figure 4.6:

i) *Development or improvement of the ecological main structure in combination with reduction of other stress factors (e.g. fragmentation, eutrofication, or desiccation)*

The replies to the ecosystem questionnaire (figure 4.5) indicate that policies to create more space for nature are thought to be the most efficient measure to reduce the impact of climate change (= development of the ecological main structure). The most often given explanation was that this strategy gives the most ideal circumstances in order to create robust ecosystems in which species can migrate (migration = adaptation to climate change). The robustness of ecosystems can be optimised by reduction of additional stress factors, like eutrophication. In the workshop it was stated that climate change *combined* with the current fragmentation of ecosystems in Europe is the key issue in relation to European biodiversity conservation. The suggested strategy is thus not strictly bound to the issue of climate change.

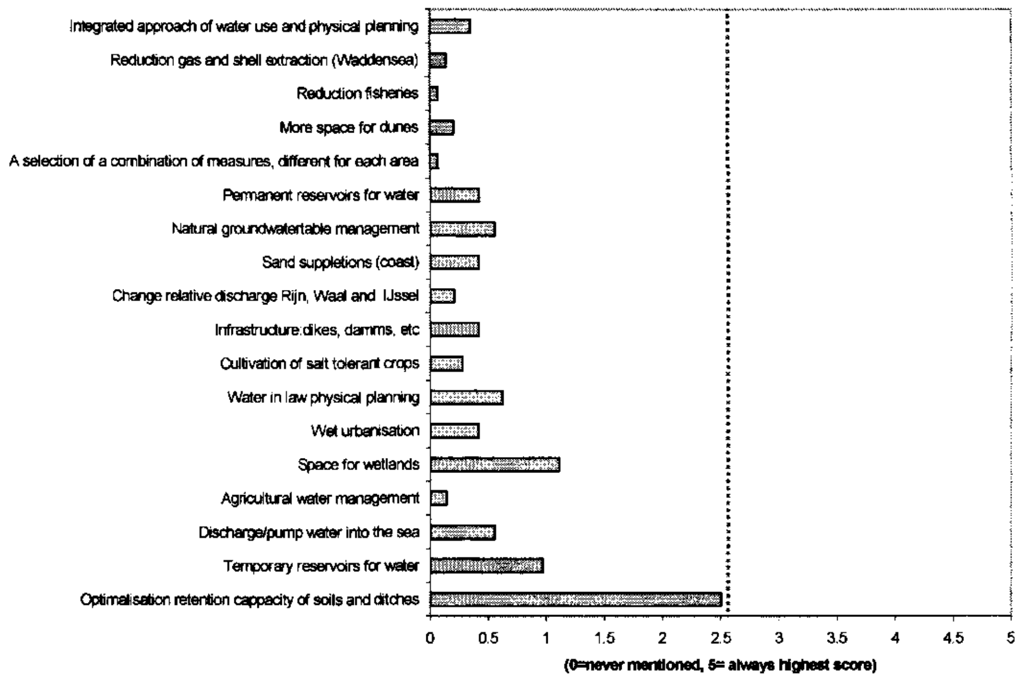


Figure 4.7 Perceived effectiveness of adaptation options to climate change in water management, rating on scale of 0 (never mentioned) to 5 (mentioned by all respondents). Extra input = items added to the list by respondents

ii) Establishment of wetlands and more natural groundwater management

The establishment of more wetlands seems logical, because of the prospected increased precipitation and river discharges. Due to the high space demand in the Netherlands it is difficult to 'design' these areas in such a way that their natural value is optimal. Policy makers in the Netherlands seem to search for a strategy that land and water are used in a multifunctional way, i.e. not only the natural function of the space should be taken into account. An important constraint of natural groundwater table management (reduce desiccation of natural areas) is the fact that it reduces the effectiveness of measures to reduce the impact of water flooding and the other way around.

iii) Mitigation: reduction of greenhouse gas emissions

Ecosystems can adapt naturally to climate change (phenology, migration, etc) if the rate of change is not too high (i.e. not more then 2°C in 50 years). Above mentioned strategies focus on reduction of additional stress factors. Based on current greenhouse gas emission scenarios (see chapter 2) expected rate of change is higher than 2°C in 100 years (IPCC, 2001). Therefore some participants considered it essential to focus on mitigation strategies, rather than on adaptation strategies.

Adaptation options for water- soil systems

Respondents to the water system questionnaire indicated that optimisation of the water retention capacity of soils and the local surface waters (eg., ditches) is the best adaptation option. Also the Commission of Water Management in the 21st century advises this adaptation option as the most important one. Second and third favorite adaptation options were the creation of wetland areas ~~in order~~ to create more space for water and the creation of temporarily basins for water storage. The wetlands have more natural values while these temporarily basins have more functions (i.e. combination of agricultural, natural and recreational functions). Some particular adaptation strategies were mentioned in relation to the Wadden Sea (reduction of fisheries, minimalisation of oil and gas exploitation) and the Rhine-Meuse estuary (restoration of the salt-freshwater gradient). Integrated tools for physical planning and water management are als often mentioned.

'Reforestation upstream is an important adaptation option in the river Rhine catchment which will delay peak discharges during extreme precipitation events. Reforestation could be combined with forestry (production function), paper industry, recreation and nature conservation '

'A stakeholder opinion'

Perceptions of interactions with other sectors and environmental trends

Within the natural systems questionnaires it was asked to evaluate the respondents favourite adaptation option in relation to:

- economic, socio-cultural and ecological opportunities and constraints of implementation
- positive and negative interactions with the other sectors. The sectors within the scope of this study were given, but it was possible to add also other sectors.

i Optimalisation of water retention capacity

ii Ecological main structure

As shown in figure 4.6 and 4.7 a large number of adaptation options were evaluated. The two most mentioned adaptation options are (i) optimalisation of the water retention capacity within the catchment, (ii) the implementation of the Ecological Main Structure. Fig. 4.8 shows the linkages between these 2 adaptation options and other environmental issues.

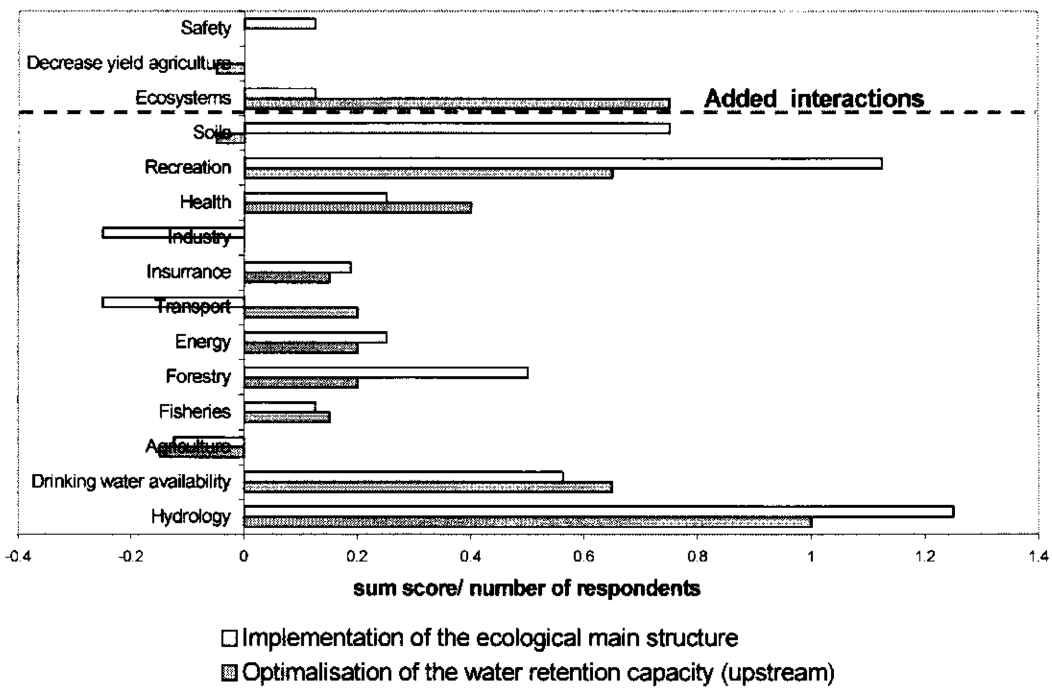


Figure 4.8 Benefits and constraints (interactions) of implementation of strategies to optimalise water retention capacity). Rating on scale of -2 (strong negative interaction) to 2 (very positive interaction). Added interactions = items added to the list by respondents.

The first clear conclusion that can be drawn from figure 4.8 is that the respondents generally see more opportunities than constraints for other sectors in relation to optimalisation of the water retention capacity within catchments and the implementation of the ecological main structure.

The interactions are discussed in the following order: (1) strong positive interaction/big opportunities, (2) on average a positive perceived interaction but opinions differ, (3) negative interactions (constraints).

Major opportunities (++)
It is perceived by the respondents of both the hydrology and ecosystem questionnaire that the implementation of respectively the ecological main structure and the optimalisation of the water retention capacity of watersheds creates chances for multifunctional land and water use. Conditions are optimized for nature conservation, water availability and recreation.

Medium opportunities (+)
In general respondents saw neutral to positive opportunities for *insurance* (less damage, thus less risks). It is perceived that *forestry* will profit from both adaptation options in relation to the production function (paper industry) and natural values (biodiversity conservation). In relation to *energy supply* positive

(eg. less energy necessary for water management) and negative impacts (eg. less possibilities for hydropower) are mentioned. Respondents perceive often no interaction in relation to *health*, some see positive psychological impacts of the experience of nature, two respondents refer to negative impacts of the optimalised wet conditions (potential habitats for mosquitoes, like malaria). Some respondents see opportunities for maintenance of freshwater fish and chances for recreational *fisheries* (natural values), but in general no positive or negative interactions were perceived. Respondents generally see positive consequences for soils as a result of implementation of the ecological main structure. On average a neutral interaction is perceived as a result of optimalisation of the water retention capacity. Individual perceptions are different however: some people see positive impacts (less dessication of soils), others negative impacts (more leaching of pollutants towards the groundwater).

Constraints (-)
More space for water and nature will mean less space for allocation of industrial areas and traffic roads. However, also some positive impacts are mentioned, like: 'navigation will profit of better managed surface water tables'.

Respondents see most interactions between adaptation options for ecosystems and water management with agriculture. On average the respondents perceive negative consequences for agriculture of the implementation of the ecological main structure and optimalisation of the water retention capacity. Both adaptation options will lead to less space for agriculture. Most of the respondents perceive this as a negative impact, but others see extensification of agriculture as positive which creates new chances for the farmers. Other respondents see chances for a sustainable multifunctional agriculture.
It is seen as a positive consequence for agriculture that water availability will increase as a result of optimalisation of the water retention capacity. A noticed negative social-cultural impact is that farmers may loose their job. It should be noted that this questionnaire was mainly filled in by stakeholders of water management and nature conservation. However, also opportunities were mentioned by some of the respondents with an agricultural background:

'It is true that agriculture will loose area at the expense of nature and water and that higher groundwater tables have negative consequences for yields in the short term. However, if we anticipate timely by creating more space and retention capacity for water COMBINED with technical measures (increased pumping capacity to the sea) chances are created in the long-term for agriculture in the lower parts of the Netherlands'. It is also important that the costs to ensure safety are not only paid by the agricultural sector because the objective to ensure safety is beneficial for the whole Dutch society.'

'a stakeholder opinion'

iii) Creation of water buffering areas ("more space for water")

This adaptation-option is mainly proposed by the hydrology sector, but has also positive effects on economic sectors (more safety) and could provide additional space for nature and recreational activities, depending on the type of buffer: eg renaturlised flood plains, urban sewage discharge buffering, "emergency floodplains", sediment buffers.

Other involved sectors are land use (competition for space), transport, energy (biomass), and health.

Box 4.1 Opportunities and constraints of creation of water buffering areas for other sectors.

Constraints:

- On a relatively small surface in the (emergency) floodplains unnatural and unpredictable hydrological dynamics will occur. This, in combination with current water quality (nutrients) of the rivers, will result into low natural values from a conservation perspective.
- In emergency floodplains it is not possible to allocate powering stations or capital intensive infrastructure and buildings.
- Water quality problems might occur if urban water buffering areas/systems are insufficient.
- Only effective in case integrate implementation within the whole catchment: high river discharges are also in future with adaptation inevitably downstream, despite increased water retention capacity upstream
- Increasing ground prices and ground speculation, nearby urban areas are seen as a constraint for implementation

Opportunities:

- Although natural values in water buffering areas might be low from a conservationist point of a view, they are sufficient for the recreational function of these areas.
- The nutrient richness of the water, which is led into the buffering areas creates chances for biomass production (reedbeds, willows).
- Water buffering areas contribute to the openness of the landscape
- Optimisation of groundwater recharge. Less water (with other water quality) from outside the regional hydrological system is necessary to recharge the groundwater stock.

iv) Technical measures: dikes, dams, riverbed construction, pumping capacity, sand suppletion

This adaptation option was mainly proposed within the hydrology questionnaire. These respondents agree spatial measures are necessary, but spatial measures will only sufficient combined with technical measures. Especially in the lower part of the Netherlands stakeholders indicate that spatial measures will only be efficient when also to pumping cappacity towards are improved.

Box 4.2 Opportunities and constraints of implementation of technical measures.

Opportunities

- No spatial claim, minor consequences for current land use and physical planning
- Sand suppletion: maintenance of the beach: recreation

Constraints

- The risk of failure: if due a technical failure a pump does not work or a damm breaks through the economical consequences are very large for all sectors
- The sea-level rise will lead to an increase of water to be drained, and for this purpose a lot of energy will be needed.
- Conservation interests along river beds will conflict with strengthening dikes

v) Restoration of salt-freshwater gradient in estuaries

It is assumed that the restoration of the interconnection between the arms of the southern delta and the sea will increase the ecological robustness in general and will mitigate the impacts of increased freshewater seepage as a result of changed precipitation patterns. From an ecological point a view the area will become less vulnerable to climate change and other environmental pressures. From a socio-economic point a view the area will become more vulnerable (see ecology versus safety debate in the 1970's). The ecological stakeholders assume that this increased flooding risk as a result of the re-establishments of the interconnections can be mitigated by improving the dikes.

Box 4.3 Opportunities and constraints of restoration of salt-freshwater gradient.

Opportunities

- Biodiversity: The estuaries would gain from more natural dynamics regarding the transition zone from freshwater to the marine environment
- Restoration of lost saltmarsh habitats
- Shell fisheries
- Channels in this part of the estuary will deepened by erosion because the tidal fluctuations will increase. The sand from this erosion process can be used for development of outside delta's and coastal dunes.

Constraints

- Destruction of very expensive engineering works
- Institutional barier: the Netherlands has agreed with Belgium to guarantee a tidalfree contection between Antwerpen harbour and the sea
- Dikes should be raised to ensure safety

vi) Making the coastal zone more dynamic

Allocation of more space for natural succesion within dunes, no phisical barriers for wind and water will increase dynamics and will increase the ecological robustness.

Box 4.4 Opportunities and constraints of a dynamic coastal defense

Opportunities

- *Improvement of ecological regulation functions of nature within the coastal zone*: Natural areas (like dunes, coastal salt marshes, peatlands and other wetlands) can function like a sink for sediment (mitigation to soil subsidence) and increase also the water retention capacity of the coastal zone (adaptation to reduced freshwater availability as a result of saltwater intrusion caused by sea level rise)
- If space is allocated for natural succession of dunes, their robustness will increase and safety is easier ensured.

Constraints

- The relocation of facilities on the coast may be possible, but still many drawbacks are encountered. It is expensive, you can not just build anywhere and the proprietors prefer to be as close to the beach as possible. Maybe there is a possibility to construct facilities off shore.

Furthermore, it was asked for a selected specific ecosystem, soil system or water system what the importance was of climate change in relation to other environmental problems (for example, eutrophication and fragmentation).
Dessication, fragmentation and spatial claims induced by economical growth and urbanisation were considered to be more important drivers for environmental pressure than climate change. Issues, like acidification, soil pollution and disturbance were considered to be less important. The perceived importance of eutrophication compared to climate change was different between respondents of the water questionnaire and the ecosystem questionnaire; i.e conservationists perceive impacts of eutrophication of greater importance, while water management stakeholders perceive climate change more important. Some respondents indicated that artificial water management is a more important pressure in relation to safety and natural values than climate change. Land use change in the river Rhine basin in the past upstream (deforestation) was by some participants considered to have more impact on hydrological dynamics than future climate change.

Finally, it was asked who is responsible for implementation of adaptation options within water management and nature conservation:
The answers within the water questionnaire indicate that the regional water boards and the provinces are perceived as first responsible institutions for implementation of adaptation measures. Also the national ministry of traffic affairs and water management was often mentioned.
The answers within the ecosystem questionnaire indicate that nature conservationists perceive the Dutch ministry of Agriculture, Nature Conservation and Fisheries as main responsible for implementation of the Ecological Main Structure. Some respondents mention that implementation of adaptation strategies in both water management and nature conservation should be done within an

European context. Some respondents in both questionnaires suggest that responsibility should also be taken by the sector (in particular are mentioned: agriculture, fisheries, energy and transport sector).

Box 4.5 Perspectives on water management and nature conservation in the 21st century: some stakeholder views.

Forests

'If climate change is as serious as predicted in the provided scenarios and additional environmental stress will be reduced, the distribution of pine forests will be reduced at the expense of broad leaved forests (with low age differentiation and species diversity). Some involved stakeholders perceive this as a positive impact of climate change. However, will additional environmental stress be reduced? If, in particular, the exposure to dessication will increase, pine forests will not be replaced by broad leaved forests'

Water management in general:

A vision of a regional water board: *'At this moment a lot of attention is being paid to physical planning and water management, which is expressed in slogans like "Space for water". I think that multifunctional use of land and water (water retention combined with recreation and nature conservation) will create socio-economic benefits which will justify the investments. If no societal awareness is build up in the 21st century that "space for water"is necessary, the government will have to invest in higher dikes and pumping capacity in future'*

A vision of a regional agricultural interest group: *'We have observed changed dynamics within our regional hydrological systems, and allocation of space for water is necessary, but an economically healthy agricultural sector should be guaranteed. However, the current dialogue between water management and physical planning puts too much focuss on functional combinations between space for water retention combined with nature conservation and recreation. The dialogue should be focussed on problem solving and should also take into account the financial consequences for the agricultural sector'*

A vision of an environmental interest group: *'The current hydrological system in the Netherlands is artificial.We should restore the system into a more natural state. In the 21st century, the first action should be extensification of agriculture combined with the creation of wetlands. Than the allocation of urban areas should be reconsidered at locations where water retention is necessary'*

The Scheldt estuary:

'The Southern Dutch estuaries may become very vulnerable ecosystems, artificial turbid aquaria if they do not get a chance to grow with the sea. Maintenance of ecological robustness can be combined with maintenance of safety of human society, but it will ask substantial investments, like deconstruction of the so-called compartment-dams in the Scheldt estuary, increase of the heigth of the bridges and acceptation of the tidal fluctuations in the Scheldt-Rhine canal. This will have consequences for the ratified protocol between Belgium and the Netherlands in which the Dutch government guarantees tidal-free navigation between Antwerpen and Rotterdam.'

4.2.2 Workshop on natural systems

The workshop on *Natural systems* was attended by 24 participants with various backgrounds (eg. science, policy, interest groups) The workshop was divided into three sessions on (1) Impacts, (2) Interactions, and (3) Adaptation options. A fourth session was held together with the group on *Land use and fisheries* to identify cross-sectoral impacts and adaptation issues.

SESSION 1: ***What are the most important impacts of climate change for soils, water systems and ecosystems in the Netherlands?***

The group decided that the importance of an impact is a function of the probability of a given impact and the seriousness (both positive and negative). It was also decided that in session 1 only "natural" adaptations (for example, a species adapt to climate change by getting more offspring) should be taken into account (in session 3 society induced adaptation measures were discussed).
A region or ecosystem is this called "vulnerable" if: (1) the probability of the impact is high, (2) the region or ecosystem is sensitive to the impact and (3) adaptations possibilities are absent or not effective enough.

Table 4.1 shows the results of the sticker session in which participants were asked to express their personal views on the probability and seriousness of the possible impacts. For each "system" (soil, water ecosystems) three possible impacts were already given by the project team based on the results of the questionnaire. In table 4.1 , the impacts brought forward by the participants are printed in italics.

a) Impacts of climate change on water systems

The participants decided to focus the discussion of the impacts of climate change on water systems in relation to consequences for natural values. This focus was clearly different from the focus of the questionnaire, where safety was an important issue. The divergence was explained by the different backgrounds of the participants of the workshop. Most of the participants were working in the field of environmental research and nature conservation. As a result, the group decided to discuss 'Problems in relation to flooding' in the light of the negative impact of climate change on natural dynamics within the water system. In the questionnaire 'problems in relation to flooding' were defined as the socio-economic damage due to increased flooding risks. Impacts of climate change in relation to safety of people and goods were not discussed during the workshop.
Some participants noted that the impact of climate change on water dynamics is narrowly correlated with water quality. An advantage of the word 'dynamics' is that it is applicable to several regions: the coast, rivers, or ecosystems

(1) Impacts of changed dynamics in the hydrological cycle on natural values of changed dynamics within the hydrological cycle

In general, the participants thought that the probability of the impact of climate change on natural dynamics will be high; flooding will occur more frequent and peak discharges will become higher than at present, which will have impacts on the robustness of ecosystems.

(2) Impacts of climate change on (fresh)water availability
The participants did not think that climate change would have a serious direct impact on available (fresh)water resources (needed to maintain the ecological integrity of natural systems) in the Netherlands. Some participants indicated that there might be indirect impacts because agricultural practices may adapt to climate change by increased exploitation of freshwater. In this case, less freshwater will be available for natural systems.

(3) Impacts of climate change on water quality and aquatic ecology
In contrast to the results of the questionnaire, many of the workshop participants indicated that changes in water quality and aquatic ecology are very probable and also are serious impacts of climate change on natural systems. In this session this was not yet discussed in depth (see further).

Table 4.1 Overview of votes of participants in session 1 in order to identify the most serious impacts.

Impact on	Probability	Seriousness
Water		
(Safety/economic damage): *Natural dynamics within the hydrological cycle*	35	32
Water Quality and Ecology	17	15
Space claims (and fragmentation of nature)	8	19
Water availability	6	4
The geological gradient of the Netherlands	2	2
Soils		
Salinisation	20	17
Desiccation/groundwater tables	17	18
Leaching of nutrients and micro-pollutants	7	7
Emissions of greenhouse gases	6	5
North Sea soil	2	2
Carbon balance of soils	1	2
Ecosystems		
Biodiversity (decline)	24	20
Phenology and growth	31	5
Frequency fires and storms	11	14
Pest and diseases	7	7
Change distribution area	4	5
Increase dynamics (Floodplains, coast)	5	3 (positive)
Instability		

(4) Space claims and fragmentation of nature

Although this is actually an adaptation issue, the discussion about competition for space in relation to climate change and the fragmentation of nature in Europe was already raised in the "impacts-session". It was concluded that: a) the pressure of space is an autonomous development and due to climate change this pressure will further increase.

b) Urbanisation in combination with climate change is a key issue for European environmental policies.

b) Impacts of climate change on ecosystems

(1) The impact of climate change on biodiversity

Most of the participants indicated that the impact of climate change in combination with the current fragmentation of nature in Europe will lead to considerable changes in biodiversity because the Netherlands is situated in a particular bio-geographical setting with many borders of distribution-ranges crossing the country. Although, climate change alone will have both positive and negative effects on the number of species in the Netherlands, the overall impact will probably be negative due to the combination of factors involved (see table 4.1).

(2) Impact of climate change on phenology

For most of the impacts listed in Table 4.1, the score for probability and seriousness was more or less the same. An exception was the impact of climate change on phenology: The participants indicated that an impact of climate change on phenology is very probable but they do not think it is serious (in general). Somebody explained that changes within phenology could be seen as an adaptation strategy of species to climate change. It will increase the chance of a species to survive under changed conditions. It was mentioned that species and ecosystems always have to deal with changes, i.e. changes are natural. However, others indicate that the current rate of climate change (caused by human activities) is too fast for several species in order to be able to adapt. Opinions differed about the question of whether it is possible to identify changes in phenology caused by climate change. Monitoring programs have to deal with both natural variations and other environmental impacts (eutrofication, micro-pollutants, fragmentation, etc) that may effect phenology.

Some participants raised the issue of the possible impact of climate change on the frequency of pests and diseases (Table XX). This possible impact is closely linked with impacts on phenology. If plagues appear earlier in the season, their natural predators may be absent. As a result the impact of a plague may become worse.

(3) Regional differences in relation to vulnerability of ecosystems (table 4.2)

From the questionnaire and workshop-discussions rivers were seen as very vulnerable to climate change. A policy maker question is whether the riverine region is more vulnerable than the North Sea. In the riverine region a lot of changes already occur and why would this system be particular vulnerable to climate change? A nature conservationist answers: *"A first conclusion in relation to the vulnerability of the Dutch riverine region would be that ecosystems are adapted to flooding. However, the flooding in the future will be completely different from ' natural flooding' as a result of human induced climate change".*

It is concluded that the Wadden Sea is vulnerable for sea level rise, which is a different conclusion than made by scientists (see chapter 3). Furthermore, according to the Wadden Sea Union, the impact of increased water temperatures is probably more serious than thus far anticipated.

Peat and bog systems have a high natural value because they are particular.
They are vulnerable for changes in water temperature and changes in groundwater tables (induced by climate change and adaptation options to climate change within water management). In particular "Hoogveen" is vulnerable for climate change. A difference between peat and bog systems compared to riverine systems in the Netherlands, is that riverine systems also have to deal with climate change outside the Netherlands, because the catchment is larger than the Netherlands.

Table 4.2 Overview of votes of participants regarding regional and system difference of vulnerability within the Netherlands

System/region	Sum score vulnerability
The coastal zone	28
Rivers	26
Wadden Sea	22
Brook catchments	16
Peat and bog systems	15
The Rhine/Meuse estuary	13
The lake IJssel region	11
Urban water systems	9
Heather (Heide)	8
Forests	7
North Sea	6
Scheld estuary	4

c) Impacts of climate change on soils:

(1) Dessication
The most important impact chosen by the workshop participants was desiccation. Due to time restrictions this issue was, however, not discussed in-depth.

(2) Salinization
The second most selected impact was salinisation. However, the participants explained that the impact of salinisation was not very important in relation to

natural values. In the questionnaire the impact of salinisation was more often indicated as an important impact but it was than evaluated in relation to negative consequences for agriculture.

(3) Soil as sink for C

In relation to impacts of climate change on soils also *benefits* were identified by the participants. If regional hydrology would be able to adapt to climate change, soils would be able to function as a sink for carbon dioxide.

(4) Pollution of sediments

One participant indicated that climate change could not only have impacts on functioning of terrestrial soils but also may have impact on "*water soils*" (i.e. sediment), for example in the North Sea. Reference was made to the 'chemical time-bomb' hypothesis: raised temperatures may bring chemicals now "fixed" in the sediment back into solution, because geochemical conditions (e.g., redox potential, pH, organic matter content, etc) in water-soils are clearly different from terrestrial soils. Moreover, transport rates for micro-pollutants are clearly different between soil-atmosphere and soil-water borders (Salomons and Stigliani, 1996).

Summary of session 1

It was concluded that climate change, in combination with fragmentation, will probably decrease the stability of natural systems in the future. As a result, overall biodiversity will probably decrease in the Netherlands and Europe, although there may be regional differences, and some areas may experience an increase in biodiversity

It was decided to discuss the following issues more in-depth in the next session on interactions: (1) biodiversity loss, (2) changed water dynamics, (3) phenological changes, (4) changes in water quality and ecology, and (5) desiccation and salinisation.

SESSION 2: *What are the most important interactions between natural systems and the other sectors?*

In this session, the question was to what extent climate change impacts (and adaptation measures) related to water dynamics, water quality, biodiversity, phenology, desiccation, and salinisation interact with the other "sectors" included in this project:

a) Interactions within Natural systems (e.g. soils, water, climate or ecosystems)
b) Interactions with Land use
c) Interactions with Socio-Economic sectors
d) Interactions with human aspects (health and tourism).

a) Internal interactions within natural systems

The participants decided to focus on ecosystems during the discussion about interactions. It is agreed that biodiversity is an important factor that determines the robustness/vulnerability of ecosystems in relation to pressures like climate change. The robustness increases with the number of species. It is stated that Dutch physical planning in relation to natural areas is too static. In order to adapt to climate change a more dynamic way of physical planning is necessary that takes into account the temporal and spatial variation in nature.

Table 4.3 Overview of votes of participants regarding interactions between impacts of climate change within natural systems.

Impact	Soils	Water	Ecosystem
Water dynamics	3	1	13
Water quality	1	3	18
Biodiversity	0	4	14
Phenology	0	0	10
Salinisation	7	1	13
Dessication	3	0	6
TOTAL:	14	9	74

Most workshop participants found effects of changes in water quality and biodiversity on ecosystems the most important interaction (table 4.3); followed by effects of water dynamics and salinisation.

b) Interactions between impacts on natural systems and economic sectors

Economic damage with consequences for safety due to increased flooding is seen as the most important interaction between impacts of climate change on natural systems and economic sectors (table 4.4). Furthermore, changed water dynamics may have impact on transport and energy. Power stations (cooling water) depend on dynamics in water quality (temperature) and water quantity (availability) of river water. Climate change will have an impact on both.

More energy may be needed in the future to pump water from the reclaimed areas in the lower parts of the Netherlands into the sea. Insurance companies will have to deal with increased claims.

Table 4.4 Overview of votes of participants regarding interactions between impacts of climate change on natural systems with economic sectors.

Impact	Transport	Energy	Insurance
Water dynamics	17	4	18
Water Quality		1	1
Biodiversity			
Phenology			1
Salinisation			1
Dessication	1	2	
TOTAL:	**18**	7	**22**

Some participants suggested that medical claims for insurance companies may increase due to increased frequency of hay fever or other health problems. Others, however, claim that medical costs may decline if climate change will result in less foggy and cold weather, leading to less respiratory diseases and road accidents.

c) *Interactions between impacts on natural systems and land use*

Interactions between impacts on natural systems and land use are seen by the participants as the most important (table 4.5). Increased dynamics in precipitation and discharge of the rivers will result in desiccation and salinisation in summer with consequences for agriculture. Seasonal rotation of cultivation will become more difficult, and the agricultural sector would have to deal with production loss. (note that this perception diverges from the opinion within the land use workshop).

Table 4.5 Overview of votes of participants regarding interactions between impacts of climate change on natural systems with land use and fisheries.

Impact	Agriculture	Forestry	Fisheries
Water dynamics	20	8	3
Water Quality	7	2	9
Biodiversity	7	6	7
Phenology	6	4	2
Salinisation	15	13	0
Dessication	15	0	0
TOTAL	**70**	**31**	**21**

Changed water dynamics are narrowly correlated with water quality: due to climate change sewage discharge will occur more frequently, because capacity of the sewage system is insufficient in the future. Concentrations of nutrients and contaminants will increase as a result of these increased discharges, in combination with more frequent summer droughts. These (indirect) impacts of climate change on water quality may have consequences for the health of cattle and possibilities for irrigation. If water quality is too poor it cannot be used for irrigation.

A decrease in biodiversity within both natural, agricultural and forestry ecosystems may have consequences for productivity ("cultivation facilitating biodiversity"). It might, however, be also true that agricultural systems will have to deal with more plagues and diseases originating from natural areas. The participants think that policy should promote (by subsidising) cultivation management that aims to increase (agricultural) biodiversity. This is seen as a new opportunity for agriculture. However, currently only nature conservation organisations and farmers get financial fees based on species diversity facilitating management. The financial budget for conservation may decline, under current nature conservation policies due to climate change. Some boreal species may become extinct as a result. The present financial fees for conservation are based on the presence of target species selected by policy makers.

Forest soils may become unstable caused by changed water dynamics, and forestry may face increased wind damage. Maintenance of biodiversity is for forestry more important than for agriculture according to some of the participants, because the cultivation cycle of a forest is several decades, while the cultivation cycle of an agricultural system is only one year.

Changed water quality due to climate change (temperature and eutrofication) may have consequences for bivalves fisheries in the Wadden Sea. One participant argued that maintenance of biodiversity is also important for fisheries.

d) Interactions between impacts on natural systems and human health and recreation

Changed water dynamics (quantity and quality) have impact on quality of swimming water. Physical stress due to flooding, increased mosquito plagues in recreational areas or hay fever have also impacts on health. One participant points out the warmer summers have also constraints for tourism: Intense precipitation events might occur more frequently. Other participants, however, indicate that this is not an serious impact. Someone state that the nicest period for recreation is actually in late spring and early autumn. It is considered that holidays in the Netherlands may become relatively more popular compared to holidays in other countries. An interesting statement is made about interactions between impacts of climate on phenology and related impacts on tourism (see below).

Table 4.6 Overview of votes of participants regarding interactions between impacts of climate change on natural systems with human health and recreation.

Impact	Health	Recreation
Water dynamics	12	8
Water Quality	8	10
Biodiversity	2	11
Phenology	8	1
Salinisation	3	6
Dessication	0	1
TOTAL	**33**	**38**

'Japanese tourists come in April to the Netherlands to visit the Keukenhof. They would not enjoy future visits as much if flowering is delayed as a result of climate change' (or they would have to come at another time of the year).'
'Expert opinion'

SESSION 3: Discussion in relation to possible adaptation options

In table 4.7 the adaptation options are presented which where preferred by the respondents of the questionnaire. The participants of the workshop decided to discuss the "Ecological Main structure" as an adaptation option to climate change in relation to two aspects: a) increase of number and size of areas, b) reduction of fragmentation. Somebody warned that adaptation options for ecosystems are only effective if the temperature increase is not more than 2°C in 100 years. If temperature increase is higher (and faster) only mitigation measures are effective in order to reduce the impacts on ecosystems. To focus the workshop-discussion, and the "sticker-session with placing post-its on Table 4.7), it is decided to consider a temperature change of 1-2°C until 2050 and a maximum increase of 4°C in 2100. If people take a higher increase into consideration they are invited to explain what this means for the adaptation options.

It is stated that *space for water* does not necessarily mean *space for nature*. The participants would like to make a distinction between wet nature and water retention buffering. It is concluded that ideally these two adaptation options should be combined.
Participants think it is difficult to make a distinction between 'flexible natural water table management' and "Optimisation of the water retention capacity of soils and ditches (upstream)". They will be discussed together.

Table 4.7 Overview of votes of participants regarding effectiveness of adaptation options for natural systems.

Adaptation option	Soils	Water	Ecosystems
a) Flexible water table management/ optimalisation of water retention capacity of soils and ditches	18	23	12
b) Accelerated implementation of the Ecological Main structure (space for nature)			46
c) Water buffering areas/basins ("space for water")	9	9	
d) Extensification Agriculture	15		
e) Increase pumping capacity	6	6	
f) Change fertiliser management	1		
Restoration of mussel banks and seagrass habitats	1		
Ecological Agriculture	1		

a) Flexible water table management

Constraints

- The optimal water tables for nature are not optimal for agriculture in surrounding areas. In natural systems optimal conditions for biodiversity and productivity are reached if water tables are high in summer. In surrounding agricultural areas crop shifts should be considered, for instance grassland in stead of cereals or potatoes. Grassland is less productive compared to this crops
- Space is necessary for implementation of these adaptive measures
- Urban areas also will have to deal with higher groundwater tables

- Measures will only be effective if they are implemented within international co-ordination: catchment approach. Institutional barriers are seen as a constraint.

Opportunities:
- Opportunities for extensification of agriculture, chances for cultivation of other crops and reduction of land use related greenhouse gas emissions. (It was stated that agriculture should get an financial fee for this sink function)
- Optimisation of drinking water exploitation possibilities
- Reduction of impacts of desiccation on natural values. An opportunity for regional water systems in the lower parts of the Netherlands is that less water is necessary from outside the system. Water from outside the system has another water quality, which is a disadvantage.

b) Accelerated implementation and expansion of the ecological main structure

Constraints:
- In the Netherlands there is a lack of space
- High prices of land
- Current Dutch physical planning tools that define the function of areas are not flexible
- Current Dutch/European nature conservation policies are not institutionalised in regional/local environmental planning. Regional and local policy makers do not know how to implement these national/European policy objectives.

Opportunities:
- Increased robustness of ecosystems
- Better conditions for maintenance of biodiversity
- New possibilities to enhance recreation
- Multifunctional space use
- Ecological agriculture
- Sustainable space use.

It was concluded unanimously that the development of the Ecological Main Structure will be only effective if it is institutionalised and implemented at a European level. It was concluded that implementation should be done in the first place to reduce the impact of fragmentation (caused by urbanisation) on the robustness of ecosystems. A secondary result of implementation is that ecosystems will also be more robust for impacts of climate change. The development of the *Ecological Main Structure* creates better conditions for maintenance for biodiversity. However, combined with climate change it creates also possibilities for introduction/migration of exotic species. We will have to discuss the definition of exotic species: species outside the Netherlands or species outside Europe?

It is stated once more that current physical planning tools are a constraint for implementation of the Ecological Main Structure. Dutch physical planning tends to separate or to combine functions within areas. Dutch physical planning do implement an functional gradient within the landscape. On the other hand the existence of physical planning tools is an advantage compared to other European countries where such tools are often lacking.

A policy maker questions if it is not better to change our nature policy objectives in relation to target species and target natural types which we try to achieve with the implementation of the *'Ecological Main Structure'*. The distribution and proliferation chances of the target species will change as a result of climate change. As a result also the chance of successful nature policy. This statement is argued by some nature conservationists because it will also reduce our ambitions in relation to nature conservation. A policymaker argues that anticipation on impacts of climate change on policy objectives in relation to target species and target natural types would have significant (undesirable?) impact on current management. For example, anticipation to climate change within current nature conservation policy would also implicate that afforestation of beeches within Dutch natural areas is not recommended because the species could be absent in the climate of the Netherlands in 2100.

c) Implementation of water buffering areas/space for water)

Constraints:

- On a relatively small surface in the (emergency) floodplains unnatural and unpredictable hydrological dynamics will occur. This, in combination with current water quality (nutrients) of the rivers, will result into low natural values from a conservation perspective
- In emergency floodplains it is not possible to allocate powering stations or capital intensive infrastructure and buildings
- Water quality problems might occur if urban water buffering areas/systems are insufficient.

Opportunities:

- Although natural values in water buffering areas might be low from a conservationist point of a view, they are sufficient for the recreational function of these areas
- The nutrient richness of the water, which is led into the buffering areas creates chances for biomass production (reedbeds, willows)
- Water buffering areas contribute to the openness of the landscape
- Optimisation of groundwater recharge. Less water (with other water quality) from outside the regional hydrological system is necessary to recharge the groundwater stock.

Somebody states that water-buffering areas are not an ideal adaptation option. However, you will need them: high river discharges are also in future with adaptation inevitably downstream, despite increased water retention capacity upstream. Increasing ground prices and ground speculation, nearby urban areas are seen as a constraint for implementation. However, the participants think that the scarcity of space is a more important problem than the high financial price of ground. The participants state the following question for themselves: *How to improve the functionality of these water buffering areas, how to create chances instead of constraints? (Their answers: see above)*

A particular example of a type of buffering area is given: In Limburg they use water quantity buffering areas (big holes) to collect erosion material from slopes. The original functions of these buffers was to reduce the necessity to enlarge brook beddings. However, they could also be used as quantity buffers for climate change. Other particular water buffering types: "Stromende berging": Enlarged river floodplains and restoration of side streams and brook valleys combined with restoration of natural morphology.

(4) Extensification of agriculture in combination with agricultural nature conservation

An opinion from a member of the water board from the higher parts of the Netherlands:
' Flexible water table management, combined with the development of the ecological main structure creates opportunities for extensive agricultural practices (grassland with an agricultural production function and a nature conservation function). Grassland in the brook valleys with sandy soils are able to cope with flexible groundwater table management, contrary to arable farming. Lower production yields, compared with intensive agriculture, could be counter-balanced by a strategically selection of grassland species, extra income could be generated out of nature management..'

Contrary to the above statement, other participants point out that extensive agriculture on sandy soils is uneconomic and the extra generated income out of nature conservation (fees from the government) is marginal. Furthermore, the regional hydrological system is one unit. Flexible water table management in agricultural areas might result to damage in buildings in urban areas. The water retention capacity of regional soil and hydrology systems will become lower when water tables become higher. As a result more water will be discharged into the rivers and the possibility of flooding could increase. In other words: measures to reduce the impact of desiccation on natural areas are, in potential, in conflict with measures to reduce the risk of floodings. Only at a catchment level/international level it is possible to optimise measures to reduce impacts of desiccation and reduction of flooding risks. Dutch water management is depended on water management in France, Germany and Belgium.

SESSION 4: plenary session to integrate results from land use and natural systems Workshops

At the end of the first day at the workshop, the results from the Land use and fisheries discussion and Natural system discussion were presented in a plenary discussion session (for details on the Land-use and fisheries workshop see chapter 4.2). Several issues were raised.

Biodiversity
A decrease of biodiversity within both natural, agricultural and forestry (eco)systems may have negative impact on productivity, e.g. increased frequency and intensity of plagues and diseases and less success from "cultivation supporting biodiversity" for pest and disease management
Participants from the land use and fisheries workshop doubted whether implementation of the ecological main structure is an adaptation option to climate change as migration rates of species are not able to follow the rate of temperature change, especially forest species. However, from a policy makers' point of view, the Ecological Main Structure aims to strengthen the robustness of ecosystems This is related to water management, which is in turn related to climate change.

Agriculture
In the land use and fisheries group salinisation as a result of climate change is considered as a serious impact for agriculture in the lower parts of the Netherlands, while this impact was not perceived as serious by the participants within the natural systems workshop. The possible adaptation options are:
- shift to salt tolerant crops
- accept that agriculture will not be sustainable in certain areas in the coastal zone, e.g. reclaimed land in the Wieringen polder in the province of North Holland; LTO-Nederland considers that agriculture will not be sustainable in this area)
- create water retention and buffering areas to supply water to wash away saline water

Fisheries
The participants from the land use and fisheries workshop agreed that sea level rise is probably the most important impact of climate change on fisheries. Fauna, which is not able to migrate is particular vulnerable, e.g. mussels. Most fish can swim away from the impact and are thus not vulnerable to climate change in their view. Fisheries can adapt to climate change by following the fish, as a result the fisheries sector is not vulnerable to climate change. Temperature change is not considered to have a significant impact on aquatic ecosystems: the rate of temperature change within water is slower than in the air. Further, cooling water discharges from powering stations are a more important factor with an impact on the temperature in the aquatic ecosystem of rivers. Higher mortatility due to

parasites and higher temperatures could occur incidentally but will not be an major impact, nor is UV radiation.
This conclusion is clearly different from the conclusion within the natural system workshop. The participants in this group concluded that (in the context of the Wadden Sea), the water temperature change is as much as important as the sea level rise. It was stated that changing water temperature would have significant impact on fisheries stock.

4.2.3 Conclusions and discussion for natural systems

Here, an overview is given of impacts and adaptation options for natural systems, based on the outcome of the questionnaire, workshops and literature review.

Impacts
From this analysis, 6 main impacts and adaptation options were identified.
The six most important impacts of climate change on natural systems (including biodiversity, water-issues and soil) are: (1) surface water dynamics (safety and biodiversity), (2) water availability, (3) water quality and aquatic ecology, (4) salinization, (5) species loss & distribution changes, (6) changes in phenology and thereby increase in pests and diseases
Stichting Reinwater (2000) carried out a similar study on a regional level. The study assessed increased flooding and safety risks in combination with constraints in physical planning as the main climate change issue. Sea level rise and soil subsidence were assumed to have a medium impact, while salinisation and problems with water availability were assumed to be not serious.

Adaptations:
The main adaptation options are (see table 4.8 for overview):
(1) More space for nature (EHS/EMS), including reduction of terrestrial barriers (i.e. fragmentation), creation of wetlands and expansion of river-beds
(2) More natural & flexible management (of both terrestrial and aquatic ecosystems, and groundwater tables -> "keep water in the system"
(3) Creation of water-buffers, both "natural" (see point 1) and artificial (eg. retention polders and basins in urban areas)
(4) Increase pumping capacity, in combination with higher dikes and dams
(5) Multi-functional land use (planning): eg extensification of agriculture, more mixed forestry
(6) Improve monitoring of environmental change (eg., water quality, species distribution and phenology, forest fires, and storm damage)

Table 4.8 Linkages between impacts of climate change on natural systems in the Netherland and adaptation options.

Adaptation options: / **Main impacts:**	EHS/EMS (more space for nature)	More natural & flexible management	Creation of water buffers	Increase pumping capacity + higher dikes	Multi-functional land use (planning)	Monitoring (eg. species, water, fires)
Surface water dynamics	+	++	++	++	+	+
Water quality & aquatic ecology	+	++	+		+	
Lower groundw. tables (dessication)	+	++			+	
Salinization (due to sealevel rise)		++		+		
Species loss & distribution	++	++			+	++
Phenology -> incr. pests & diseases	++	++			+	++

+: this adaptation option is useful (or very useful = ++) to mitigate a given impact

Impications of adaptation for other sectors

During the workshops, opportunities and constraints of the main adapatation options were discussed in detail. Table 4.9 gives a summary of the main points.

Table 4.9 Key adaptation options within natural systems and their opportunities and constraints.

ADAPTATION OPTION	**OPPORTUNITIES**	**CONSTRAINTS**
1) Accellerate and expand creation of EHS/EMS (more space for nature)	- nature conservation - multi-functionality (recreation, ecol. agriculture, carbon-sink) - flexibility - stimulus for international & institutional collaboration	- limited space - expensive - current planning & land policy - lack of EU institutional support - species-specific (lack of knowledge)
2) More natural & flexible management (of ecosystems and groundwater)	- improves water balance - extensivation of agriculture - C-fixation compensation - fits in EU-policy	- loss of agricultural productivity - spatial needs - water problems in urban areas - international collaboration
3) Creation of water buffers "natural" and artificial (eg. retention polders and basins in urban areas).	- costs little space - recreational opportunities - natural resources (eg reed) - provides open space - -more clean water	- unnatural - with excessive rainfall run-over may cause water quality problem

From the workshop and questionnaires it was concluded that the interactions between impacts of climate changes on natural systems and agricultural land use were considered to the most important.

Land use (agriculture, forestry and fisheries)
Changes in species distribution and abundance may lead to changes in agricultural pests and diseases, drought and higher temperatures in summer will substantially increase the agricultural water demand, which will result in a decrease in the groundwater table and the water level in ditches and canals, and an increase of the water inlet from rivers. Less water will be available for natural systems, which also have higher requirements because of the drought. In contrast with the summer drought problems, an increase in the frequency and the intensity of rain in spring can cause erosion of agricultural fields resulting in changes of sedimentation of the waterways. Biodiversity in aquatic ecosystems will be negatively affected by the resulting changes in water quality.
Forest soils may become unstable caused by changed water dynamics, and forestry may face increased wind damage. Maintenance of biodiversity is for forestry more important than for agriculture according to some of the participants, because the cultivation cycle of a forest is several decades, while the cultivation cycle of an agricultural system is only one year.
Participants of the natural system dialogue state that changed water quality due to climate change (temperature and eutrophication) may have consequences for bivalves fisheries in the Wadden Sea, while the participants from the land use workshop state that sea level rise is probably the most important impact of climate change on fisheries.

Economic sectors (energy, transport and insurance)
The increasing winter peak floods require measures to ensure safety of people and infrastructure. During the summer period water availability for agriculture, drinking water and industry (use of cooling water) will be more limited. Inland navigation could face problems with large ships in summer due to low water levels. Given drier, warmer summers, many soils would shrink more extensively than hitherto, and in winter under wetter conditions, would swell again, with major economic consequences for building and infrastructure in the peat areas. More energy may be needed in the future to pump water from the reclaimed areas in the lower parts of the Netherlands into the sea. Insurance companies will have to deal with increased claims.

Health and tourism & recreation
A change in climate, and associated with this a change in presence of (wet) ecosystems (as an adaption option to climate change) might increase the number of vector borne diseases within and outside the Netherlands (e.g. leishmaniasis, tick borne encephalitis). However, it is unlikely that 'tropical' diseases such as malaria or dengue would become re-established in Western Europe if control

measures are maintained, although, the risk of localised (autochthonous) outbreaks of malaria may increase (Parry, 2000).

Changed hydrological dynamics are narrowly correlated with water quality: due to climate change sewage discharge may occur more frequently, because capacity of the urban sewage system is insufficient in the future. Combined with more frequent summer droughts concentrations of nutrients and contaminants may increase. These changes in the water quality, combined with higher temperatures (e.g. by an increase in algae) can have major health impacts. Other trends may also be important. The participants within the fisheries dialogue argue that the rate of temperature change within water is slower than in the air. Besides, cooling water discharges from powering stations are a more important factor that has an impact on the temperature in the aquatic ecosystem of rivers. Further, increased urbanisation concentrates water demand in certain areas which can lead to over exploitation of local water resources and increase the risk of microbiological contamination. Urbanisation also increases the requirement for hygienic and efficient networks for the disposal of sewage (EEA/WHO, 1999). Changed water dynamics (quantity and quality) have impact on quality of swimming water. Physical stress due to flooding, increased mosquito plagues in recreational areas or hay fever have also impacts on health.
A temperature induced earlier start of the growing season might change the start of flowering and thus the start, length and intensity of the hayfever season (which is relevant for about 10% of the people in the Netherlands).
Sea level rise and weather extremes will increase the risks for the tourism and recreation sector. Especially the tourist facilities along the coast and the major rivers may suffer from coastal erosion and floods. Probably insurance companies could come up with products to cover those risks. This would be favourable for the tourism sector, despite the associated increase of insurance premiums.

4.3 Land use and fisheries: results of questionnaires and workshop

4.3.1 Outcome of questionnaire

The NOP impact project interacted with stakeholders by sending out a questionnaire early 2001 to approximately 500 persons and a workshop (March 29 and 30, 2001). The aim of this interaction was to get quantitative and qualitative information on impact of climate change and on vulnerability and adaptation option. Some 80 responses to the questionnaire for land-use were received. At the workshop, these issues on impact, vulnerability and adaptation options were discussed with a selected group of 15 stakeholders.

The questionnaires were developed to obtain insights in the perception of vulnerability, adaptation options and interactions with other than land-use sectors from stakeholders in the sector land-use. We give general results (see A), results for agriculture (see B) with separate sections on crops, animal husbandry and greenhouse production and results for forestry (see C) and fisheries (see D) on production, recreation and nature, respectively. All questionnaires asked for general information, adaptation options and relations with other sectors. Participants were invited to answer those parts of the questionnaire that were relevant to them.

A) General results questionnaire

Out of 28 respondents to *agriculture*, most were researchers and consultants followed by policy makers and sector representatives; from the financial sector no forms were returned (figure 4.9). In figure 4.10 the relation with the sectors is presented, please note that a person may have connections to more than one sector. The responses were well distributed among activities within the agricultural part of land-use.

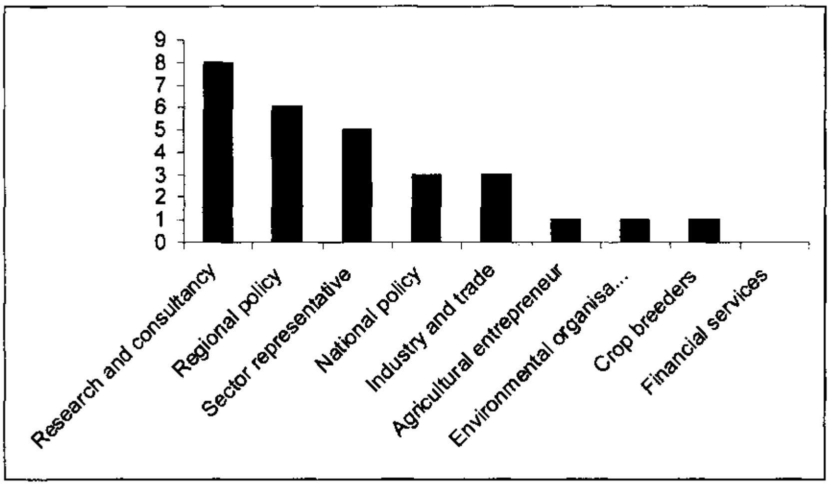


Figure 4.9 Responses from the agricultural sector in relation to professional background.

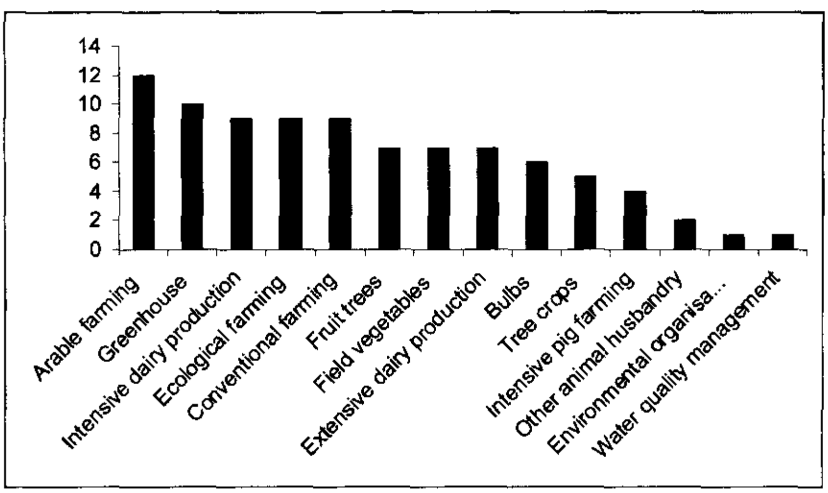


Figure 4.10 Professional involvement in the sector Agriculture.

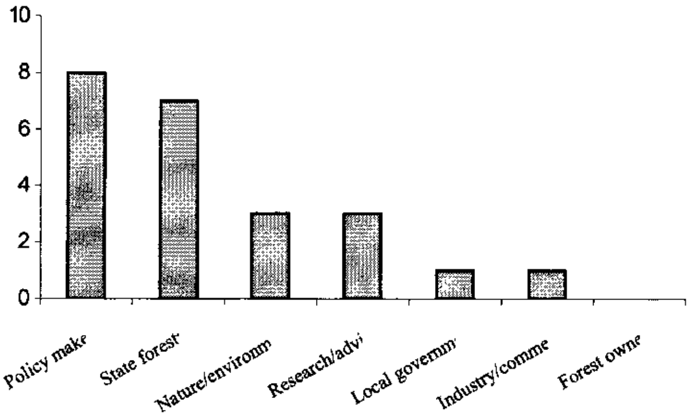


Figure 4.11 Distribution of answers over the sectors.

Figure 4.11 presents the distribution of the 28 respondents to the forestry questionnaire. It shows that each of the sectors contributed to the questionnaire and that it can be considered representative for the opinions from entire forestry sector in the Netherlands. For the fisheries questionnaire 28 responded; many restricted their comments and opinions to a very specific expertise or business (see results section for details).

B) Agriculture

First an inventory on the perceived effects (figure 4.12) and on the perceived vulnerability (figure 4.13) on the different agricultural activities was made. No outspoken differences in effects between agricultural activities are recorded. Arable farming and field vegetable closely followed by bulbs are regarded negatively impacted by climate change. These sectors are directly influenced by changing climatic conditions, the dry summer and wet winter seasons are expected to have a net negative impact. In other activities, positive or neutral impacts override negative effects. Intensive pig farming is regarded neutral to climate change.
Impact studies (TAR) on the other hand report for a few degrees temperature increase a small yield increase for cereals; temperature increases beyond 2-3 degrees always have a negative impact on yield levels. Changes in cropping patters or new crop choice with the objective to positively influence production are not part of this section but are included in the adaptation section of the questionnaire.

"Greenhouse production systems are not vulnerable; however, damage to constructions may increase as a result of higher storm frequency"

' stakeholder opinion'

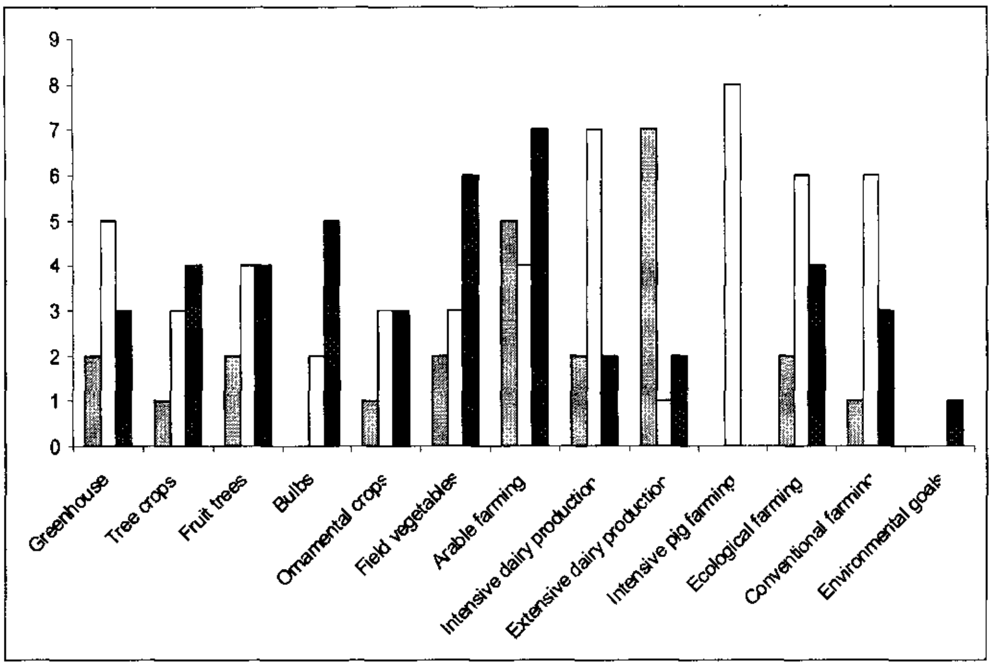


Figure 4.12 Effects per agricultural activity; bars indicate positive, neutral and negative impact from left to right.

With regard to vulnerability, again no outspoken vulnerable activities have been identified. Organic or ecological farming is considered most vulnerable to climate change (figure 4.13). The general idea is that the robustness of the system is not enough to compensate for lack of options to react to the changing environment.

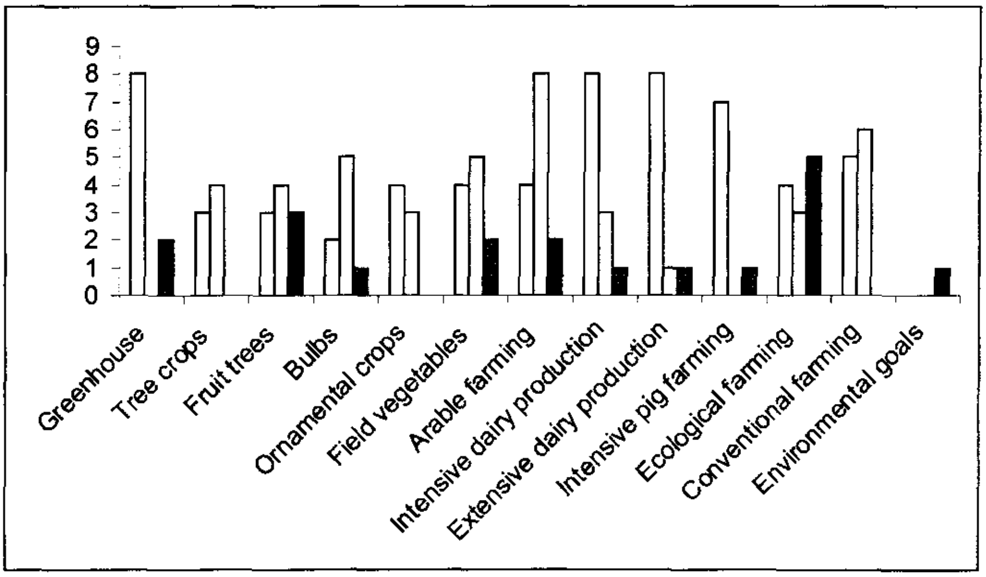


Figure 4.13 Vulnerability in agricultural activities.

A further question addressed the vulnerability per region (figure 4.14). For the Netherlands, the coastal and river areas are regarded as vulnerable. The flooding danger in these areas is the single issue underlying this classification. All climate change studies point to sea level rise and for all scenarios the low-lying coastal areas are thus at risk. For rivers where snowmelt is an important source of water, changes in winter and summer precipitation will affect peak flows and river dynamics.

' Growing bulbs on sandy areas near the coast is possible because of technological options, given the high net return the investments will also be possible under changed environmental conditions. '

Opinion of a stakeholder

'For the river and coastal areas drainage of surplus water will be a major concern.'

Opinion of a stakeholder

Bulb producing activities in the sector have high net returns and claim to be able to counter act potential negative impacts of climate change. The greenhouse sector in the coastal region requires good quality water; hence, increased salt contents in the groundwater will force the use of more expensive tap water instead.

'Sandy soils are drought susceptible but only in extreme years (1959 and 1976) this resulted in extreme yield reduction.'

Opinion of a stakeholder

'For the high sandy areas drought management will require adjustments in the way we handle water, are we doing the right thing given the predictions?'

Opinion of a stakeholder

The high sandy areas already suffer from dry spells during the summer period, this is expected to increase as a result of climate change. Already actions are formulated to reduce the vulnerability to dry spells, it is unclear whether these measures take into account the projected changes in climate.

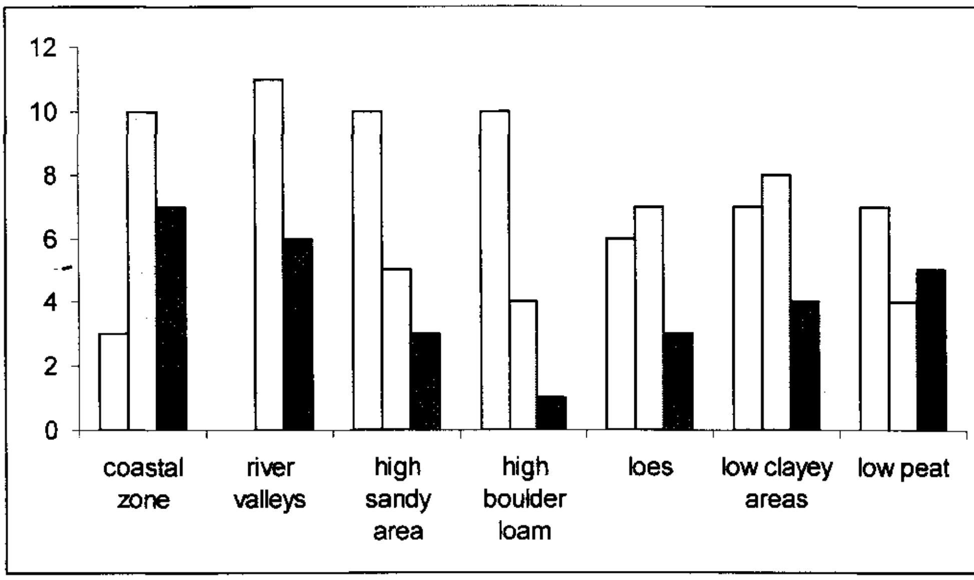


Figure 4.14 Vulnerability per region; bars indicate neutral, vulnerable and very vulnerable from left to right

Effects of a longer and dryer growing season

A longer and dryer growing season is regarded positive for most crops; only in bulb production, negative impact as a result of higher temperatures and no positive impact was recorded.

Especially for sandy areas, drought stress will be a major concern for agriculture. Irrigation is regarded essential to maintain high yields.

> *' No problems expected if irrigation remains an option, there is sufficient water to satisfy the demands from agiculture. '*
>
> Opinion of a stakeholder

> *' Bulbs require a temperate and moderate climate, higher temperatures and more droughts will result in stress and higher vulnerability to pests and diseases. '*
>
> Opinion of a stakeholder

Effect of a wetter spring and autumn on yield

Wet conditions are very explicitly classified negative for yield quantity and quality for all crops considered.

Sowing and planting of most crops will be retarded and harvesting of tuber crops will be more difficult. Wetter spring and autumn will limit exploitation of the longer growing season.

Respondents mention:

- Damaged flowers (outdoors production) are more likely to occur.

- The sowing date for sugar beets is strongly related to rainfall in February-April. Sowing is only possible after a good seedbed is prepared, this is one of the reasons that since 1988, during hot springs sowing was still late.
- Wetter conditions will increase the costs of drainage and harvest for tuber crops. Sugar beets are an exception because little soil transport is required when harvesting.
- Wetter conditions will hamper maturing and sugar production for sugar beets.
- All crops that are harvested during autumn in the low areas will encounter problems. Carrying capacity or trafficability of the soil will decrease rapidly.

' Wetter autumn means higher risk during harvest, wetter spring means later sowing and hence a shorter growing season.'

'A wet spring will result in higher pressure from fungi, trees will enter winter in poor condition.'

'Wet autumns result in poor harvesting conditions.'

Opinions of some stakeholders

Pressure of pests and diseases is expected to increase, this is in agreement with the findings of the Third Assessment report (IPCC, 2001). The combination higher temperatures and wetter conditions during spring is expected to be beneficial for pest and vectors of diseases (IPCC, 2001).

Effect of late frost during spring on yield

Fruit trees are particular vulnerable to late frost, specialised cropping systems such as bulbs and field vegetables are also regarded vulnerable. Seed potato production is expected to be negatively effected via increased pressure of pests

'Late night frost will negatively effect yield of fruit trees, reduce quality and result in irregular yields in the coming years.'

'Less frost and higher temperatures will increase pressure of diseases.'

Opinions of some stake

and diseases. Other important crops (cereals) are expected to be neutral to climate change.

Effect of pests and diseases

Pests and diseases are of major concern in agriculture in the Netherlands; the participants acknowledged this by classifying the effect as negative. Consensus is that increased temperature in combination with less frost days will increase the pressure of pests and diseases. For biological or ecological farming systems the effect is expected to be more negative because these systems lack the means to efficiently respond.

Effect on the product quality

The effect of a longer and dryer growing season with more sun is regarded either neutral or positive. A longer growing season results in better maturing of sugar beets and higher processing efficiency of the sugar. For drought prone sandy areas a negative effect is expected. Especially when additional irrigation remains an option the negative effect of drought will be cancelled, after which only the positive effects remain.

' Diseases also increase because of a more rapid reproduction of organisms responsible for those diseases.'

'More sunshine hours will improve the appearance of fruit. Cereals will improve in quality and may prove suitable for bread wheat, sugar content in sugar beet will increase. '

Opinions of some stakeholders

Effects on animal husbandry

Few respondents indicate positive or negative effects of climate change on the activities in animal husbandry and most indicate neutral effects. They neither indicate that these activies are vulnerable to climate change.

Effects on greenhouse production systems

Greenhouse production will be effected indirectly via mainly water and extreme events (figure 4.15). Overcasts days during the onset of the growing season will have a direct negative impact on the production levels. Water related problems (quality, seas level rise, and quantity) are considered to be negatively effected by climate change. Extremes may result in structural damage to the greenhouse construction. Higher temperatures may even be beneficial and reduce the energy requirement for heating.

'Sea level rise will increase seepage pressure and result in saline conditions. Longer dry periods will reduce the water quality in the polder areas.'

'Protected cultures, such as greenhouse, may get a competitive advantage, as other parts of Europe will become hotter'

Opinions of some stakeholders

Greenhouse production systems in the Netherlands are vulnerable to water related aspects and extremes such as storms and floods (figure 4.16).

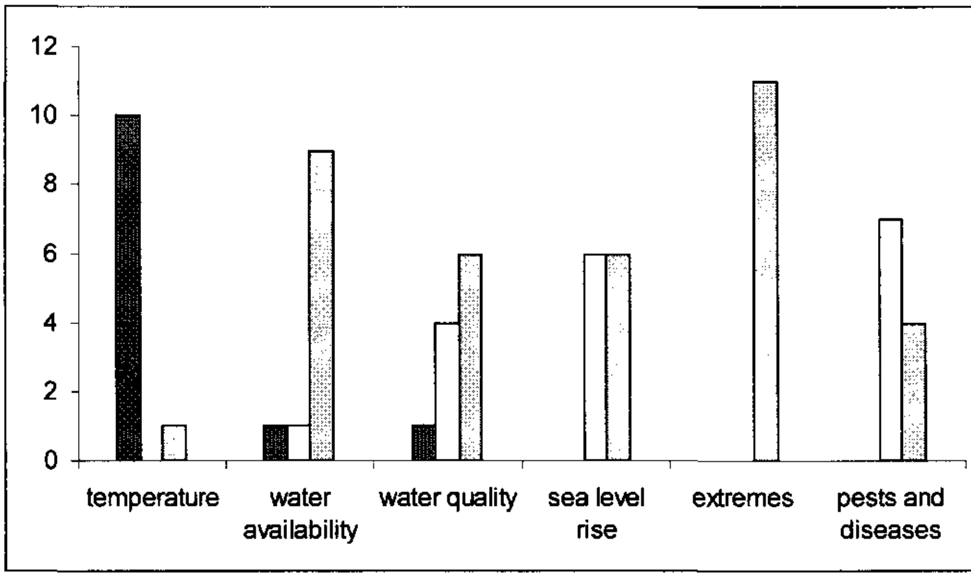


Figure 4.15 Effects on greenhouse production systems.

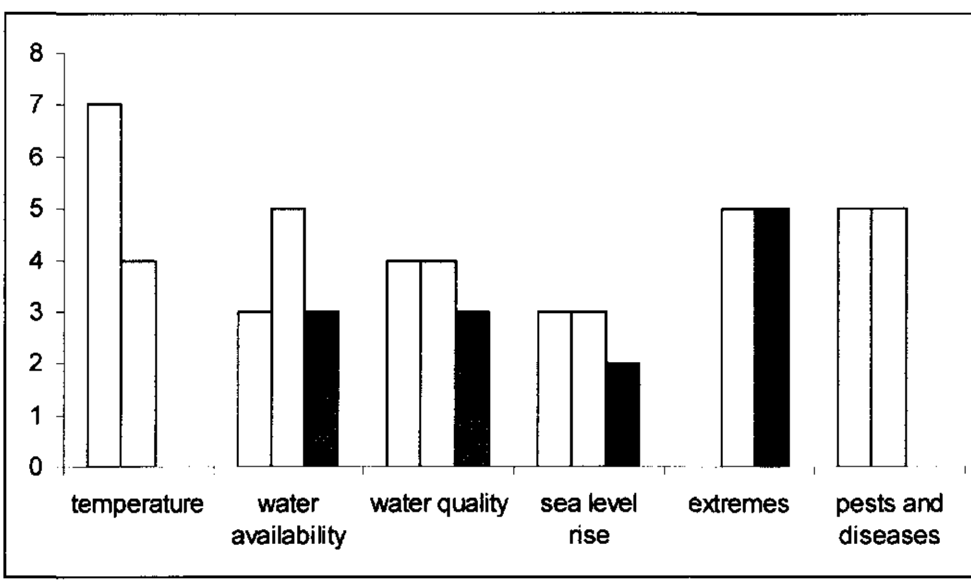


Figure 4.16 Vulnerability of greenhouse production systems.

Adaptation options

'Not only look at technological or management options but also focus on entire new farming systems aiming also at social services.'

Opinion of a stakeholder

Most important adaptation options that were mentioned within the questionnaire fall within the scope of regular farm management (Figure4.17). The general opinion is that most effects can be dealt with without large structural changes and are part of normal risks related to agriculture. Other external factors such as changes in society and policy are more important drivers of changes in the agricultural sector. The questionnaire asked respondents to distinguish between operational cost and investment cost. The response to this particular aspect was low.

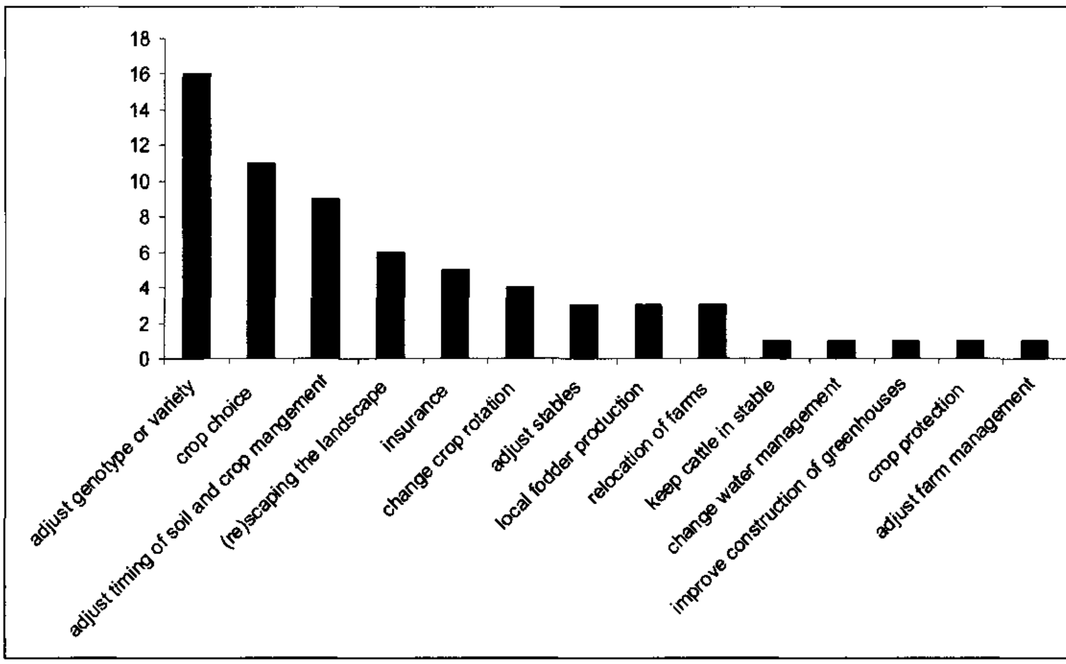


Figure 4.17. Adaptation options for agriculture.

Relation with other sectors and activities

Land bases agriculture in the Netherlands in particular is expected to follow and not lead the discussion on the restructuring of the rural areas in the Netherlands. Respondents consider that those changes will have a relatively larger impact than climate change will. The largest interactions are expected to occur in the area of water management, water quality and land use planning (Figure 4.18).

'Space claims for agriculture are low.'

'In general the role of agriculture will change to functions as requested by society, these will not be guided or steered independent from climate change.'

Opinions of stakeholders

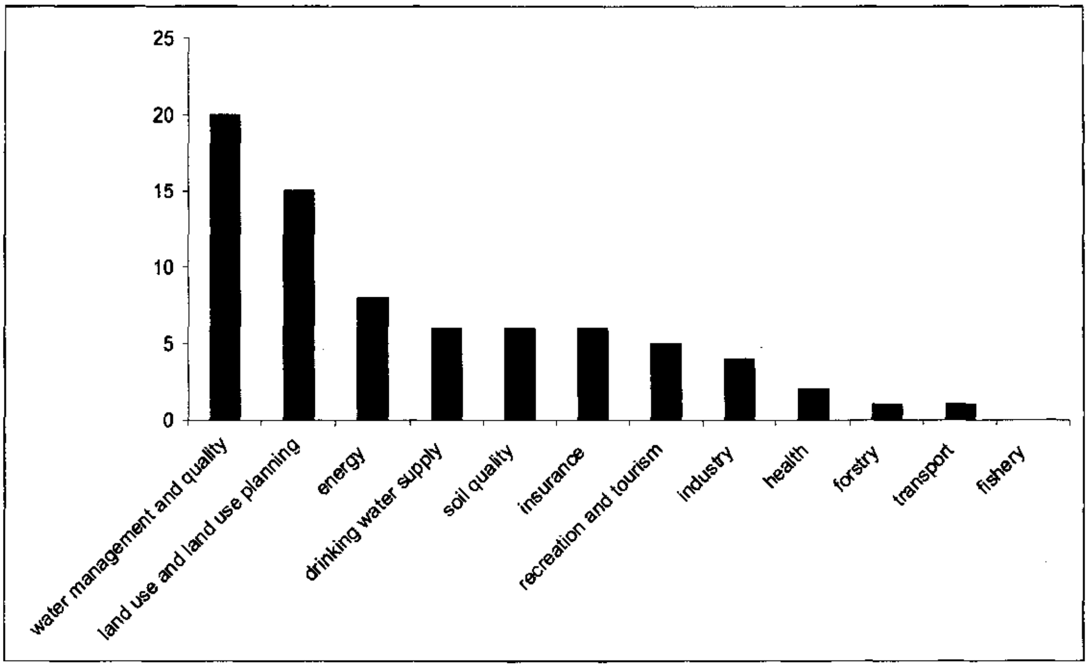


Figure 4.18. Relation with other sectors and activities for agriculture.

C) Results forestry questionnaire

In the following the results of the questionnaire are described. The questions are separated for the 3 forest functions: production (P), recreation (R) and nature (N). The main questions to be answered by this questionnaire include 1)

1. which are the *impacts* of climate change
2. which are possible *adaptive* measurements to reduce possible negative impacts, provided climate change will continue at the anticipated manner
3. what interactions between forestry and other sectors in society (agriculture, infrastructure, urbane area's etc.) are envisaged that may counteract or facilitate the effectiveness of the adaptive measurements recommended.

Based on the responses the impacts-section could best be quantified. These results will therefore be presented as such for the different forest functions. For the adaptation- and interaction sections most responses where by means of written comments. These results will be outlined such that all viewpoints are represented.

Impacts

The general impression of the respondents is that climate change will have an important impact on production and nature function of Dutch forests, but not on it's recreation function (figure 4.19).

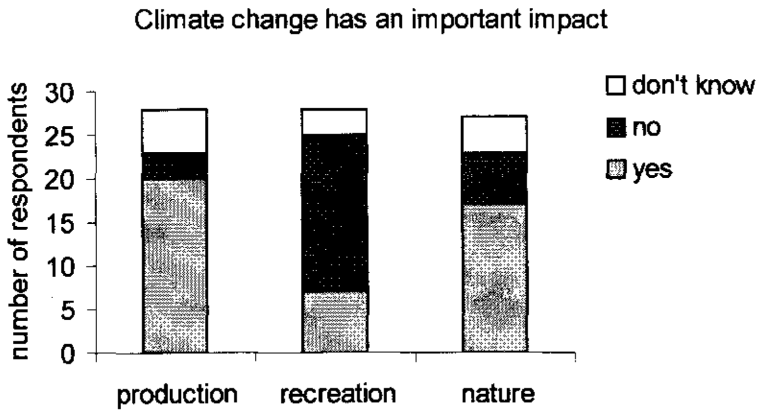


Figure 4.19 Respondent's impression of importance of climate change impacts on production, recreation and nature function of forests.

The respondents feel that the nature of this impact is generally neutral on the P-function, unfavourable on the R-function, and slightly more unfavourable effect on the N-function (figure 4.20). Moreover, for the N-function, the possible general effect of climate change on rich soils is felt slightly stronger than on poor (sandy, dry) soils. In general, no differences between coniferous, deciduous are anticipated.

When asked which forest type is most vulnerable for which climatic factor and which forest function is most affected, the respondents agree the P-function is most vulnerable both to a change in precipitation (more rain during winter, longer and more severe summer droughts) and to an increase in storm frequency. This is especially the case for coniferous forests (figure 4.21a). Only 5 respondents considered the R-function vulnerable for a change in precipitation patterns, irrespective of forest type (figure 4.21b). A change in precipitation and temperature is felt to be the most important for the N-function of the forest (figure 4c). There is no agreement which forest type is the most vulnerable. The different respondents consider both deciduous and coniferous forests vulnerable.

Zooming in to the species level, respondent only feel confident to comments on the climate change impacts on the P-function of forests. Figure 5a enlists the species from most unfavourable to most favourable considering the impact of climate change. The most important criteria affected by climate change include an increase in volume and in ring-width (figure 4.22b). Although both criteria are clearly strongly related, it must be noted that a larger ring-width reduces the quality and thus price of the wood. Most respondents agree that the most vulnerable species are Douglas fir, Larix and Norway spruce (figure 4.22c) and that this vulnerability is especially cause by the anticipated changes in precipitation and temperature (Figure 4.22d).

The respondents mentioned several mechanisms for the impacts of climate change. An increase of precipitation during wintertime may cause that the sandy soils in the Veluwe and Drenthe become very wet during this period. Mortality of most tree species may then strongly increase because they are not adapted to the anaerobe situations that occur under these conditions. Furthermore, the vulnerability of trees to windstorms may greatly increase under wet conditions because the roots loose foothold in the soil. This will even be the case if the storm frequency remains as it is. If windstorm frequency were to increase then this is felt to be catastrophic for the production function of all Dutch forests. An increase in summer drought is not considered to be an important effect on these soils and forest types by several respondents.
For the richer soils (more moist and nutrients), however, the effects of summer drought can be very severe for area's where the current groundwatertable is lowered beneath the rooted zone during summer. The trees will then be more vulnerable to secondary effect such increased levels of plague organisms and become defoliated.
The anticipated impact of a higher temperature is thought to be most important in relation to water availability. I.e. if the intensity (no water *and* high temperatures) of the summer drought were to increase due to climate change then this will have a very negative effect on many forests.
Other impacts of climate change, e.g. on natural regeneration are considered to be rather hypothetical because little is known about it.

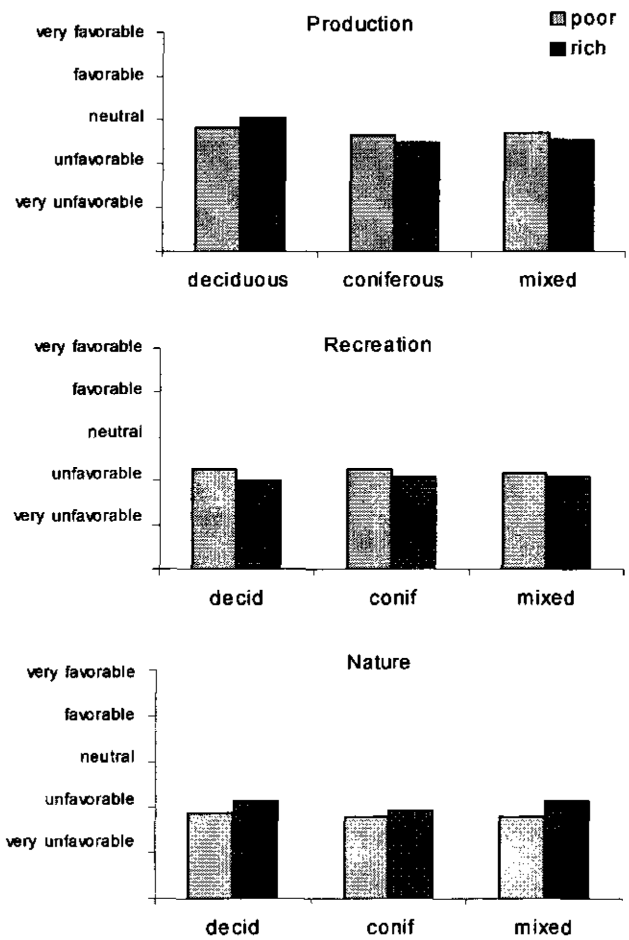


Figure 4.20 Nature of the effect of climate change on production, recreation and nature function of forests of deciduous, coniferous of mixed forests, on poor or relatively rich soils.

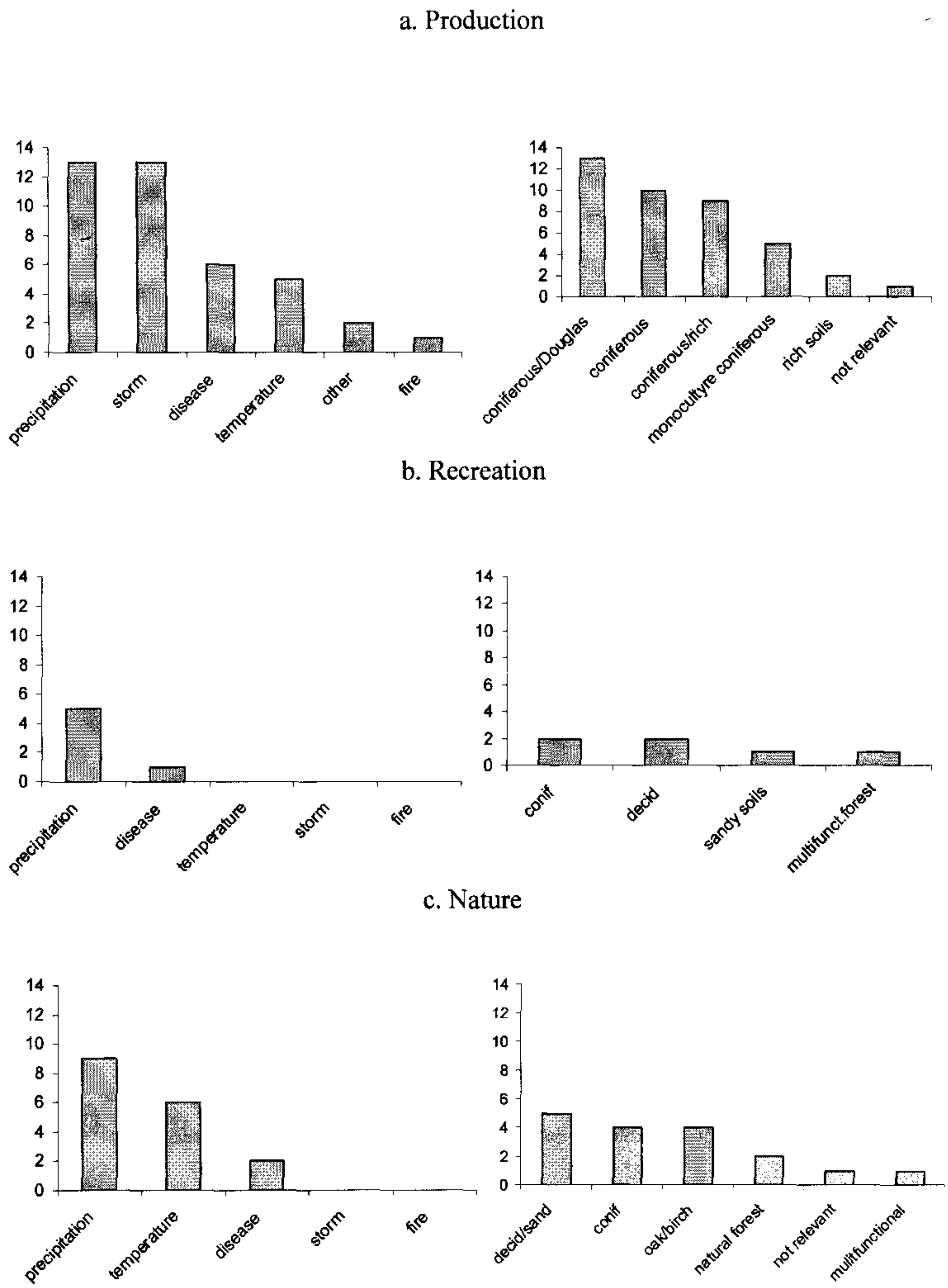


Figure 4.21 Respondent's impression of most vulnerable forest types and most important climatic factors for production, recreation and nature function of forests.

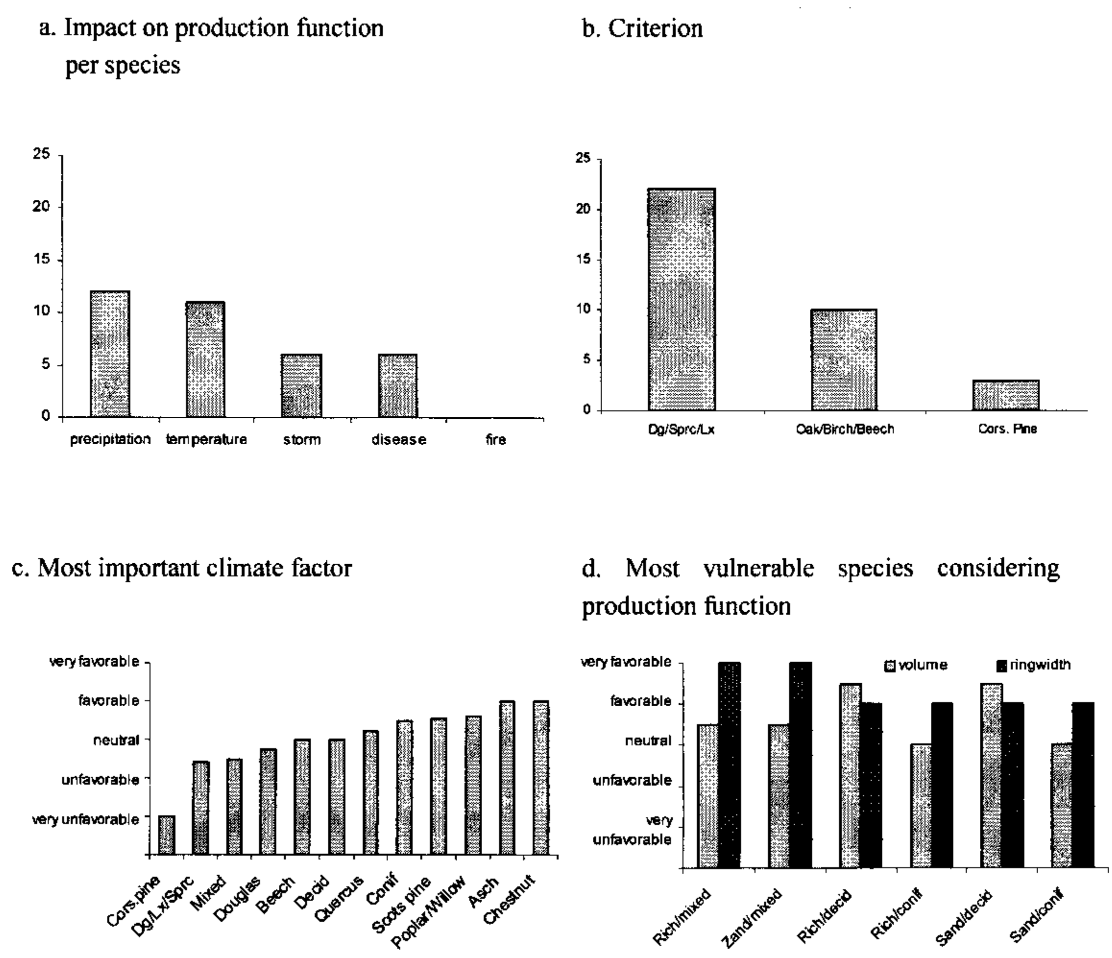


Figure 4.22 Impact of climate change at the species level on production function of forests. a. nature of the effect; b. criterion; c. climatic factors; and d. vulnerability.

Adaptation

The respondents were asked for their opinion on possible adaptive measurements to prevent or alleviate possible negative effects of climate change. They were asked to distinguish between forest types and tree species both on poor (dry, sandy soils), and on rich (moist, fertile soils). This level of splitting-up was considered too detailed by most respondents.

An outline of responses will therefore be presented for the different forest function

Production function of forests

Most respondents agree that a proper water management and forest management aiming at a small-scale, structure-rich, mixed-species, uneven-aged forest are the most important options to adapt to climate change.

The proper water management depends on soil type (see above) and could include a better drainage of the forest where the negative impacts of water logging during winter are considered to be most important. Alternatively, the water should be kept as long as possible in the forest to replenish the groundwater table for those situations where the negative impacts of intensive summer drought are considered to be most important.

Considering the structure of the forest, the respondents generally agree that risks should be spread as far as possible. The forest thus has the opportunity to adjust to the new climatic conditions by itself, but it also allows for flexibility in future management because a range of management options remain open. This spread of risks includes a wide variety of species – "no more monocultures!"- with more emphasis on species with their geographical distribution south of the Netherlands. The spread of risks includes furthermore a large genetic variability of the species that are already available. Again with emphasis on southern provenances rather than on northern provenances.

The respondents, however, disagree to what extend the forest manager should be active beyond these general adaptive measurements. Recommendations vary from "it is to early to tell.. so no measurements need to be taken" ; "nature is flexible and is able to adjust accordingly"; "most impacts for the production forest are positive, so no recommendation for adaptive measurements"; "accept as it happens, most effects will be negative, especially deterioration of oak, but there is little we can do about it" to recommendations for active forest management. This active management should include more frequent and heavy thinning both to guarantee that the forest consist of vital individual trees that can withstand climate change impacts, and to obtain a well ventilated forest that is less susceptible to windstorms. Based on the number of respondents it is not possible to say which is the most prevailing opinion in the forestry sector.

Recreation-function of forests

- The respondents felt in general that recreation is little affected by climate change as long as there are no very large changes in the forest due to e.g. windstorm damage or fire etc. The recreation function was considered not to be affected by a gradual change in the forest such as a change in species composition. Hence, the respondents indicated that little adaptive measurements needs to be taken to maintain this function of the forest.
- The most negative effect mentioned is water logging during winter. If the accessibility and passability of the forest is restricted because the forest is wet, then this is very negative for recreation. Adaptive measurements to be taken thus include a better drainage of the forest. This may conflict in specific

locations with a forest management to conserve water in the forest to reduce the impact of summer drought on its production function could thus negatively affect the recreation function.

- Another point mentioned is that especially mixed coniferous forests are used for recreation during the winter period. A reduction of these forests, either directly by climate change or as a consequence of forest management, is unfavourable for recreation. Adaptive measurements to be taken thus include maintenance or expansion of this forest type.
- Finally, savety is an important aspect of the forest for the recreant. Thus, dangerous trees, hanging branches above roads etc. need to be removed. In case of increased windstorm damage this activity may need to be intensified.

Nature function of forests

Most respondents have the opinion that little adaptive measurements need or can be taken to reduce possible negative impacts of climate change on to protect specific species or "nature types" that are characteristic of forests. The reasoning behind this are, however, diverse: either too little is known to make sensible adaptive measurements, or the negative aspects (loss of valuable species, replacement with less valuable species) cannot be circumvented anyway, or the future nature should be considered to be as valuable as the current nature. I.e. what is "natural": the vegetation before the man-induced climate change or the spontaneously developed new vegetation after a global climate change?

- Water management was considered by these respondents by far the most important adaptive measurement to be taken. Wetter forests are generally assumed to have higher natural values. Thus, restoration of previous water regimes, while avoiding strong annual fluctuations is of key importance. These measurements are most important for the richer soils with oak hornbeam forests, and forests along brooks. For forests on poor, dry and sandy soils such adaptive measurements are not recommended as they are assumed to be less vulnerable to climate change.
- Fragmentation of the landscape is also an important factor preventing nature to adapt to other climatic conditions. Connecting zones between large natural area's can be helpful, however, for many species is the rate of dispersal low compared to the anticipated rate of change of the local climate. So the effect of such adaptive measurements will be marginal and relevant for few species only.
- Furthermore, the usefulness of current policy of protecting species and "nature types" that is aimed for to attain in a given reserve needs to be evaluated. The aims set can be unrealistic in a future climate because the climatic conditions required do not prevail anymore.

Interactions with other sectors

Adaptive measurements that can be taken to reduce the negative impacts of climate change on forests may interact with the functioning of other sectors in society. There was broad agreement on the speculative nature of these interactions as well as the importance of them. It is speculative because much uncertainty still remain on the future climate, especially on the occurrence of extreme events, and also because of other developments in society (e.g. urbanisation, infrastructure, agriculture or recreation). The latter are felt to be far more important than a gradual climate change. Nevertheless, several respondents stressed that adaptive measurements for forests can only be sensibly considered together with the developments in other sectors of society that construct the landscape.

Most respondents contemplated on the interactions between forestry and other sectors of society of water requirement and claims for space. Considering water management, there are strong interactions between forestry and agriculture. An increase in groundwater table that is considered essential for the restoration of forest ecosystems enabling them to resist and to adapt to future changes in the local climate and other environmental factors, is in many cases detrimental for an self-sustained and economically viable agriculture of a neighbouring area.
If some of the current forests were to be used for water storage during peak supplies of water then mortality of trees may periodically increase, lowering the price of wood on the market. Other respondents also see more opportunities to develop new forests with potentially high biodiversity. E.g. reconstructing current brook systems into meandering brook systems with fringing forests. Furthermore, those parts of the 'high'-Netherlands that used to be extensive swamp areas but are now mainly in agricultural use can be set aside to increase the water buffering capacity, allowing the development of new forests and natural reserves.
With respect to other claims of space the respondents feel that there will be much more pressure within the current forests on dry sandy soils for recreational use, i.e. summer cottages, camp sites, golf area's and other recreational and tourist facilities. Furthermore, the current forest area is likely to be reduced by infrastructure and urbanisation, whereas expansion of the forest area will be increasingly difficult if agriculture is extensifying, thus requiring more space for the same productivity.
Finally, one respondent considered that there could be an interaction between the forestry and energy sector. Forests may be used to provide sustainable energy. This would require that forests with short rotation are constructed. Thus, adding to the list of claims for space.

Discussion

The general impression of the respondents is that the impacts of (previous) management on current forest functions is much more important than the possible impacts of climate change. Furthermore, there are many interactions with other environmental factors (N-deposition, pollution, fragmentation, etc), causing multiple stresses on the forest system so that the impacts of a single climate signal cannot be assessed. It is felt that there will be strong local differences and opposite impacts depending on the effect of the climatic factor and the forest type and tree species considered. Much depends on the climate change scenarios. The impacts will not be severe if a gradual change in the climate is most likely. However, if there is and increase of storms and summer drought, then the impacts will be very severe. Thus, the possible impacts are felt to be rather hypothetical, difficult to assess because of lack of knowledge, and far from the day-to-day and practical problems the respondent.

Despite these uncertainties there was a broad agreement between the respondents considering the adaptive measurements to be undertaken to avoid possible negative impacts. The single most important measurement recommended by many respondents is a properly adjusted water management. Depending on the groundwatertable and water holding capacity of the soil, a proper water management could either include the retainment of water in the forest to alleviate the anticipated increase of summers droughts, or to drain the forest more efficiently to reduce its vulnerability to winter storms. The respondents furthermore agreed that a rich forest structure, a broad species composition of the forest, and a large genetic variation of the available species are important measurements to be taken so that both the impacts of climate change can be mitigated and enabling the forest to adapt to future climatic conditions.
Most respondents have the view that climate change impacts of forests are to be accepted as they come if the above mentioned measurements are taken. Some with a positive point of view: nature will be sufficiently flexible to respond, and the new nature, adjusted to the then prevailing climatic conditions, will also be valuable. Some with a negative point of view: we will loose much more valuable aspects than we gain, but there is little that we can do about this.

The respondents also strongly agree that the interactions between the forestry sector and other sectors of society for adaptive measurements are water management and claims for space. Both aspects include potential opportunities to expand the forest area with forests with high biodiversity, and threats of loosing forest area for stronger claims by recreation and tourism, agriculture, infrastructure, urbanisation etc.. The final outcome of this balance clearly depends on how society values forests compared to other use of the area.

D) Fisheries

In the questionnaire on fisheries, 3 functions of aquatic ecosystems were distinguished, i.e production, nature and recreation (see also forestry). Many respondents did not express an opinion on the whole range of functions and systems that were addressed. Many restricted their comments and opinions to their specific expertise or business. The consequence is that the scores for most questions are rather unbalanced. Out of 28 returned questionnaires, 21 address the production function, 14 the nature function and only 6 the recreation function (table 4.10)

Table 4.10 Response to the question "Do you expect important effects of climate change on the production, nature or recreation function of aquatic systems?

Function	Yes	Don't know	No	(no response)
Produktion	21	3	2	2
Recreation	6	16	4	2
Nature	14	8	3	3

Fish production: impacts and adaptation

With respect to fisheries, 4 ecosystems were distinguished for which different answers might be given: freshwater, estuaries (e.g. Wadden Sea), the marine environment (North Sea) and the continental shelf . Scores on the level of seriousness of an effect of climate change ranged from +2 (very positive effect) to –2 (very negative effect). The respondents indicate a small positive effect on productivity in freshwater and a small negative effect (less than –1) on productivity at sea (table 4.11). No clear effect was indicated for estuaries and the shelf.

Table 4.11 Do you expect serious effects of climate change on the fish production in different aquatic ecosystems?

Measure of impact	Freshwater	Estuaries	Marine	Shelf
2				
1	5	3		2
0	2	3	6	4
1	2	5	4	1
-2		1	1	
Average score	3	-4	-6	1
Sum score	0.4	-0.2	-0.6	0.7
(n)	(9)	(12)	(11)	(7)

Table 4.12 Which ecosystem is most vulnerable in your opinion? What is the main cause of this vulnerability? (question 1b and 1c).

	Most vulnerable	Temp	Rainfall	Storm	Currents	Sea level rise
Freshwater		1				1
Estuaries		7	3	2	3	4
Marine		3		2		
Shelf	1	1		1		
None	4	7	2	2	1	
(n)	(16)	(18)	(3)	(6)	(6)	(6)

In 12 cases respondents identified a specific ecosystem as most vulnerable to climate change and in 16 cases there was no opinion or no response. Estuaries were identified most freqently as being most vulnerable (table 4.12; figure 4.23).

Higher temperature was in general seen as the most likely cause, though higher rainfall, storm frequency, changes in water circulation and sea level rise were also mentioned.

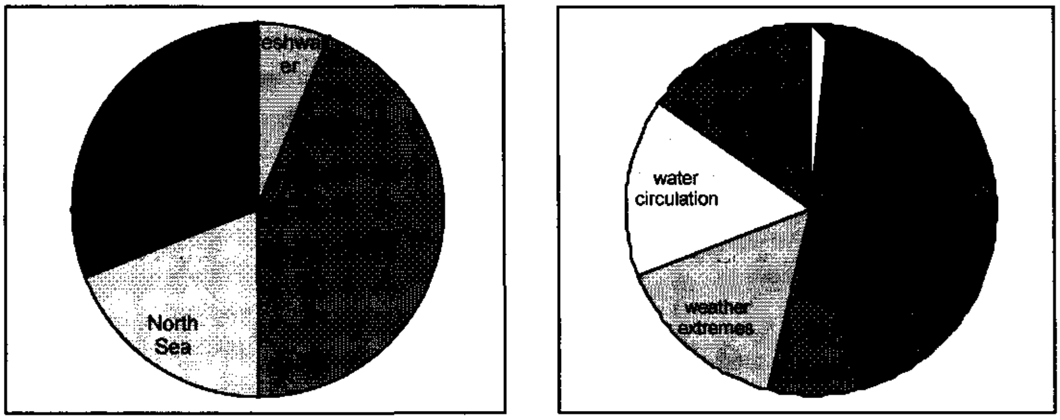


Figure 4.23 Which ecosystem is most vulnerable?(question 1b) and what is the main cause?

The answers to the question what kind of adaptive measures might be taken clearly revealed that the additional problems that climate change may cause for the fisheries are subordinate tot the existing management problems of overexploitation (Box 4-6). Only in respect of the fishery in Lake IJssel (a freshwater reservoir created by closure of the former "Zuiderzee" by a dam) and of the shellfish culture were more specific measures brought forward that could mitigate effects of climate change (sluice management, reduction of the use of fresh water for cooling, re-arrangement measures). Several respondents considered adaptation measures unnecessary, because they expected that production would increase or because nature would create a new equilibrium by itself.

With reference to effects on individual species, very few respondents covered the entire range of species in their answers and most concentrated on those with which they were professionally most familiar. This caused large differences in response rates among species (table 4.13). Scores on the level of seriousness of an effect of climate change ranged from +2 (very positive effect) to –2 (very negative effect). Only in respect of cod was a majority convinced that climate change would have a marked negative effect, whereas the effect on eel, perch and particularly on 'southern species' (e.g., bass, red mullet) was thought to be markedly positive. Expectations were lightly positive for the majority of exploited fish and shellfish species considered. The rationale given was often complex. In general, higher temperatures were supposed to have a positive inflence on growth, but in specific cases recruitment or survival was supposed to be negatively affected by other factors. Therefore, it is almost impossible to make an overall evaluation of the factors considered most important.

Box 4.6 Which adaptation measures would you think are appropriate to mitigate potentially harmful effects of climate change on the production function?

- Freshwater fisheries (Lake IJssel)
- Regulation of freshwater/seawater gradient, sluice management
- Heavy exploitation is a problem by itself that has to be solved first
- Adapt the closed season to match earlier spawning
- Restrictions on cooling-water effluents
- Rearrangement measures to enhance diadromic species
- Shellfish fisheries (Estuaries)
  - Sluice management (2x; but further research required)
  - Unnecessary
  - Dynamic licence plot management (4x); hatchery development
  - Use potential created by new species for fishery and culture
- Cutter fishery (North Sea)
  - Reduction in quota is a first priority (should allow a better evaluation of the effects of climate change)
  - Establishment quota regime for presently unregulated species
  - Complete closure during the spawning season (2x)
  - Further restriction on engime horse power
- Trawler fishery (Shelf)
  - Reduction in quota is a first priority
  - Establishment quota regime for presently unregulated species
- General remarks:
  - Not applicable: production function increases!
  - Let nature resolve the problem (2x)
  - Not possible

Table 4.13. Can you indicate what kind of effect you expect of climate change on each of the commercial spec ies? Species are ranked according to the mean score (-: negative effect; +: positive effect).

Species	Score	(n)
Cod	-1.09	11
Brown shrimp	-0.22	9
Plaice	-0.20	10
Mussel	-0.18	11
Cockle	-0.08	12
Herring	0	4
Perch	0	6
Whiting	+0.17	6
Mackerel	+0.25	4
Smelt	+0.29	7
Spisula	+0.38	8
Horse mackerel	+0.40	5
Sole	+0.45	11
Eel	+0.63	8
Pikeperch	+0.63	8
'Southern species	+1.43	7

Respondents proposed a large number of possible metrics, which might be affected by climate change and which might be used to develop criteria for the production function of exploited aquatic ecosystems in relation to the type of fishery e.g. recruitment/spat-fall, growth, natural mortality, production (kg ha^{-1}; catch-per-unit-of-effort), spawning stock biomass, species composition or area of distribution. Population size of the Japanese oyster was proposed by one respondent as a possible indicator species in estuarine waters, because this species might be able to extend its distribution if temperature increase. The expected effects were highly species-specific and can not easily be classified.

Recreation function fisheries: impacts and adaptation

This part of the questionnaire was skipped by most respondents, because they felt unfamiliar with this aspect. In fact, those that did respond put the emphasis on the recreational fishery rather than recreation in general. Higher temperatures were expected to make sportfishing more attractive, but more rainfall might have a negative effect on reaching the preferred fishing grounds in the freswater environment (Table 4.14). Only two respondents dared to answer question 2b and mentioned inland water bodies and large rivers, respectively, as the most vulnerable system in respect of the effects of climate change on the recreational fishery function.

Table 4.14 . Do you expect severe effects of climate change on the recreation function of various types of aquatic ecosystems?

MEASURE OF IMPACT	Inland waters	Large rivers	Estuaries	Coastal waters	North Sea
2	-	-	1	-	-
1	2	3	-	-	1
0	1	-	-	-	-
-1	1	1	-	1	-
-2	-	-	-	-	-
Sum score	1	2	1	-1	1
(n)	4	4	1	1	1

Respondents did not offer many suggestions for adaptive measures, but one saw possibilities in the construction of buffer areas along the large rivers to limit the impact of floods and to increase accessibility for angling. Species diversity, population size structure, water transparency and available surface area were mentioned as suitable criteria for the recreation function in relation to climate change. The biomass of rheophilic (riverine) species was considered a suitable measure specifically for river systems.

Nature function fisheries: impacts and adaptation

In the original questionnaire, respondents were asked to distinguish between the nature function of aquatic ecosystems as influenced by fisheries and without fisheries, but this did not yield significantly new views and therefore, the answers have been combined here. The expected effects of climate change on the nature function were in general positive, with the exception of the inland waters (Table 4.15). Nevertheless were the estuaries considered to be the most vulnerable ecosystems (5x), followed by inland waters (2x) and the large rivers (1x). The main factors why this would be so were also diverse: temperature (8x), rainfall (3x), frequency of storms (4x), altered currents (1x) and sea level rise (5x).

Table 4.15 Do you expect severe effects of climate change on the nature function of different types of aquatic ecosystems?

Measure of impact	Inland waters	Large rivers	Estuaries	Coastal waters	North Sea
2	-	-	-	-	-
1	3	4	5	3	2
0	3	4	2	2	3
-1	4	-	3	2	-
-2	-	-	-	-	-
Sum score	1	4	2	1	2
(n)	10	8	10	7	5

For inland waters, the most important adaptive measure was considered to be the reduction of the level of eutrophication, because a poor water quality in combination with high temperature may enhance anoxic conditions. Regarding large rivers, solutions might be found in a reduction in the use of cooling-water in power plants and other industries, because effects of climate change would be superimposed on rises in temperature that have already taken place. Also, rearrangement measures within the flood plain (creation of buffer areas) might reduce problems caused by low run-off. The estuaries would gain from more natural dynamics regarding the transition zone from freshwater to the marine environment. Measures to prevent introduction of non-indigenous species were also mentioned. One respondent is of the opinion that adaptive measures to enhance nature sooner or later perverts to gardening.

Suitable criteria for the nature function comprise naturalness ('characteristicity'), diversity, productivity and dynamics. Characteristicity would decrease as a consequence of a shift to southerly species, while diversity might increase. The expected increase in the run-off dynamics of large rivers might positively affect characteristicity in terms of the original riverine fish populations. The selection of suitable criteria depends to a large extent on the definition of nature function used, while its normative use must be assayed against societal preferences.

Interactions fisheries with other sectores

The open question 4 (Could you indicate interactions that you might foresee between adaptive measures intended for different societal sectors?) yielded the following reactions:

- Climatological effects will probably not be noticeable at the present exploitation rate of fish stocks; a significant reduction in fishing mortality would anyhow have a positive effect on the nature function.
- The fishing industry should not become a victim of for instance wind energy parks in the sea.
- The changes in hydrological regime (regulation of rivers/restoration within catchment area) are strongly related to land use and extraction of drinking water.
- Reduction in nutrient loading (eutrophication) has large implications for other societal sectors (particularly when tackling diffuse sources; i.e. agriculture).
- Reduction in thermal pollution of surface water has large economic consequences.
- Creation of more wetland in the floodplains will be at the cost of other users (current management).
- Natural values will taste defeat of climate change as long as priority is given to economic interests; sometimes it is better not to do anything than to do something.
- The building of sea walls has devastating effects on fish communities (Delta works, Afsluitdijk); straight dikes unfavourable for shellfish culture.
- Fish culture affects price and profitability of wild catches; fisheries must cut down or switch.
- If adaptive measures for the benefit of other societal sectors lead to lower production of shellfish, people will eat something else.
- In the past, the fishery has always paid the costs when there were conflicts in estuarine waters between nature function and production function, because fisheries represent one of the few control variables; Fisheries run this risk again when effects of climate change become apparent.

Conclusions fisheries

The results of this poll has certainly brought forward some of the ideas and feelings that are present among those people that depend on fisheries for their livelihood and those that have a keen interest in aquatic resources. The response rate of 30% in itself indicates that the issue of climate change does not pass unnoticed among the parties concerned. However, the scope of the poll certainly has been insufficient to draw firm conclusions about likely effects and priority issues. A particular problem is that we tried to cover the entire range of aquatic habitats, from freshwater ponds to the open sea, in one questionnaire, whereas the effects of climate change will vary widely among these. Also, most people tried their best in providing answers to all questions but obviously concentrated on those aspects they were most familiar with. This leads to bias when trying to draw some general conclusions, because not all societal sectors were equally well represented among the respondents.

Another observation that might be made here is that the contradictory views expressed by individual respondents probably exaggerate the differences in opinion, because a complex issue like climate change may not lend itself comfortably for formulating simple questions and/or simple answers. Many comments in the margin indicate that respondents had considerable difficulties and the answer is likely to reflect whatever cam to mind immediately. As exemplified by the output of the workshop, an in depth discussion may easily reconcile some of those first impressions that people have. The realistic value of the different expectations is therefore limited. Rather the results of the poll should be seen as an inventory of thoughts and views and not much weight can be attached to the outcome in quantitative terms.

Nevertheless, some generalizations may be made. It is quite obvious that climate change is not seen as something bad per se for aquatic production and fisheries, nor for the nature function or even recreation. There are good things about it and less good things and most respondents take a balanced view. Also, there is broad agreement that in the open sea environment climate change is not the most important issue, that the effects are unpredictable because of uncertainty about its effect on oceanography and that, if there would be any effects, little could be done in terms of adaptive measures anyway. There is also broad agreement that estuaries probably represent the most vulnerable aquatic ecosystem, both in terms of production and nature function. Here, the potential to mitigate effects by appropriate management action is somewhat better. And finally, although freshwater ecosystems are probably most affected by climate change, they are not seen as vulnerable because the production function is less relevant and because the nature function is partly enhanced by increased dynamics. But of course, the intrinsic value of these inland waters and rivers will be subject to most interactions with other sectors, because water is used for a large variety of sectors within society and because it presents a threat to safety.

4.3.2 Workshop report on land use and fisheries

Stakeholders and scientists discussed and evaluated climate change impacts on and adaptations of the sector agriculture, forestry and fisheries and related these to other sectors through interactions. Participants (see appendix) were encouraged to put forward their opinions about the impact of climate change and adaptations and about the relative importance by placing stickers on listed issues to prioritize their choices. They were given a chance to add issues to the list that was provided on the basis of the literature and questionnaires. Participants were given ample time to motivate their decisions and all could then re-assess their evaluations. The discussion focussed on adaptation to climate change and explicitly not on the mitigation (reduction of the impact and effect) of climate change in the

Netherlands. This sometimes is very difficult since direct and indirect effects may result from actions and measures abroad, such as European agricultural policies and world trade ruling.

A) Impacts on land use and fisheries

In a first session participants responded to the question "*What is the probability for presumed effects of climate change to land-use in the Netherlands and how severe is the impact?*" (table 4.16 and 4.17). The discussion on impacts on *agriculture* yielded 5 issues, which were considered either most probable to occur and having most severe impacts by the participants (A2, A8, A4, A6 and A9).

Higher temperatures in winter will reduce the heat used for greenhouses though the impact is considered low, as the economic return is low (A2). Participants consider the salt damage almost inevitable and hard to prevent. The urgency is high as a large part of the Netherlands up to 800.000 hectares including the greenhouse production can potentially be affected. Among the major crops in the Netherlands, maize is most likely to benefit from higher temperatures, whereas beets and potatoes according to participants are less likely to benefit (potato is vulnerable to wet conditions in autumn and beet may benefit only if the land will not become to wet to harvest later. It is likely that more fungal diseases will occur (as is usual in the north of France today) and intensity of application of pesticides may increase at higher economic and environmental cost. Last but not least, participants consider the current varieties not as stress resistant as required. Adaptation of breeding programs is required.

In *forestry*, 3 issues (B2, B4 and B7) were considered likely and important. In general, the resistance to wet conditions is high in forests but light evergreens tolerate wet conditions better than do dark evergreens. Species composition is highly likely to change and this will alter the looks of the Dutch forest. Some species may disappear quickly whereas the return of new species may take longer. The participants do not consider this a serious problem. Further, is a highly fragmented forest, the response to disturbances may be problematic for species but not for productivity of the forest. Wetter conditions in winter may restrict the accessibility for recreational purposes.

In fisheries, participants considered the impact at the coastal zone and estuaries and especially the production of mussels the most important, though all did not consider this impact critical or important. Second but highly important is the impact that the gulfstream (or absence) may have on fish production.

Table 4.16 What is the probability for presumed effects of climate change to land-use in the Netherlands and how severe is the impact?

A. Agriculture – issue	**Probability**	**Impact**
A2. Greenhouses – lower energy demand at higher temperatures	13	6
A8. Agriculture – damage through saline water intrusion in low areas and low water quality	10	7
A4. Arable farming – wetter spring and autumn reduce possibilities for soil management and mechanical work on the land; this limit a positive effect of a longer growing season (mais benefits through earlier planting in spring, beets benefit in autumn through higher yield and longer growing season, potato no effect)	9	4
A6. Agriculture – higher chances for pests and diseases in warmer and wetter spring	8	10
A9. Agriculture – current varieties of species are not stress tolerant	7	6
A3 Cattle farming – longer growing season enhances grazing possibilities but suitability of pastures for grazing decreases when spring and autumn are more wet	6	2
A1. Greenhouse production – more physical damage due to weather extremes	3	3
A10. Agriculture – more crops in one growing season as result of faster ripening and longer growing season	2	-
A5. Ecological agriculture – higher vulnerability due to higher temperature and more most and less management options as in conventional agriculture	-	-
A7. Agriculture – (quality of) soil structure in low areas is vulnerable in warm winters with less frost periods	-	2

Table 4.17 What is the probability for presumed effects of climate change to land-use in the Netherlands and how severe is the impact?

B Forestry– issue	**Probability**	**Impact**
B2. Evergreens (especially dark wood) vulnerable in winter (wetter and more storms) and more so than deciduous trees	9	6
B7. Quality of nature will change with lower number of species	9	2
B4. Recovery of forest upon major disturbance is less due to fragmentation.	6	8
B3. Recreation is not vulnerable to climate change	5	
B8. Shorter residence of carbon in forest ecosystems	4	
B6. Recreation is more vulnerable than other functions of forests	2	1
B5. Insect plagues decrease in forest in wetter and warmer winters, but fungal deseases in eggs increase	1	-
B1. Production of the forest is vulnerable to wetter conditions	-	-
C Fisheries – issue	**Probability**	**Impact**
C1. Coast and estuaries most vulnerable to climate change due to changes in streaming pattern and weather extremes with higher incidence of damage (e.g. mussel banks).	12	12
C5. Marine production capacity depend on the Gulfstream (for nutrients) and change and impact thereof is unclear.	6	4
C6. Change in de size and location of the tidal zone will impact productivity	4	3
C2. Production in freshwater will benefit from higher water temperatures	2	-
C3. Quality of nature in freshwater ecosystems will be negatively influenced consequence is anaerobiosis and eutrofication and reduced representativeness of the fauna	2	3
C4. Higher temperatures are good but extreme water discharges in rivers and weather extremes are disadvantages to recreation at or on the water	-	1

B) Interactions land use to other sectors

In this session participants responded to the question *"Which interactions of impacts in agriculture, forestry or fisheries can be identified in relation to other sectors (natural systems, economy and health and recreation) and what is the nature of these interactions?"* (Table 4.18). A total of 8 interactions were identified in the discussion. Most of these relate to water and water management.

Agricultural interest in creating sufficient freshwater storage to wash away saline water in low areas could facilitate recreational opportunities and drinking water storage. Many actors are involved as "Rijkswaterstaat" is responsible for large storage volumes of freshwater whereas local water authorities are responsible for the local water levels and washing in polders.

Any necessary re-location of agricultural enterprises will increase the competition for limited land areas. Economic activities could be relocated to eastern parts of the Netherlands and make room for agriculture in lower areas following damage due to salinization and a need for greater safety for civilians and industry upon sea level rise. Forestry may claim larger areas to reduce the strong fragmentation and become more resistant to disruptions. This, however, will interfere with other land uses (i.e. agriculture) though recreation may benefit.

Any change in the species composition of forests could already now be accepted by civilians and policy makers as it seems "a mission impossible" to maintain the current species composition. On the other hand, it is not sensible to start introducing and planting tree species that only after 60 years from now will meet their optimum conditions for growth and now have a marginal existence. Participants feel that due to climate change forests will be closed more regularly when plagues become more frequent (i.e. "processierups"). Numbers of ticks may increase and end up on pet animals. Other adaptations may relieve possible watershortage: replacing evergreens by deciduous forest reduces the evapotranspiration. On the other hand may the need for supplying bio-energy increase the water needed in evapotranspiration.

Opportunities to reduce the need for cooling water depend on proper economic incentives the expected temperature rise in freshwaters; other industries could apply the heat (economics). A higher sense of safety with inhabitants and tourists in the low coastal areas may be achieved by adjusting the regimes of freshwater discharge to open sea (Recreation and health).

Table 4.17 Which interactions of impacts in agriculture, forestry or fisheries can be identified in relation to other sectors and what is the nature of these interactions?[(a)]

Issue (from session 1)	Interact with:	Nature of the interaction
1. Salinization	Water and recreation	The need to minimise saline seepage water requires the set up of freshwater storage basins which may create recreational opportunities
2. Animal husbandry and the need for grazing	Water	Extending the water storage capacity to prevent flooding in lower parts of the Netherlands limit the available area for grazing
3. Greenhouse production suffers from flooding and low water quality	Water	Competition for land to store water and either prevent flooding
4. Replacing evergreen by deciduous forest	Water	Is an attractive option as evapotranspiration is reduced saving more water for drinking water
5. Vulnerability of forest to disturbances & changes in species composition	Agriculture, economy & recreation	An ecological network to reduce fragmentation creates competition for land with other actors (negative) and increases the natural area for recreation (posititve)
6. Production of bio-energy	Water, Economy	Production of biomass for energy creates a larger water need for evapotranspiration
7. Water temperature rise in freshwater	Water Economy	Use as cooling water increases the temperature rise in addition to the rise due to climate change
8. Changed Salt- freshwater gradient	Recreation	Consequence of the need for better protection to sea level rise and changes in discharge regimes to remove excess water.

[(a)] All participants agree that the environment (other sectors) is a more important driving variable than climate change is

C) Adaptation options to climate change

In this session, participants discussed the adaptation options that could mitigate the impacts identified earlier and addressed the questions of cost of these adaptations, any possible barriers or interactions with other sectors (table 4.19).

In *agriculture*, the infrastructure of greenhouse production (i.e. glasshouses) does not require modifications upon climate change. In agriculture, participants agree that given wetter autumns, crops need to be harvested earlier. Many do not see any objection, as many crops will grow faster and mature sooner during a warmer summer and possibly earlier planting date. The net-result in terms of productivity may very well be null. Maize is the only crop that could be sown earlier in spring. In case climate change will bring a sharper separation between spring and summer, it would help if water could be removed sooner to make the land accessible for machinery for soil management and fertilization. More frequent weather extremes result, if they occur, in higher insurance costs. In the end, farmers will face the question as to what risk can cost-effectively be insured and what risk cannot. Participants feel that introducing more biological farming principles could make agriculture less vulnerable.

Table 4.18 Which adaptation options can be identified to reduce the impacts mentioned earlier and what are the costs and priorities, what are the constraints and opportunities with other stakeholders in society?

Adaptation	Effectivity/ priority	Constraints	Opportunities for other sectors:
Agriculture			
Prevent salinization by storing freshwater to wash away saline seepage water	11	7	10
A longer growing season requires farmers to change planting and harvest dates and soil management but does not result in loss of production – no cost anticipated	7		3
Develop new genotypes or varieties of crops) – no additional cost anticipated	5	3	4
Agriculture may insure higher risks – operational costs increase	3	8	2
Greenhouse production may prevent damage through flooding by re-location of enterprises - investment cost)		6	
Forestry			
Accept changes in species composition	10	7	3
Keeping water longer in wetter habitats reduces damage of drought – investment cost	7	7	6
Change origin of planted tree species to increase genetic variation – higher operational cost	4		7
Adapt choice of tree species with species from southern warmer places – no additional cost	4	3	4
Fisheries			
Adapt the need for cooling water in industry limits the temperature rise in freshwater – more investment cost in other industries to use heat	5	4	6
Change discharge regime of freshwater to prevent loss of gradients	2	2	2
At sea, no or little adaptation is possible other than change species caught or fishing technique or location	Not possible		
Climate change may urge mussel farmers to change location of mussel banks.			

The group felt that in the end climate change is relatively marginal and that most adjustments and adaptation options fall well within the normal agricultural practices of adjusting to year to year variations in weather. Exceptions are the building of freshwater storage to fight salinization. Some of the participants realized that this might be done at the expense of agricultural land, though anticipated higher productivity at the remaining agricultural land.

In *forestry*, few straightforward adaptations are possible. The relative vulnerability of dark evergreens could be overcome by replacing with deciduous trees; the establishment of mixed forests was considered as a good solution. Faster release of water is a simple solution to prevent damage in wetter winters and the reverse may be done to prevent drought damage in other areas or seasons – investments are required to achieve this. Production in forests is slow and this makes adaptation of species composition an activity difficult to plan though it is part of the natural rotation.

In *fisheries*, the gradient between freshwater and seawater may disappear as a result of pumping away the discharge of rivers. Adjustments in the pumping regimes seem the correct answer. Nurseries of mussels may have to find other locations if weather extremes become more frequent. This and other areas of fisheries are relatively easy to relocate (fishermen are used to find the fish).
The need to take in freshwater for industrial cooling processes and power plants could be reduced to limit temperature rise in freshwaters. This would reduce the risk at anaerobic conditions and improve water quality.

D) Interactions with other sectors

Finally, interactions between land use (agriculture, forestry and fisheries) and natural systems were discussed in a plenary session. The most important impacts in the sector natural systems were: lower biodiversity, changes in water dynamics, changes in phenology, changes in water quality and desiccation and salinazation (table 4.20).

Table 4.19 Adaptations to climate change from the perspective of natural systems and interactions with land use (see also adaptation option in section on Natural systems).

	Adaptation
1	More flexible and natural management of water levels and storing of excess freshwater
2	Accelerate and expand the creation of the ecological network EHS)
3	Creation of water buffering either in natural systems or in basis and (new) infrastructural facilities

From the participants in land use the following issues were put forward:

- *Salinization* in low areas in the Netherlands requires serious attention. Possible adverse affects could be countered by building storage for freshwater for use in washing away saline water from polders, changing to a more salt tolerant agriculture or vacate the land and relocate the businesses to provide spaces for recreation, infrastructure or industry.
- Changes in *discharges* of rivers and precipitation patterns could make agricultural activities more difficult to plan and result in economic loss. This would especially be true if water management (dumping sewage water in

combination with summer droughts) results in lower water quality that would be needed for irrigation purposes and drinking water for cattle.

- The expected changes in *biodiversity* in forests and trees and agriculture may result in changes in the occurrence of pests and in early frost damage for fruit growers. Several participants recognize a potential problem in the timing of pest management through natural agents (production supporting biodiversity) in agriculture
- Some participants expect negative impact by higher UV radiation though experts do not consider this a high risk. In fish production, it is not nutrition or sea level rise but especially water temperature that is important. This may cause problems incidentally, i.e. through parasites, but generally water bodies have large buffering capacities for changes in temperature. In case of changes in the intensity or direction of the gulfstream, changes in temperature and nutrition are likely, but until now uncertain.

Climate change may also bring new *opportunities*:

- Extensification of agriculture is possible in combination with the development of an (international) ecological network. Re-wetting low areas could sequester carbon on former agricultural land, which bring money to farmers and also secure drinking water and prevent desiccation. Such practices, however, inevitably lead to loss of agricultural production, could increase the risk of flooding in neighboring communities and seems only achievable if conceived in an international context.
- Realization of the ecological network may be possible if combined with changes water management to achieve larger storage capacity. This however, should then be realized on limited areas of available and otherwise expensive land. Further, the current policy of "doelsoorten en –typen" in which specific species and vegetation types are targets for specific ecosystems is not flexible or robust to withstand climate change.
- The need for water buffering capacity may bring unpredictable and unnatural dynamics to regions and result in "low quality" nature. These retention areas do not allow for costly industrial activities and low water quality may limit the suitability for nature (or agriculture) unless low quality water is kept separate from good quality water. There may be options to create attractive natural systems here that attract recreation or to produce biomass for fuels (willows)

Last but not least: participants do wonder to what extend climate change is already considered in policies. The intended ecological network creates robust interconnections between ecological elements that enable systems to recover from disturbances more easily than without, but some of the participants really doubt whether this network would indeed facilitate species to follow and migrate with climate change into new areas. Participants recognize that climate change issues are considered in the policies on water management for coastal zones, coast and river discharge.

4.3.3 Conclusions and discussion for land use & fisheries

In the workshop, participants have dealt with several issues concerning the consequences of climate change. Participants feel that research so far have judged effects on elements and not integrated and may be based biased towards negative impacts and damages. Knowledge on vulnerability and positive impacts enable selection of timely and justified investments. If regional differences would exist within the Netherlands, these have not been discussed during the workshop. Further, agriculture, fisheries and forestry develop not only in response to climate and climate change; other environmental issues (desiccation, eutrophication, acidification, pollution, fragmentation), trade and management (globalization and free trade, EU, extensifying agriculture, closing element cycles and shortening of production chains) and the large dependence upon resources from overseas play very marked roles and need to be considered in combination with climate issues.
In general, the response to the questionnaires agreed with the opinions expressed by the participants at the workshop. Yet, knowledge about direction and magnitude of climate change seems rather limited among stakeholders.

The participants agreed and expect that proper farm management can deal with the impacts of climate change. Regional problems relate to water management (desiccation and salinization) and require actions at regional and national scales. The impacts to fisheries are considered minimal. Options for adaptation in this sector are minimal, as the oceans are not manageable. In forestry, especially the quality of the nature function in forests will be impacted negatively. Anticipation is possible by supporting the development of the ecological network and by changing the expected species and accept species changes which are inevitable.

Agriculture
Greenhouse production benefits, as energy consumption is lower in a warmer climate
It is not clear whether the current genetic basis of crops in agriculture provides sufficient stress tolerance to continue to function well in a future climate. Adaptations are required through specific breeding (and biotechnology).
Agriculture is used to manage changes and adaptations to the stresses and variations in nature; farm management is considered able to cope with a gradual climate change and minimize negative effects and capitalize opportunities. Some effects are positive (longer growing season for maize and possibly beets and possibly for pests reduction), some are uncertain (potatoes and growing season) and some are negative (some pests).
Sea level rise in combination with ongoing soil shrinkage and summer droughts will have major impact to lower areas in Dutch coastal zone. More saline seepage water could reduce the suitability of the region for agricultural production and additional measures from local and regional water management and landowners are required to implement the necessary adaptations. Technical options are available (freshwater basins and washing the polders or creation of freshwater

shields) and are focussed on the sense of safety. However, this will reduce the available area of land for agriculture and may increase the demand for energy.

Forestry

The general impression among participants is that forest and tree species will not be strongly affected by gradual climate change. Some species may suffer damage by wetter winters and windstorms. Some characteristic species to Dutch forests that occur at the southern boundary of their geographic distribution are likely to disappear in a warmer climate. This is a natural process and cannot be stopped. On the other hand, new opportunities for species will appear of which the Netherlands in close to the northern boundary of their geographical distribution. However, natural dispersal rates are low and likely can hardly follow the rate at which climate change is anticipated. Extensive fragmentation of the habitats is an important obstacle for this process of extinction of old species and replacement and colonization by new species.
The participants indicated that the most successful adaptations to minimize negative effects are:

1. Accelerated formation of an (international) ecological network structure
2. Adjust water management to prevent conditions too wet or too dry
3. Manage forests towards mixed and structurally richer forests

The participants to the workshop clearly put more emphasis on these adaptations that did the respondents to the questionnaire. Consistent with the results of the questionnaire was the quest for improved water management, forest structure and more species and genetic variation. Both groups to a large extend agreed that changes in the species composition and looks of forests can only be accepted and focus our expectations towards forests that are better adapted to future climate conditions.
Adaptation from the forestry with other sectors involves more competition for limited space and adjustments in water management. More space is required to create larger forested areas that are more robust to climate change and other environmental stresses; this conflicts with agricultural, infrastructural and recreational needs in society. Changes in water management could be either beneficial or detrimental to forest and depend on exact location and direction of change.

Fisheries

In fisheries activities, adaptation options are considered to be limited as fishermen go where they find fish. Processes at a global scale impact regional production more than do regional or national policies (i.e. the North Atlantic Gulf Stream). The estuaries (the Waddensea) is likely to adapt to soil shrinking and sea level rise by adjusting sedimentation and soil forming processes. Higher winter and spring discharge of freshwater will negatively affect gradients in sea but adaptations in discharge regimes may overcome these adverse effects.

4.4 Economic sectors

4.4.1 Questionnaire evaluation

The aim of the survey amongst the stakeholders of economic sectors was to gain quantitative and qualitative information about the impacts of and vulnerabilities from climate change as well as about potential adaptation options in the energy, transportation and insurance sectors, according to the views of the stakeholders. A carefully selected target group received the questionnaires, involving businessmen, financiers, agents, policy makers and scientists, to include a diverse group with different background and interests. There was a response rate of 10.5% for the 200-300 questionnaires on the economic sectors. The highest response rate (almost 35%) was received from scientists, who are probably more up-to-date with the climate change issues, and hence give a higher priority to responding to questionnaires. The lowest response rate appeared amongst financiers, businessmen and policymakers.

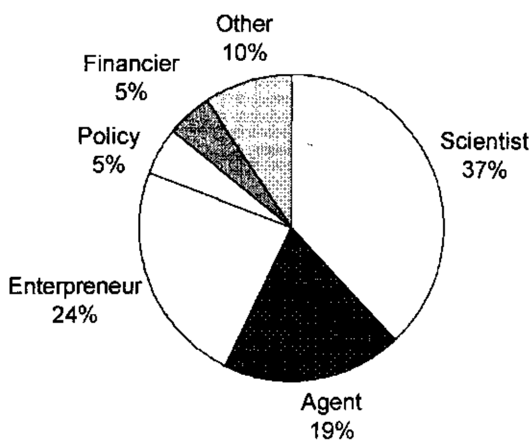


Figure 4.24 Background of the respondents (n= 250, response = 10,5%).

Each questionnaire on energy, transportation, and insurance industry contains two sections: (1) the most important impacts and (2) the most important adaptation options, which provides quantitative information for our research. The importance of the impacts is measured by a *'vulnerability index'*, which is the factor of severity and frequency of occurrence. The adaptation options are compared with a fairly subjective *'preference ratio'* based on cost-effectiveness. Open questions prompted the respondents to provide qualitative information on the specific impacts and adaptation options within their field of interest. (For the full questionnaire see http://www.dow.wau.nl/msa/nopimpact.htm.)

Though the scope of the study is on the impacts of and adaptation options to climate change on *the Netherlands*, it is difficult to draw a line between impact and adaptation, as well as adaptation and mitigation. Four main 'impact' categories are discussed in this paper: (1) temperature rise, (2) precipitation, (3) extreme weather, and (4) sea level rise. According to our definition 'adaptation' is the human response to the impacts of climate change, while 'mitigation' is the human action to combat climate change. Though we try to focus on the adaptation options in this study, several stakeholders claimed that - at least in the economic sector - the best adaptation is mitigation. Adaptation and mitigation will likely take place simultaneously in the coming decades, so we must consider the impacts of climate change on potential energy resources, for example biomass. Also it was emphasized by the stakeholders, that the impacts of climate change in the Netherlands will be much less significant for the economic sectors (excluding insurance) than the impacts of mitigation policies.

Based on the results of the questionnaire the top four energy demand categories influenced by climate change ranked by importance are (1) coastal zone management, (2) space heating, (3) water management, and (4) air conditioning. Cooling (other than air-conditioning for example refrigeration) and water pumping will also be affected. Some additional energy will be required for the cleaning up cost of disasters, related to extreme weather (see figure 4.25).

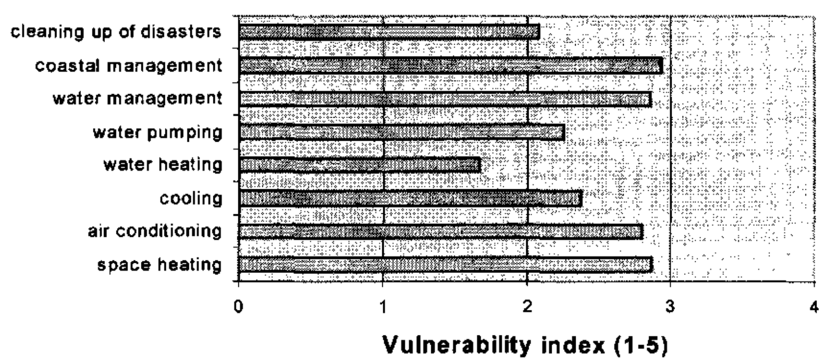


Figure 4.25 . Impacts of climate change on the energy consumption - questionnaire results (0 means no impact, 5 means very sever impact).

Analysing the impacts on energy supply, it seems that the current and potential renewable energy sources are the most sensitive for climate change, because of their high dependence of the weather. Figure 4.26 shows that biomass is one of the most sensitive energy sources according to the views of the stakeholders. The high index value of waste incineration and fossil fuel are likely to reflect the impact of energy policies.

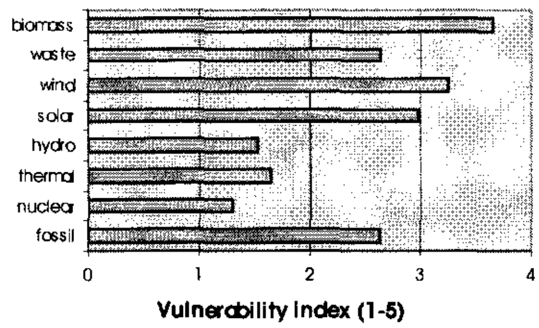


Figure 4.26 Impacts of climate change on the energy sources - questionnaire results.

The impacts and adaptation options are grouped in four categories: temperature rise, sea level rise, excessive precipitation and extreme weather. The impacts of sea level rise received the highest vulnerability index, and naturally the adaptation options against sea level rise: more and higher dikes against sea level rise (3.36) advanced planning to avoid worst impacts (3.31), and resistant infrastructure (3.31) received the highest importance rate from the stakeholders.

The main adaptation options to improve water management are: (a) water storage (2.92), (b) improved riverbed and dikes (2.8), (c) water pumping (2.67), and (d) insurance for flooding damages (2.59). Damages caused by windstorm and hailstorm are also considered important.

The impacts and adaptation options to temperature rise received the lowest vulnerability index. The slow global warming allows easy adaptation, and it does not have significant impact on transportation and insurance, but there is considerable impact on the energy consumption. Adaptation options against temperature rise are simply less energy use for space heating, and increased use of cooling equipment with higher energy intensity. One might argue, however, that these adaptation options are rather impacts, but according to our initial definitions it considered here as adaptation options. Technological development is expected to play significant role in increasing energy efficiency. Dry summer could also increase water pumping for irrigation.

The impact of climate on transportation in the short term is not very significant, and in the long term there is capacity to adjust the infrastructure and transport items. However, extreme weather can create a situation, in which transportation can be vulnerable. The impacts could be divided into two broad categories: impacts on transport infrastructure (e.g. road, rail lines, ports) and impacts on transport services (e.g. safety, delays and passenger's comfort). For a short summary on the impacts see table 4.21.

Table 4.20 Impacts of climate change on transport -questionnaire results.

Transport modes	Infrastructure	Safety	Delays	Passenger comfort
Road	**	**	**	*
Railway	**	*	***	*
River and Marine	**	*	***	
Air	**	**	***	**

Note: the number of stars shows the intensity of the impact

Amongst the adaptation options the flooding related adaptation options received the highest priority: e.g. improved riverbeds and increased dikes. Research and development will take significant part in improving reliability of weather forecast and "disaster-preparedness" to avoid large-scale damages of extreme weather. There is continuous research on how to improve safety of transport items.

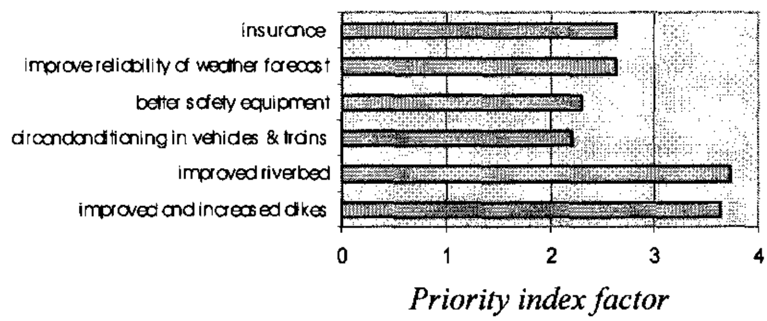


Figure 4.27 Relative implication of adaptation option for the transport sector – questionnaire results.

In the previous figures we could see that insurance is considered as one of the adaptation options in other economic sectors. Therefore insurance companies expect increasing demand for risk coverage. Careful financial planning should be made, however, to avoid high exposure to damages. The value of damages according to Munich Re (2000) increased exponentially in the last decades. The survey below shows the major climate and socio-economic factors, which contributed according to the experts to the fast growth rate of increasing damages reported by insurance companies. The result shows that the changes in socio-economic conditions (economic and population growth, population density) are the main factors behind the exponential rise rather than climate change, though flooding is a major threat for the insurance industry. Flood damages just recently became insurable in the Netherlands, in specific cases, whereas storm insurance is on the market for a long time.

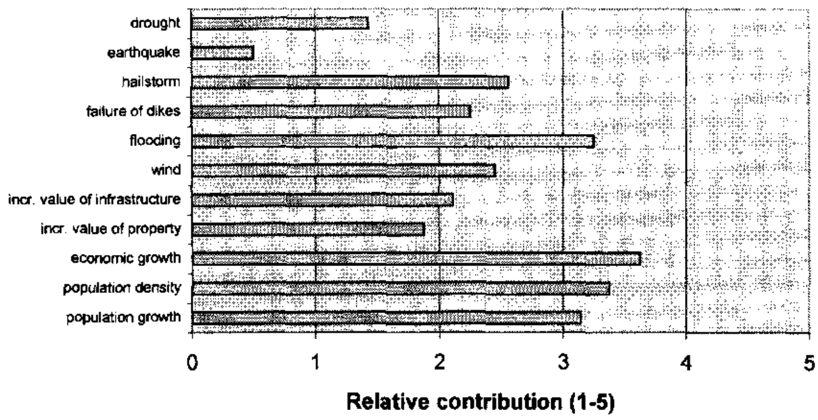


Figure 4.28 Contribution to the increased insured damages in the Netherlands - questionnaire results on the scale of (0-5).

The respondents were asked to give their expert opinion on the impacts and adaptation options in the insurance sector. The information covered the following aspects:

- insurance companies in general are not at risk in the Netherlands.
- major part of the risk of larger scale damages are reinsured.
- the important aspect is to derive the premium for the next year.
- adjusted premium is based on previous 5 years profitability.
- a gradual change of temperature can easily be taken into account.
- increased weather variability increases (e.g. same amount of rain per year but more concentrated on a short period).
- higher risk increases the insurance demand and insurance premium, therefore the available liquid capital.

4.4.2 Workshop report on economic sectors

Prior to the workshop it was agreed to focus on the *adaptation* to climate change and not on how to reduce climate change (*mitigation*). Also it was planned to discuss the direct impacts of climate change *in the Netherlands* and not the possible indirect effects abroad. Some of the participants did not consequently maintain this distinction, partly because mitigation and adaptation measures can sometimes be intertwined. The climate scenarios used in this study are based on a gradual climate change and do not include thresholds or unexpected sudden events. The participants showed their specific fields of interest and opinions about the effects of climate change and the adaptation options, by means of putting stickers on several impacts and adaptation options in the economic sector. The results are presented in the appendix. The first session dealt with the impacts of climate change. The second focused on the interaction with other sectors, like land use, health and recreation. The third session concerning possible adaptation measures yielded most issues for discussion. The main vulnerabilities and opportunities can be found in the energy sector and the insurance sector, while the adaptation options are more limited and possibly less effective for the insurance sector than for the energy sector.

A) Impacts

Energy sector (table 4.22)

The participants expect the largest impacts on wind energy. It would be a substantial positive effect as a result of more wind and a more general trend in favour of sustainable energy. Also, the flexibility to implement wind energy will increase. A small negative impact may occur due to more damage from storms on windmills and the impacts of sustainable energy on landscapes and scenery.

Many foresee a large impact on water management. The sea-level rise will lead to an increase of water to be drained, and for this purpose a lot of energy will be needed. Another relevant topic is the energy required for cooling and space-heating systems. Whether an increase in energy use as a result of incremental demand for cooling, will actually happen depends on many factors, such as the extremity of weather conditions, possible decrease in space heating, energy awareness and construction policies (depending on the degree of accustoming to air-conditioning).

The impact on solar energy will be quite large and predominantly positive for the development of sustainable energy. The weather conditions (especially increase in cloud formation versus increase in hours of sunshine) will count as well. The participants are divided whether the amount of hours of sunshine will eventually increase or decrease.

Concerning the effects on biomass as a source of energy no consensus exists. Climate change may stimulate formation of biomass, but only to a certain extent as it depends on the area of land available in the Netherlands and that will not change substantially. The cost-effectiveness is unknown and biomass has not been sufficiently well developed so far. Finally, limited effects are expected on the availability of cooling water for energy plants.

The opportunities to provide in energy demand are considered to be higher for wind energy than other sustainable energy sources (e.g. solar energy or biomass). The choice for a certain source of energy will mainly depend on the (extreme) weather conditions and the liberalisation of the energy market. According to some participants, the liberalisation of the energy market will have a much larger impact on the current energy-infrastructure than climate change.

Table 4.22 Most important impacts and adaption options for climate change in the energy sector and their effectivity and cost efficiency.

ENERGY	Adaptation Options	Effectivity	Cost efficiency
Energy supply:	*Adaptation to new weather condition:*		
Biomass energy sources	• Rotation of short-term crops	4	5
+ biomass production is likely to be increasing	• Choosing crops with high tolerance for temperature extremes	4	5
(replacing fossil fuels)	• Choosing crops with high tolerance for excessive precipitation or drought	2	4
	• Dikes and water management against flooding	2	1
Wind power + potential increase	• Higher wind-speed could allow expanding wind generators to new areas	6	7
	• Stronger infrastructure to avoid damages by strong wing	3	4
Solar energy - slight decrease due to cloud cover	• Better use of solar energy in construction	14	11
Energy demand:	• Less energy for space heating	3	3
Space heating and air-conditioning	• More energy for air-conditioning	2	2
	• Solar energy for space heating	3	1
	• Tax on energy	1	1
Water and coastal zone management	• Increasing dikes to avoid spillovers	9	7
	• Flood-control	3	2
	• Water storage and increase of hydro energy	5	2

Transport sector (table 4.23)

The participants foresee no significant impacts and vulnerabilities on transportation. However, the largest impact, according to many, is the disturbances of the weather conditions on transport safety. Injures and losses of human lives can hardly be expressed in monetary values. Low water levels can hamper water transport in summer, while in winter high water levels may, for instance, cause collisions with bridges. This will lead to economic damages, because the transport will be (partially) stopped, and this kind of damage is not insurable. No extra damage is, however, expected to occur to sluices and the infrastructure, even though adjustments to the water infrastructure will be necessary.

The infrastructure of roads will be damaged, and within the planning of infrastructure more attention should be paid to climate risks (for example more expansion of asphalt due to higher temperatures). More accidents will take place in the transport sector as a result of extreme weather conditions. No large impacts are expected for air traffic, except for a temporarily decrease in capacity of airports because of extreme weather conditions. The electric safety support system will be subject to some damage: disturbances in supply of electricity which affect traffic lights, railways and other electric equipment.

In conclusion the transport sector will be affected by climate change to a limited extent, as transport systems are designed as such to be able to maintain their functions in extreme circumstances. One should consider the future capacity of water transport. Also a flexible attitude of the transport sector is required to be able to respond timely to impacts of climate change.

Table 4.23 Most important impacts and adaption options for climate change in the transport sector and their effectivity and cost efficiency.

TRANSPORT	Adaptation-options	Effectivity	Cost efficiency
Risk of more accidents	• Icy road/heavy rain/fog...		
	• Identify and monitor the most dangerous spots (adaptation according to the identified problem)	2	-
	• Better safety equipment in transport items	1	1
	• Compulsory speed limit according to the weather condition	3	3
	• Reduce the risk for disturbance of electric safety support system (e.g.traffic lights)	-	-
Delays or cancellation of transport items due to weather conditions	• Be prepared for extreme conditions by a reliable weather forecast and reduce its impact	6	4
	• Water management (e.g. water storage) to avoid flooding or drought	11	4
	• Improve train lines	1	
	• Choice of airport and port location	1	
	• Insurance for delays in logistics		
Damages in infrastructure	• More resistant infrastructure		
	• Dikes against sea-level rise and flooding	13	10
	• Insurance		
Longer winter service on rivers	• Expanding services		
Disturbance of electric safety support system (traffic lights, air-control)	• Developing weather resistant technology	4	2
	• Reliable weather forecast	1	

Insurance sector (table 4.24)

The largest impact on the insurance sector is by far the increase in demand for insurance. This is especially positive for insurance companies but negative for other industry branches. The pressure on the government will increase and the issue of how to divide the burden of uninsurable risks should get priority. According to the principle of solidarity, the existing Law for Disaster Relief (Wet Tegemoetkoming Schadekosten), could improve through special coverage from the insurance board, for example precipitation coverage, by calculating the climate effects into the insurance of real estate or through facilitation of reinsurance in certain postal code areas. Abroad these risks are treated in various ways and insurance is possible in many situations. In some countries insurance against flooding is standard available. These kinds of risk are in other countries, amongst which the Netherlands, only partially insurable at the moment.

Table 4.24 Most important impacts and adaption options for climate change in the insurance sector and their effectivity and cost efficiency.

INSURANCE	Adaptation-options	Effectivity	Cost efficiency
Profit loss due to flooding	• Insurance with well defined conditions(risk management) • Alternative pricing (risk premium) • Reinsurance • Globalization of the insurance industry (insurance portfolios) • Going out of highly exposed markets • Cancel coverage on highly vulnerable coastal areas • Lobbing government to improve river beds and water management • Lobbing government to reduce CO_2 emission	6 1 1 3	4 1
Increasing demand for insurance	• Market opportunity (if the conditions are well defined)	4	4
Profit loss due to hail or wind storm	• Insurance with well defined conditions (risk management) • Alternative pricing • Risk premium • Reinsurance (see above)	2 1 1	1 1 1
Profit loss due to failures of dikes	• No current insurance (but disaster relief) • Lobbying government to increase dikes and safety • Insurance with well defined conditions (risk management) • Alternative pricing (risk premium) • Reinsuranc (see above)	 4 2 1 1	 2 2

More specifically the large impacts on the insurance companies would be expected to occur through an increase in precipitation resulting in more floodings. Floodings are not insurable and increasing flooding will most likely bring no change to this fact. According to the insurance companies the risk area is too small to raise sufficient financial support and this would make the premium too high and thus unattractive for the involved people. The pressure is put on the government and at this moment any solidarity agreement is missing. On the other hand, other important effects of climate change, like wind- and hail storms are insurable to some extent. The position taken by re-insurance brokers will be decisive: re-insurance brokers profit from higher premiums are inclined to estimate rather high potential damages from climate change.

With respect to storms it is important to study its frequency and intensity, and to assign the premium according to calculations by using models. Also for hailstorm, a premium adjustment will take place.

A breakdown of the dikes and other consequences of sea-level rise are not insurable. Some fear a decline in availability of insurance for certain calamities. In general the insurance sector is organised as such that future losses can be prevented in time by adjusting the premiums and conditions.

The division of powers and responsibilities between insurance companies and the government is determining the consequences of climate change on the insurance sector. To what extent are insurance companies prepared to adjust to climate change and what does the government offer? How much can be done with solidarity, without impediment of the free economic interchange? To what degree will it be possible to differentiate premiums according to risk area? How can one cover the effects of sea-level rise? Also the government should try to find an answer to the question of how to deal with increasing social pressure to provide compensation for damages of floodings and other natural disasters.

B) Interactions

During the second session the emphasis was on the (possible) interactions of the predominant impacts on the economic sectors with impacts on other fields of interest: 'natural systems', 'land use' and 'health and recreation'. Especially the handling of claims for land (agricultural sector 60%) and a re-orientation of spatial planning are important. Also the risk of floodings and excessive rains has consequences for several fields of interest. The participants paid most attention to the interactions with natural systems.

Ecosystems, water and soil

Interactions between effects on economic sectors and ecosystems are directly visible through wind energy and biomass, but also indirect interactions are possible through intersection of the ecological core structure, and the foundation of large distribution centres. The consequences of water storage in natural areas to cope with floodings, can turn out to be both beneficial and detrimental.

Changes related to transport, which is an important sector the Netherlands, have major impacts on surrounding countries as well. An increase in flexibility of the railways and water transport is considered to be necessary, for example with respect to assessing the capacity for heavy cargo transport and its effects on land and water quality. It is unlikely that the insurance sector can exert decisive influence on the choice of residential areas (through premium differentiation for risk areas).

One should try to create a win-win situation. Re-orientation of spatial planning may take place to co-ordinate conflicts between transport systems and natural systems: Good water management is a prerequisite to limit the effects on the economic sectors.

Agriculture, forestry and fisheries
The interaction between the insurance sector, agriculture and forestry is the main interaction in this category. As was already mentioned in the first session in the case of treatment of (un)insurable risks, the insurance companies and the government have to look together for solutions, for example in the case of harvest damage. A side issue is that the insurance companies are important players in forestry, as they own large areas of forest in the Netherlands.

The interaction between agriculture and transport is relevant, because agriculture is responsible for one third of all cargo transport. The expected climate impact, however, is limited. Some refer to the possibilities for creating a different distribution network in the Netherlands along with a different type of distribution of agricultural production and supply.

The main interactions between effects of climate change and agriculture are especially interesting with respect to the uninsurable risks, new insurance options and the role of the government concerning disaster relief. Also the solidarity issue is of concern. And, finally, a new agricultural spatial planning is desirable. The interaction between impacts on transport sector and agriculture is of limited relevance.

Health, tourism & recreation
The participants put as first priority that human health should never suffer from adverse environmental effects from any kind of energy source. The interaction between the energy sector and health is of limited proportions and seems to depend on the composition of energy sources and degree of energy use. The switch from conventional to sustainable energy sources will generally improve health, except in case of energy from biomass, which can cause harmful effects if insufficiently clean technologies are being used.

Another interactive effect from climate change could be that price reforms, which take place in the energy sector, e.g. through environmental taxes, could have consequences for tourism as well, especially those related to air traffic. Also the negative impacts of climate change on transport can indirectly affect tourism, but these effects are considered to be minor.

The composition of energy sources is influential on the extent of interaction between economic sectors and health. The internalisation of climate effects and other external effects in energy prices will affect the transport sector and tourism as well.

C) Adaptation options

During this session the opinions were more diverging than in the two previous sessions. The adaptation options are apparently so diverse that it is hard to align the most effective and efficient priorities. Hence this field of interest does deserve further discussion. In this session it was also remarkable that only a few adaptation options were considered relevant for the insurance sector, among which adjustment of premiums.

Energy sector

The participants find adaptation of *behaviour* the most effective and cost effective adaptation option, eventually resulting in energy saving. This is repeated several times and is considered to be a versatile solution, although it is strictly speaking in the category of mitigation options. Energy saving behaviour should become as ordinary as the recycling of glass. It seems useful to pay attention to it at schools. Also energy labelling seems to be a good option. At the same time, however, some participants note that behavioural adjustment is not feasible in all domains. The development of new and more efficient technology is also relevant but not sufficient, as consumers, when obtaining energy saving light bulbs or green energy, may make more use of electric equipment (the so-called rebound effect). One problem is that to be able to achieve behavioural adjustment, external effects should be internalised in the prices. A "green" fiscal system may also stimulate behavioural adjustment.

The participants foresee less adaptation options in the energy sector itself, as sustainable energy is only possible to a limited extent in the Netherlands. The energy demand for biomass will increase and adaptation options are crop rotation, cultivation of crops with a high tolerance for extreme temperatures, drought or excessive precipitation.

Wind energy could expand as well, hence an increase in wind velocity will make more locations suitable for windmills. At the same time a reinforcement of the existing infrastructure is necessary to prevent damage from strong wind. In order to be able to use wind and solar energy at a large scale, several investments are needed. Many consider it worthwhile to encourage the construction sector to incorporate the adaptation options for active and passive solar energy and the utilisation of daylight.

In general a decline in energy use through less heating costs can be expected, but an increase through use of air-conditioning as well. With the notice that accustoming to comfort probably stimulates the demand for air-conditioning more than climate change. Also more energy will be needed for water- and coastal management, among which the increase of dikes, the control of floodings and water storage.

Most options are to be found in behavioural adjustment, which can be stimulated not only through good marketing and energy labelling, but also through internalisation of external effects in energy prices and a greener fiscal system. The energy sector itself should stimulate the use of wind and solar energy as much as possible.

Transport sector
Preventive measures and adaptation options are closely related within the transport sector. The most effective adaptation option for damage to infrastructure is strengthening of dikes. This is a task for the government together with large stakes for the industry. Secondly, optimal water management (e.g. creation of water retention areas) is mentioned to battle floodings and drought. The learning process of making reliable weather forecasts, especially extreme weather events, is thought to be relevant as well. Other potential tasks of the government are restriction of maximum speed limits adjusted to weather conditions, better safety equipment in means of transport, improvement of the railway network, and adjustment of harbours and airports. The electronic safety support system (e.g. traffic lights, radar and safety equipment of airports) should be made more weather proof.

The most effective adaptation options in the transport sector are strengthening of dikes and water management, which are basically seen as government tasks. Also the learning process of making reliable weather forecast is considered as important.

Insurance sector
As a first priority a clear distinction between the role of the government and the role of the insurance companies should be made and implemented. The government should intervene in the insurance market as least as possible, and should focus mainly on the organisation and coercion of national solidarity and the collection of sufficient tax revenue. Also the government can anticipate more than she does now. The construction of real estate in riverbeds, for example, can be treated as government failure.

Concerning the reduction of losses resulting from floodings (at the moment not insurable, only some compensation by the government), the insurance companies should especially prevent adverse selection. One other possibility is to apply premium differentiation for risk areas, not only for current risk areas, but also for future risk areas. Therefore both well-defined conditions and risk management are of importance.
According to some participants the most cost-effective solution could be to let the insurance companies select the areas that will be sheltered by the solidarity

principle. Others think the insurance sector itself should take more responsibility than it currently does, and should not shift responsibilities too much to the government and industry.
Experts expect increase in demand for insurance, hence the insurable risk will be solved by the insurance market itself. The insurance market is a reasonably well functioning market, which does not need much government intervention. The insurance companies could actively contribute to CO_2-reduction by green investment and (more) energy saving, especially as symbolic gesture to the society and the government. The lobby with the government concerning CO_2-reduction is seen as an important tool, but is seen more as a preventive measure than an adaptation option. Strengthening of dikes against flooding and safety precautions are considered necessary options.

Priority is not on how to design insurance suitable for covering the negative effects of climate change, but on how to divide the tasks and the responsibilities between the insurance sector and the government.

4.4.3 Conclusions and discussion for economic sectors

The participants of the workshop expected moderate impacts on the economic sectors. The largest impact was expected on the energy sector, especially on the supply of renewable resources. Insurance was considered an adaptation policy in itself for the other economic sectors. Transportation may experience damage mainly on the infrastructure.
It is important to visualise the effects of climate change in order to create sufficient support for efficient adaptation measures. Climate change can work as a catalyst on existing developments and measures. Adaptation policy is very well possible in the Netherlands, whereas mitigation policy is only useful if carried out at a global level. Even though it is often hard to draw a line between adaptation and mitigation, it is sensible to untangle both. The amount of support for an individual mitigation policy in the Netherlands will depend on the reaction of the Netherlands to impacts of climate change. Impacts of climate change in the Netherlands will most likely be much less significant for the economic sectors (excluding insurance) than the impact of mitigation policies. However the Netherlands should not be discouraged and should be involved in both mitigation and adaptation.

The possibilities for carrying out the adaptation options mentioned above differ per sector. Most important is proper adaptation in water management and coastal protection. If these are granted no large efforts are needed for the transport sector. Only water transport needs more adaptation. This also counts for the agricultural sector, which is very sensitive to weather conditions. The effects of climate change and the necessary adaptation options are closely related to the course of climate change. The workshop is based on a gradual course of climate change, but we would like to emphasise that in reality climate change might be more abrupt. The risk of a sudden climate change, e.g. through stagnation of the Atlantic Ocean conveyer belt, is a crucial aspect as a society has to be able to anticipate on what is coming next. The policy makers should also be aware that global warming may come about much faster or may come with very extreme weather conditions. This may lead to problems, partly because it is still unknown how to adjust to stronger fluctuations.

4.5 Health, recreation and tourism: dialogue with stakeholders

4.5.1 Outcome of questionnaire

The aim of this survey was to gain quantitative and qualitative information about the impacts of and vulnerabilities to climate change as well as about potential adaptation options in the health, tourism and recreation sector, according to the views of the stakeholders. A carefully selected target group received the questionnaires, involving health professionals, tourist agents, policy makers, interest groups and scientists to keep a diverse group with different background and interests.

Each questionnaire on health and tourism and recreation contained two sections: (1) the most important impacts and (2) the most important adaptation options, which provides quantitative information for our research. The importance of the impacts is measured by a 'vulnerability index' (ranging from not vulnerable (0) to very vulnerable (5)) , which was explained as the product of severity and frequency of occurrence. The adaptation options are compared with a fairly subjective 'preference ratio' based on cost-effectiveness. Open questions prompted the respondents to provide qualitative information on the specific impacts and adaptation options within their field of interest.

Human health

Figure 4.29 shows the response to the question: *What are the most important health effects related to climate change?* Allergy effects (hay fever/pollen, glycyphagus /fungus at home) were valued as the most important health effect of climate change, followed by the adverse health effects due to a worsening of the air quality. Food- and waterborne diseases were thought to be the least important health impact. The difference between the impacts with the highest and lowest importance was, however, only 0.9.
The respondents were also questioned about *what future developments will also have an influence on our health and whether these developments will be relatively more or less important for public health in the Netherlands than climate change?* In general, climate change is considered to be of less importance than the developments that were mentioned (ageing, urbanisation, population growth, economic growth, increasing mobility, disruption of ecosystems, increasing immigration).

In the second part, the questionnaire addressed the options to adapt to the possible health effects due to climate change in the Netherlands. Figure 2 shows the response to the question: *What adaptation options are considered to be most effective and desirable?* In general, the respondents feel that the Netherlands will be capable of coping with possible health effects due to climate change. Possible measures that are frequently mentioned to reduce the impacts include education (one can think of campaigns against sunbathing on warm days, etc.) and the monitoring of changes in health determinants (see Figure 4.30). In other words, a lot can be gained through preventative healthcare and through improved knowledge linked to financial incentives that result in adaptive behaviour. These preventive measures were generally considered to be the most cost-effective adaptation option; many negative impacts can be prevented by monitoring/warning systems and education (although these can not be strictly separated). Especially the media, like radio and television can play an important role.

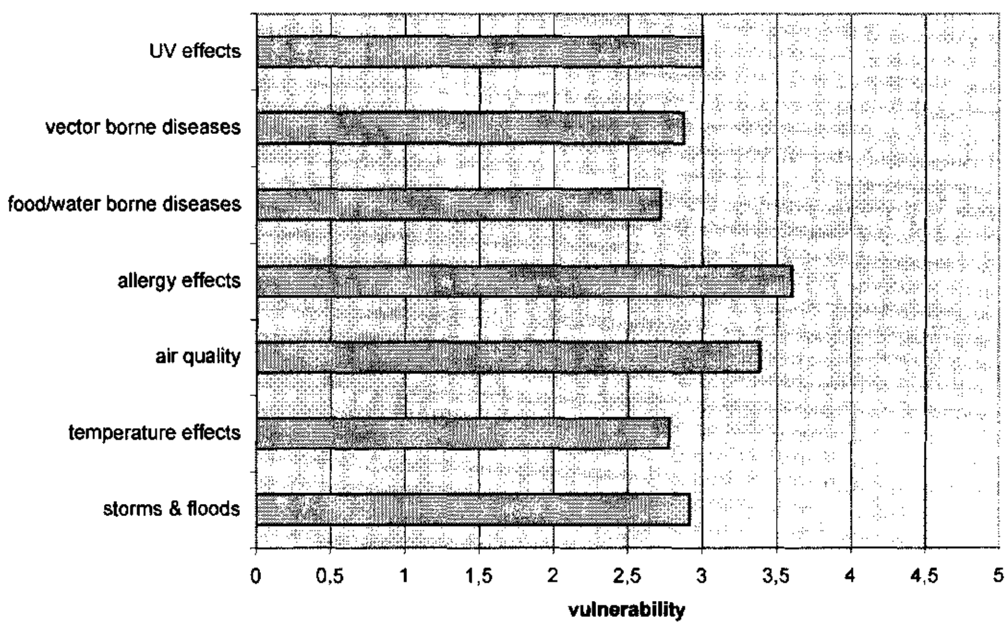


Figure 4.29 Main health impacts due to climate change (vulnerability index 1-5).

Specific adaptation possibilities that were mentioned are improvement of ventilation and increasing the resistance of children (controlled exposure to myco and other bacteria). Adaptation possibilities in relation to the floods in river- and coastal areas: heighten the dikes and coastal barriers (safety first) and no house construction in the river foreland.

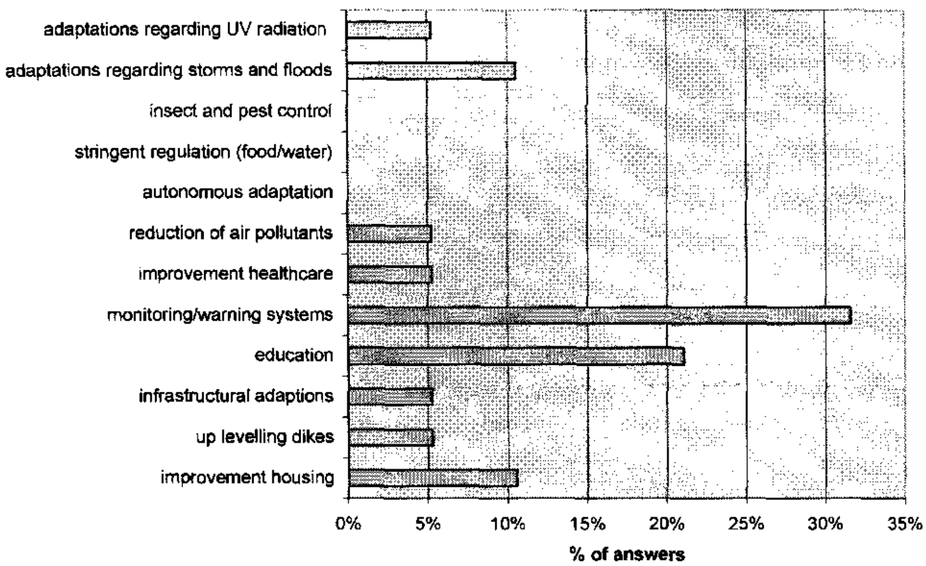


Figure 4.30. Adaptation options considered as important/effective to reduce the health impacts of climate change (% of answers given).

To evaluate the effect of the proposed adaptation options on other sectors, it was also asked *whether one or more of the adaptation options could have a negative/positive influence on the other sectors?* Some of the issues that were raised regarding this question are listed below:

- Air-conditioning influences energy consumption;
- Reducing air pollution leads to constraints on transport;
- Infrastructure change may harm ecosystems in many areas;
- There could be some positive influence on hydrology and possibly ecosystems, for example if the water storing capacity of river zones is extended;
- Infrastructural adaptations and the up-levelling of dikes may have a negative effect on flora, fauna and ecosystems;
- Reclaiming wetlands to reduce the growth of contagious diseases would be disastrous for our vanishing wetlands;
- The promotion of aforestation and tree planting originally intended to reduce net CO_2 emissions may contribute to other goals as well, such as temperature reduction in urban areas, noise reduction and air quality control;
- Positive effect of infrastructural measures to ensure the insurance options of risks (like the prohibition of house construction in the river foreland);
- Energy policy less based on fossil fuels (to reduce air pollution), also in the transport sector, may possibly lead to a greater efficiency in using more clean production systems and may even be financially beneficial for the sectors themselves.

At the end of the questionnaire, the respondents were asked to give there opinion on five given statements on health and climate change. The first statement was: *The ultimate effect of climate change on the public health in the Netherlands will be unfavourable.* Of the respondents 55% agreed and 45 % disagreed. Important comments of the respondents regarding this statement are listed below:

- The effects of climate change in the Netherlands may possibly be countered by additional climate changes (for example, in case the North Atlantic Gulf Stream cool off);
- The effects of climate change can be anticipated by improving health care and education;
- Direct negative effects may be limited by adaptation and compensated by higher economic growth whenever we start to profit from greenhouse technology;
- The effects are countered by positive changes.

More agreement was expressed on the second statement: *Despite the fact that effects of climate change on public health are larger in developing countries, the effects of climate change on health in the Netherlands will be noticeable.* The larger part of the respondents agreed with this statement; 85% agreed versus 15% disagreed. Comments on this statement were:

- Particularly in the measures that have to be undertaken, not in the ultimate effect;
- I expect that these effects are not measurable, they disappear statistically speaking;
- I think the near future will surely bring extreme weather conditions that will predominantly cause inconvenience through floods;
- It is unclear whether these effects will be positive or negative;
- The amount of imported diseases (from developing countries) in the Netherlands will be noticeable. Unfortunately the increasing mobility will only encourage this. The effect of climate change alone will be hard to measure;
- Especially storms and contagious diseases.

The third statement was: *Because of different globalisation processes and a world wide increase of mobility the Netherlands will feel the indirect effects of climate change stronger (through the effects that take place in other parts of the world that can influence the Dutch public health) than the direct effects. For example the outbreak of an epidemic of the West –Nile virus elsewhere that increases the chance of an outbreak in the Netherlands.* Of the respondents, 83% answered that they agreed with this statement, whereas 17% responded that they disagreed with it. The following two comments were given:

- I think that those (indirect) effects are even harder to measure than direct effects;

- It is unclear whether that will be positive or negative

Accordingly it was stated that *there is a real chance of a malaria outbreak in the coming decades in the Netherlands.* Almost all respondents disagreed; 92% disagreed versus 8% agreed. Several comments were given on this statement, which are listed below:

- This is impossible due to social economic circumstances;
- The right form of malaria can not survive here;
- Based on the current situation we can calculate that the chance of a malaria epidemic is negligible; the ideal circumstances are not there and the vector density is too low. Also our current situation is unfavourable for malaria transmission: previously close contact between man and cattle used to make the malaria mosquito sting humans instead of the cattle (the primary host);
- The non-endemic malaria versions do not have a chance in the Netherlands in the future;
- the Netherlands have financial resources to give priority to pest control and prevent epidemics (like in Florida-USA);
- the Netherlands naturally has a climate that makes malaria transmission possible. A warmer climate does not enlarge the chance of an epidemic;
- Think of the "Grensmaasproject" where warm stagnant water holes occur filled with polluted water of the river Meuse. This could be a favourable condition for the spread of some diseases like, for example, malaria.

The last statement was: *With limited extra investments the Netherlands will be able to undo the health effects of climate change.* There was less conformity among the respondents on this; 58% agreed and 42% disagreed. This disagreement also shows from the comments, which are listed below:

- Investments are relatively small in comparison with other countries and other sectors in the Netherlands;
- Globalisation also requires investment elsewhere;
- We will have to put money in education. Dependent on this we will have to decide whether extra investments are necessary:
- In a well devolved health care system, relatively not much extra has to be invested to cope with the expected effects;
- Extra investments in the up-levelling of dikes and coastal works seem necessary;
- It will cost much extra, for example the up levelling of dikes and drinking water supply.

Tourism & recreation

Figure 4.31 shows the response to the question: *What are the most important effects on tourism and recreation related to climate change?* In the questionnaire, all five sources of effects were on average considered almost equally important. The effects of sea level rise were the ones considered most important, especially through damage to beaches. The level of consensus varied considerably, being by far the highest for the effects of temperature change and the lowest for the effects of extreme weather events.

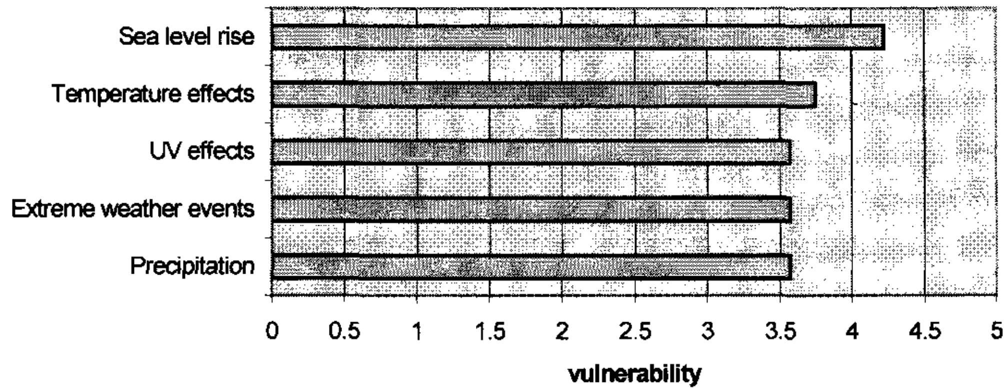


Figure 4.31 Relative importance of the effects of climate change on tourism and recreation (vulnerability index 1-5).

Besides climate change, developments in the other sectors also have an effect on tourism and recreation. The respondents were asked *about the influence of the other sectors on the tourism and recreation sector*. The results of the questionnaire showed the following influences of natural systems, land use, the economic sectors and human health on tourism and recreation:

- Natural systems: Land and water are considered to be building blocks of tourism. If the landscape becomes less attractive (for example because of urbanisation), it may have a negative influence on tourist experiences. Nature development and a higher diversity and quality of the landscape will positively influence outdoor recreation. One of the respondents pointed out that tourism adjusts rapidly to local circumstances. The features of the natural system do not matter for the volume of tourism; they are building blocks, but not major determinants. Respondents also pointed at the influence of water quality and sea level rise on tourism, in combination with the domestic water storage capacity.
- Land use and fisheries: It is generally expected that agriculture will give way for other kinds of land usage. Some expect that this will result in more woodlands and recreation areas, which will create possibilities for outdoor recreation. This corresponds with the growing trend of outdoor activities. Others expect, on the other hand, that agricultural areas will disappear in favour of industrial areas, motorways and residential areas; in this case there would not be more space available for recreation. Ago-tourism would turn into a very exclusive product.
- Economic sectors: Congestion and accessibility are recurrent themes. Mobility growth goes hand in hand with a deterioration of recreational experience; people will stay close to home if they know they will otherwise get stuck in a

traffic jam. Good infrastructure and accessibility are important for the Netherlands' competitive position. It is expected that the insurance contribution will rise because of storm damage. One of the respondents also notes that an additional rise of income will go hand in hand with more recreation.

- Health: On the influence of health on recreation and tourism the opinions seem to differ. According to some, health is increasingly important for tourism and recreation and creates a source of innovation. Others believe that people rarely decide consciously whether or not to undertake recreational activities because of health reasons. "One would expect that people take diseases or accidents into consideration, but they do not." One respondent takes an intermediate position and believes that estimates on health risks are strongly determined by experience and proven effects (and not by experts' opinion). In the future changes may occur in certain health effects, like the risk to get the Lyme disease because of growing thick populations.

The second part of the questionnaire addressed the options to adapt to the possible impacts on tourism and recreation due to climate change in the Netherlands. Figure 4.32 shows the results concerning the effectiveness of the adaptation options that were given in the questionnaire. The answers of the respondents indicate that dealing with the impacts of climate change is not yet considered to be a priority in the tourism sector. Currently the main issues of interest are economic factors and mobility problems. Still there are ideas on the urgency of adaptation options. A number of respondents state that diversification is most urgent, even in the absence climate change. Diversification does make the Netherlands less vulnerable for change in general and leads to a better usage of the existing capacity throughout the year. One of the respondents notes that diversification does not only have positive sides, because the limitation of risks also leads to a more moderate result. Not bad, but also not very good. Besides diversification also the assimilation of the growing demand for recreation is an important theme. According to some respondents the solution lies in the expansion of recreation areas. One of the respondents notes that this may generate money to carry out other measures. Others want to stimulate city tours, because it takes the pressure off other forms of recreation and creates space to realise adaptations. One of the respondents points at education as the most important measure. If climate becomes more intense this could become effective, since tourists are the most sensitive for information during crisis situations.

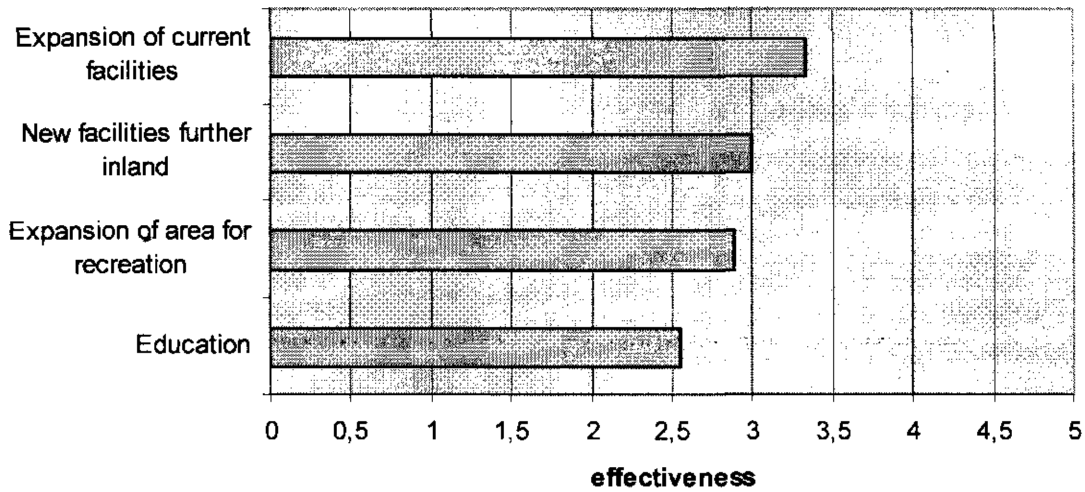


Figure 4.32 The effectiveness of adaptation to climatic changes, ranging from ineffective (0) to very effective (5).

The questionnaire also included a section about *the influence of the adaptation options against the impact on tourism and recreation on the other sectors.* Only half of the respondents have filled out these questions. Some indicate that they found the influence of adaptation options insignificant or speculative. The results of the questionnaire showed the following influences of the adaptations on natural systems, land use, the economic sectors and human health:

- Natural systems: A number of respondents comment that the movement of facilities away from the see and the opening of new recreation areas have a negative effect on ecosystems. There will be pressure on areas that are under little pressure today.
- Land use and fisheries: All options that lead to extra spatial claims (for example the location of facilities, the expansion of recreation areas and the extended capacity of existing facilities further inland) naturally cause effects on land use. Land taken out of agricultural and forestry use, can be used for recreation, which can be both positive and negative from a landscape perspective. Besides that new natural landscapes can develop on the coast because of disappearing tourist facilities.
- Economic sectors: Locating the recreation facilities further inland may lead to a reduction of the needs for mobility. On the other hand the growth of outdoor recreation will lead to more transport on the short and medium distance and therefor possibly to more congestion. The increase of transport will lead to larger energy consumption. Also in connection to the increase of indoor activities a larger energy consumption is expected. One of the respondents expects indoor activities to be less risky; the insurance premium may therefore decrease.

- Health: To many respondents this question appeared to be unclear. Only some of them made the connection with health effects, but these effects were considered to be too complex and too hard to predict.

The effects of climate change on tourism and recreation themselves could also have an influence on the sectors of special attention. The questionnaire included a question regarding this subject. The answers to this question are listed below:
- One of the respondents notes that ecosystems just behind the beach will change because of the inland shift of the beaches. Besides that the rise in tourist numbers will have impacts on the quality of nature in the Netherlands.
- The growth of recreation needs will lead to a larger spatial claim of tourism and recreation, at the cost of agriculture and forestry.
- According to several respondents more damage to tourist facilities will result in a higher need for insurance and higher insurance premiums. These same respondents also see a connection between the growing numbers of tourists and the energy and transportation sectors in the Netherlands; after all they will cause more transportation and therefor more energy consumption.
- One of the respondents notes that an increase in outdoor recreation may lead to more health problems because of ozone.

At the end of the questionnaire, the respondents were asked to give there opinion on four given statements on tourism, recreation and climate change. The first statement was: *Climate change will put high pressure on beach tourism in the Netherlands*; 78% of the respondents agreed and 22% disagreed. The respondents make clear that climate change does not have a univocal effect on beach tourism. Coastal erosion due to the sea level rise and storms has an effect on the beaches and therefore negatively affect the tourist potential. The dangers of exposure to UV radiation can be added to that as a negative factor. On the other hand the temperature rise makes the beach more attractive for tourism.
The second statement was: *The net-effect of climate change for tourism and recreation in the Netherlands will be positive.* 80% answered that they agreed with this statement, while 20% responded that they disagreed with it. Several respondents note that it is hard to say something about this. One of respondents remarks that it is hard to determine whether the average temperature will increase or decrease. Moreover, there are many (unpredictable) processes other than climate change that determine the outcome. Some of the respondents indeed expect a positive net effect, because of the temperature rise; the negative effects of climate change can largely be countered with technical measures.
There was more agreement on the third statement, which was: *The diversification of tourism-supply and -demand is the most robust answer to the uncertainties associated with the effects of climate change.* All respondents agreed with this statement, but for different reasons. Diversification is seen as a method to spread the risks and to deal with uncertainties, but also as a competitive edge in a world that is starting to look more and more uniform. Still there are respondents that are less positive about diversification. Ultimately everything circles around what the

tourist wants; we can not just determine that diversification is the answer. Besides that diversification is a safe, but also a mediocre solution: the risk of failure is reduced, but so are the chances on a great success.
The last statement was: *Because of the higher chances of rain during the Dutch summer, climate change will become an important driving force behind the trend of holiday's abroad.*
The majority of the respondents agreed: 70% versus 30% who disagreed. Many respondents agree that rain has some influence, but stress its relative importance. First of all rain is only one of the many factors behind a tourists choice for a destination. Secondly, the relative situation of the Netherlands compared to other holiday destinations is important. If precipitation increases in the whole of Western Europe, the effect on the Netherlands will not be very large. Please note that precipitation in summer may be reduced as a result of climate change.

4.5.2 Workshop

A) Introduction

The workshop aimed to make an inventory of what effects climate change could have on health, recreation and tourism in the Netherlands. Also the workshop aim to gain insight in the influences on other sectors and the possibilities to adjust health, recreation and tourism to climate change.

One is aware that climate change is only one of the driving forces. Climate change also does not impact the Netherlands only but will have worldwide effects. During the workshop it is assumed that climate change will occur as described in the climate scenario developed for this project and presented at the workshop.

According to one of the participants (health, recreation and tourism) a temperature rise of two degrees is quite limited; already there are such differences in the Netherlands: the Brabant climate would shift to Friesland. We have to bear in mind that we are talking about averages here; the extremes are also expected to rise.

The workshop was divided in three sessions. In the first session attention was given to the possible effects of climate change. Session two focused on the interactions with other areas of special attention (economic sectors, natural systems, and land use). The adaptation options were dealt with in session three.

In order to assess the opinions of the participants, sticker sessions and post-its sessions were carried out. On the flip charts a number of possible answers are given per session. In session 1 these answers were for example a number of possible effects of climate change, as they appeared from the questionnaire. The participants all had a limited number of stickers (60 in total) to express their preference in the different sessions. There was also a possibility to add extra categories through the post-its. A complete overview of the sticker sessions can be found in the appendix II. The corresponding tables will be referred to in the text.

B) Session 1: The effects of climate change

Human health (see appendix II – table 1)
During the sticker session not much attention was given to the indoor climate (see the low score of glycyphagus and fungus at home in table 1 in the appendix), research proves however that moist problems at home have important effects on health. It is questionable whether there is an important relation between climate change and moisture at home.

During the sticker session there was, just like in the questionnaire, much attention for pollen and hay fever. The hayfever season will start earlier and because of the higher temperatures more pollen will be in the air. During the discussion it was mentioned that bronchial complaints particularly relate to air pollution. Climate change reinforces air pollution; higher temperatures lead to a higher production of ozone in the living areas and more harmful emissions as a result of an increasing use of air conditioning. Climate change decelerates the recovery of the ozone layer. UV-radiation is also more effective with higher temperatures and causes for a higher risk on skin cancer.

It is believed that in the water not only the concentrations of blue algae increase but that the quality of the water gets worse in general. Because of more people that are involved in outdoor recreation and swimming this could lead to health problems. In the course of the day the quality of the swimming water was taken into consideration in stead of only the concentration of blue algae.

A higher temperature during the winter leads to less mortality while a high temperature in the summer causes more mortality. An increase in extreme temperatures (cold or hot) will lead to more mortality.

The additional post-its proved that the participants think that especially the physical effects, like storm and floods, have to be looked at. The number of victims may be small but the effects of the incidents are very serious.

The group agreed upon that it is not favourable to classify every effect in order of importance. Such a classification is too much dependent on the construction of the group and the pre-selection of the project team.

Tourism & recreation (see appendix II – table 2)
The participants claimed that in the pre-selection too much attention goes out to the effects on the beach; this may be caused by the automatic association of tourism with the beach. The effects of recreation and tourism during the winter and the effects of outdoor day recreation are still under exposed.

Because of the higher temperatures less typical winter recreation (ice-skating) will be possible in the Netherlands. People will search for alternatives or travel to foreign countries. In case of bad weather during the spring there is usually an increase in the number of summer holidays in foreign countries. Maybe for the winter season we may expect something similar in the future, when the winter turns into an extension of the autumn.

Day recreation is very extensive in the Netherlands. Higher temperatures will probably not lead to more recreation (people are restless, they have to do something) but it may lead to a shift in activities. On beautiful days many people will want to go to the Veluwe or the coast.

The beach will probably not be endangered. The coastline is not fixed: there are constant processes of erosion and sedimentation. Tourist facilities on the coast (like restaurants) may get in to trouble because of coastal erosion in extreme conditions.

Weather extremes will probably occur in a more unexpected manner. This may lead to more victims and water sports enthusiasts that are unpleasantly surprised by extreme whether events.

To structure the thoughts on the influence of climate change on tourism and recreation it was suggested that it could be useful to make use of the following simplified contradictions:

- tourism vs. day recreation;
- indoor vs. outdoor recreation;
- domestic vs. international tourism;
- snow tourism vs. sun tourism.

Accordingly, it was decided to use these terms to clarify the remaining discussions during the workshop.

Tourism is a fashionable industry and very much dependent on the economic structure. Especially young people travel. The Dutch are very hectic. Tourism trends are hard to predict and the influence of climate change on tourism is relatively small, compared to other determining factors. It is even hard to say whether climate change will turn out positive or negative for the Netherlands.

B) Session 2: interactions

Human health (see appendix II – table 3 and 4)
The sticker session showed a strong expected interaction with the economic sectors. Because of health effects the pressure rises to decrease the emissions of pollutants. However, higher energy consumption due to the increase in the use of air-conditioning during the summer results in an increase of emissions, which means a lower air quality. The most important effects of climate change may reach the Netherlands through other countries, maybe even through migration.

Vector-born diseases contain risks for people working outdoors and may lead to higher insurance premiums. There is an increase of risk for the Lyme disease. Climate change causes for more ticks and more outdoor recreation, so the number of infected day tourists will probably increase. Maybe these developments calls for adaptations in land use. There is also a chance that other diseases reach the Netherlands. The Hanta virus, for example, marches on from the Balkan and Italy. Because of nature development and climate change the conditions for the transit hosts are favourable. Besides that the mobility leads to an accelerating spread of the disease.

There is an important interaction between the water quality and recreation. Climate change leads to both poor water quality and more day tourists. The pressure on the swimming water will only increase and negative swimming advice is already waved off. Heat stress will probably lead to a search for ways to cool down, for example on the beach.

Tourism & recreation (see appendix II – table 5 and 6)
The growth of outdoor recreation will influence natural systems and land use. The pressure on the fragile dune ecosystems and the Veluwe will increase. Besides that there is the question of spatial allocation. The growing recreation sector will claim new recreation areas. This may stimulate the conservation of existing areas and the development of new areas.

An increase of recreation will lead to larger water consumption. Particularly golf courses demand a lot of water; this may have negative impacts for other sectors and natural systems.

During the sticker session several relations are laid with health. The ozone problem causes health risks and water sports will become more dangerous because of weather extremes. A growing chance on these weather extremes may lead to higher insurance premiums, for example for tourist facilities on the coast.

C) Session 3: adaptations

This session does not only deal with the effectiveness of adaptation options but also with the feasibility: what are the constraints?

Human health (see appendix II – table 7)
The discussion during the sticker session proved that the effect of education is strongly dependent on the risk perception. Only if people consider something to be risky they will be sensitive for education or warnings. Also the time that passes between cause and impact is important. Education for allergy is more effective normally because people notice the effect directly. In the case of the quality of swimming water certificates may be attributed as a means to realise improvement. Safe swimming areas will be easier to detect.

Concerning glycyphagus problems ventilation is a good adaptation often. The higher temperatures during the winter probably will moisturise the carpet. Ventilation can help; now isolation is emphasised.

Adaptations to the negative effects of climate change can be found in the limitation of pollution, for example by limiting the number of cars in city centres. Also the average concentration of ozone has to be reduced.

Tourism & recreation (see appendix II – table 8)
It generally becomes clear that the costs are an important obstacle for adaptation in the tourism sector; the profit margins are already limited in this sector.

The relocation of facilities on the coast may be possible, but still many drawbacks are encountered. It is expensive, you can not just build anywhere and the proprietors prefer to be as close to the beach as possible. Maybe there is a possibility to construct facilities off shore.

The possibilities for extending recreation areas leads to discussions. According to one of the participants, recreational land claims cannot compete with economic expansion. The economy is stronger than recreation, which will limit the amount of land available for recreation. Others do see options for utilising agricultural land for recreation purposes. One can think of possible combinations between water storage and recreation, and agriculture and nature.

Many adaptation options will cause extra pressure on the available land: there will be a fight for land (see the Fifth Note on Spatial Planning), stirred up by climate change. Tourism and recreation, on its turn, do not only need nature areas but also land for built facilities.

4.5.3 Conclusions and discussion for health, tourism & recreation

An important question that we have to ask ourselves is whether healthcare is capable of dealing with the health effects of climate change.

It is emphasised that the workshop functions as a start off for indicating effects of climate change; no encouraging spearheads for policy have been provided. We have seen that there is a fairly clear image of what will happen, however a lot is dependent on the regional context. There is a lot of knowledge of a very speculative nature. We have to aim at developing assessable hypotheses. The effects of climate change have to be mapped more systematically.

Among the participants the opinions differed with regards to the importance of climate change compared to other developments. Based on the discussions and conclusions drawn from the workshop some of the participants claim that the effects of climate change turn out better than expected: the Netherlands will be able to adapt easily. Others do see dangers, especially when talking about the effects of weather extremes and non-marginal climate changes, like the reversal of the warm North Atlantic Gulf Stream. In the last example the effects of climate change would be very determining, however during the workshop the impacts of this scenario have not been elaborated.

At the end of the questionnaire some respondents remark that climate change is not considered to be very important yet for the tourism-recreation sector. The attention goes out to economic and mobility dynamics. Because of the large share of small and medium sized businesses, short-term considerations are determining. The influence of climate change is considered not to be very big in the Netherlands because of the economic position and technological adaptation options. Of greater importance is the contribution of the Netherlands to developments elsewhere.

5 An integrated assessment: the key-issues

5.1 Introduction

In the previous chapters we have described a large number of climate change impacts and adaptation options in the Netherlands for the 11 sectors of this study. Because many elements and processes in both natural systems and human society are closely linked, climate induced impacts and activities aimed at adapting to the changes in one sector might have consequences for other sectors. Figure 5.1 gives an overview of some of the most important impacts for 'Human Society' and for 'Natural Systems', and some of the most important adaptations options and interactions. In the center of the figure the 'Key issues' are represented, that were identified in the project. These key-issues are: safety (section 5.2.1), water availability (section 5.2.2), biodiversity (section 5.2.3), energy (section 5.2.4), food and fibre production (section 5.2.5), health (section 5.2.6) land use change and spatial planning (section 5.2.7).

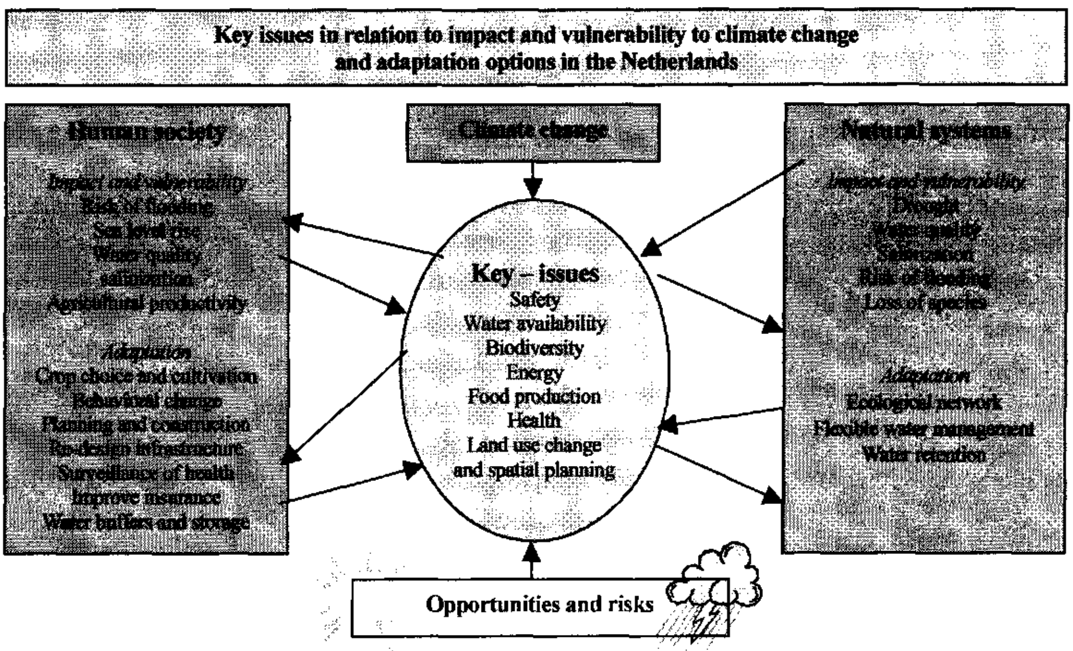


Figure 5.1 Key issues in relation to impacts and vulnerability to climate change and adaptation options for Human society and Natural systems in the Netherlands. This diagram illustrates some of the impacts and adaptations that were identified within 'Human society' and 'Natural systems' and how they translate into seven key issues where adaptation is considered by a forum of scientists and stakeholders. The diagram further illustrates that many interactions were identified with climate change and opportunities and risks.

To visualise and identify these key issues and the many existing interactions between impacts and adaptation options within different sectors, we have created an integration framework in the form of a fully linked website: www.dow.wau.nl/msa/nopimpact.htm

The structure of the website is given in figure 5.2. The computer screen of the website is built up in several frames. Frame 1 is the main navigation frame of the whole site as its content does not change during the navigation. It provides direct links to the different sectors discussed during the project from where an overview is given to climate change impacts for that specific sector. Frame 1 also provides a search tool to scan the whole integration module for key words. Finally, this frame provides the visitor the possibility to write down notes or to copy text from the integration website in a text box while navigating through the website. After the navigation the visitor can print the selected notes.

Frames 2 to 4 enable the visitor to get an overview of the existing interactions between impacts and adaptation options for those sectors they are interested in. In Frame 1 the visitor selects one of the sectors after which a list of issues (climate change impacts of this sector) is provided. After selecting an issue, Frame 3 provides a description of the selected issue. In most cases, many other issues (within the same sector or in another sector) influence the climate change impact. Of these other issues, several are influenced by climate change themselves. Especially these interactions are adding to the complexity of the climate change problem and are important to visualise. Therefore, underneath the description of the impact, a list of 'causes' is given. Furthermore, the climate change impact described at the top of Frame 3 might also influence other issues. Therefore, next to the list of 'causes' a list of 'consequences' is given. Only those causes and consequences are included in the list that are part of one of the sectors discussed, and which are influenced themselves by climate change in a direct or indirect way.

By clicking on an issue in the list of 'causes', Frame 2 provides a description of the issue selected. By clicking on an issue in the list of 'consequences', Frame 4 provides a description of the issue selected. This structure enables the visitor to quickly get an overview of the issues involved. By clicking on the issues in Frames 2 and 4, the selected issue will become the central one in Frame 3. Finally, underneath the lists of 'causes' and 'consequences', Frame 3 provides an overview of adaptation options (if identified during the project).

The integration framework provides a new tool to quickly analyse the complexity of climate change by visualising many linkages of different issues within and between different sectors. This website could form the basis for future studies and activities aimed at integration of climate change impacts and adaptation options.

To give a more detailed insight of the many interactions that occur, the integration aspects for a number of key-issues identified during this study have been worked out in more detail (Key issues, see figure 5.1)

<table>
<tr><td colspan="4">Frame 1:
Header which also includes links to other parts of the website</td></tr>
<tr><td rowspan="4">Frame 2:
Section with causes of change

Issue 1
Several rows with a description of the impact (same as the description text in frame 3). This is at the same time a link to a full description of the factor. By clicking it will be loaded in Frame 3.

Issue 2

Other issues are covered in a similar way.</td><td colspan="2">Frame 3:
Title of the impact

Description
Several rows with a description of the impact</td><td rowspan="4">Frame 4:
Section with consequences of change

Issue 1
Several rows with a description of the impact (same as the description text in frame 3).
This is at the same time a link to a full description of the factor. By clicking it will be loaded in Frame 3.

Issue 2

Other issues are covered in a similar way.</td></tr>
<tr><td>Causes
List of links to issues that influence the impact described above. By clicking on a link the issue will be displayed in Frame 2.</td><td>Consequences
List of links to issues that are influenced by a change of the impact as described above. By clicking on a link the issue will be displayed in Frame 4.</td></tr>
<tr><td colspan="2">Expected impact of climate change
Description of the expected impact under a change in climate.</td></tr>
<tr><td colspan="2">Adaptation options
Overview of potential adaptation options related to this impact.</td></tr>
</table>

Figure 5.2 Main structure of the integration section of the website on integration.

A set of selected adaptation options and interactions between sectors that were identified in the dialogue of the project, have been ranked to fit seven key issues that were considered as most relevant in the project (table 5.1). Most of the adaptation options are relevant to more than just on sector or to tree of four sectors. This illustrates the complexity of the adaptations that were identified. Furthermore, impacts to water resources and responses are crucial in many of the adaptation options.

Table 5.1 Selected adaptation options for 7 key issues and 4 sectors in the Netherlands (√ notes the sector that identified the option and • notes for which sector(s) interactions have been identified.

	Sector			
Key issues and adaption options	**Natural systems**	**Landuse & fisheries**	**Economy**	**Health & tourism**
Safety				
☐ Increase of water buffering areas and basins	√	•	•	•
☐ Improve insurance against the impact of extreme weather events in both public and private sector.		•	√	
☐ Adapt coastal defense and water management to prevent damage to economical infrastructure and tourist facilities	•	•	√	√
Water availability				
☐ Flexible water table management and optimalisation of water retention in soils and ditches (note: also adaptation to impact on safety)	√	•	•	•
☐ Flush saline seepage water with freshwater	•	√	•	•
☐ Land use planning to allow for water management	•	•	√	•
Biodiversity				
☐ Accelerated implementation of the ecological network ("more space for nature")	√	•	•	•
☐ Increase possibiulities for dynamics in the coastal zone	√	•	•	•
☐ Extensification of agriculture	√	•		
Energy				
☐ Change land use planning to allow for sustainable energy production	•	•	√	
☐ Exploit the opportunities of changed climate for sustainable energy	•	•	√	
Food and fiber production				
☐ Adjust genotype or variety of crops in agriculture and species in forestry	•	√	•	
☐ Crop and rotation choice in agriculture or species choice in forestry		√	•	•
☐ Adjust farm (pests and diseases, soil cultivation, water) or forest (water) management	•	√	•	
☐ Better forecast of weather extremes for agriculture		√	•	•
Health				
☐ Efforts to reduce social and economic disparities			•	√
☐ Provide incentives for behavioral change for health aspects (e.g. UV)			•	√
☐ Use of technical protective devices			•	√
☐ Climate-related construction and urban planning			•	√
☐ 'Weather-watch' warning systems		•		√
Competition for space and land				
☐ Adapt infrastructure and real estate to changed climate (e.g. extreme weather events)		•	√	
☐ Change land use planning to allow for water management and sustainable energy	•	•	√	•
☐ Evaluate planning and location of mussel banks	•	√		•
☐ Stimulation of tourism & recreational that take the expected climatic circumstances into account	•	•	•	√
☐ Re-allocation of human activities towards sea				
☐ Diversification of tourism	•	•	•	√

5.2 Key issues

5.2.1 Safety in the coastal zone and the riverine areas

Safety: exposure and sensitivity[15] *to climate change: regional differences*
Riverine and coastal communities in the Netherlands are the most sensitive regions to climate change in relation to safety. In particular the coastal zone is sensitive to climate change because this region is exposed to changed precipitation patterns and sea level rise. In addition, the coastal zone is more sensitive to climate change because soil subsidence occurs cause by land use. The riverine region is sensitive to changed precipitation patterns affecting river discharges. In addition to possible human toll, potential economic damages are high and may increase. Economic and population growth will probably continue in the 21st century in the Netherlands (chapter 2).
It is difficult to maintain a (semi-) natural dynamic and safe coastline, given prolonged current trends of urbanisation combined with sealevel rise. Limited space combined with environmental law opened the discussion to expand economic activities in the North Sea. However, urban and industrial developments at sea may have impact on morphological processes (sedimentation and erosion), with consequences for the robustness of the coastal protection system. As a result, the Dutch coastline may become more sensitive to climate change, both from a socio-economic (safety) and ecological point a view (biodiversity).
In the river valleys of the rivers Meuse, Rhine and Scheldt the risk of floods in winter and spring but also low water tables in summer (section 5.2.2) will increase. Globally the cost of weather-related events has risen rapidly in the last decades despite improvements in infrastructure and disaster preparedness. This sensitivity for flooding and impacts of extreme weather events is likely to have significant influence on the insurance industry, for those risks that are covered. For other risk categories a reconsideration of public compensation schemes will be needed.

Adaptations and interactions within the coastal zone
The most important adaptation options and interactions to ensure safety are: 'Increase of water buffering areas and basins','Adapt water management to prevent damage to economic sectors', 'Improve insurance against the impact of extreme weather events in both public and private sector' and 'proctection of tourist facilities on the coast' (table 5.1). If regional specific implemented the optimalisation of wate retention in soils and ditches can also be an adaptation to increased flooding risks. This adaptation is also an adaptation to increased summer drought (section 5.2.2).

[15] *Senssitivity* is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. Climate-related stimuli encompass all the elements of climate change, including mean climate variability, and the frequency and magnitude of extremes. The effect may be direct or indirect. *Vulnerability* is the degree to which a system is susceptible to, or to cope with, adverse effects of climate change, including climate variability and extremes. Vulknerability is a function of the character, magnitude and rate of climate change and variation to which a systems is exposed, its sensitivity and its adaptive capacity (IPCC, 2001).

- *'Increase of water buffering areas and basins'*

In general this adaptation option is not favourite by most of the stakeholders. However, a lot of the stakeholders consider this option is inevitably, because measures like 'optimalisation of the water retention capacity' upstream and technical adaptation options downstream (dikes and pumping capacity) will be insufficient to mitigate increasing river discharges. The main constraint is scarcity of space within the Netherlands (section 5.2.7). In emergency floodplains it is not possible to allocate powering stations or capital intensive infrastructure and buildings. Water quality problems might occur if urban water buffering areas/systems are insufficient. Also from an ecological point a view this adaptation option is not ideal: on a relatively small surface in the (emergency) floodplains unnatural and unpredictable hydrological dynamics will occur. This, in combination with current water quality (nutrients) of the rivers, will result into low natural values from a conservation perspective. Although natural values in water buffering areas might be low from a conservationist point of a view, they are sufficient for the recreational function of these areas. Furthermore, the nutrient richness of the water within the buffering areas creates chances for biomass production (reedbeds, willows), water buffering areas contribute to the openness of the landscape. The water buffering areas contribute to groundwater recharge, as a result less water (with other water quality) from outside the regional hydrological system is necessary to recharge the groundwater stock (see also section 5.2.2).

- *' Improve insurance against the impact of extreme weather events in both public and private sector'*

As a first priority a clear distinction between the role of the government and the role of the insurance companies should be made and implemented. The government should intervene in the insurance market as least as possible, and should focus mainly on the organisation and coercion of national solidarity and the collection of sufficient tax revenue. Also the government can anticipate more than she does now. The construction of real estate in riverbeds, for example, can be treated as government failure.

Concerning the reduction of losses resulting from floodings (at the moment not insurable, only some compensation by the government), the insurance companies should especially prevent adverse selection. One other possibility is to apply premium differentiation for risk areas, not only for current risk areas, but also for future risk areas. Therefore both well-defined conditions and risk management are of importance. Experts expect increase in demand for insurance, hence the insurable risk will be solved by the insurance market itself. The insurance market is a reasonably well functioning market, which does not need much government intervention. The insurance companies could actively contribute to CO_2-reduction by green investment and (more) energy saving, especially as symbolic gesture to the society and the government.

- *'Adapt coastal defense and water management to prevent damage to economical infrastructure and tourist facilities'*

One should think of mainly technical measures like: increased pumping capacity towards the sea, strenghtening dikes, construction of engineering construction works into the sea in order to promote sedimentation processes and maintenance of the coastline by sand suppletion on the beaches and compensation of sand lossses in the deeper water.

This adaptation option was mainly proposed by stakeholders within the economic sectors, tourism and agriculture. These stakeholders consider that in addition to water retention upstream and water buffering areas along the rivers technical measures are necessary in the coastal zone. In contrary to policymakers within water management, who try to minimalise the use of technical measures. The most important Opportunity of technical measures is that it has minor consequences for current land use and physical planning. However, there is a risk of failure: if due a technical failure a pump does not work or a damm breaks through the economical consequences are very large for all sectors. Increased pumping capacity will require a lot of energy. Conservation interests along river beds will conflict with strengthening dikes

Adaptations within the riverine areas

Extension of space for the river in the floodplains in order to increase the safety of people and economic goods could be achieved in combination with the re-establishment of natural values, recreation focussed on natural values, exploitation of clay and grind and re-establishment of landscape and cultural values (Rijkswaterstaat, 2000). This could be done by implementing the floodplains within the ecological main structure of the Netherlands/Europe. Although there is a lot of support for this adaptation options, some Dutch environmental interest groups point out that more frequent (controlled) inundation of the riverine floodplains may have negative consequences for nature conservation within the floodplains, if water quality is not improved.

If the suggested adaptation policies are implemented, the landscape of the floodplains will become attractive for recreation. Public support for water management measures to adapt to climate change may increase as a result of increased attractiveness of the riverine regions for tourism. However, agriculture will loose fertile productive areas, and Van Tatenhove (1996) indicates that Dutch rural communities fear an increase of recreational potential of the rural area, because the rural area could become the garden for the urban area.

5.2.2 Water availability: quantity and quality

Water availability: exposure and sensitivity to climate change: regional differences

The high part of the Netherlands

Changes in precipitation regime (both for quantity and distribution) will have an impact on water availability (quantity and quality) in the high, mainly sandy, parts of the Netherlands. Water management in these areas should focus on the mitigation of water shortages during the summer period and on drainage in periods of excessive precipitation. Intensive precipitation during spring may result in increased leaching of nitrate to the groundwater. For areas sensitive to soil erosion (like province of Limburg), increased soil erosion will impact surface water quality.

The coastal zone

Water availability within the coastal zone is less sensitive for more frequent summer droughts compared to the high part of the Netherlands because the water retention capacity of clay soils is generally higher than the sandy soils in the higher parts of the Netherlands. However, in contrary to the higher part of the Netherlands, water availability in the coastal zone is also exposed to sea level rise.

Sealevel rise causes not only a physical threat but it will cause also salinisation of the groundwater resources in the lower coastal areas, thus affecting crop production and drinking water production.

Not only sea level rise and altered meteorological conditions near the land surface (Postma *et al.*, 1995) will result in salinisation of freshwater resources within the Dutch coastal zone in the 21st century. Scenarios for freshwater use (WIN, 2000) indicate also increased saltwater seepage as a result of soil subsidence, changed water management (Haringvliet sluices) drinking water use, recreational water use (golf courses), nature conservation (creation of more freshwater ecosystems) and agricultural water use in the 21st century. It is indicated that under the assumption that land use does not change, the freshwater demand may increase with 40% (WIN, 2000). The area in the central part of the Netherlands (with the Dutch name 'Utrechts-Hollands veenweide gebied') is particularly sensitive to climate change due to these accumulating pressures on freshwater resources.

These accumulating pressures may induce also changes in ecological processes and biodiversity in coastal saltwater marshes in the lower parts of the Netherlands. In the coastal zone of the Netherlands this impact is seen as positive, as this habitat has become scarce at the expense of fresh/brackish marshes as a result of the engineering works in the past (Zuiderzeewerken, Deltawerken). However, in the riverine region and in the high parts of the Netherlands (brooks) the ecological freshwater demand (the necessary amount of freshwater to maintain the ecological integrity of the created freshwater ecosystems) will increase because it is the intention of the Dutch government to increase the area for water in combination with the development of the ecological network in the Netherlands. Mosquitoe plagues may increase as a result of the re-establishment of (brackish) wetlands in the lower parts of the Netherlands due to sea level rise and changed water management (Haringvliet). Re-establisment of wetlands in combination with temperature rise (migration of southern plague species to the North), may have consequences for human health. Several diseases are transmitted by blood-feeding vectors, like mosquitoes. On the other hand, allocation of space for water and nature provides good opportunities for inland recreation (multifunctional land and water use).

The riverine regions

In summer more frequently low river discharges will occur, in addition to the impact of climate change on groundwater resources in the high parts of the Netherlands and sealevel rise in the coastal zone. Low flow events are relevant for various human activities such as drinking water exploitation, agricultural water use, cooling, industrial use and inland navigation (Van der Geijn *et al.*, 1998; Warmerdam *et al.*, in prep.). Natural systems may benefit if natural hydrological dynamics are re-established, but some negative impacts related to reduced water quality may occur.

Adaptation and interactions within the high parts of the Netherlands and riverine areas

The most often considered adaptation option is 'a more natural and flexible groundwater table management/ optimalisation of the the water retention capacity of soil-water systems. Also changes in land use planning is often mentioned (see section 5.2.7). It is perceived that *forestry* will profit from both adaptation options in relation to the production function and natural values (biodiversity conservation). In relation to *energy supply* positive (eg. less energy necessary for water management, chances for biomass production) and negative impacts (eg. less possibilities for hydropower) are mentioned. A negative impact on natural values could be that more nutrients (nitrates) could leach towards the groundwater). Experts emphasize that optimalisation of water retention capacity of soil and water systems to mitigate impacts of declining groundwater tables may result in higher flooding risks if regional specific characteristics are neglected. If the soil and water systems becomes saturated, during extreme events this may result in high peak floods in watersheds.

Adaptations and interactions within the coastal zone

Mainly agricultural stakeholders emphasize that measures like optimalisation of the water retention capacity of the system but also the increase of water buffering areas in order to reduce the risk of economical damage and safety risks (section 5.2.1) are not sufficient to solve these issues. In order to guarantee the agricultural function in the coastal zone, in addition technical measures are necessary, like the increase of the pumping capacity in the coastal zone and increase of flushing with freshwater to reduce saline seepage. Stakeholders within nature conservation, water management but also some stakeholders from argue that the problem of scarcity of freshwater is shifted towards other regional soil/water systems with consequences for ecological values, drinking water availability but also other agricultural sectors.

Implications for policy, institutions and management
Historically, water resource management plans have assumed a stable climate. Allocation frameworks, for example, are often based upon average precipitation and runoff patterns. In the Netherlands measures are currently taken to mitigate to intense flooding, mainly in winter and spring. But less attention is paid to policies that anticipate to long-term summer droughts, which may result in wide-scale crop failures, severe damage to infrastructure, human discomfort, and ecological degradation in both the coastal zone and high parts of the Netherlands.

International, national and local institutions responsible for water resource management are generally not closely linked to those responsible for addressing climate change nor with those responsible for disaster recovery. As a result, communication between these communities is sometimes lacking. New mechanisms will need to be developed to deal with the uncertainty of climate change impacts on water resources.

5.2.3 Biodiversity

In order to assess the impacts of climate change on biodiversity, and formulate effective adaptation options, insight in the many interactions with the other 'sectors' discussed in this report is essential. Agriculture, transportation, tourism and other human activities, often unintended, affect biodiversity in various ways (e.g. climate induced changes in land use and tourism will have positive or negative effects on biodiversity). On the other hand, impacts of climate change on biodiversity might affect socio-economic activities and human health. An example is the direct impact of an increase in temperature on the timing of phenological processes like start of leaf unfolding, caterpillar growth and nesting date. The difference in response results in numerous changes in species-species interactions like competition, predation and pollination. This, in turn, may lead to outbreaks of pests and diseases with many socio-economic consequences.

These kinds of interactions are often poorly understood and add significantly to the complexity of assessing climate change impacts on biodiversity, and formulate potential adaptation measures. An integrated approach is therefore essential and this section will present some examples of the main interactions between climate change impacts on biodiversity, and adaptation options, with economic activities, land use and human health.

Interactions related to impacts of climate change on biodiversity

Interactions with land use
The workshop and questionnaires indicated that the interactions between impacts of climate changes on natural systems and agricultural land use are very important.
Most of the examples provided below deal with the agricultural sector or fisheries:

- *Pests and diseases*: Changes in species distribution and abundance may lead to changes in agricultural pests and diseases, which directly affect agricultural production. Consequently, the use of pesticides may increase, which has repercussions for flora and fauna in both the agricultural areas and neighbouring natural habitats.

- *Freshwater competition*: Drought and higher temperatures in summer will substantially increase the agricultural water demand, which will result in a decrease in the groundwater table and the water level in ditches and canals, and an increase of the water inlet from rivers. Less water will be available for natural systems, which also have higher requirements because of the drought.
- *Erosion*: In contrast with the summer drought problems, an increase in the frequency and the intensity of rain in spring can cause erosion of agricultural fields resulting in changes of sedimentation of the waterways. Biodiversity in aquatic ecosystems will be negatively affected by the resulting changes in water quality.
- *Start of the growing season:* A good example of often-unexpected interactions between sectors is that an increase in temperature and the associated earlier start of the growing season will change the timing of agricultural activity on the land (e.g. first mowing date). The earlier start of mowing directly increases the mortality of insects and birds. This effect will decrease if the winters and springs become wetter, which restricts the use of combine-harvesters on the agricultural fields.
- *New crop varieties:* A change in climate conditions may result in the use of new crop varieties (for example, salt tolerant species) and changes in cultivation techniques (pesticide use, fertilisation). Depending on the crop choice and management this may have positive or negative consequences for biodiversity.
- *Forestry*: In addition to interactions with agriculture, there are also some interactions with forestry. A change in forest management towards more variety in species composition and forest structure (to prevent storm damage) will initially lead to an increase of biodiversity. In the long run, however, biodiversity at the landscape level will decrease if large forest areas develop, since forests edges have the highest biodiversity.
- *Fishery*: Climate change might change the population size of important commercial fish species and thereby changing the total catch (like e.g. the Sole).

Interactions with economic sectors (other than cultivation)

The impacts of climate change on the economic sectors included in this study (energy, transportation, industry and insurance) have limited additional consequences for biodiversity. One important interaction, however, might be the likely increase in demand for water from consumers and industry. This increase will enlarge the drought problem in natural systems during dry summer months.
Other indirect effects are hard to predict at this moment. For example, climate induced geographical changes in production of certain crops might lead more, or less, transportation with an associated increase or decrease of pressure on biodiversity.

Interactions with human health

Several interactions between biodiversity and the human health sector have been identified.

- Vector born diseases: A change in climate, and associated with this a change in presence of (wet) ecosystems, might increase the number of vector borne diseases within and outside the Netherlands (e.g. leishmaniasis, tick borne encephalitis). However, it is unlikely that 'tropical' diseases such as malaria or dengue would become re-established in Western Europe if control measures are maintained, although, the risk of localised (autochthonous) outbreaks of malaria may increase (Parry, 2000).
- Water quality: Changes in the water quality, due to higher temperatures can have major health impacts (e.g. by an increase in algae).
- Allergies: Finally, a temperature induced earlier start of the growing season might change the start of flowering and thus the start, length and intensity of the hayfever season (which is relevant for about 10% of the people in the Netherlands).

Interaction with recreation and tourism

An increase in temperature will probably increase the environmental pressure by outdoor recreation activities of Dutch people in the Netherlands. In addition, more people from foreign countries will spend their vacation in the Netherlands, which results in an increase in pressure on natural areas (especially concentrated on the beaches but also in forests and water sports areas). This could manifest itself in an increase in disturbance, water consumption, water pollution, air pollution, and damage to natural areas and more introduced species

The increase in recreational activity can also have beneficial effects for natural systems in case increased demand for natural systems leads to increased funding for preservation measures.

Interactions related to biodiversity adaptation measures

In chapter 4.1 two main types of adaptation measures where proposed to counteract possible climate change impacts on nature: 1) increase the quantity (e.g. expand surface area and network of protected areas) and 2) increase the quality of natural systems (e.g. extensification of agriculture, increase possibilities for dynamic coastal systems and reduce pressure from pollution).

Especially in the case of increasing the quantity, spatial planning is the central issue. The Ecological Main Structure (EMS) in the Netherlands is often mentioned as an important tool in giving natural systems the ability to adapt to climate, and other environmental changes. During the discussions at the workshop, it was stressed that the EMS can only be successful if it is established in a European context. More information on the functioning of the existing network, and more concrete planning of the future network are thereby essential.

At the workshop it was concluded that the extra space many sectors will claim might become a problem and that proper spatial planning, including multi-functional land use, is essential (see Section 5.7).

The possible impacts of adaptation measures in other sectors (e.g. water management or changes in cultivation methods and spatial needs) on biodiversity are discussed there.

5.2.4 Energy sector

In this section we discuss the main impacts and adaptation options for the energy sector and their relations with other sectors. Even though strictly speaking mitigation measures were not the main objective of this impact assessment of climate change, within the energy sector the most promising adaptation measures are closely linked to mitigation measures.

Energy demand

The total primary energy use in the Netherlands for the period of 1980-1995 shows a slight increase with some fluctuation in the mid-80's. The pattern of the energy demand is presented in Table 5.2. With continuation of the current trend, energy demand will keep on increasing in all sectors, especially in the transport sector. This expected increase in energy demand may facilitate implementation of more sustainable and efficient technologies and behaviour.

Table 5.2 Energy use per sector in PJ (after temperature correction) for the period 1980-1995 (sources: CBS 1980; 1985; 1990; 1995).

Sector	1980	1985	1990	1995	Average energy use (%)
Residential	516	461	458	468	17.2
Transport	349	350	400	444	13.9
Agriculture and horticulture	131	102	161	175	5.1
Industry	985	887	1010	1056	35.5
Other	233	289	304	311	10.3
Energy sector	348	325	350	381	12.7
Refineries	151	111	151	174	5.3
Others	8	-27	14	20	0.0
Total	2721	2498	2848	3029	100

The main sectors in energy use are industry, transport, energy and residential sectors. The chemical industry is to a large extent independent of climate change, but will be affected by mitigation policies, and increased energy prices. The transport and residential sector are expected to be more vulnerable.

Energy efficiency is an important factor in the analysis of energy trends. The energy intensity in the Netherlands decreased by 19% over the period 1980-1994, or 1.6% per year, as shown in table 5.3 (Farla and Blok, 1997).[16] The largest part of the total efficiency improvements was achieved in the period 1980-1985, when the high energy prices stimulated efficient use of energy. Since this period, the energy prices have been on a record low level, and the energy efficiency improvements have slowed down.

Table 5.3 The average annual decrease in the energy intensity per sectors in the period 1980-94 in the Netherlands.

	Average annual decrease in energy intensity (%)
Agriculture	2.5
Light industry	1.5
Heavy industry	1.7 - 2.0
Construction and Services	0.5 - 0.7
Households	2.9
Transport	0.4
Overall	**1.6**

Source: (Farla and Blok, 1997).

The main impacts to be expected are increased demand for air-conditioning in summer and reduced demand for space heating in winter. Milbank (1989) estimated that for Northern Europe a 4.5°C temperature rise would more than double the electricity consumption of air-conditioning systems. It is not expected that these changes have severe impacts on other sectors.

Many foresee a large impact on water management, because temperature rise and change in precipitation pattern may have considerable impact on water management. The Directorate-General of Public Works and Water Management (RWS) has calculated that the pumping capacity of the 'Afsluitdijk' has to be increased with a factor of 250 relative to the current capacity, given an expected sea level rise of 60cm (which is according to the 'middle' scenario of the Royal Netherlands Meteorological Institute (KNMI).

An increase in awareness of the impacts of climate change may stimulate the process of energy efficiency in industries, and in the residential sector.

Energy supply

Many renewable energy resources (such as wind and solar energy, biomass and hydropower) are strongly affected -positively and negatively- by climate change, more than conventional energy supply systems (such as fossil and nuclear energy) (IPCC, 1998). Together the renewable energy resources make up about 1% of the total Dutch primary energy demand in 2000.

[16] Overall, the primary energy consumption increased 9% between 1980 and 1994. In the same period the economy (GDP) grew with 35% (2.2% annually).

In the Netherlands the renewable energy is dominated by electricity generation in waste incineration plants (76%), which is basically independent of climate change. The remaining renewable energy resources in the Netherlands are wind (12%), biomass (8%) and other resources. Large mainly positive impacts of climate change are expected on wind power, followed by solar energy. The impact on biomass is uncertain.

It is expected that the growth in fossil fuel use will slow down, and even become negative, in favour of renewable energy sources. One reason for this development is because of policy measures focusing on reduction of greenhouse gases. Also an increase in occurrence of extreme weather events may hamper offshore oil and gas extraction.

Changes in energy supply as a result of climate change may have impacts on other sectors if biomass, solar and wind energy will play more important roles.

Interactions with respect to direct and indirect impacts of climate change on the energy sector

Interaction of energy demand with agriculture

Sustainable water management is essential for agriculture and a certain groundwater level should be maintained. In general the groundwater level is high in the Netherlands, and excessive precipitation will increase the current level. Water management will require more energy and the incurred costs necessary for adaptation need to be covered. Another water management related interaction is the need of agricultural firms for more energy for irrigation in summertime.

The energy use in agriculture is not significantly affected by climate change itself, but mitigation policies (e.g. higher energy prices) enhance the investment in higher energy efficient equipment. Energy demand in agriculture is dominated by the rapidly growing horticulture sub-sector with heated greenhouses.

Interaction of energy demand with tourism

Tourism is also a rapidly expanding sector in the Netherlands. Climate change might modify the tourism pattern, indirectly affecting the transport and energy demand. It is, however, unclear whether positive or negative impacts will dominate. Higher temperatures may stimulate more outdoor recreation, but could also reduce travelling to holiday destinations in tropical and sub-tropical countries. Mitigation policies (resulting in higher fuel prices) have slight impact on short distance travellers, but could have a stronger impact on long-distance travellers.

Interaction of energy demand with health sector

Several adaptation options - applied to avoid negative health impacts - require additional energy demand. Air-conditioning in buildings and vehicles can reduce the impacts of heat waves. Pumping equipment reduces the risk of flooding, to which the local population is vulnerable.

Mitigation policies and extension of sustainable energy may have positive impacts on health as a result of reduced air pollution.

Interaction of energy supply with other sectors
Mitigation options concern prevention or at least slowing down of further climate change by using less energy and renewable energy resources. Adaptation measures are relevant as well, as they enable us to anticipate on uncertain future events in order to reduce possible future damage.

The stakeholders foresee some, but not many, adaptation options in the energy sector itself, because sustainable energy is only possible to a limited extent in the Netherlands. The energy demand for biomass will increase and adaptation options are crop rotation, cultivation of crops with a high tolerance for extreme temperatures, drought or excessive precipitation.

Wind energy could expand as well, hence an increase in wind velocity will make more locations suitable for windmills. At the same time a reinforcement of the existing infrastructure is necessary to prevent damage from strong wind. Climate change could have a positive impact on solar energy. If the average sunshine increases it enhances the use of solar energy. However, uncertainties exist with respect to eventual cloud cover.

In order to be able to use wind and solar energy at a large scale, several investments are needed. Many consider it worthwhile to encourage the construction sector to incorporate the adaptation options for active and passive solar energy and the utilization of daylight.

Integration of adaptation and mitigation measures

In the previous section the impact and adaptation measures for the energy sector have been discussed.

The energy sector will be affected by a temperature rise only to a minor extent, but a higher risk is expected as a result of change in precipitation pattern and extreme weather events. Adaptation measures are needed and can be implemented in time as the Netherlands has sufficient financial resources and knowledge to adapt. However, these investments may not comply with the objective of the Dutch government to create a sustainable economic structure.

The potential negative implications of climate change also necessitate a wide range of mitigation measures including renewable energy, energy efficiency improvement, emission reduction of greenhouse gases and change in land-use planning to allow for water management and sustainable energy.

Most opportunities to reduce the demand for energy are to be found in behavioral adjustment and improved energy efficiency, which both can be stimulated not only through good marketing and energy labeling, but also through internalization of external effects in energy prices and a greener fiscal system.

On the energy demand side, the transport, construction, energy and household sectors have been identified as key sectors which are most apt to adaptation and mitigation measures.

National and international agreements about emission reduction targets, like the Kyoto protocol, may result in changed energy policies and energy management within industry, energy supply and transport. Management strategies based on a shift from fossil fuels to renewable energy sources may possibly lead to a greater efficiency as well, which in turn will lead to a decline in energy demand. The opportunities to provide energy at a large scale, are considered to be higher for wind energy than other sustainable energy sources, e.g. solar energy and biomass. The eventual composition of energy supply will mainly depend on the developments and structure of the energy market after liberalization. To ensure sufficient availability of sustainable energy sources government regulation is necessary. It is therefore essential to internalize externalities of CO_2-producing energy sources in the prices. The energy sector itself should stimulate the use of wind and solar energy as much as possible, considering both the risks and the opportunities of a changing climate.

5.2.5 Food and fibre production

Arable and animal farming are influenced by climate factors in both positive and negative ways and sensitive to direct (temperature, precipitation) and indirect effects (pests, water quality). Also, plant production is sensitive to the atmospheric concentration of CO_2 where mostly higher concentrations will increase production. In agriculture, farmers are used to managing their agro-ecosystems to deal with the day to day variation in weather and with the heterogeneity in environment. As such, agricultural shifts are likely as the climate changes and farmers will select new crop varieties and species that are better adapted to new climatic conditions. This is to a large extent normal agricultural practice and Dutch farmers have been highly successful in doing so given that they have adequate technical training and financial resources. However, current scientific insight in occurrence and frequency of extreme weather events and its consequences such as droughts, floods, frosts and pests and diseases is limited. This restricts an ecological and economic assessment of damage and costs.

Agricultural production depends on the availability of sufficient quantities and good quality water. Climate change will affect the water dynamics in several regions in the Netherlands. Stakeholders view saline water intrusion, excess winter discharge as the critical issues in climate change for agricultural production. Adaptation options for farmers depend on the regional availability of additional water for irrigation or flushing out saline water. Thus, farm level adaptation strategies to climate change will interact with regional issues on land and water claims in other sectors and regions, such as relocation of entire farms and other agricultural enterprises (see also section competition for space).

Current agricultural policies at both national and European level do strongly influence the adaptation agenda of the farmers. Climate change and possible shifts in crop choice and farm management options may conflict with other environmental goals, such as restricting fertilisation, irrigation and timing of soil management. Intensive summer rains may influence leaching. To allow farmers to adapt other policies may require to be reconsidered in the light of climate changes.

The adaptation capacity is determined by financial, technological and knowledge aspects. These include: profitability of activities, availability of adapted crop varieties, knowledge on the consequences of their choices and changes in management. Some of these depend on decisions by farmers themselves and financial institutions but others depend on decisions by policy makers and industries.

5.2.6 Health: direct and indirect impacts of temperature change

Broadly speaking, the various potential health effects of global climate change upon human health can be divided into direct and indirect effects, according to whether they occur predominantly via the impacts of climate variables upon human biology, or are mediated by climate-induced changes in other biological and biogeochemical systems. In healthy individuals, an efficient regulatory heat system enables the body to cope effectively with thermal stress. Temperatures exceeding comfortable limits, both in the cold and warm range, substantially increase the risk of (predominantly cardio-pulmonary) illness and deaths. Directly, an increase in mean summer and winter temperatures would mean a shift of these thermal related diseases and deaths. An increased frequency or severity of heat waves will also have a strong impact on these diseases. If extreme weather events (droughts, floods, storms, etc.) were to occur more frequently, increases in rates of deaths, injury, infectious disease and psychological disorder would result.

Many health impacts could also result from deterioration in physical, social and economic circumstances caused by rising sea levels, climate-related shortages of natural resources (e.g. fresh water), and impacts of climate change on population mobility and settlement. Conflicts may arise over decreasing environmental resources. The climate change process is associated with air pollution, since fossil fuel combustion produces various air pollutants. Furthermore, higher temperatures would enhance the production of various secondary air pollutants (e.g. ozone and particulates). As a consequence, there would be an increase in the frequency of allergic and cardiorespiratory disorders and deaths caused by these air pollutants.

The potential health impacts of climatic change are of uncertain dimension and somewhat unfamiliar context (see table 5.4). Some health impacts of global climate change can be predicted by reasonable extrapolation with simpler cause-effect models: for example, the change in the number of thermal-related deaths and serious illnesses as a result of a change in ambient air temperature. However, most impacts would not occur via the familiar toxicological mechanisms that mediate the effects of localized exposure to environmental pollutants. Rather, they would arise via more complex processes that result from disturbances of natural biogeochemical cycles, and would impinge on whole communities rather than on individuals. For example, changes in global climate may alter the distribution (altitude, latitude) of vector-borne infectious diseases, the supplies of fresh water, or agricultural yields. Further, climate change would not affect human health in isolation, but simultaneously and in conjunction with other ecological and demographic changes. The net impact of global atmospheric changes would therefore depend on various interactive phenomena: multiplicative exposure effects, feedback pathways, and differences in the vulnerability of (local) populations.

Table 5.4 Summary of known effects and uncertainties regarding some health impacts of climatic changes.

Health effect	Known effects	Uncertainties
Thermal stress	Mortality (especially cardiopulmonary) increases with cold and warm temperatures Older age groups and people with underlying organic disease are particularly vulnerable During heat waves mortality increases sharply	What is the balance between cold and heat related mortality changes? To what extent do heatwaves take their toll among terminal patients? What is the role of acclimatization of people to warmer climates?
Vector-borne diseases	Climate conditions (particularly temperate) necessary for some vector to thrive and for the micro organisms to multiply within the vectors are relatively well known	Indirect effects of climate change on vector borne disease, such as changes in vegetation, - agriculture, sea-level rise, or migration Effects of socio-economic development or resistance development
Water/food borne diseases	Survival of disease organisms (and insects which may spread them) is related to temperature Water-borne diseases most likely to occur in communities with poor water supply and sanitation Climate conditions affect water availability Increased rainfall affects transport of disease organisms	For many organisms the exact ambient conditions in which they survive and are transmitted are not known. Interaction with malnutrition is not well known.

The data imply that many of the health effects will be noticed in the Netherlands, though probably on a much smaller scale than in the tropics, for instance. The effects of temperature on mortality (predominantly cardiorespiratory) and the increases in frequency of allergic disorders, as a combined effect of increase in temperature and air pollution levels, may be assessed with reasonable confidence. However, some impacts, which may be of more importance in terms of illness and deaths, are less certain; for example, the effects of climate change on infectious disease transmission.

Main implications for other related sectors and trends
The selected adaptation strategies to reduce climate change induced health effects (table 5.1) all show strong interactions with the economic sector. This is primarily due because they all require economic investments. Some of them will require even considerable amounts of money. Secondly, most of these adaptation options could have an influence on the insurability of climate change related health risks. Efforts to reduce (urban) air pollution will also lead to transport constraints. Furthermore, infrastructural adaptations (e.g. spatial planning, uplevelling of dikes) may have a negative effect on flora, fauna and ecosystems.
It is important to note that there is a need to think more broadly than the health sector for effective interventions for many threats to public health. Therefore, awareness of the potential health impacts of climate change may have substantial implications for policy making in the various 'upstream' sectors (e.g. environment, industry, public water supply, construction and agriculture) that would mediate some of the effects of climate change. Public policies that reduce socio-economic and physical-environmental vulnerability are necessary for populations to adapt to climate change (McMichael and Kovats, 2000). Public agencies are, in most countries in Europe, the main stakeholders within the health sector. Health sector institutions and processes, however, are not able to eliminate health problems on their own. The task is multi-sectoral. A structured approach for cross-sectoral strategies and international co-operation is therefore required, entailing explicit reference to environmental health impact assessment of all policies.

Health impact assessment needs to be more fully integrated into environmental impact assessments. Intersectoral collaboration should be strengthened so that public health considerations are addressed in the implementation of adaptive strategies for climate change. Climate change is now being seen as a priority within the health sector. A declaration on climate change and health was recently signed at the recent Third Ministerial Conference on Environment and Health in Europe.

Water quality and water supply
High levels of water quality and water supply must be maintained under climate change, affecting both demand and supply. Other trends may also be important: for instance, increased urbanization concentrates water demand in certain areas which can lead to over exploitation of local water resources and increases the risk of microbiological contamination. Urbanization also increases the requirement for hygienic and efficient networks for the disposal of sewage (EEA/WHO, 1999).

Urban development
The trend for urbanization is continuing in Western Europe, as in the rest of the world, although growth is focusing on medium-size cities rather than the expansion of 'megacities'. Projection is that more 80% of the population of Europe will be living in cities by 2020 (WHO, 1997). Cities are associated with

many environmental problems that adversely affect health. In Western Europe, air quality is probably the major concern. Increases in thermal stress and air pollution in urban centers are likely to have a detrimental impact on local activities.

Tourism and leisure industry

Increases in domestic tourism are projected in northern European counties. This has implication for increased exposure to solar radiation and thermal stress. In a warmer world, patterns of personal exposure to solar radiation (e.g. sunbathing in temperate climates) are likely to change. Stratospheric ozone shields the Earth's surface from incoming solar ultraviolet radiation, which has many harmful effects on human health. It is also possible that increases in heat stress will affect some tourist destinations.

5.2.7 Land use and planning: competition for space

It can be concluded from this study that population growth and economic expansion are the most important drivers for spatial claims. However the participants in the dialogue acknowledge that also climate change is a driver that may result into an increased competition for space in future. Furthermore, the Netherlands will be come more sensitive for climate change, as in future economic developments (like capital intensive buildings, infrastructure, and recreational areas) and population growth are allocated in the most exposed area of the Netherlands to climate change: the coastal zone. The adaptation options to the impact of climate change on the Dutch water system explain most of the space claims related to climate change in a direct way. A distinguishing characteristic of current Dutch water management is that solutions to water problems not only are sought in technical measures but also in spatial measures, in contrary to the past (Commissie Waterbeheer 21e Eeuw, 2000; CPB, 2000). In the same coastal zone are (inter) national important natural systems situated, which are sensible to climate change, like the Wadden Sea, which is an internationally recognized resting area for a wide array of migratory birds. Like most wetlands the Wadden Sea has many ecological functions and socio-economic values (for example recreation, fisheries). Climate change may thus alter Dutch welfare (from a socio-economic, cultural and ecological point a view) if adaptation to climate change occurs in current physical planning and development of new infrastructure.

Adaptation strategies to climate change in physical planning, water management, infrastructure and land use may also facilitate policies to mitigate the impacts of climate change. For example, in the lower parts of the Netherlands, much of the peat soils are currently drained, as a result these soils have a low carbon sink capacity compared to natural peat soils (Van Amstel *et al.*, 1999). The carbon sink capacity of the soils in the lower parts of the Netherlands may increase as a result of changed water management as adaptation to climate change. Also the further establishment of the ecological networks (EMS) is not only an adaptation option for ecosystems (by facilitation of migration possibilities for species, which is a mechanism to adapt to climate change) but also a mitigation measure to climate change as natural areas (forests) also act as carbon sink.

Implications for policy, institutions and management
The last decade achievements have been made in relation to integrated water management in the Netherlands. The current issues in relation to physical planning seem to ask for a further integration between terrestrial bound policies (agricultural land use, physical planning, infrastructural policy), water management (NRLO, AWT, RMNO, 2000; Rathenau instituut, 2000) and policies in relation to the climate change and atmosphere.

Historically, water resource management plans have assumed a stable climate. Allocation frameworks, for example, are often based upon average precipitation and runoff patterns. In the Netherlands measures are currently taken to mitigate to intense flooding, mainly in winter and spring. But less attention is paid to policies that anticipate to long-term summer droughts, which may result in wide-scale crop failures, severe damage to infrastructure, human discomfort, and ecological degradation in both the coastal zone and high parts of the Netherlands.

International, national and local institutions responsible for water resource management are generally not closely linked to those responsible for addressing climate change nor with those responsible for disaster recovery. As a result, communication between these communities is sometimes lacking. New mechanisms will need to be developed to deal with the uncertainty of climate change impacts on water resources.

5.3 Conclusions

Within these key-issues many of the identified impacts and adaptation options for the Netherlands are related to water and either water shortage, excess water discharge or rainfall or water quality e.g. salinization. The Netherlands is a low area situated in a delta and relative to sea level low area, is particularly vulnerable to changes in precipitation and sea level rise. Both water, land and biodiversity are identified as the crucial factors in adapting to climate change in the Netherlands in the 21st century. Many effective adaptation options are available and recognized by stakeholders in the Netherlands. Though some may be easy to achieve, others will be expensive and/or require additional space in a highly competitive market with high prices for land, e.g. measures to increase water storage or water retention and combat increased drainage and salinization. It is therefore essential to anticipate climate change and to introduce adaptive measures in an early stage in order to avoid excessive damages or increased implementation cost of adaptation in case of late responses. This may be difficult to achieve as it may be necessary to take adaptive measures well before stakeholders or civilians will recognize risks or actually experience damage. It is crucial to develop early warning systems based on clear indicators of climate change or its effects.

5.4 Concluding remarks

This report dealt with the main impacts of climate change and adaptation options for the Netherlands. For the interpretation of the results it is essential to consider that the impacts and adaptations options have been based on a specific set of scenarios for economic development and climate change till the end of this century. The results of the study are only valid within the context of these scenarios, and its is important to note that the impacts may be completely different, if the pattern of climate change turns out to be less gradual and more hectic or more substantial than assumed in the climate scenario of this study.

We also would like to emphasize that this study only focused on climate impacts and adaptations options in the Netherlands, whereas most of the impacts and adaptation options refer to other countries in the world that may be more vulnerable to climate change or that have by far less adaptation options than the highly organized society of the Netherlands.

The results of this study are based on literature survey, a dialogue with experts and stakeholders. In this manner we covered many aspects of the scientific information, the expert views and the stakeholder views related to the original aims of the study. Stakeholders who participated in the workshop easily agreed on most impacts and adaptation options that have been identified. We are aware however that a wide variety of judgements and perceptions on climate change issues exist, both in the scientific community and amongst stakeholders. Despite these observations, we are convinced that the report represents the most essential and relevant aspects of the impacts and adaptation options for climate change in the Netherlands, given the scenario setting of this study, the state of the art of current scientific knowledge, and today's expert and stakeholders' perceptions of the issues at stake.

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Appendix I – Workshop participants

Participants March 29, 2001

Session Natural systems: facilitator: D.S. de Groot*

- J.A. van Ast, Erasmus Universiteit Rotterdam
- H.J.M. van Buggenum, Waterschap Roer en Overmaas
- M. Friele, Waterschap Brielse
- M. Janssen, Stichting Duinbehoud
- G.J. Heij, Nationaal Onderzoeksprogramma*
- B. Hermans, Stichting Natuur en Milieu
- M.M.T.E. Huynen, project-team (aandachtsveld gezondheid en recreatie en toerisme)*
- E.C. van Ierland, project-leider*
- E.P.J. Koekkoek, Vrom/DGM/dKvI*
- D.G. Koskamp, RIKZ
- R. Leemans, RIVM
- J. van der Leun, AZU: dept of dermatology *
- P. Martens, project-team (aandachtsveld gezondheid en recreatie en toerisme)*
- O. Oenema,WU, Omgevingswetenschappen Bodemkwaliteit en Alterra
- M. Ossewaarde, RMNO-bureau
- H. Siebel, Natuurmonumenten
- J.M. Stoop, de Waddenvereniging
- J. Szonyi, project-team (aandachtsveld economische sectoren)
- W.A. Takken, WU; Vakgroep Entomologie*
- J. Vis, Ministerie LNV: Dir. Natuur LNV
- J. Veraart, project-team (aandachtsveld natuurlijke systemen)*
- A. van Vliet- project-team (aandachtsveld natuurlijke systemen)*
- M. Walles-de Vries, de Vlinderstichting
- S. Werners, Resource Analysis

Session Land use: facilitator: P.J. Kuikman*

- W.G. Albrecht, Platform Biologica*?
- B. Amelung, project-team (aandachtsveld gezondheid en recreatie en toerisme)*
- W.P. Daamen, bosbouwkundig adviseur
- N. Daan, project-team (aandachtsveld landgebruik)*
- A. van Egmond, NHTV*
- K. Kramer, project-team (aandachtsveld landgebruik)*?
- J.J. Neeteson, Plant Research International
- L. Oprel, Expertisecentrum LNV
- R. Sikkema, FORM Ecology Consultants
- W.H. Streekstra, LTO-Nederland
- G. van Tol, Expertisecentrum LNV: Afdeling Natuur
- J. Verhagen, project-team (aandachtsveld landgebruik)*?

* Both days present (29 and 30 maart 2001)

Participants March 30, 2001

Session Economic systems: facilitator E.C. van Ierland*

- W.G. Albrecht, Platform Biologica
- G. Annezwaag, Vereniging van Afvalverwerkers
- M.A.P.M. van Asseldonck, WAU: Dept. of Economics and Management
- P. Brouwer, Fortis International
- G.H.J. van Emst, AON Re Netherlands
- D.G. de Groot, project-team (aandachtsveld natuurlijke systemen)*
- L. Hall, Milieufederatie Groningen
- M. Kok, Nationaal Onderzoeksprogramma
- P.J. Kuikman, project-team (aandachtsveld landgebruik)*
- M. Ossewaarde, RMNO-bureau*
- J.M.P. Papenhuijzen, Innovatie Netwerk
- J.W. Pulles, Ministerie van V&W: DG Rijks Luchtvaart Dienst
- A. Stevens, Stichting Natuur en Milieu
- J. Szonyi, project-team (aandachtsveld economische sectoren)
- J. Verhagen, project-team (aandachtsveld landgebruik)
- J. de Wilt, Innovatie Netwerk
- J.J. de Wolf, KEMA KPS/ Sustainable Energy

Session Health and tourism & recreation: facilitator: P. Martens*

- B. Amelung, project-team (aandachtsveld gezondheid en toerisme and recreatie)*
- R. van den Berg, Consultancy and Research for Environmental Management
- L. van Bree, RIVM
- B. Brunekreef, WU, Leerstoelgroep Gezondheidsleer
- N. Daan, project-team (aandachtsveld landgebruik)*
- A.van Egmond, NHTV*
- T.S. van Es, KUB, Telos
- P.J. van den Hazel, GGD Arnhem
- M. Helmer, Rode Kruis
- G.J. Heij, Nationaal Onderzoeksprogramma Klimaatverandering*
- M. Huynen, project-team (aandachtsveld gezondheid en toerisme and recreatie)*
- E.P.J. Koekkoek, Vrom/DGM/dKvI *
- K. Kramer, project-team (aandachtsveld landgebruik)*
- J. van der Leun, AZU: dept of dermatology*
- W.F. Passchier, Gezondheidsraad
- W.A. Takken, WU, Vakgroep Entomologie*
- A. van Vliet, project-team (aandachtsveld natuurlijke systemen)*
- J. Veraart, project-team (aandachtsveld natuurlijke systemen)*
- Zwart Voorspui, Gemeente Den Haag, Dienst Onderwijs, Cultuur en Welzijn

* present both workshop days (March 29 and 30, 2001)

Appendix II – Results of the workshop sessions on Human health

Session 1: The effects of climate change

Table 1 Sticker session of session 1 for health.

Effects of climate change on health	*Proba-bility*	*Level of impact*
• Water-related: blue algae	10	9
• Allergy: hay fever/pollen	14	12
• Allergy: glycyphagus/fungus at home	2	1
• Effect of worsening air quality on bronchi	15	16
• Storm and floods: psychic effects	7	6
• Delayed recovery ozone layer: skin cancer (plus other effects like stare)	8	9
• Vector-born diseases: Lyme disease	8	3
• Temperature effects: cold/hot	9	9
Additional/post-its		
• Demographic risk populations	8	1
• New kinds bacterial / viral disorders	2	4
• Exposure 'eikenprocessierups'	1	1
• Swimming water quality general	3	4
• Physical effects storm/floods/ extremes	2	3

Table 2 Sticker session for session 1 for recreation and tourism

Effects of climate change on health and tourism	*Proba-bility*	*Level of impact*
Sea level: beach tourism endangered	15	12
Extreme conditions: danger for water sports	2	2
Temperature: more people on beach	8	4
Ozone: beach tourism more risky	3	5
Extreme conditions: stay on the beach more dangerous	3	3
Additional/post-its		
More outdoor / indoor recreation	8	7
Change of popular summer destinations	4	5
Winter sport (decrease, unfavourable for sector, relocation to other areas)	4	1
Less ice-skating on natural ice	4	8
More people on holiday during the winter in the Netherlands	1	-
Harmful effect on product in general terms, more specific, like cultural heritage	-	-
Extension of season > more holiday spread	-	-
Worsening swimming water quality has bad influence on tourism	2	1
Loss of biodiversity (birdwatchers)	3	1
More disaster tourism	1	1

Session 2: The interactions

Table 3: sticker session of session 2 for health (part 1).

Effects of climate change on Health and recreation & tourism	Interaction with Health and recreation & tourism	Interaction with Natural systems (ecosystems, hydrology and land)
Health		
General poor health	Climate change contributes to a generally more poor condition; more diseases	More environmental diseases leads to more attention for environment> more nature preservation
	2	6
		Also interaction with recreation, more nature supply creates impulse for more nature based recreation (EHS and recreation hand in hand)
Swimming water quality	(negative) influence on recreation and tourism	4
	16	
Allergy: hay fever/ pollen	3	6
	Plus mosquito's and ticks (outdoor recreation)	
Allergy: glycyphagus/ fungus at home	1	
Effect of poor air quality on bronchi	2	
Storm and floods: physical effects	3	
Slow recovery of the ozone layer: skin cancer	(negative) influence on recreation and tourism	
	6	
Vector-born diseases: Lyme disease	8	3
Temperature effects: cold / hot	7	2
	Temperature very important explanation for tourism-demand (impulsive or not)	
More biting and stinging insects: harassment	4	
Additional		

Table 4: Sticker session of session 2 for health (part 2).

Effects of climate change on Health and recreation & tourism	**Interaction with Land use (agriculture, forestry, fisheries)**	**Interaction with Economic sectors (energy: insurance, industry and transport)**
Health		
General poor health	1	Negative effect of number of labour forces 4 Especially elderly are sick so not really applicable (insurance care)
Water-related: blue algae		4 Water systems urban area, more sewerage overflow – temperature effect of algae blooming not really relevant compared to thermal pollution of water
Allergy: hay fever /pollen	Farmers / foresters can not carry out their work very well 3	4
Allergy: glycuphagus / fungus at home		1
Effect of poor air quality on bronchi	4	12
Storm and floods: psychic effects	6	4
Slow recovery of ozone layer: skin cancer	Special risk for farmers / foresters / fishermen 2	5
Vector-born diseases: Lyme disease	7	3
Temperature effects: cold / hot		9
Additional		
Other new infectious diseases through mutation	2	5

Table 5: Sticker session for session 2 for recreation and tourism (part 1).

Effects of climate change on Health and recreation & tourism	**Interaction with Health and recreation & tourism**	**Interaction with Natural systems (ecosystems, hydrology and soils)**
Recreation & tourism		
Sea level: beach tourism endangered		5 Pressure on dune ecosystems because of resort development
Extreme conditions: danger for water sports	Physical danger 8	
Temperature: more people to the beach	negative effect on health (skin cancer) 2	Overflow of coastal ecosystems 9 During temperature extremes
Ozone: beach tourism more risky	More attention for health during holidays 7	
Extreme conditions: stay on the beach gets more risky	Physical danger 1	
More outdoor recreation	5	16 More trash and noise in nature, water quality, more demand for land because of nature tourism
Winter escape because of autumn weather during winter	1	1 Pressure on ecosystems in ski areas
Additional /post its		
Adjust water management to climate change: chances for tourism		

Table 6: Sticker session for session 2 for recreation and tourism (part 2).

Effects of climate change on Health and recreation & tourism	**Interaction with Land use (agriculture, forestry and fisheries)**	**Interaction with Economic sectors (energy, industry and transport)**
Recreation and tourism		
Sea level: beach tourism endangered	3	Higher insurance premiums for acilities near the beach 5
Extreme conditions: danger for water sports		Higher insurance for water sports 2
Temperature: more people going to the beach		Congestion 12 Infrastructure sufficient?
Ozone: beach tourism becomes more risky		
Extreme conditions: Stay on the beach becomes more dangerous		3
More outdoor recreation	14	10
Winter escape because of autumn weather during the winter		4
Shift of summer and winter destinations abroad		1 Effects for aviation

Session 3: Adaptation options

Table 7: Sicker session for session 3 for health.

Effects of climate change on Health and recreation & tourism	Adaptations	Priorities	Constraints
Health			
Swimming water quality (blue alleges)	Education	6	One does not listen
	Monitoring / warning systems	5	
	Regulations	6	
	Improve healthcare	0	
	Purify/prohibition of swimming/sewer enlargement	6	
Allergy: hay fever/pollen	Improve housing	1	
	Monitoring/ warning systems	6	
	Education	3	One does not listen
	Improve healthcare	0	
Allergy: Glycyphagus / fungus at home	Improve housing	7	
	Monitoring/ warning systems	1	
	Education	4	
	Improve healthcare	1	
Effect of poor air quality on bronchia	Education	4	
	Monitoring/ warning systems	2	
	Drive back air pollution (for example ban cars form city centres)	19	Money- restricting mobility
	Improve health care	0	
Storm and floods: psychic effects	Infrastr. adjustments	6	
	Up levelling of dikes /coastal works	1	Money- damage to ecosystems
	Monitoring/ warning systems	2	
	Improve housing	0	
	Education	0	
Slow recovery of the ozone layer: skin cancer	Education	9	
	Monitoring/ warning systems	7	
	Improve healthcare	1	
Vector-born diseases: Lyme disease	Education	4	
	Monitoring/ warning systems	2	
	Improve healthcare	1	
	Insects / pest control	4	In case of pesticide damage to ecosystems – water quality
	Restrictment of tourists in Lyme areas	3	
Temperature -effects	Education	4	
	Monitoring/warning systems	5	
	Drive back air pollution	5	
	Improve housing (airco)	4	
	Improve healthcare	4	
Additional		1	

Table 8: sticker session for session 3 for recreation & tourism.

Effects of climate change on Health and recreation & tourism	**Adaptations**	**Priority**	**Constraints**
Tourism			
Damage to facilities because of sea level rise	Relocation further inland of existing facility	3	Costs money
	Relocation further inland of new facility	9	Costs money
Coastal erosion because of sea level rise	Levelling the beaches (longitudinal embankment)	11	
Increasing demand due to temperature rise	Expanding of capacity in existing locations	2	2
	Expanding the number of recreation areas (nature development: eco-tourism a la Costa Rica)	17	4 Spatial planning: more land claims than land available
	Limit / regulation of growth	5	How?
Danger of extreme weather conditions	Education/ warning	10	
Decreasing demand due to more precipitation	Stimulating city tours	0	1
	Stimulating indoor activities	6	
More outdoor recreation	Expanding the areas	6	Spatial planning: more land claims than land available
"winter escape"			
Congestion due to tourism / recreation	Infrastructural adaptations	3	
	Improve public transport	6	Hard to get people out of their cars
Additional issues			
general	Discouragement of cheap air age holidays (reduction of emissions)	7	

Appendix III – Climate scenarios

Introduction

In the scientific world there is a growing consensus about the fact that global warming is taking place, and that warming will continue in the future. It is, however, a fact of life for climate research that there is a great deal unknown about the changes that are still to come. Especially the *size* of change is uncertain. Uncertainty has inevitably lead to a great diversity in the approaches for obtaining climate scenarios. Most impact researchers use direct or indirect output from General Circulation Models (GCM's) as input for their climate studies. However, GCM's differ in their output. Therefore the choice of GCM determines to a significant extent the results of impact research. The program management of the NRP wishes to compare results of all impact projects. To achieve this, a common scenario had to be used in all impact projects. For this reason the NRP has commissioned the Hadley Centre for Climate Prediction and Research to provide them with a scenario for European weather in the period 1980-2100 (Viner and Hulme 1998, Verweij and Viner 2001). A weather series has been generated by Hadley's general circulation model with a grid cell size of 3.75 degrees in longitude and 2.5 degrees in latitude (figure. 1).

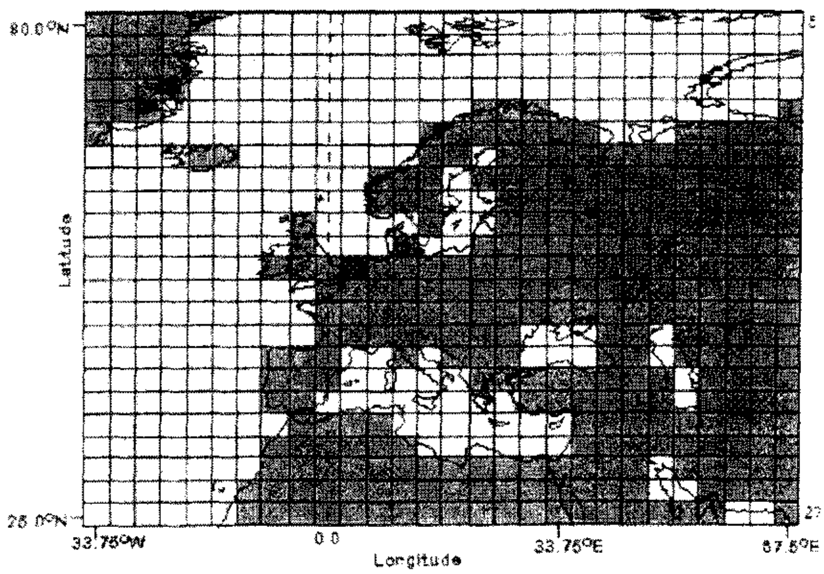

Figure 1 *Grid of Hadley General Circulation Model (GCM) for Europe. The Netherlands is largely located in the dark grey cell; for the climate scenario for the 21st century for the Netherlands in this project, the cell due east of the dark grey cell was used (see text for explanation).*

In the Hadley model a yearly increase of 1% greenhouse gas concentrations is assumed, meaning that by the year 2100 there will be a doubling of concentration compared to the current situation. The predicted global warming for 2100 is approximately 3.0°C. This makes the Hadley scenario a sort of middle-of-the-road scenario: some climate models predict higher temperature increases, some lower.

The data generated by the Hadley GCM can not be used directly for regional climate-impact studies, as will be explained below. The scenario supplied by Hadley was also not meant to be the *only* one used; so we were free to investigate some further variations. But before discussing the followed methodology, we first give some general considerations that are important for understanding the reasons behind the followed approach.

It first should be realized that the GCM-generated series is a 'realization' of a model that has a stochastic component, meaning that the series is partly determined by random events. The series should of course not be taken as a literal prediction. With respect to the climate, we wanted to make predictions for the conditions at different dates in the future. For doing this it will not suffice to just choose single-year periods as such a moment in the future, because such single years certainly do not contain the full variability of the weather. So it is necessary to choose *sub-periods* centered on the focal years of interest. These *sub-periods* of the 1980-2100 series should be long enough to fully describe the range of possible weather conditions. But they also should not be too long, because otherwise the climate will significantly change within the *sub-period* itself. In this study, we use intervals of 30 years, i.e. 2005-2035 for the focal year 2020.

Secondly, the data generated by the Hadley GCM represent a specific area, a so-called grid cell. The size of these Hadley cells are roughly 200 km in diameter, whereas in the Netherlands the long-term mean of the precipitation can differ by 15% over a distance of just 20 km. So, the Hadley results do not necessarily do justice to the local variations of the precipitation. That also applies, but to a lesser extent, to the temperature, relative humidity and short-wave radiation. Here we are confronted by a *scale* problem: the scale of the Hadley model is too large to describe the small-scale variability of the local climate.

To bridge the gap between the Hadley model and local conditions some form of *downscaling* procedure is needed. With precipitation there is a further complication, because not only the long-term mean differs from those at a local scale, but also the frequency distribution: the frequency distribution of the daily precipitation is much less skewed for a grid cell of the GCM than what is seen in a measured series. The reason for this is the averaging-out of events in the large grid cells of the model, meaning 'that it nearly always rains' in a GCM. In figure 2 the comparison between the measured precipitation and the Hadley precipitation is given for the southern part of the Netherlands. In the Hadley cell it rains on 70% of the days, whereas in reality this holds only for 50% of the days.

As indicated above, there is a growing consensus about the fact that global warming is taking place, but also that opinions differ greatly about the *size* of change that is still to come. That especially holds for the expected change of precipitation. The Hadley GCM for instance does not predict a significant increase of precipitation for the Netherlands. The Royal Dutch Meteorological Institute KNMI, on the other hand, predicts a substantial increase of the precipitation. Since many studies have adopted these predictions, it is important to also make use of them in the current study; otherwise it will be difficult to compare our results with other research done outside the NRP-program.

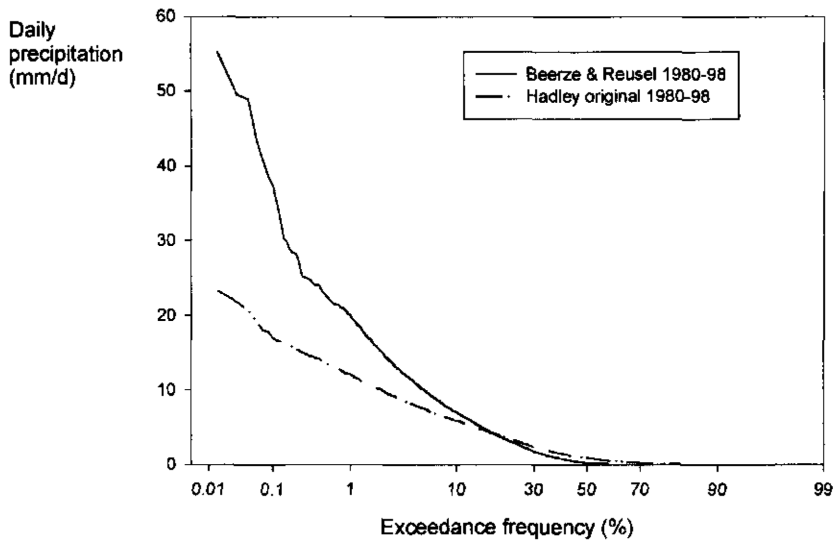

Figure 2 Comparison between frequency distributions of daily precipitation for a measured regional series (upper curve, for Eindhoven, Beerze and Reusel region) and the original Hadley series for 1980-1998 (lower curve)

Approach

Given the above considerations, the following 4 steps have been followed in order to obtain weather series defining possible future climate scenarios for various regions in the Netherlands:

1. Choice of the Hadley grid cell that is moist suitable
2. Choice of sub-periods within the period 1980-2100 that will be used for defining the scenarios
3. Downscaling of the Hadley data to the local climate of a region (locations *De Bilt*, *Eelde* and *Eindhoven*
4. Applying different assumptions when there are great differences of opinion between diverse research institutes, i.e. between the Hadley prediction and that of KNMI.

Choice of Hadley grid cell and subperiods of weather series (steps 1 and 2)

The cells of the Hadley GCM that cover Europe are shown in figure 1. For the Netherlands the best-centered grid cell of the Hadley GCM is not the most suitable one. The reason is that the grid cell has a substantial part of its area over the North Sea, and therefore it has a too moderate temperature regime. We had a choice between the cell to the south and the one to the east. The one to the south-east was ruled out from the start, because that cell is too distant from the coast, and does not properly represent the maritime climate of the Netherlands. The choice between the one to the south and the one to the east would in principle depend on the region of the Netherlands for which we want to make predictions (*De Bilt*, *Eelde*, and *Eindhoven*). Of the two possible options we chose the one to the east, because the one to the south is influenced by the higher hills of the Belgian Ardennes, whereas the one to the east is in the plain. Only perhaps for the most southern tip of the Netherlands would the cell to the south have been the best option.

The grid cell chosen (Eastern Longitude between 5.625° to 9.375°, Northern Latitude between 51.25° to 53.75°) has its center at roughly the same Northern Latitude as Amsterdam, and lies about 50 km east of the eastern border of the Netherlands. The most westerly boundary of the cell cuts through the center of the country.

For the sub-periods we decided to use periods of 30 years. From the point of view of climate change a period of 20 years would have been slightly preferable, because during a 30-year period the change of climate is not negligible. But on the other hand the changes are so gradual, that we decided to attach more importance to a full representation of the variability of weather conditions. For that variability a period of 30 years has always been considered the minimum. In fact the current climate is *defined* as being the full range of conditions during the past thirty years. The sub-periods we used for defining a sequence of scenarios are:
- 2005-2035, for the focal year 2020
- 2035-2065, for the focal year 2050
- 2070-2100, for the focal year 2085

Downscaling of Hadley cell to local data (step 3)

The Hadley weather variables used for this study are daily values of: precipitation (mm/d), temperature (°C), relative humidity (%), and total downward surface short-wave flux ($W/m^2/d$). In table 1 a comparison is made between the long-term means of the weather variables for the Hadley grid cell and the means of measured weather variables for the locations *De Bilt*, *Eelde* and *Eindhoven*. This comparison for the period 1980-98 shows that there are significant differences between the Hadley cell and the locations. The differences between the locations are much smaller.

Table 1 Comparison between long-term means of Hadley weather series and the means of measured variables for three locations in the Netherlands, for the period 1980-1998.

Weather variables	Hadley cell	*De Bilt*	*Eelde*	*Eindhoven*
Precipitation (mm/y)	746	813	800	794
Summer precipitation (mm/y)	403	385	382	377
Winter precipitation (mm/y)	343	428	418	417
Temperature (°C)	9.13	9.84	9.28	9.87
Relative humidity (%)	88	82	86	82
Total downward surface SW flux ($W/m^2/d$)	114	109	107	113

The differences shown in table 1 between the Hadley cell and the local gauging stations have to be somehow reconciled, otherwise the use of the Hadley weather series for predicting

effects of *future* climate would also include effects of differences for the *current* climate. The latter differences, for example the difference between the precipitation of 746 mm/y and 813 mm/y for *De Bilt*), would cause a systematic error in the prediction for the future climate if the Hadley data were used without having first corrected them. If this would not have been done first, the effects caused by the differences for the *current* climate would have been *included* in the predictions, which would be an artifact. To avoid this, the Hadley weather series was first *downscaled* to the three locations. Only after this step, the series has been used for predicting effects of climate change.

For temperature, relative humidity and short-wave flux the downscaling of the Hadley series was done in the following simple manner (using the data of *Eindhoven* as an example):

- the daily temperatures of the Hadley series (1980-2100) were increased by 0.74 °C, to account for the difference between the long-term mean of 9.87 °C of the measured daily values for 1980-98 and 9.13 °C of the Hadley series
- the relative humidity and the short-wave flux were adjusted by multiplying with the ratios derived from the data in table 1

In order to do justice to the measured daily variation of the precipitation, the precipitation of the Hadley series has to be transformed in some manner. In the literature (e.g. Wardlaw *et al.* 1996), various methods are reported for transforming GCM-rainfall data to a regional series with a realistic daily variability. These methods nearly all involve the use of stochastic weather generators like WTHGEN (Richardson 1981). The disadvantage of such methods is that the link between the original data and the calibrated ones becomes rather indirect. For this reason we have chosen a more direct approach. The method involves the following steps:

- the precipitation data for the period 1980-1998 are ordered according to their magnitude, for both the measured regional data and the original Hadley series

- the original Hadley data are downscaled to regional ones by using the ordered sets of precipitation data as a *lookup table*; so if for instance a daily rainfall of 10 mm in the Hadley series for 1980-1998 has the same exceedance probability as 15 mm in the measured series, then a daily precipitation of 10 mm in the 1980-2100 Hadley series is replaced by a value of 15 mm
- long term means are computed of the transformed Hadley series and of the measured regional series, separately for winter and summer, for the period 1980-98
- the daily values of the transformed Hadley series (1980-2100) are multiplied by the ratio between the long-term mean of the measured regional series and the transformed Hadley series for the same period as for the measurements (1980-98); this procedure is applied separately for the winter and summer period

The last step will be explained in more detail, first in more general terms and then using data of the selected period.

By calibrating to the long-term means separately for winter and summer it is ensured that the long-term means of the transformed Hadley series are reconciled with the long-term means of the measured series, for both winter and summer. That is hydrologically and ecologically important, because the dominant processes are different in the winter and summer half-year.

To illustrate the followed method, the relationships between some of the data shown in table 2 are explained, using the summer precipitation as an example: The daily data of the transformed and calibrated series have been adjusted in such a manner that:

$$P_{summer,H2070\text{-}2100S} = P_{summer,E1980\text{-}98} * (P_{summer,H2070\text{-}2100} / P_{summer,H1980\text{-}98}) \quad (2.1)$$

in which P_{summer} is the long-term mean of the summer precipitation, with the subscripts referring to the scenarios in table 2. Seen in this way, the percentage increase of H2070-2100 with respect to H1980-98 – which is the predicted climate *change* – is superimposed on the current climate of a specific location, thus avoiding artifact mentioned earlier in this chapter.

An example of a comparison between the frequency distributions of the measured regional series and the calibrated Hadley series is given in figure 2 for the measurement period. The distributions are not quite identical due to the calibration factors for the long-term averages in summer and winter. In this context it is relevant to realize that the step 3 of the method uses the cumulative frequency tables of the Hadley cell for 1980-98 and that of the measured series as a *lookup table*. In the Hadley original series of 2000-2099 there are eight rainfall events that are more extreme than the highest daily rainfall in the Hadley series 1980-98. The highest daily rainfall in the Hadley series is 31.5 mm in the year 2056, and the highest one in the period 1980-98 is 23.2 mm. So when the lookup table is used for these eight events, each time the highest rainfall event in the *measurement* period is returned as the transformed value.

Table 2 *Long-term means of precipitation for Eindhoven (Beerze and Reusel region) of downscaled Hadley scenario. Explanation of symbols for series:*
- E1980-1998: measured regional series
- H1980-1998: original Hadley series for the grid cell, for 1980-1998
- H2005-2035: original Hadley series for the grid cell, for 2005-2035
- H2005-2035S: downscaled and calibrated Hadley series, for 2005-2035

Scenario	P (mm/y)	P_{summer} (mm/y)	P_{winter} (mm/y)	T (°C)	Relative humidity (%)	SW-flux ($W/m^2/d$)
E1980-98	794	377	417	9.87	82	113
H1980-98	746	403	343	9.13	88	114
H2005-20035	697	357	340	9.72	-	118
H2005-2035S	745	337	408	10.45	-	116
H2035-2065	717	365	352	10.61	-	119
H2035-2065S	770	341	429	11.30	-	117
H2070-2100	720	373	347	11.90	86	120
H2070-2100S	771	349	422	12.60	80	118

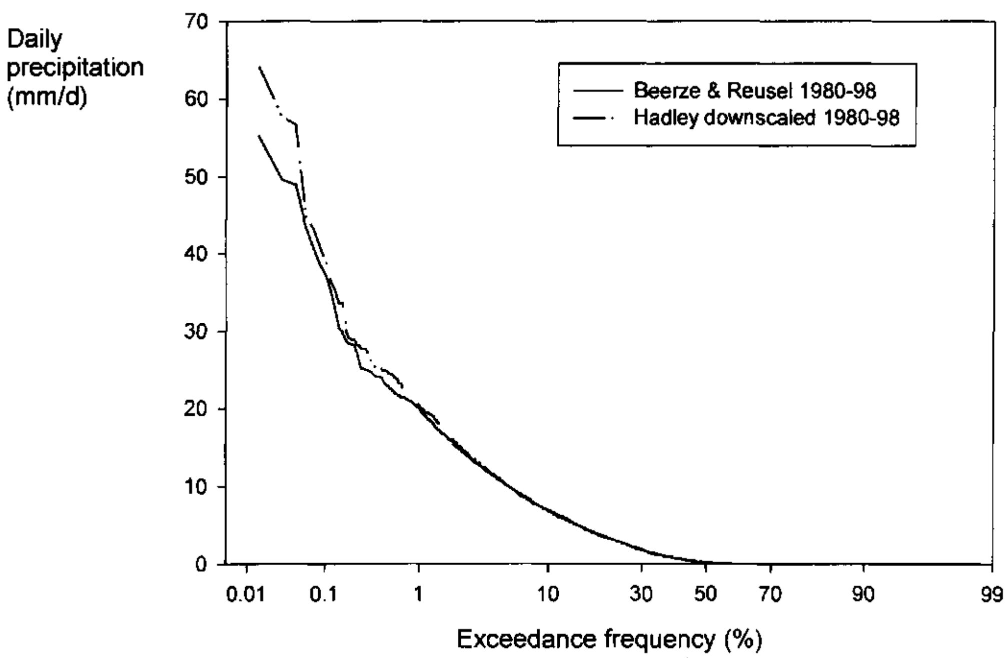

Figure 2 *Comparison between frequency distributions of daily precipitation for the measured regional series (Eindhoven, Beerze and Reusel region) and the downscaled Hadley series for 1980-1998.*

Strictly speaking the returned value should have been higher. It is however expedient to have to *not* done any form of extrapolation, because as was seen above, the calibration factors cause an 'artificial' increase. The two kinds of error work in different directions, and therefore they (roughly) compensate each other. And given the fact that the extremest rainfall event did not occur towards the end of the series, but in the middle, there is no indication for a real trend.

The extreme events not covered by the lookup-table only concern the 8 to 10 highest precipitation events in a 120-year period. Since the weather is a stochastic process, the most extreme events in a weather series should anyhow be treated with great care when used for predictions. That is because they are subject to pure chance: if the weather series had been twice as long, the 6th highest daily precipitation would no doubt differ substantially from the 3rd highest in the series of 120 years. In many kinds of impact predictions these extreme events do not play a major role, because they do not happen often enough to have a lasting impact.

KNMI method for adjusting precipitation (step 4)

In the Netherlands, extensive use has been made of a rule-of-thumb advocated by the Royal Dutch Meteorological Institute KNMI for modifying precipitation data based on changes of the mean temperature (Können *et al.* 1997). KNMI admits of course that there is great uncertainty involved.

The method actually involves corrections of daily precipitation based on the daily temperature and the change of mean temperature involved in the climate scenario. The direction of the corrections is invariably upward. Application of this method to the time series for *De Bilt* (located in the center of the Netherlands) yielded the following shifts of long-term averages per °C of temperature increase:

- 1% increase of the mean summer precipitation
- 6% increase of the mean winter precipitation

This has been made into a so-called 'rule-of-thumb'.

In order to cover a broad range of possible scenarios, it was decided to also include a scenarios using the KNMI rule-of-thumb. The daily precipitation has been adjusted in such a manner that the change of long-term is according to the KNMI-rule-of-thumb applied tot the measured precipitation in the *specific location*. These scenarios are listed in table 3 for the location *Eindhoven*.

Similar tables have been made for the locations *De Bilt* and *Eelde*. The way in which these locations systematically differ from the *Eindhoven* one can be seen in table 1.

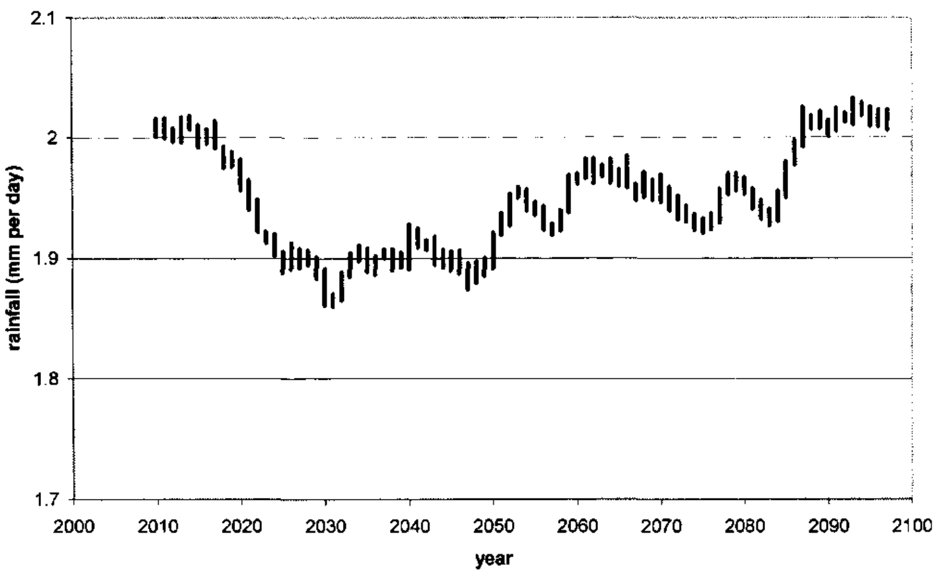

Figure 2 Average rainfall in mm per day calculated as 20-year moving averages on the basis of the HADLEY climate model runs

Table 3 Long-term means of precipitation for Eindhoven (Beerze and Reusel region) of downscaled Hadley scenario and applied KNMI-rule-of thumb. Explanation of symbols for series:
- H2005-2035S: downscaled and calibrated Hadley series for 2005-2035
- H2005-2035SK: downscaled and calibrated Hadley series, and adjustment of precipitation using rule-of-thumb of KNMI for 2005-2035

Scenario	P (mm/y)	P_{summer} (mm/y)	P_{winter} (mm/y)
E1980-98	794	377	417
H2005-2035S	745	337	408
H2005-2035SK	811	379	432
H2035-2065S	770	341	429
H2035-2065SK	834	382	452
H2070-2100S	771	349	422
H2070-2100SK	872	387	485

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