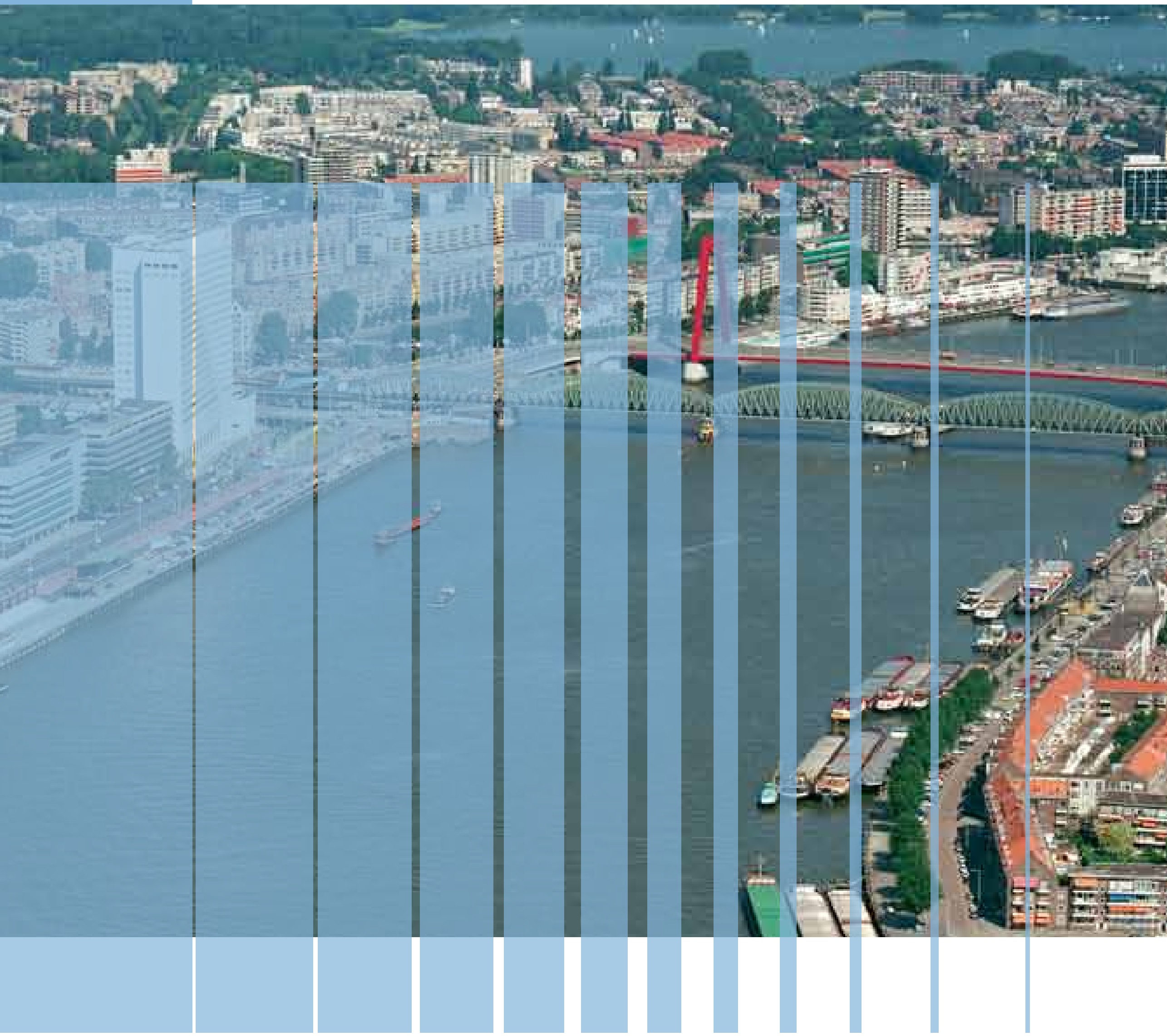
Roadmap to a climate-proof Netherlands



Netherlands Environmental Assessment Agency

Roadmap to a climate-proof Netherlands

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Roadmap to a climate-proof Netherlands
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Preface

The Netherlands must face the consequences of climate change, both positive and negative, together with the rest of the world. The negative consequences, such as the increasing temperature and the frequency and intensity of weather extremes, increasing river discharges, and sea level rise are topics of much discussion. Trends are expected to continue, although there is still substantial uncertainty about the rate of climate change itself and the possible impacts.

What does this all mean for the spatial development in the Netherlands? At the request of the Dutch Ministry of Housing, Spatial Planning and the Environment (VROM), the Netherlands Environmental Assessment Agency (PBL) explores which challenges are most relevant to a climate-proof spatial strategy, on the basis of available information and expertise. This study is the first step in this exploration. In a follow-up study, we expect to present well-founded options for a long-term spatial strategy towards a climate-resilient Netherlands.

The present study shows that climate-proofing is a factor of importance in the decision-making process around spatial developments in our country. Choices to be made in the years and decades to come will inevitably influence the future vulnerability of the Netherlands. Thus, new preconditions have to be developed, to increase the climate resilience of, for instance, urban and nature areas. Building energy-efficient city structures, and creating parks and ponds in urban areas, are examples of combining multiple policy goals of urban development. As for nature, the concept of the National Ecological Network forms a sound basis for increasing nature's resilience. Possible impacts of climate change, however, need to be considered when choices are made on the finalising of this ecological network. The actual policy agenda, thus, provides the opportunity to incorporate climate-proofing in the decision-making process.

Professor Maarten Hajer

Director of the Netherlands Environmental Assessment Agency

Contents

Key messages

- ## Future vulnerability of the Netherlands influenced by spatial development

  Climate change is having many effects, also in the Netherlands. Although uncertainty exist, it can be assumed that – based on current knowledge – Dutch society in general will be able to adapt to these changes. Knowledge about the vulnerability of the Netherlands to worst-case climate change scenarios, however, is still incomplete. The adaptive capacity is considered limited or uncertain with respect to spatial developments, because of their relative slowness and irreversibility. Spatial choices and spatial developments concerning infrastructure, urban areas, nature areas and the water management system, have long-term effects and, therefore, have consequences for many future generations. Choices in spatial development that will be made in the decades to come, thus, will also determine the future climate resilience of the Netherlands.

- ## Identified focal points for a climate-proof spatial strategy

  Five focal points have been identified for a climate-proof spatial strategy on a national scale: (a) long-term safety from flooding, (b) ensuring freshwater supply – linked to its use by agriculture and nature, (c) more climate-proof nature development, (d) increasing climate resilience in urban areas, and (e) reducing the vulnerability of transport networks and energy supply. Additionally, the possible risks of climate change for public health, animals and crops, deserve attention, acknowledging the uncertain but potentially severe societal impacts.

  The issue of climate proofing the Netherlands is a new challenge and requires a new approach in decision-making about spatial development. This may lead to new preconditions for spatial developments and land use in the Netherlands. Some of these preconditions have already emerged from this study, for example, concerning the further development of urban areas and the National Ecological Network. The follow-up research planned for 2010 is expected to provide broader and more detailed insight into this issue.

- ## Long-term spatial strategy: an integral task in various governance arenas

  For the focal points, the long-term climate proofing of the Netherlands requires i) coordination of strategy between various policy areas, and ii) coherence in the decision-making and policy implementation at various levels. Given the focal points, various governance arenas can be indicated:
  - The national water bodies and the coastal zone, where issues such as long-term safety against flooding, and freshwater provision come together. Here, the national government is primarily responsible, but in cases where consequences for spatial development are involved, the provinces and municipalities also play an important role.
  - The freshwater availability for agriculture and natural areas, where the choices about the water supply from the national water bodies and the demand for water from the rural areas come together. The governance challenge is complex, because of the required coordination between strategic choices and implementation at the national and regional levels, and the complex

interactions between land use, salinisation, soil subsidence, the availability of fresh water, and the requirements for the National Ecological Network.

- The integral development of urban areas: here, climate change calls for measures to counteract flooding, water nuisance and possible negative health effects, as well as to make buildings and facilities more heat resistant. In addition, during restructuring and new urban developments, synergy can be achieved with measures focusing on reducing the emission of greenhouse gases and improving the quality of the physical environment. The initiative here lies primarily with the municipalities, but, via various policies, national and provincial governments can also influence the developments.
- Transport networks and the energy supply are primarily vulnerable to extreme weather events and require attention, because of their importance for the functioning of society. The aims of the current government regarding the development of sustainable energy sources in the Netherlands also provide opportunities to improve the climate resilience of the energy supply. An important choice in this respect is, for instance, the choice for a centralised energy supply or for a more decentralised approach.

Windows of opportunity emerging from the current policy agenda

Because of the long-term effects of spatial choices and the relative irreversibility of initiated developments, the current policy agenda requires choices to be made now, in the light of future climate resilience. This applies, for example, to urban development in relation to protection against flooding, and to development of the National Ecological Network in a more climate-resilient fashion. Furthermore, there are multiple windows of opportunity, in the short term, for combining challenges of climate resilience with other government aims. Especially in urban areas, major investments will be made, in the near future, for increasing urban density, urban restructuring, and in building one million new houses. This provides opportunities for combining these tasks with objectives, such as improving the quality of the living environment, reducing energy consumption and cutting emissions of greenhouse gases. Recent studies have shown that the additional costs of energy-saving buildings and utilising sustainable energy in urban areas can be recovered within 10 to 15 years. Although the expertise and technologies are available, climate proofing the urban areas will not take place by itself.

Summary

1

1.1 Introduction

Setting

The climate is changing, also in the Netherlands. Therefore, an important question, also for the Dutch Government, is how to meet this significant challenge, given the fact that:

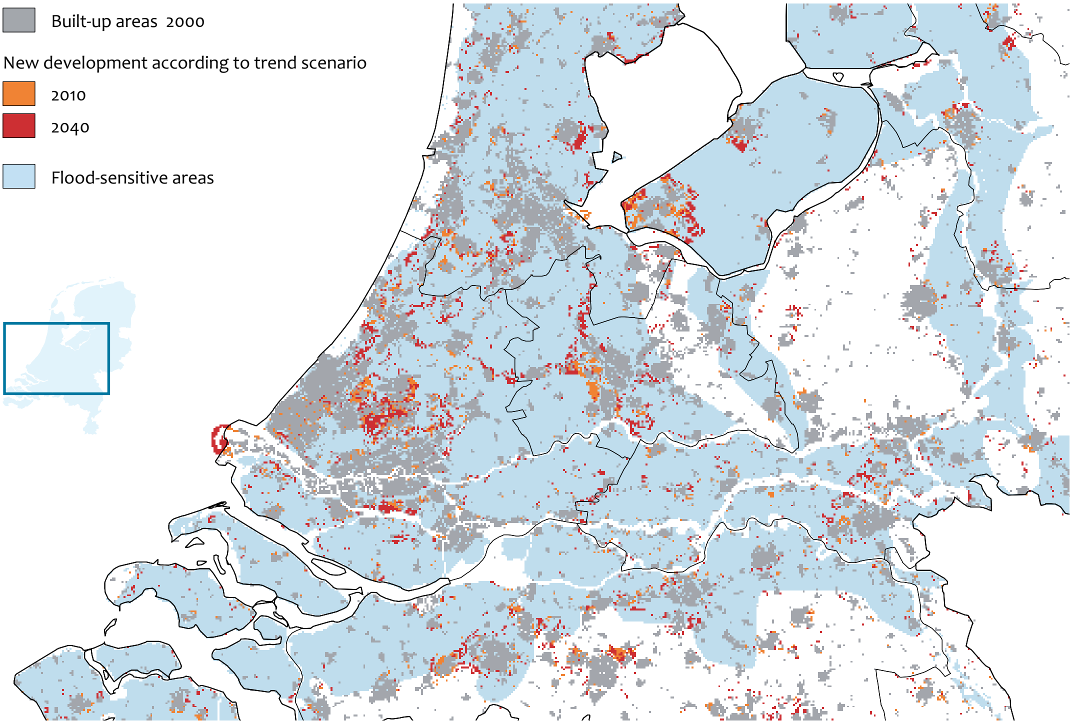
- The Netherlands form a delta where four European river basins meet, namely those of the Rhine, the Meuse, the Scheldt and the Ems.
- Twenty-six per cent of the area of the Netherlands is located below sea level (by as much as 7 metres) and around 55% of the area is prone to flooding, either from the sea or from rivers. The low-lying areas are made habitable with man-made constructions such as dykes, sluices and pumps, and major alterations in the natural morphology and hydrodynamics of watercourses and water bodies.
- The low-lying areas are densely populated and, here, around 70% of the GDP is earned.
- For the next decades, a further increase in urbanisation is expected, and a million new houses will be built, primarily in the areas prone to flooding (MNP, 2006). The economic value at risk will increase two- to threefold, depending on economic growth (Figures 1 and 2).

Although surrounded with uncertainties, the expected climate change, in combination with the expected economic and social developments, calls for a reconsideration of how to develop the Netherlands and to investigate how to reduce the potential vulnerability, addressing a wide variety of impacts: sea level rise, changing river discharges and precipitation patterns, increasing drought and, possibly, also heat extremes and changing patterns of health-related risks (allergies, distribution of vector borne diseases).

A climate-proof spatial strategy: setting the agenda

The Dutch Ministry of Housing, Spatial Planning and the Environment (VROM) has asked the Netherlands Environmental Assessment Agency (PBL) to provide building blocks for a climate-resilient development of the Netherlands. This, because the national government wants to acquire more insight into the vulnerability of the country to climate change, in the shorter and longer term, and in how to reduce this vulnerability by structural measures and spatial development, combined with sectoral or technological measures. By the middle of 2010, the PBL, with contributions from various universities and research institutes, will deliver a framework with various coherent packages of adaptation measures focusing

Built-up areas in flood-sensitive areas **Figure 1**

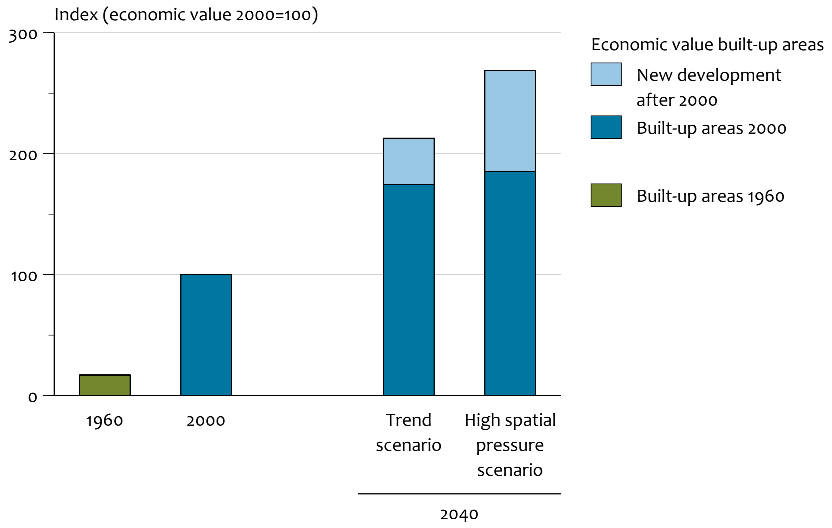


Planned urbanisation in the flood- prone parts of the Netherlands. For the coming decades, a million new houses are expected to be built, resulting in a substantial increase in urban areas. Source: MNP (2007).

on increasing climate resilience. Where relevant, adaptation measures will be examined in relation to other policy areas, such as those of nature, agriculture, urban development, transport and the quality of the living environment. In addition, measures to reduce greenhouse gas emissions are a component of the adaptation measures to be considered. For the ultimate policy choices, it is important to acquire a clear picture of the advantages and disadvantages of various packages of measures, and possible positive or negative feedbacks between various policy fields.

Recently, the Delta Committee published its policy advice on the long-term challenges with respect to climate change and water management in the Netherlands. The analysis of the committee focused on the protection against flooding and the availability of fresh water. In view of the broad context and intended integral character, our study should be seen as a supplement to the study and advice of the Delta Committee (2008).

Figure 2 **Potential ecnomic damage in flood-sensitive areas**



Because of autonomous growth and newly-developed built-up areas, the potential damage in the flood-prone areas of the Netherlands will increase two- to threefold, from 2000 to 2040. Source: MNP (2007).

The work presented here is a summary of the scoping phase of the project (PBL, 2009). In this phase, the vulnerability of the Netherlands was mapped out and focal points for policy were defined that should make the country more climate resilient.

1.2 Main findings

Changing climate in the Netherlands

As in the rest of the world, the climate is also changing in the Netherlands, and more changes are projected for the coming decades and centuries. The Royal Netherlands Meteorological Institute (KMNI) has defined four possible futures, differentiating between global temperature increase (in line with most global climate model projections) and whether or not atmospheric circulation patterns will change over Western Europe. Given these four scenarios, the climate is represented by many different indices, related to both average and extreme climate (Table 1). Some of these future changes are more uncertain than others. Annual precipitation, for example, might increase or decrease, whereas for many other indices, such as sea level rise and temperature, only the magnitude of change differs between the scenarios.

As for many other deltas in the world, the expected sea level rise is of prime importance for the long-term safety of the Netherlands. However, such a future rise in sea level is surrounded by large uncertainties, because of still incomplete knowledge about the functioning of the Earth's climate system, uncertainties about

Climate scenarios for the Netherlands: projected changes up to 2050 — Table 1

		G	G+	W	W+
Worldwide increase in temperature		**+1 °C**	**+1 °C**	**+2 °C**	**+2 °C**
Change in air circulation		No	Yes	No	Yes
Annual average	Average temperature NL	+0.9 °C	+1.3 °C	+1.8 °C	+2.6 °C
	Average annual precipitation	+3%	-1%	+6%	-2%
	Potential evaporation	+2%	+5%	+5%	+9%
	River Rhine discharge	+3%	-4%	+6%	-8%
Winter	Average temperature	+0.9 °C	+1.1 °C	+1.8 °C	+2.3 °C
	Coldest winter day	+1.0 °C	+1.5 °C	+2.1°	+2.9 °C
	Average precipitation	+4%	+7%	+7%	+14%
	Number of wet days (>0.1 mm)	+0%	+1%	+0%	+2%
	Ten-day precipitation total, which is exceeded once every ten years	+4%	+6%	+8%	+12%
	River Rhine discharge	+7%	+6%	+14%	+12%
	Highest average daily wind speed	+0%	+2%	-1%	+4%
Summer	Average temperature	+0.9 °C	+1.4 °C	+1.7 °C	+2.8 °C
	Hottest summer day	+1.0 °C	+1.9 °C	+2.1 °C	+3.8 °C
	Average precipitation	+3%	-10%	+6%	-19%
	Number of wet days (>0.1 mm)	-2%	-10%	-3%	-19%
	Ten-day precipitation total, which is exceeded once every ten years	+13%	+5%	+27%	+10%
	Potential evaporation	+3%	+8%	+7%	+15%
	River Rhine discharge	0%	-13%	0%	-24%
Sea level	Absolute rise	15-25cm	15-25cm	20-35cm	20-35cm

Source: KNMI (2006), Klein Tank en Lenderink (2009), RWS en Deltares (2008)

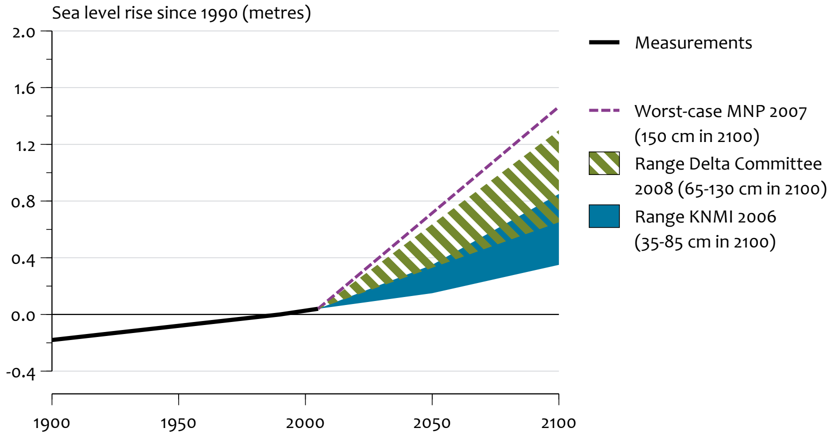
the melting of ice sheets, uncertainties in climate-change models, and uncertainties about future greenhouse gas emissions. The KNMI scenarios indicate a sea level rise of 15 to 35 centimetres, up to 2050 (Table 1), and 35 to 85 centimetres, by 2100 (Figure 3). Others have explored possible rates of sea level rise, based on worst-case scenarios concerning temperature rise and melting of ice sheets. The MNP (2007) suggests a worst-case sea level rise for the Netherlands of 1.5 metres per century, while the Delta Committee (2008) presented 'high-end' estimates of 65 to 130 centimetres, for the period up to 2100 (Figure 3).

Deltares (2008) showed that, based on the KNMI scenarios, on average, increasing discharges of the rivers in winter and early spring are to be expected. The expectations about future discharges in the summer and future peak discharges still remain uncertain. Until now, on an annual basis no significant trends in extreme river discharges have been found.

The adaptive capacity of the Netherlands: a mixed picture

Although magnitude and rate of climate change and the severity of their effects for the Netherlands are still uncertain, one may assume that, in the next decades, climate change impacts will increase. These impacts can involve both positive and negative aspects. Agriculture, for example, can benefit from increased CO_2 concentrations, higher temperatures, and an extended growing season. Similarly,

Figure 3 **Sea level rise**



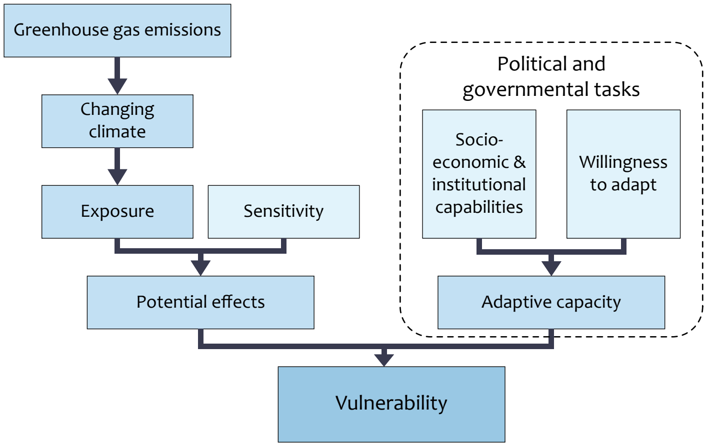
Based on KNMI scenarios, a sea level rise may be expected of 35 to 85 centimetres, by 2100. Other studies, in worst-case scenarios, provide a possible sea level rise of 65 to 130 centimetres (Delta Committee, 2008), or a maximum of 1.5 metres (MNP, 2007).

tourism in the Netherlands can benefit from improved weather conditions. At the same time, effects, such as accelerated sea level rise, increasing river discharges, and more frequent extreme weather events (peak precipitation, heat, drought, severe hail, dense fog and storms) will have negative impacts through increased risks of flooding, water nuisance and more frequent periods of drought, decrease in quality of natural habitats, adverse health effects, such as increased heat stress, summer smog, infectious diseases and allergies, as well as increased risks of pests and diseases in animals and crops.

Knowing these possible impacts of climate change and their uncertainty, the vulnerability of the Netherlands to climate change depends on how quickly the country can adapt to the above effects. In this study, the term 'adaptive capacity' is used to describe the ability to adapt to change (Figure 4). The adaptive capacity is largely determined by the potential response rate of society in relation to the rate (and predictability) of the effects of climate change. The response rate of society, in turn, depends strongly on the current political, economic and social conditions in the Netherlands, and the political and governmental capacity to implement the necessary adaptations.

A mixed picture emerges from the analysis of the adaptive capacity of the Netherlands. The risk of flooding has been studied the most. It appears that protection against flooding from the sea can be ensured with the available methods and expertise, even in a worst-case scenario of 1.5 metres increase in sea level per century (e.g. PBL, 2007, Ligtvoet et al., 2008, Deltacommissie 2008). However, it is likely that such a worst-case scenario would call for structurally different types of measures, after 2100, in the riverine areas, controlling peak discharges of rivers.

Vulnerability to climate change **Figure 4**



Analytical framework showing the relationship between adaptive capacity and vulnerability. Source: EEA (2008)

In such a case, the present Dutch policy strategy 'Room for the River' (Ministry of Transport, Public Works and Water Management 2005) will be insufficient and needs additional spatial and technical measures (RWS and Deltares, 2008).

A critical issue of climate change, for the Netherlands, is the freshwater availability, especially in low-lying areas. The adaptive capacity concerning the freshwater supply is considered limited in the current setting, due to the complexity of administrative coordination and dominant position of agriculture. With a further temperature increase and a growing deficit in precipitation (KNMI, 2006), this could lead to severe problems, especially in case of a dry climate change scenario (RWS and Deltares, 2008).

Apart from the issue of availability of water, the sectors of agriculture, energy and transport can, in principle, respond adequately to gradual climate change. This is because the necessary changes in crop production and agricultural systems and the replacement of infrastructural facilities all have a relatively short reaction time compared to the gradual climate changes. The agricultural sector is primarily anxious about increasing risks of pests and diseases and an increase in weather extremes. The urban areas and the transport and energy networks are also vulnerable to the disruptive effects of weather extremes. In view of the population densities in urban areas, the importance of transport networks, and the energy supply to the functioning of society, a further analysis of the vulnerability and possible measures is desirable.

Nature is already changing (PBL, 2008), and irreversible effects due to the temperature increase are already observed in some freshwater ecosystems, such as the IJsselmeer (RWS and Deltares, 2008). Consequently, with continuing climate change, achieving existing policy targets of nature conservation will

Table 2 Summary of analyses of adaptive capacity and vulnerability

	Adaptive Capacity	Worst-case resistant	Possible tipping points
Protection against flooding	adequate	likely	2100-2200: in case of more than 1.5 m sea level rise
Freshwater availability	limited	no	2050 in case of dry scenario
Agriculture	adequate	?	?
Nature	?	?	?
Urban areas			
- heat stress	adequate	?	?
- water nuisance	limited	?	?
Transport	adequate	?	?
Energy supply	adequate	?	?
Health (diseases)	uncertain	?	?

Summary of analyses of adaptive capacity and vulnerability under worst-case scenarios, and existing knowledge about tipping points. Source: PBL (2009), Directorate-General for Public Works and Water Management (RWS) and Deltares (2008).

become increasingly uncertain. Although the knowledge about the long-term effects of climate change on species and ecosystems is still limited, knowledge is available about the possible measures that can be taken to strengthen the adaptive capacity of nature. These measures include connecting national and international ecological nature reserves, improving environmental conditions and the linkage with hydrological systems. The possibly increased risks of epidemics and pests to people, animals and crops is uncertain, but the adaptive capacity with respect to these risks appears to be limited. Additional research into the possible control of such pests and diseases is desirable, especially in view of the potential magnitude of the societal impact.

Incomplete knowledge about vulnerability to worst-case scenarios

The vulnerability of the Netherlands to worst-case climate change scenarios is largely unknown (Table 2). Only for sea level rise and freshwater availability, the potential impact of worst-case scenarios has been explored and possible tipping points have been identified. Although the probability of unexpected changes leading to worst-case scenarios cannot be assessed at this time, the potential impacts are large – as is the time delay between required research, development and deployment of response options, and their climate effects. Therefore, it makes sense to start evaluating possible response options, in advance, to be able to make informed decisions, in case an urgent situation would arise in the future.

Flexible and adaptive strategy needed because of uncertainties

Reducing the vulnerability of the Netherlands can be achieved in different ways, for example, by means of spatial structure and development, behavioural adaptations in case of weather extremes (e.g. additional public information provided during heat waves), improved warning systems for weather extremes, and sectoral and technological adaptations. Behavioural adaptations can be implemented in the short term, and warning systems – for example, warnings about weather extremes or infectious diseases and pests – can be improved in the relatively short term (years/decades), or expanded when necessary. Sectoral and technological adaptations are, in fact, taking place continuously, whether driven by climate change or not.

As stated previously, choices that have been made about spatial structure and development have a long-term effect, are relatively irreversible, and have consequences for a number of generations. The choices that are going to be made in the coming decades, therefore, will partly determine the future climate resilience of the Netherlands, and the room for solutions that will remain for adaptation, if climate change proceeds differently (greater weather extremes) or more rapidly (temperature rise, sea level rise) than expected. The slowness and inertia of spatial developments require a robust spatial strategy for the long term.

It is a major challenge to develop a strategy which not only takes account of the spatial tasks in both the short term and the long term, but which also provides room to take advantage of the continuous emergence of new – sometimes unexpected – insights into magnitude, rate, interrelationship and manageability of the consequences of climate change. The biggest challenge will be to choose the moment of intervention as carefully as possible: intervening too soon could lead to excessive investments and unnecessary limitation of societal activities, while intervening too late could seriously increase the damage, resulting in exponential cost increases for the required adaptations, afterwards.

Priority areas for climate-proof spatial development

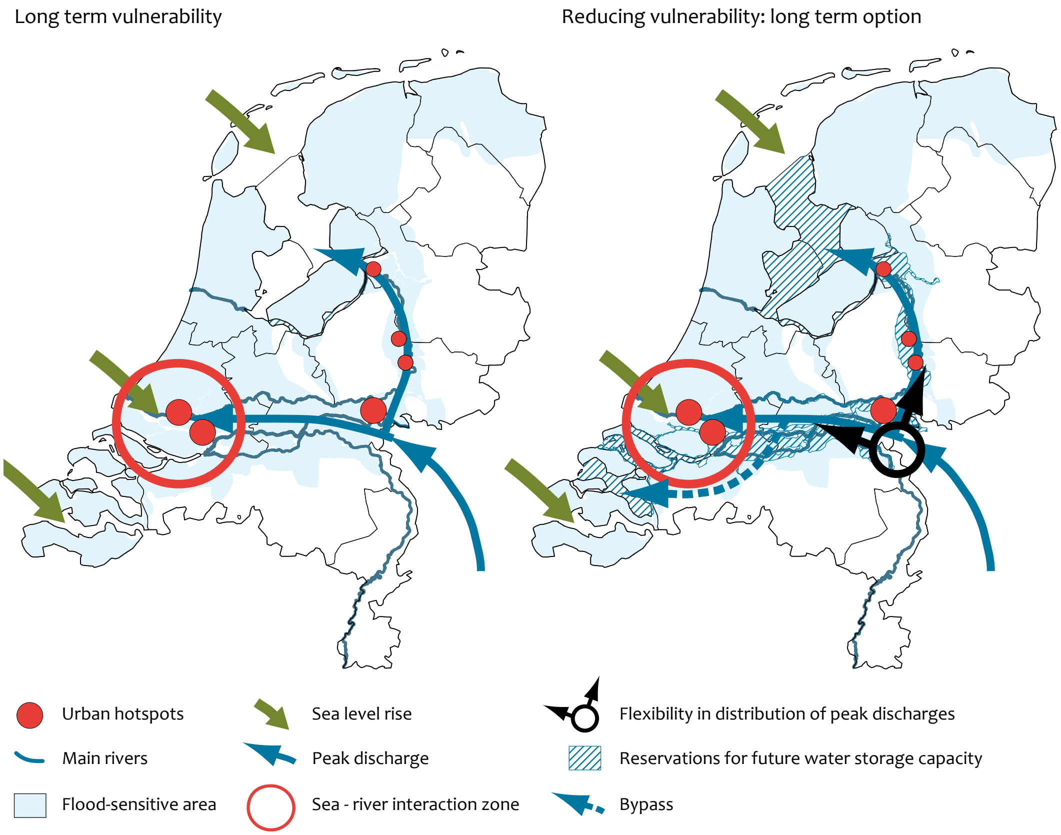
A spatial strategy should depend not only on climate effects, but also on societal attitude about the physical environment. People have intervened in the spatial structure of the Netherlands for many centuries. During this process, land use in the Dutch delta region has been able to develop more and more independently of the initial hydro-geological situation. The most important aspect of this development is the development of the water management system that has made virtually all parts of the Netherlands secure against flooding and suitable for agriculture or urban development. These spatial developments now largely determine not only the policy tasks in the area of safety from flooding, but also the challenges that are faced in the lowest-lying areas with active drainage (water nuisance and salination), the peat-soil regions (salinisation and soil subsidence), the higher located sandy soils (falling water tables), urban areas (water nuisance), and nature (falling water tables and a lack of spatial coherence).

The analysis of the adaptive capacity and the spatial tasks in the above areas has shown that the following five issues are the most important when designing a climate resilient spatial strategy for the long term.

1. Long-term security against flooding

The threat of flooding from sea can be successfully controlled with the current methods of sand suppletion and strengthening of coastal defences, even if the sea level rises in accordance with the worst-case scenario of approximately 1.5 metres per century. The vulnerability increases primarily in the lower river areas, with important cities, such as Rotterdam and Dordrecht. A rising sea level will increasingly hamper the outflow and peak discharges of the major rivers. With

Figure 5 **Long term vulnerability: interaction of sea level rise and river discharges**



It is expected that the Netherlands can cope with sea level rise, even in a worst-case scenario. However, the combination of sea level rise and peak discharges from the main rivers may, in the long run, require structural measures, especially in the river areas.

a sea level rise of more than 1.5 metres, the current safety system in the area dominated by the major rivers may become inadequate (RWS and Deltares, 2008), and structural adaptations in spatial development may be required (Figure 5). This problem will not occur in the short term, and only if the sea level rises according to the worst-case scenario, in the 2100-2200 period. The potential consequences for spatial developments in the coming decades are not clear, yet, neither are the costs and benefits, and advantages and disadvantages of various safety strategies that also deal with a sea level rise of more than 1.5 metres. Especially important are the urban developments in areas dominated by the major rivers, as a whole, and near hotspots, such as Rotterdam, Dordrecht, Arhem and cities along the IJssel, the northern branch of the Rhine (Figure 5).

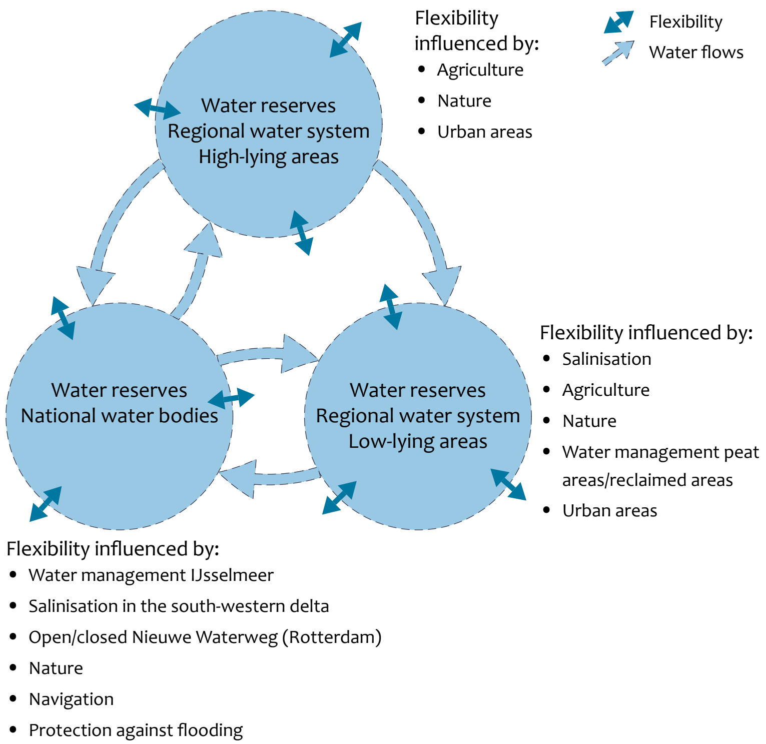
Rotterdam, located in the lower reaches of the Rhine, is one of the hotspots concerning the Netherlands' long-term vulnerability to flooding. The storm surge barrier 'Maeslantkering' can be closed to protect Rotterdam in case of high waves and storm surges, but with respect to high rates of sea level rise, the way to best protect Rotterdam and its surrandings is still being studied. Photo: Rijkswaterstaat.

2. The freshwater supply of the Netherlands

Climate change aggravates the existing problems of freshwater management. These problems concern the salinisation in the south-western region of the Netherlands and the lowest-lying areas with active drainage, freshwater shortages in summer on the higher located sandy soils, and excessively high water temperatures (and related algal blooms and limitations on cooling water and drinking water extraction). In the current situation, the adaptive capacity for the freshwater supply and water quality, partly in relation to agriculture, has been evaluated as limited because of the complexity of the water management system (Figure 6). In the future, this capacity will probably be inadequate, certainly under a pessimistic scenario (RWS and Deltares, 2008).

In view of the complexity of the hydrological system, potentially successful variants to improve the regional freshwater supply (as much as possible) will be investigated, in relationship with the possible water supply from the main hydrological system. In the ultimate evaluation, and when making strategic choices for the main hydrological system, the above-named safety requirements and the demands of shipping and nature must also be involved. Because of the uncertainties concerning future problems with falling water tables in the

Figure 6 **Complexity freshwater supply**



The adaptive capacity in the Netherlands with respect to the fresh water availability is considered limited, because of the complexity of the water management system, the close interaction with existing agricultural use and the large number of authorities involved in the decision-making process.

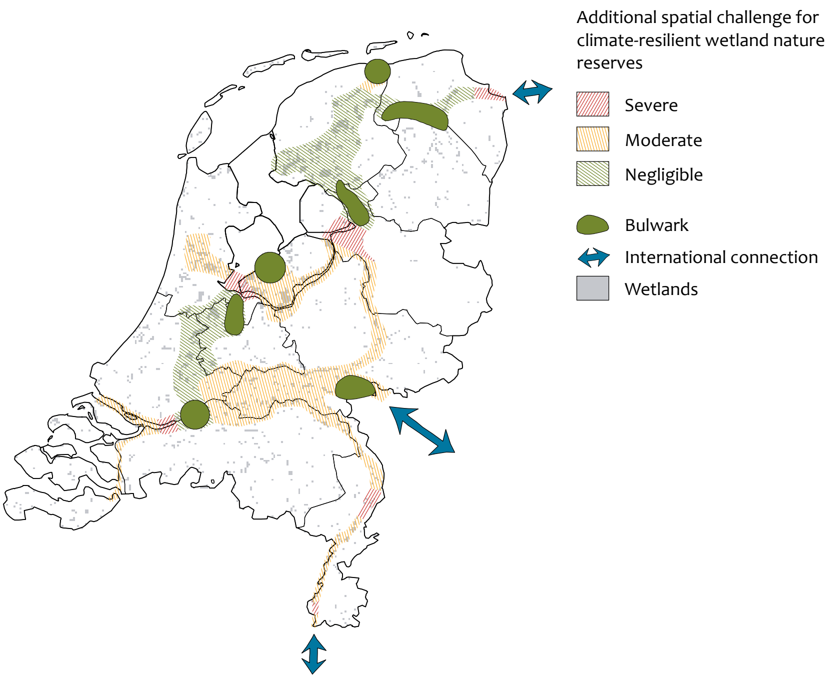
Netherlands, it is desirable, under any circumstance, to investigate a variant with minimal costs and maximum flexibility.

3. Reducing the vulnerability of nature in the Netherlands

The effects of climate change have already become clearly evident in the prevalence of species in Dutch wildlife habitats: some species are disappearing, new species are appearing, and some interactions between species and certain functions of ecosystems are being disturbed (PBL, 2008). Partly as a result of these changes, the achievement of the conservation targets in current nature policy has become uncertain. The knowledge about the vulnerability of nature itself is limited, and the ultimate effects on nature will depend strongly on the rate of climate change. However, knowledge is available on the way in which the resilience of nature can be increased: i) by means of larger nature reserves with improved connections to each other; ii) by improving environmental conditions (preventing overfertilisation and falling water tables, improving structure); iii) by making more use of natural gradients and the physical system in creating new

Climate corridor of wetland nature reserves

Figure 7



Connecting important wetland areas nationally and internationally will increase the resilience of wetland related nature to climate change. Source: PBL (2008).

nature (river habitats, peat bogs, stream valley systems and seepage zones), and iv) by strengthening international cooperation, so that transnational nature reserves can improve their connections to each other. The concept of the National Ecological Network (EHS; see Figure 7) is a good point of departure for increasing the resilience of nature. The aim of the current government is to complete the delineation and development of the EHS by 2018. During the planning and development of the remaining EHS areas (many tens of thousands of hectares), it is desirable to take climate change into account.

4. Climate proofing of urban areas

Urban areas are faced with the combined task of controlling both water nuisance due to heavy rainfall and heat stress. Moreover, due to their dense populations, these areas are vulnerable to possibly increased risks related to allergies and infectious diseases transmitted by vectors. The climate resilience of urban areas can be increased through spatial and non-spatial measures. Especially during urban restructuring and the development of new urban areas, there are good possibilities for combining the task of providing climate resilience with other aims of national government policy, such as improving the quality of the physical environment and reducing energy consumption (including related greenhouse gas emissions). Such

Parks and ponds in the urban environment improve the quality of the physical environment and, at the same time, contribute to reducing the vulnerability to extreme weather events (extreme rainfall, heat waves). Photo: RIVM Beeldbank

measures could include increasing the area and attractiveness of terrestrial and aquatic nature in and near cities (where water storage capacity will be increased and heat stress will be reduced), energy-saving buildings and new sustainable energy technologies, such as solar cells or thermal energy storage. Recent studies have shown that the additional costs of energy-saving buildings and utilising sustainable energy in urban areas can be recovered within 10 to 15 years.

During the next 30 years, it is expected that nearly one million new houses will be built in the Netherlands. Given this construction task, in the decades to come, many billions of euros will be invested in urban areas. At the same time, spatial flexibility is limited: once neighbourhoods and buildings are completed, the costs of possible adaptation rise quickly. In the light of climate change, this limited flexibility calls for important choices to anticipate the best way to structure and develop the space, both above and below ground (sewerage systems, underground thermal energy storage). The expected investments and the spatial development or restructuring of urban areas can be a window of opportunity for simultaneously achieving multiple objectives. Utilising this window of opportunity will not happen by itself, as shown in the strategic policy document 'Randstad towards 2040', in which climate resilience is given an important role, but no linkage is provided with the energy conservation task for urban areas.

5. Reducing the vulnerability of transport networks and the energy supply

The transport networks (air, road and rail traffic, shipping, ICT) and the energy supply are primarily vulnerable to weather extremes. Because these networks are very important for the functioning of society, a further analysis of the vulnerability of these sectors is justified (including their vulnerability under extreme climate scenarios) and the possibilities for reducing this vulnerability. At the same time, a broad analysis is desirable of the energy supply and energy networks, partly in the light of government aims for reducing greenhouse gas emissions by means of energy savings, and developing sustainable energy sources before 2020. The choices to be made when working out government goals on development of sustainable energy sources can contribute to reducing climate vulnerability of energy networks. During this process, this question will arise: to what extent should sustainable energy be developed centrally (wind turbine parks) or locally (thermal energy storage systems and solar energy in urban areas)?

Long-term strategy needed with respect to health, diseases and pests

As a result of climate change, several types of health problems may increase, in the Netherlands, in the decades to come. Warmer summers, also with an increased risk of heat waves and periods of summer smog, will lead to more illness and premature mortality among vulnerable populations, such as the elderly, the chronically ill and infants. Likewise, decreased (surface) water quality and vector-borne spreading of a variety of insects and parasites will presumably increase the risks of infections. The increased growing season, with more intense release and spreading of

Using sea water for cooling, power plants along the coast are less vulnerable to climate change, for example, this power plant on the Maasvlakte near Rotterdam. Increasing the share of wind energy and other forms of renewable energy, also contributes to a climate-proof energy supply. Photo: Nationale Beeldbank

Climate change affects human health in multiple ways, like (1) higher temperatures result in broader distribution of vectors and thus infectious diseases like Lyme; (2) increasing temperatures cause more frequent blue algae blooms (Cyano bacteria); (3) longer growing seasons result in more allergic disorders like hay fever Source: Beeldbank RIVM

allergenic pollen and increasing frequency of humid periods, may result in more allergies and hay fever. The rise in average temperatures also has a positive side effect: less temperature-related premature mortality during winter periods. Because of a lack of data, however, it is difficult to indicate the exact magnitude and severity of the negative climate effects on mortality and disease. It is expected that, as a consequence, these effects will eventually give rise to an increased health-care burden and some societal dislocation, although the level will depend on the vulnerability and on the ability to adapt.

Various spatial and non-spatial options and strategies can be defined to lower health risks to humans, although there is a lack of knowledge on the beneficial impacts. Spatial restructuring, building reconstruction, and more green and blue (water) areas in the urban environment, for example, could result in a certain reduction in the 'heat island effect'. Similarly, the use of less allergenic plants and trees is expected to reduce allergies. Already, with existing regulations (or with small changes to them), many of the options can be implemented, and often in a relatively cheap manner. It is unknown, however, whether some of these measures have counterproductive effects, for instance, increased use of surface water for cooling purposes versus an increased risk of waterborne infections, or urban greening aspects versus an increase in pollen and vectors that transmit infections. These sorts of phenomena and the overall lack of empirical knowledge on health benefits from interventions and specific measures, warrants the need for more integrated monitoring and modelling research, and development of targeted, spatial and non-spatial, long-term incremental adaptation strategies in this field.

These studies must reveal whether some of the health impacts are the true result of climate change or if they are also influenced by globalisation and international transport movements and other processes. In the Netherlands, Lyme disease, for example, has become more widespread, and elsewhere in Europe outbreaks of 'new' infectious diseases have occurred in recent years, such as avian influenza, blue tongue (affecting sheep) and Chikungunya fever (affecting both humans and animals). It is difficult to estimate the risks of such outbreaks. However, because societal dislocation can be significant, a more stringent and expanded international surveillance strategy is desirable, in a global context (improving monitoring and knowledge exchange, coordinated by the World Health Organization). Additional measures at national and European scales can also be considered.

The National Spatial Structure provides a solid base for a national climate resilience strategy

The National Spatial Structure (NSS) lies at the hart of Dutch national policy on spatial developments (VROM, LNV, V&W, EZ, 2006). The NNS comprises the main hydrological system and basal coast line, the urban networks and the Randstad, including the Green Heart, the most important transport links and the main ports of Rotterdam and Schiphol, the National Ecological Network, the Greenports and world heritage areas, and the National Landscapes (Figure 8). The policy tasks at national level comprise many components of the National Spatial Structure. For example, the integral task for the national water management system and the coastal zone comprises the long-term security against flooding, ensuring freshwater supply and conserving nature. The task concerning water availability in rural areas, in relation to agriculture and nature, involves, among other aspects, the Greenports, the National Ecological Network and the National Landscapes, including the Green Heart. The integral and climate-proof urban development task comprises the urban networks and the Randstad, where there is also an important interaction with the transport and energy networks.

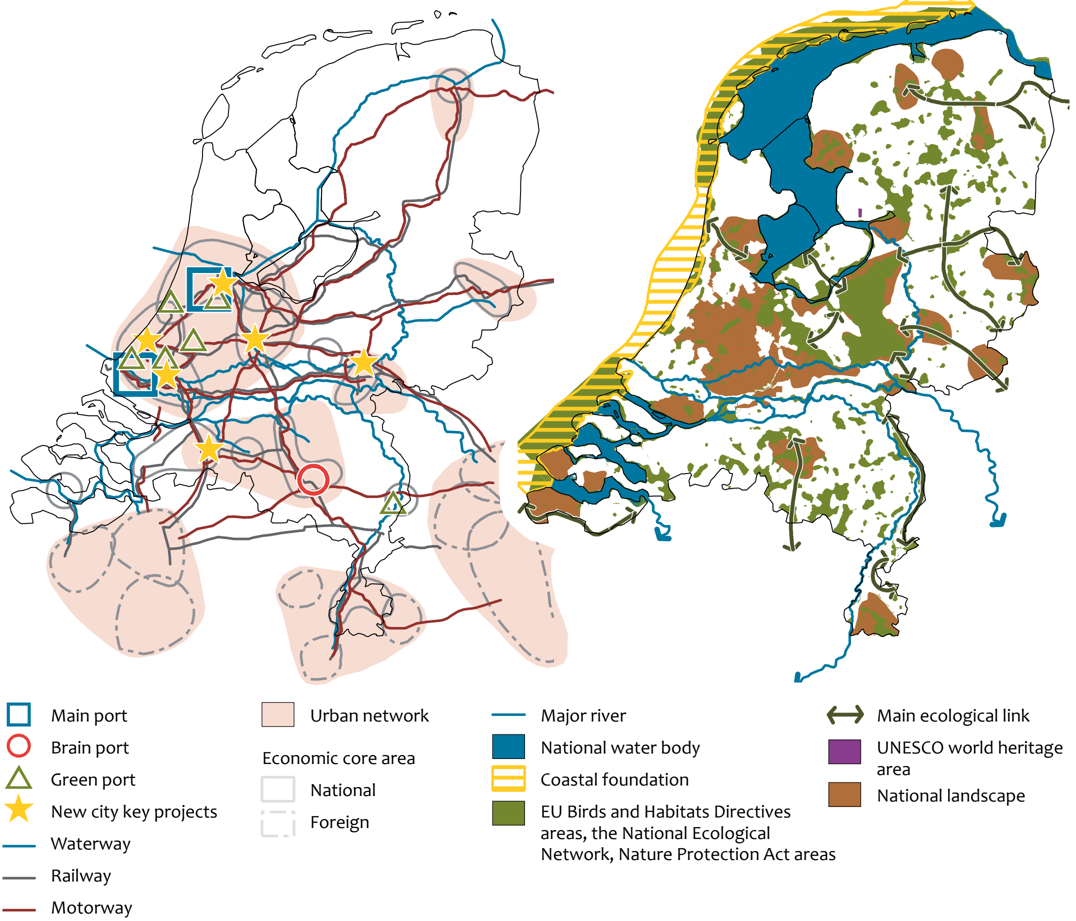
It can be concluded that the components of the NSS provide an important foothold for a climate-proof, long-term strategy at the national level. As shown by this preliminary study, however, the preconditions for the development of the NSS and the possible specifications of specific components require adaptation, if greater climate resilience is envisaged. The follow-up research aims to provide additional insight into this topic.

In the short term, there are opportunities to improve the coherence between choices at various levels, and in various policy dossiers. Important and ongoing policy dossiers that can be utilised for this purpose are the strategic policy document 'Randstad towards 2040', the National Water Plan 2009-2015 (including the redefinition of the policy against flooding), the developments in the National Ecological Network and the Natura 2000 sites, the National Structure Plan for the IJsselmeer Region, and at provincial level the new provincial spatial structure visions.

Figure 8 **National Spatial Structure**

Economics, infrastructure and urbanisation

Water, nature and landscape



The economic, infrastructural and urban elements (left) of the National Spatial Structure, including water, nature and landscapes (right). Source: VROM, LNV, V&W, EZ (2006).

Follow-up

By the middle of 2010, a follow-up of this study will be published concerning options for a climate-proof spatial strategy for the Netherlands. To this end, coordination with the follow-up research to the National Water Plan 2009-2015, and the provincial climate atlases, will be assured. The follow-up track will be implemented in close cooperation with ongoing research programmes, such as the ‘Knowledge for Climate' programme, the 'Climate Changes Spatial Planning' programme, and various universities and research institutes in the Netherlands.

After this, based on the assessment of long-term strategic options, an iterative process will be initiated to generate a clear picture of a desired adaptive long-term strategy. This process will not be an exclusively scientific exercise, but requires interaction between policy, societal actors and science.

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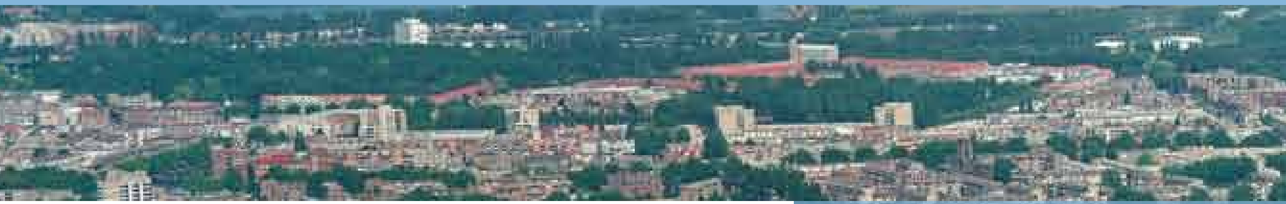
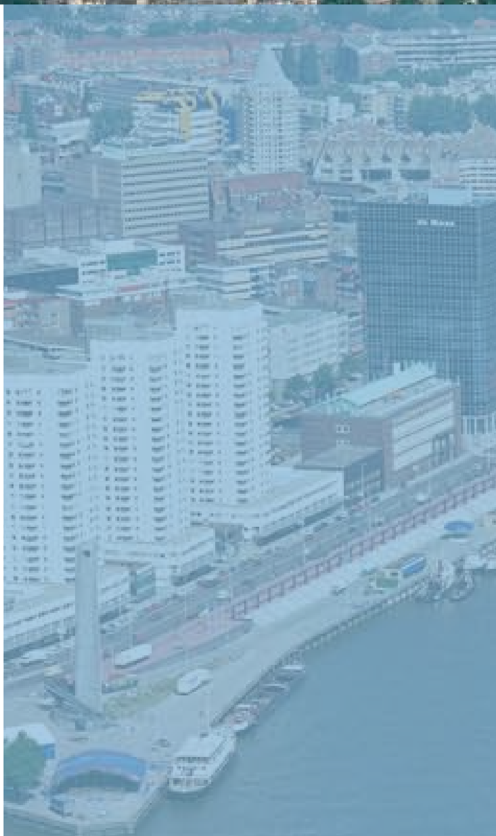


Spatial planning reduces vulnerability to climate change

Climate change causes multiple effects – also in the Netherlands. The temperature and sea level are rising and patterns of rainfall and river discharges are changing. The rate of climate change itself and its possible impacts are surrounded with substantial uncertainties.

Acknowledging the uncertainties, the main challenges to be incorporated in a long-term spatial strategy for the Netherlands are: long-term protection against flooding, securing the availability of fresh water, and reducing the vulnerability of nature, urban areas, and transport and energy networks.

A consistent long-term spatial strategy requires coordination between various policy terrains, and coherence in decision-making and policy implementation at national, provincial and municipal levels. The actual policy agenda, in the short term, already provides chances for reducing the vulnerability of the Netherlands to climate change. Especially in restructuring and developing new urban areas, opportunities exist for reducing this vulnerability (adaptation), for reducing greenhouse gas emissions (mitigation), and simultaneously improving the quality of the living environment. Although the expertise and technologies are available, these developments will not take place by themselves.



Netherlands Environmental Assessment Agency, December 2009