Scientific Synthesis Report

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Colophon

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Content

Preface

The national research programmes **Climate changes Spatial Planning** (CcSP; 2004-2011) and **Knowledge for Climate** (KfC; 2008-2013) were initiated by the Dutch government to support research regarding adaptation and land use related mitigation strategies to climate change in the Netherlands. The programmes operate in the middle of a challenging interface between science, policy and the private sector.

The ambition of both programmes is twofold: On one hand, the programmes aim to generate internationally competitive scientific results. On the other hand, the programmes stimulate joint learning and co-production and valorisation of knowledge about climate adaptation.

This document gives an overview of research highlights. These results have already found their way into international science and were used in decision making about future infrastructure of the Netherlands. However, we have also had examples of failures. Moreover, we keep on experimenting with different perspectives on, for example, knowledge transfer, knowledge valorisation, future climate research funding philosophies and more recently, with the positioning of climate science in societal and political debate. The programmes have often to navigate their way between their twofold ambitions, as prisoners between **Scylla and Charybdis**[1].

The CcSP and KfC Boards have decided to install a Societal Advisory Council and an International Scientific Advisory Council (ISAC). The ISAC has been asked to prepare an advice on the embedding of the research activities and results into international research and policy networks, the transfer of (scientific) knowledge towards society and further research directions. This document provides background information in order to formulate this advice.

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[1] **Scylla** and **Charybdis** were two sea monsters of Greek mythology. Later Greek tradition sited them on opposite sides of the Strait of Messina between Sicily and mainland Magna Graecia (southern Italy). They were said to be located close enough to each other that they posed an inescapable threat to passing sailors; avoiding Charybdis meant passing too closely to Scylla and vice versa.

1 Introduction

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Climate change and low-lying deltas

Dealing with climate change and climate variability is an important challenge for societies in the coming decades, both on a national and global scale. The Intergovernmental Panel on Climate Change (IPCC) presents increasing evidence of impacts of climate change and suggests that most of the warming observed over the last 50 years is attributable to human activities (IPCC, 2007).

In particular delta regions, such as the Netherlands, are vulnerable to climate change, because they are low-lying and therefore inherently hazard-prone areas. In addition deltas host vast population concentrations, large economic capital and societal stocks. The proximity to rivers and the sea place them, almost without exception, at international trade crossroads. Among the world's delta regions, the Netherlands stands out in the extent to which it has developed in terms of capital stock living below sea level. Both sea level rise and changed river dynamics due to prospected climate change require long-term adaptive planning strategies in order to reduce climate based risks, strategies defined as climate proofing concept (Kabat, et al., 2005). These strategies could generate opportunities for technological and societal innovations in economic sectors such as agro-production, recreation and water management (Kabat, et al., 2009).

Wicked problem

Although climate change is starting to become noticeable for science and policy makers, it is still difficult to take adaptive measures because not all people in society recognize increased climate based risks or directly experience damage. Concerned governmental but also private organizations are increasingly posing questions as to whether current management and business practices are able to cope with climate change and increased climate variability or whether alternative strategies are needed. However, alternative planning strategies will require willingness to invest at the public and the private level, while many involved sectors have high stakes just in continuing current practices. Involved stakeholders have different perceptions about the seriousness of the problem and the acceptable risk thresholds (De Boer, et al., 2010). Therefore, climate change issues are often typified as 'wicked problems'. A wicked problem is generally associated with a lot of uncertainties and different perspectives about both the problem and the potential solutions (Hisschemöller & Hoppe, 2001; Rittel & Webber, 1973). As a result, climate change requires a different way of production and organisation of (scientific) knowledge compared to other environmental problems (Driessen, et al., 2010). For example, due to the complexity of the issue, a variety of scientific disciplines to solve its resulting societal problems is required.

Table 1.1: Some key publications on programme level

Berkhout, F., Hertin, J., & Gann, D. M. (2006). Learning to adapt: Organisational adaptation to climate change impacts. *Climatic Change, 78*, 135-156.

De Boer, J., Wardekker, J., & Van der Sluijs, J. P. (2010). Frame-based guide to situated decision-making on climate change. *Global Environmental Change*.

Driessen, P. J., Leroy, P., & Van Vierssen W. (2010). *From Climate change to Social Change. Perspectives on science-policy interactions*. Utrecht, The Netherlands: International Books.

Katsman, C. A., Sterl, A., Beersma, J. J., Van den Brink, H. W., Hazeleger, W., Vellinga, P., et al.(2011 (accepted)). Exploring high-end scenarios for local sea level rise to develop flood protection strategies for a low-lying delta - the Netherlands as an example *Climatic change*.

Kabat, P., Fresco, L. O., Stive, M. J. F., Veerman, C. P., Van Alphen, J. S. L. J., Parmet, B. W. A. H., Hazeleger, W., & Katsman, C. A. (2009). Dutch coasts in transition. *Nature Geoscience, 2*(7), pp. 450-452.

Kabat, P., Vellinga, P., Van Vierssen, W., Veraart, J. A., & Aerts, J. (2005). Climate proofing The Netherlands. *Nature, 438*(7066), 283-284.

Lenderink, G., E. van Meijgaard and F. Selten (2009), Intense coastal rainfall in the Netherlands in response to high sea surface temperatures: analysis of the event of August 2006 from the perspective of a changing climate; Clim. Dyn., 2009, 32, 19-33, doi:10.1007/s00382-008-0366-x.

Climate Science Policy decisions in the Netherlands since 1987

Climate science policy decisions are those concerned with governing the climate science research enterprise, and can be distinguished from climate policy decisions, which are those made in anticipation of or in response to climate change (Pielke, 2009; Sarewitz & Pielke, 2007). In many cases all over the world decisions are made in the face of uncertainty about the outcomes and utility of research. The funding of scientific research is almost always justified in terms of the potential for achieving beneficial societal outcomes, which is also the case for climate research in the Netherlands.

The first publications from Dutch research about the relationship between CO_2 emissions and climate change appeared sporadically in the 70's of the previous century (For example(Lablans, 1970). In 1983 the enhanced greenhouse gas effect was for the first time issued with an advisory report in the Dutch Parliament (Gezondheidsraad, 1983). This advice had no direct political consequences, but it gave an impetus to the development of the first national programme for climate research, that was launched in 1987 by the Dutch Science Foundation (NWO) (Baede & Schuurmans, 2008; Schuurmans & Baede, 2008). In addition the Dutch Ministry of Environment (VROM) designated the National Institute for Public Health and environment (RIVM) and the Royal Meteorological Institute (KNMI) as so-called "reference research centres", which the government could approach for reliable information about the climate problem (Schuurmans & Baede, 2008; Van de Kerkhof, 1998). In the early days, climate change was within the Dutch science community addressed merely from the natural science perspective.

Climate research in the Netherlands received more attention from the policy after the foundation of the Intergovernmental Panel on Climate Change (IPCC) in 1989. Climate research was (and still is) commissioned not only by NWO (fundamental research), but to a much larger extent by the Ministries of Environment (VROM), Agriculture and Nature Management (LNV), Transport and Water management (V&W) and Economic Affairs (EZ)[2]. The Ministry of VROM launched in 1989 a research programme on Global Air Pollution and Climate Change (**NOP-I**; 1989-1995). Initially, the research agenda was designed by the meteorological community. However, also other aspects such as oceanography, water management, land-atmosphere interactions and bio-geochemical cycles received more and more attention (RIVM, 1987). This research programme was followed by **NOP-II** (1995-2001). In the face of the Kyoto protocol also climate policies (energy, mitigation, adaptation) were addressed in the second phase. NOP I&II had a budget of in total 48 million euro (Baede & Schuurmans, 2008; Schuurmans & Baede, 2008).The evaluation of NOP-II (RMNO, 2001) states that many involved policy makers and other public stakeholders had the opinion that the contribution of the research programme was more important for the underpinning and framing of the context of the general climate policy rather than serving specific measures of climate policy implementation itself .

Climate changes Spatial Planning (CcSP) and Knowledge for Climate (KfC)

Unlike the previous climate research programmes, the decision on the funding of the CcSP and KfC climate research programmes was not solely made by the Ministry of VROM. In 2001, a highly competitive call for proposals was issued by the national government. The objective of the call was to improve the Dutch knowledge infrastructure, and stimulate knowledge transfer and knowledge valorisation through better interaction and communication between science, policy and private sectors. The funding, which was € 802.000.000 for 37 knowledge programmes, can be seen as very substantial, came from national gas revenues (Ministry of Economic Affairs, 2002a, 2002b), which normally have been used to fund "hard" economic infrastructure of the country. Also the funding philosophy is different; maximal 50% of the total budget is funded from national gas revenues and the participating organizations and stakeholders are obliged to bring up the additional budget, in order

[2] As of 2011 and by the decree of the new Dutch Cabinet, the Ministry of Environment has been merged with the Ministry of Transport and Water Management, and they both formed a new entity called "Ministry of Infrastructure and Environment" (I & M). The Ministry of Agriculture, Nature Management and Food Quality has been merged with the Ministry of Economic Affaires into a new Ministry of Economic Affaires, Agriculture and Innovation (EL &I). Although the funding of the ongoing climate research programmes is guaranteed and will continue without cuts, major changes are expected about how the Dutch Climate Research will be funded in the future, after the ongoing programmes terminate.

to increase the efficiency of knowledge valorisation and to better guarantee that the new elements of the knowledge infrastructure will be adopted by the institutions involved in a “sustainable” way.

To invest a part of the gas revenues in the knowledge infrastructure of the Netherlands was one of the most important strategic and perhaps one of the most visionary decisions of previous Dutch Cabinets.[3] The Dutch climate research community proved to be able to develop two competitive, large research programme proposals which were funded through this mechanism,

A consortium of several scientific institutes, led by Wageningen University and Vrije Universiteit Amsterdam, submitted a proposal to fund the research programme **Climate changes Spatial Planning (CcSP; 2004-2011)**, that was approved and started in 2004 (total budget 80 million euro).

The Dutch government took the decision to fund the CcSP programme proposal based on an extended international scientific review organized by the Dutch Royal Academy of Sciences and Arts, and on the overall advice from an independent board of experts (in Dutch: “Commissie van Wijzen”). This independent board of experts is every 5 years appointed by the Dutch Government for the assessing the eligibility of grant applications for research proposals to be funded from natural gas revenues. The board of experts based its advice on the eligibility for grant application of the CcSP programme on an international scientific evaluation and on a social-economic evaluation from the Netherlands bureau for Economic Policy Analysis (CPB).

In 2005, the senate of the Dutch national Parliament called for the incorporation of climate based risks into long-term planning strategies (Eerste Kamer der Staten Generaal, 2005). In response the government launched a new policy initiative called ARK (Adaptation Programme for Spatial Planning and Climate), under co-ordination of the ministry of VROM. The CcSP programme which was already in initial stages of its execution played a key role in scientific, programmatic and organizational underpinning of these developments.

In 2007 the Dutch government appointed a committee - the second Delta Committee[4] - with a broad mandate and long term time horizon (2100-2200). the committee was asked to evaluate the potential effects of climate change in the Netherlands and to propose measures to "climate-proof" the country: to

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[3] It is at present highly uncertain of this funding mechanism will survive beyond 2014, since the new Dutch Cabinet has an intention to terminate it.

[4] On 29 January 1953, just before (!) the flood disaster in the Southern part of the Netherlands, the first deltaplan ‘afsluitingsplannen der Tussenwateren’ (Closure of the coastal waters) was discussed in the parliament. The first Delta commission was installed at 21 february 1953(Maris, et al., 1956; Stuvel H.J., 1962).

keep it safe from flooding, while preserving its status as an attractive place to invest in, work and live (Deltacommissie, 2008). The government has responded to the Committee's recommendations in drafting the Coastal Vision (2008) and the National Water Plan (2008). The National Water Plan calls for the design and implementation of the so-called Delta Programme along with a Delta Act and a Delta commissioner (Werners, 2009).

Climate (adaptation) research and practice became a "booming business" in the Netherlands after 2005, and it turned out that CcSP programme alone – despite of its size of 80 million Euro, could not meet the rapidly increased demand and societal need for applied knowledge on climate adaptation coming from the Dutch central and regional governments, NGOs and many sectors from semi-public and private domains. A large consortium led by Universities of Utrecht, Wageningen and Amsterdam has therefore prepared a new and complementary research programme proposal - the **Knowledge for Climate (KfC; 2008-2013)** – which was approved by the Dutch government for funding in 2008, and which has a total budget of 80 million Euros, out which 46 million Euros is funded from national natural gas revenues.

Both programmes have the mission to offer regional and national policy makers, government, the private sector and other stakeholders a clustered, high-quality and accessible knowledge infrastructure in order to develop climate adaptation strategies. The programmes aim to engage dialogue on climate adaptation between stakeholders and scientists in order to co-create knowledge between science and practice.

The programmes embrace the **climate proofing concept** as a combination of (a) targeted adaptation measures as well as mainstreaming climate change into other spatial developments, (b) risk management and coping strategies which rely on measures such as legislation schemes, governance and institutional transitions in spatial planning, and (c) opportunities for technological, institutional and societal innovations (Kabat, et al., 2005).

Because of the many uncertainties surrounding climate change issues, actors not only face the challenge to develop and implement these adjustments and transitions, but also to increase the adaptive capacity of society (Gupta, et al., 2010; Van Nieuwaal, et al., 2009). Much adaptation will be the result of autonomous or planned actions of private actors (Berkhout, et al., 2006; Stern, 2006). Moreover, many aspects of adaptation have public-good characteristics, requiring collective action. Most people expect or hope governments to safeguard them from flood, drought, and the health effects of climate change. Therefore, adaptation to climate change is not only a complex technical issue, but also a demanding matter of governance (Gupta, et al., 2010).

The science to underpin adaptation strategies needs to be developed at different scales – ranging from national to local, and for different sectors, which are often imbedded and inter-linked. For water infrastructure (both flood risk protection and fresh water availability), vulnerability to climate needs to be studied both at level of the entire rivers- and delta system including interactions with sea level rise, as well as at a level of a local polder or urban water system. Adaptation strategies for nature and biodiversity needs understanding at a level of individual species and communities, but also about how the nature systems are connected at large scales. There is an obvious synergy and possible win-win solutions in adaptation strategies when addressing both water and nature sectors together, in many cases in combination with other sectors like agriculture and spatial planning. The CcSP and KfC programmes include both sectoral as well integrated adaptation research projects.

The cross-sectoral, integrated adaptation strategies can best be examined in a regional or local setting, since that is where one finds the knowledge and experience for effective intervention strategies. This so called "hot spot" strategy (see Figure 1.1 and 1.2) is an important characteristics of the Dutch Climate Adaptation Research.

Figure 1.1: Hotspot approach as research programming strategy

Hotspots

In the CcSP programme hotspots are relatively small projects where climate science is applied in consultation with local stakeholders, while in the KfC programme the hotspots are a temporary intermediary platform to align knowledge needs and scientific research during the entire course of the programme (2008-2013). The KfC hotspots are used as a node for designing Options for Regional Adaptation Strategies (ORAS) where all relevant results and findings of the research converge and is transferred to policy makers and practitioners to base their decisions on.

In both programmes the hotspots are preferably areas where climate proofing planned investments or activities create potential high social or economic opportunities (Kabat, et al., 2009). The regional approach has some drawbacks too; proposed regional adaptation strategies could generate some negative

Figure 1.2: CcSP and KfC Hotspots

side effects, such as the transfer of problems or burdens from one region to the other, and tailoring climate information to the regional scale complicates the use of nationally consistent scenarios.

Table 1.2: Description of the KfC hotspots.

Schiphol Mainport and the Schiphol Region
The Schiphol Region is a highly dynamic area that represents a major economic interest, not only because of Schiphol airport but also because of the various investments in housing, office locations and business networks nearby the urban agglomerate, commonly referred to as Randstad. Climate change and the resulting change in weather conditions not only affect daily operations at Schiphol airport, but are also a determining factor in possible future expansion, that should be aligned with other socio-economic interests within the region.
The Haaglanden Region
The Haaglanden region has the challenge to climate proof urban expansion in combination with a high concentration of greenhouse cultivation and a spatial claim to increase the water retention capacity in order to reduce water nuisance risks, also in view of climate change. The objective is to Develop adaptation strategies for climate change for a number of pilot projects.
The Rotterdam Region
The Port of Rotterdam and the region will receive large investments in urban development, living environment, transport, navigation and industry over the next ten years. Climate change will increase the flood risk from both the sea and the rivers. The objective is to make the area both climate proof and as attractive as possible for living and working, with particular attention to be given to the port, transport and housing.
The Major Rivers
Climate change provides a new challenge as far as water management in the area surrounding the great rivers is concerned. The Dutch government has already implemented measures in policy programmes such as ‘Room for the River’ (Ruimte voor de Rivier) and ‘Flood Risk and Safety in the Netherlands’ (Veiligheid Nederland in Kaart). The objective of this hotspot is to develop knowledge regarding water safety and climate adaptation for three case studies in the area surrounding the major rivers (Biesbosch-Haringvliet, Betuwe-Lower Rhine, Kampen/IJssel).
South-West Delta
The South-western Delta is important as strategic freshwater reservoir for agriculture, for river-discharge regulation, recreation, aquaculture, nature and as gateway to the port of Antwerp. While the ‘Delta Works’ are still an international icon for Dutch water management, current policy plans put emphasis on their environmental impacts, as well as prospected climate change. The Hotspot objective is to incorporate adaptation strategies to climate change in the planning and implementation of investments in spatial planning, as specified in the Delta programme (Delta programme Commissioner, 2011)
Shallow waters and peat meadow areas

The Netherlands has many shallow water systems such as lakes and pools as well as numerous ditches and canals, characteristic of peat meadow areas. These shallow water systems form an environment type characteristic of a low lying delta, i.e. the Netherlands. The Hotspot aim is to develop knowledge regarding the effects of climate change and how to anticipate them as far as the quality and ecological status of shallow waters in the Netherlands are concerned and develop knowledge concerning soil subsidence in the peat meadow region.

Dry rural and semi-urban areas

The semi-urban area outside the Randstad is characterized by rural landscapes and a high concentration of small and medium-sized towns and villages. Large areas of countryside situated on higher sandy ground, are currently undergoing a transition from a food production landscape to a more consumerist multi-functional landscape. Flood risks and water stress are significant problems in agriculture and nature conservation, and may increase due to climate change. The Hotspot objective is to develop knowledge regarding the effects of climate change on regional development in the short and medium terms.

Wadden Sea and the Northern part of the Netherlands

The Wadden Sea, the world's largest intertidal and barrier island system, is characterised by high spatial and temporal variability. A changing climate will have a significant influence on the development of and people's attitudes to natural areas, the use of natural resources and security in the area and surrounding regions (Groningen, Friesland). It is an objective to generate knowledge regarding the resilience and sustainability of the Wadden ecosystem as a safety buffer for the surrounding areas in a changing climate.

2 Some facts and figures about both programmes

2.1 Strategic and scientific objectives

The CcSP and KfC have the following **shared strategic objectives**:

- Advance our understanding on the impacts of climate change for the Netherlands, including both the physical system, policies and the socio-economic dimensions, aligned with the most recent international state-of- the art science
- Increase the policy relevance and practical applicability of scientific research about climate adaptation by stimulation of joint learning and co-production of knowledge.
- Strengthen the economic position and the business climate of the Netherlands through development of low-emission and climate proof concepts that can be used in spatial planning and preparation of investment decisions regarding infrastructure, housing, water management and nature development projects.
- Strengthen the national research infrastructure in the field of climate change and adaptation by stimulation of joint learning and co-production of knowledge between knowledge institutes, universities, policy makers and the private sector. This will also strengthen the international scientific position of the Netherlands.

2.2 Research themes of the CcSP programme

Figure 2.1: Structure of CcSP programme

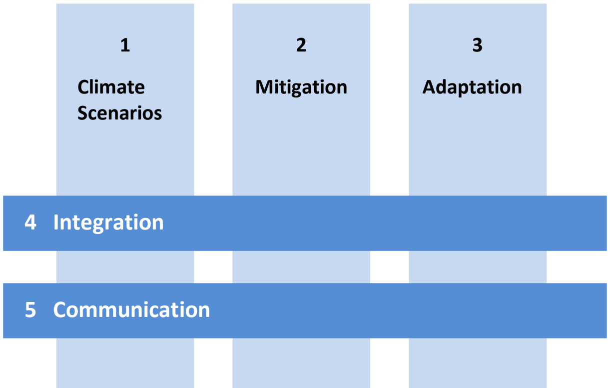


Table 2.1: Research themes **Climate changes Spatial Planning**

Climate Scenarios
The theme 'Climate Scenarios' covers the role of terrestrial, atmospheric and oceanic processes in shaping our climate, and the construction of specific climate change scenarios. It aims to improve our understanding of the climate system by supporting measurements and modelling of vital climate variables. Climate scenarios, time series and (paleoclimatological) reconstructions are developed and tailored to support spatial planning.
Mitigation
Research is focusing on mitigation strategies with opportunities or consequences for land use. It is a major aim to get a clearer picture regarding greenhouse gas emissions and sequestrations related to forestry and agriculture in order to improve accounting methods and verification systems. The implications of renewable energy for spatial planning, such as bio-energy, are also a major research topic.
Adaptation
The CcSP programme introduces a 'climate proofing' approach for adaptation from a regional and sectoral perspective. Special attention is paid to sectors and regions such as transport, nature conservation and the Rhine river basin. The idea is to focus research on combinations of infrastructural, financial and institutional adaptation strategies.
Integration
The projects under the theme 'Integration' are meant to integrate activities within the former three themes with the aim to generate comprehensive decision support frameworks for policy making. The theme also enhances consistency across the whole programme.
Communication
The objective is to allow stakeholders to interact with the research agenda by informing them about projects in an early stage. When they are involved, the practical knowledge of the stakeholders can be used in the project and hence increase the practical usefulness of the research results.

2.3 Structure Research themes of the KfC programme

Figure 2.2: Structure of KfC programme

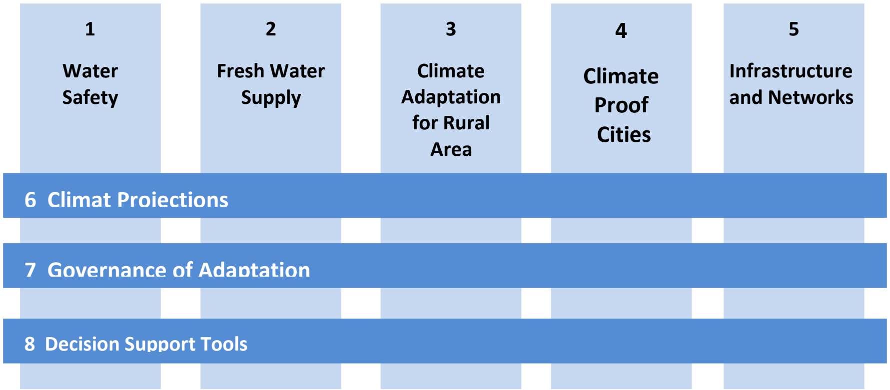


Table 2.2: Research themes **Knowledge for climate programme**

Flood risk and coastal zone management
Knowledge development within this theme focuses on flood risk management and related infrastructure, with a particular emphasis on developing a deeper understanding of the concept of robustness, in terms of function, environmental engineering, economics and society.
Fresh water resources management
The aim of the research is to develop robust, flexible and long-term solutions from a local to regional perspective which can contribute to successful strategies to bridge the growing mismatch between demand and supply of fresh water (quantity and salinity) in the changing Dutch Delta.
Rural areas
This research theme investigates the impacts of climate change and adaptation strategies for activities (agriculture, nature and other land use types) in the rural landscape of the Netherlands, taking into account the specific local circumstances and the regional functions.
Urban areas
This research programme aims at strengthening the adaptive capacity of urban areas against climate change and to develop strategies for the design of climate proof existing and future city areas. Research objects include buildings, public space, urban water management and evaluation tools.
Infrastructure and networks
The objective of this research theme is to gain insight into the effects of climate change on the Dutch transport, energy, ICT and water infrastructure and to develop robust strategies to allow these networks to maintain their function, adapting to the effects of climate change on the long-term (50 years).
Climate projections and scenarios
This research theme aims to provide high quality information on regional climate in The Netherlands, now and in the future, for developing national and regional adaptation strategies.

Governance and economics of adaptation
The main objective is how to increase the 'adaptive capacity' of our society. Analysis of the adaptive capacity will be coupled to a combination of solutions that rely on measures like legislation schemes, technical measures, governance and institutional transitions in policy domains and private sectors.
Decision support tools for adaptation
This theme focuses on embedding the concept of climate proofing in decision support tools. These are tools used in the preparation, implementation, monitoring and evaluation of policies, such as scenarios and assessment frameworks.

2.4 Strategy and criteria to define research projects

The following strategies and criteria are used to design the research agenda and to define research projects:

- The key questions addressed in CcSP/KfC research projects should reflect the Dutch priorities within the identified knowledge gaps by international research agendas, as described by programmes such as IPCC, WCRP, IGBP and IHDP.
- It is of equal importance that the addressed research questions are policy relevant. Societal knowledge needs are beforehand identified in close dialogue with national policy institutions, societal organizations and practitioners.
- CcSP/KfC research programming strategy combines a thematic and regional specific (Hotspot) approach. The total budget of a research theme or a research proposal is a reflection of the societal knowledge need and the possibility of co-funding.
- Research has preferably an interdisciplinary character and is carried out by consortia of knowledge institutes in order to enhance cooperation.
- Given the international nature of climate change and the international ambitions of both programmes, the research consortia are stimulated to collaborate with foreign research institutes and EU research programmes. Collaboration includes exchange of knowledge, joint research and participation in advisory councils on project level.

- A research proposal is formulated on the basis of a so called 'Terms of reference' (CcSP) or a 'Preproposal' (KfC). These documents are evaluated on their social and scientific relevance by a programme council.
- Both programmes intent to guarantee the scientific quality and social relevance of full proposals by carrying out independent (international) reviews of the projects before they start. The review of full-proposals is done according to internationally accepted standard procedures for scientific quality control.
- Each executive consortium is asked to identify the societal users of the research results. In addition each consortium is asked to describe how the interaction between the user and the research consortium is shaped.
- Many of the research proposals have the potential to support the operationalisation of the concept of 'climate proofing' and contribute to decision support methods for investments in spatial planning and infrastructural measures.
- Communication, knowledge dissemination and knowledge transfer is a very important part of the activities and budget of both programmes. This is accomplished through publications, conferences, symposia, debates, websites, et cetera.
- The programmes have a joint *Social Advisory Council* and the *International Scientific Advisory Council (ISAC)* that give advice in order to support both programme to full fill their mission. Their advice is intended to increase the social and scientific relevance and innovativeness of the programme.
- The programmes report on a regular basis on their budget spending, research progress and programming to the Dutch government, but also to other social organizations.

2.5 Collaboration with international research networks

In both European and global context, many of the involved research institutes within CcSP and KfC have a track of long-standing collaboration with the leading universities and research institutions. CcSP/KfC research institutes have been involved in more than 30 EU large integrated projects in the period 2004-present, of which 9 EU programmes also have co-funded CcSP research (**2.4 million Euro**). Within the 7th Framework Programme four new research programmes started in 2009 at the intersection of climate modelling, monitoring and climate adaptation: IS-ENES (Earth System modelling), ACTRIS (greenhouse gas monitoring), COMBINE (tailoring climate projections for impact studies) and

ECLISE in which the CcSP/KfC consortium is involved is one of the leading partners. The EU-ECLISE research programme aims to set a first step towards a **European Climate Service Centre**. Within the KfC programme it is also possible to commission research by international partners funded from the Dutch national natural gas revenues, in contrary to the official subsidy decree for the CcSP programme. Many of the research consortia of the eight KfC research themes (table 2.2) have used this opportunity to enhance their international collaboration.

Many of the CcSP and KfC partners participate in the European Climate Knowledge and Innovation Community (**Climate-KIC**) that was launched in 2009 as an initiative of the European Institute of Innovation and Technology (EIT). Climate-KIC is designated to drive innovation in the area of climate change adaptation and mitigation through an integrated European network of global and regional partners from the private, public and academic worlds. The network includes partners from the Netherlands, France, United Kingdom, Switzerland and Germany.

The Netherlands research on global change is well embedded in, acknowledged by and co-steering in the three large international scientific programmes in the field of global change research: the International Geosphere Biosphere Programme (IGBP), the World Climate Research Programme (WCRP) and the International Human Dimensions Project (IHDP). In the field of monitoring the GEO - Global Monitoring for Environment and Security programme (GMES) was initiated in which various EU member states have a substantial contribution, with the Netherlands making a substantial methodological contribution to development of the carbon monitoring systems (IGOS).

2.6 Examples of encountered dilemmas

The transaction costs of a research agenda in close dialogue with society

It took more than 1.5 years (2008-2010) to develop full-proposals for the 8 research themes of KFC (table 2.2). Regional parties did express interest, but remained reluctant to provide necessary resources for co-funding for a long time. This was not only due to the economic crisis and scarce financial resources, but they also feared – despite of very intensive dialogue - to have insufficient control on the research agenda. Regional parties had also difficulties to formulate research questions.

Sound climate proof science takes time but users expect fast answers

Regional water boards and provinces expressed the need to develop high resolution spatial explicit maps of the climate scenarios in order to visualise climate change effects on variables such as groundwater, water quality and biodiversity (Jacob & Van den Hurk, 2009). The first concept research proposal was initially called **"Climate Effect Atlas"**. This name, however, met resistance from various researchers. Hydrologists raised the issue that such maps would visualise a false sense of scientific reliability/certainty. At the same time there was political pressure to construct the maps in a short notice. Eventually the project was renamed into **"Climate sketch books";** this name stresses the need to take time to strengthen the scientific basis beyond the maps.

Dilemmas in tailoring climate information

In the philosophy of CcSP/KfC tailoring climate information comes down to the evaluation of multiple scenarios within the range of sensitivity of the specific sector or region. However, practice learned that in the regional policy domain this is often a though ambition for scientists because policy makers, but also impact scientists from different disciplines often prefer to stick to one single deterministic climate change scenario (Jacob & Van den Hurk, 2009). The drawback of tailoring climate information for regions and sectors is also that it becomes difficult to upscale the regional and sectoral impact assessments in order to identify national adaptation strategies (Veraart, et al., 2010).

"Unwanted" knowledge about revised greenhouse gas emission inventories

Quantifying greenhouse gas emission reduction policies is a demanding task in which scientific complexity and manageable transparent accounting systems for UNFCCC targets have difficulties to meet (Hutjes, et al., 2009). GHG emission reduction targets require investments in the public and private sector and are being negotiated by policy makers at local, regional, national and international scale. Moreover, the diffuse and variable nature of land based emissions and their mitigation also increases the need for independent verification of emission reduction claims. In order to support greenhouse gas accounting systems the CcSP programme developed a combined modelling and monitoring programme to quantify the magnitude and variability of *fluxes* of carbon dioxide, methane and nitrous oxide in various landscapes (Hutjes, et al., 2009). This type of knowledge is sometimes regarded as 'unwanted knowledge' (Hisschemöller, 2005) for policy makers because the research could also prove that for example, our forests and grasslands do not sequester as much greenhouse gas as previously thought; or that the emissions measured by these advanced techniques differ significantly from previous more simplified estimates which were at the basis of our national reporting to UNFCCC. This could make it more difficult to reach the Dutch emission reduction targets within the Kyoto protocol. The research is policy relevant, but the decision to invest in this type of research can still be contested due to political stakes in climate policies.

Desired level of mono-, multi-, inter- and transdisciplinarity

The interaction between climate scientists and stakeholders in the Netherlands is slowly but gradually shifting from a collaborative/consultative approach towards a real transdisciplinary approach in the research and design process of adaptation strategies since 2001 (Veraart, et al., 2010). Some researchers and institutions are moving faster in this transition than others. Furthermore, the consultative approach is for some of the objectives also effective, exemplified by the success of tailoring climate information. The hotspot approach within the KfC programme is promising and may result in new insights about the co-production of knowledge. These developments bring some time new tensions between classical, mono-disciplinary research approaches in climate science, including competition for funding. The right balance is still a subject of discussion.

Collaboration with the private sector

A discussion was started in 2009 by some of the CcSP board members (from the banking industry and consultants) that more emphasis is required on the economic and commercial spin-off of research. But is there really a market for climate (adaptation) products without public legislation? And which private parties should be involved? How do you prevent that entrepreneurs have to deal with complex legislation from different decentralized governments? Enterprises are reluctant to negotiate with different public parties about climate proofing their investments. The value of the capital stock at risk will be often weighed against the investment to minimize climate based risks.

Sound science, media outreach, climate sceptics and alarmism

During the course of both research programmes, many moments of considerable media attention occurred regarding the climate change issue, such as the movie ‘An Inconvenient Truth ' (2006), the publication of the third IPCC report (2007) and the hurricane disaster of Katrina (2005). The game of adversarial journalism is thereby often played with scientists. In this game researchers have to deal with dilemmas such as (1) how to respond to sceptical and alarmist messages and (2) how to communicate uncertainties.

In 2003, just before the start of CcSP, the Platform Communication on Climate Change (PCCC; www.klimaatportaal.nl) was launched by the Dutch climate (change) research community. The Platform (PCCC) was established to improve the quality, efficiency and effectiveness of the communication of Dutch climate change research (Van Dorland, et al., 2010) and to assure an independent communication platform for scientific institutes. Simultaneously, a communication strategy within CcSP was developed in dialogue between science, governments and NGOs. It was extremely difficult, if not impossible, to merge both initiatives, because the legitimacy of agenda-setting communication activities was debated between the involved parties.

3 Programme organisation and budget

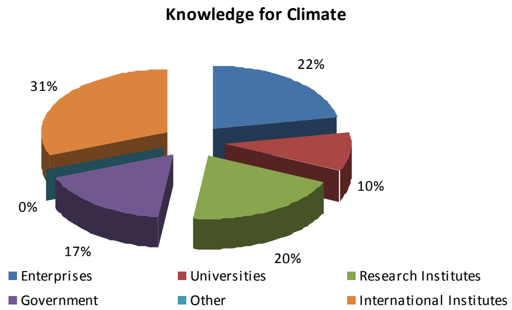
3.1 Organisation

A broad consortium consisting of scientific institutes, ministries, NGO's and regional institutional bodies are involved in both programmes. Figure 3.1 shows the composition of the involved consortia.

Both programmes have installed a Board, but share a 'Joint Board Council' since 2008. The programmes have each a Programme Council and a Programme Office. Staff unions are realised in both organisational bodies in order to ensure co-operation.

The programmes share a Societal Advisory Council (SAC) and an International Scientific Advisory Council (ISAC).

In the appendix the composition of the staff of the organisational programme bodies is presented.



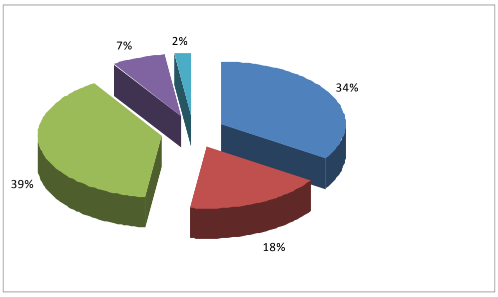


Figure 3.1: Composition of involved consortia. Above: KfC; Below: CcSP.

3.2 Budget for research themes

The distribution of the **CcSP research budget** was arranged in two ways. The knowledge project plan from 2003 was built upon a set of project ideas and related provisional estimation of research costs clustered around the research themes (Figure 2.1). The project ideas were formulated in 2002-2003, in close consultation with ministries, scientific institutes and other societal parties. In a latter stage (2004-2005) these project ideas were worked out into full proposals in several tranches. Preferences and adjustments were done based upon advice of the several involved internal and external advisory councils, such as the ISAC and the national Advisory Expert Committee (Commissie van Wijzen). Important moments that the research programming strategy was reconsidered were the launch of the ARK programme in 2005 (Ministerie van VROM, et al., 2007) and the midterm Review in 2007 (Hordijk, et al., 2007; Kabat, et al., 2007).

Tabel 3.1: budget CcSP (September 2010).

Theme	Subsidy (million €)	Co-finance (million €)	Total (million €)
Climate scenarios	*7,2*	*8,9*	***16,1***
Mitigation	*7,0*	*9,4*	***16,4***
Adaptation	8,5	12,5	***21,0***
Integration	4,5	5,5	**10**
Communication	4,2	8,0	**12,2**
Programme office and programme activities*	6,9	-	**6,9**
Reservations	1,7	-	**1,7**
Total	**40,0**	**44,3**	**84,3**

* This budget is used for scientific and administrative support from the programme office as well as for programme-wide activities such as symposia and publications on programme level

Within the **KfC programme** the research budget by theme is based on the preferences of the hotspots. The representatives of the hotspots had the opportunity to allocate budget to the themes they considered important, in an iterative way. Differences in budget reflect the difference in interest that from a regional perspective to the topics assigned.

Table 3.2: Budget **Knowledge for Climate programme** (September 2010)

Theme	Subsidy (million €)	Co-finance (million €)	Total (million €)
Flood risk	*2,6*	*2,1*	***4,7***
Freshwater	*3,1*	*3,2*	***6,3***
Rural areas	2,2	2,0	***4,2***
Urban areas	4,5	4,7	**9,2**
Infrastructure and networks	2,8	3,1	**5,9**
Climate projections & scenarios	5,9	3,2	**9,1**
Governance and economics of adaptation	4,3	2,1	**6,4**
Decision support tools for adaptation	4,1	3,4	**7,5**
Programme office and programme activities	6,3	-	**6,3**
Subsidy Agreement in preparation with project consortium	5,7	3,8	**9,5**
Not yet allocated budget	4,5	4,5	**9,0**
Total	**46,0**	**32,2**	**78,2**

Figure 3.2: Distribution of co-funding in both programmes

3.3 Communication, knowledge transfer and valorisation

When the first ideas arose about the CcSP programme (2000) there was little sense of urgency in the societal domain, to take adaptation measures to climate change. In order to develop a meaningful and socially relevant research programme a communication programme and strategy was set up by CcSP (Jansen, et al., 2005). When the KfC programme was launched in 2008 a joint knowledge transfer team was introduced for both programmes.

The current communication strategy has two objectives:

- Knowledge dissemination: developing and sharing knowledge in dialogue with knowledge users
- Knowledge valorisation: ensuring that the knowledge developed, leads to applications and products that have societal or commercial value

Knowledge dissemination has priority. The following aspects are important in the communication strategy:

- Climate change should not only communicated as a threat, adaptation may lead also to opportunities and win-win situations, also for the business community
- The results from the programmes should be widely available for our target groups, e.g. local, regional and national governments, city planners, water managers, policy makers, scientists and the broader audience.
- With the objective to achieve co-operation with our target groups

At the start of the programmes much of the communication activities were focused on putting climate issues on the agenda of the target groups. Attention was then shifted towards the articulation of research questions. The focus of communication shifts to sharing the results with the target groups when the research projects come into their final stage.

Observations:

- Knowledge dissemination is particularly successful towards national, regional and local governments. Awareness is raised for climate change adaptation, policies have been adapted or formulated and in several cases also adaptation measures have been implemented.

∇ The involvement of the business community into the climate research is still low compared with the public sector.

Table 3.3: Examples of communication activities

Exposition 'Climate change as an opportunity' (20 September – 9 October 2010)

This travelling exhibition throughout the Netherlands that started in The Hague presents five examples of climate adaptation in the Netherlands. The objective was to inspire civil servants and companies to improve the living environment combined with climate adaptation.

klimaat als kans

Holland Climate House (December 2010)

During the entire COP15, the Holland Climate House offered a broad spectrum of activities including presentations about issues such as new regional climate models and the climate-proofing of cities. Well-known scientists visited the Holland Climate House, as will the mayor of Rotterdam, Dutch ministers and Dutch water authorities.

Minor 'Climate proof regional development'

There is a need to educate technical college graduates in interdisciplinary concepts such as climate proofing. The technical colleges Van Hall Larenstein, Zeeland and Rotterdam have developed together with Wageningen University an BSC minor 'Climate proof regional development'

International Scientific Conference Deltas in Times of Climate Change (October 2010)

National Conference Dealing with climate change in Dutch governance (November 2005)

The programmes have organized many conferences. This started with the Kick-Off of the CcSP programme in 2004. Highlights are the conference for policy makers in 2005 at the National Adaptation Strategy (ARK) was launched, and the international scientific conference Deltas in Times of Climate Change.

4 Highlights: research results and societal relevance

4.1 Climate adaptation, flood risk and coastal zone management

Authors: *J.H.J.C. Aerts (VU University Amsterdam), F. Klijn (Deltares)*

Table 4.1: Facts and figures about research theme 'Flood Risk'

Involved research institutes	
VU University Amsterdam Deltares Wageningen UR (Alterra, Wageningen University) Futurewater VU - IvM PBL	TU Delft. HKV-Lijn in Water Flood Hazard Research Centre Helmhez Centre Potsdam KNMI DWW
Selection of key researchers	
J.H.J.C. Aerts (VUA), F.Klijn (Deltares), E.J. Moors (Alterra), P.Droogers (Futurewater), L. Bouwer (IVM-VU), H. de Moel (IVM-VU), M.Kok (TU-Delft), M.Stive (TU-Delft), J.Bessembinder (KNMI), A. Te linde (Deltares/IVM-VU), H. ter Maat (Alterra), H.Dolman (VUA)	
Projects (only the project numbers, see appendix for full titles)	
Finished A07, A11, A13, A09, IC03	**On-going** A20, HSGR02, HSGR06, HSHL01A, HSRR01, HSRR02, HSRR03b, HSRR06, HSRR09, Thema 1

4.1.1 The societal relevance of the research theme

The Netherlands is located in the delta of the Rhine and Meuse rivers (Figure 4.1) with a total population of about 16.5 million people. It is one of most densely populated countries in the world with 11 million people living in areas protected by flood defences. Dutch flood risk management is primarily focused on flood prevention (Lowering flood probability) and most of the flood-prone areas in the Netherlands are divided into so-called dike-ring areas. These are geographical units bound by an enclosed flood protection system (e.g. dikes, dunes, high ground). Dike ring areas have, by law, a certain level of protection. This level of protection is indicated by flood probabilities, ranging from 1/1,250 per year (dike rings along Rhine and Meuse river) up to 1/10,000 per year (densely populated dike rings at the coast). These protection levels prescribe that the embankments must be high enough to withstand water levels corresponding to the return period. Covering about 55% of the total land surface area of the Netherlands, these dike-ring areas already house the majority of the economic activity (e.g. the port of Rotterdam and Amsterdam airport) and further investments continue to take place.

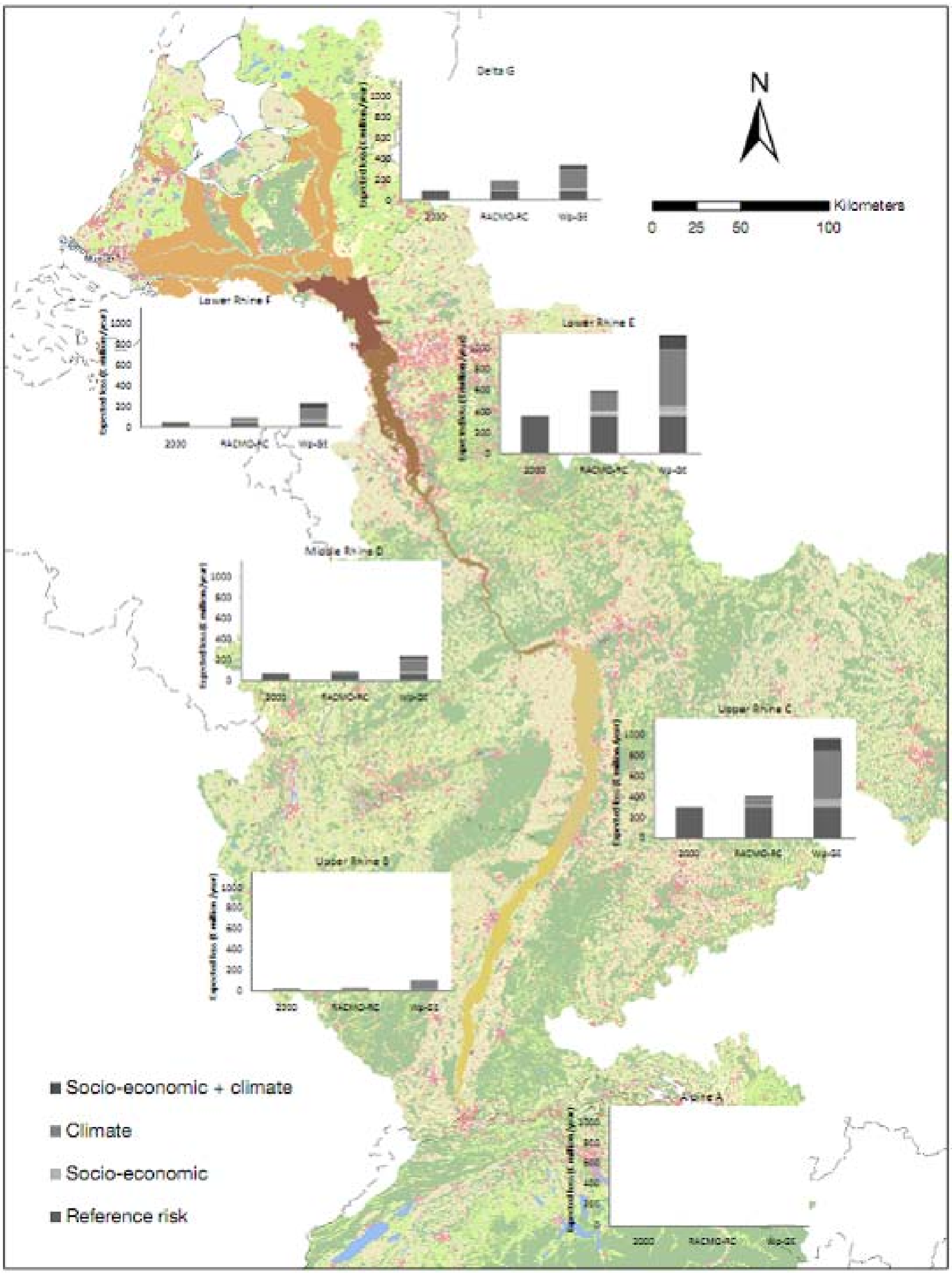


Figure 4.1: Expected annual damage (flood risk) for the reference situation and for 2030 scenarios, aggregated into 7 regions in the Rhine catchment (Te Linde, et al., 2011).

The impact of flood events on the societies and economy in the Netherlands is likely to increase further as a result of two complementary trends. Firstly, climate change is expected to increase the sea level and river discharges and hence the flood-prone area and flooding depths (Klijn, et al., 2010). Secondly, the potential economic impact of floods increases due to the growing number of people in flood-prone areas and the increased economic activity there. These issues have been addressed by the so called 2nd Delta Committee in 2008 (Deltacommissie, 2008), who advised on adaptation to climate change impacts on flood risk. Research by the CcSP programme has supported this commission and further research by KfC shall support the Delta Programme (Delta programme Commissioner, 2011) which is defined in response to this Committee's advice.

Another issue are the transboundary effects of river flooding as river floods in The Netherlands are affected by developments in upstream countries such as Germany and Belgium. We closely cooperated with Germany on this issue on research questions raised by the ICPR (International Commission for the Protection of the Rhine).

Finally, there are always residual flood risks which remain after having implemented either flood protection or flood damage mitigation measures. These deserve attention too. Currently, private flood insurance arrangements are, however, not available in the Netherlands. The only financial arrangement in place is an ex-post disaster relief arrangement, which provides partial compensation by the government through the Calamities and Compensation Act (WTS) (E. J. De Vries, 1998). The WTS, however, has several disadvantages and is, among other things, undesirable from a social-welfare perspective because the political decision to compensate losses is not based on well-defined criteria.

4.1.2 The scientific approach and the and research questions

The CcSP programme has addressed some key research questions that can be categorised as follows:

- **Development in flood risk & adaptation costs:** What are possible climate adaptation strategies in flood risk management for the Netherlands to lower either flood probabilities and/or the potential flood consequences? What are the costs of adaptation?
- **Upstream development:** What is the effect of upstream flood management measures in the Rhine basin on risk?
- **Flood insurance:** Can residual flood risks in the Netherland be covered through some kind of insurance arrangement, knowing that currently an insurance policy for failure of an embankment cannot be bought in the Netherlands?

Planned activities within Knowledge for Climate (KfC)

KfC research aims to support the national, regional and local authorities in their quest for a joint flood risk management and spatial development strategy for the 21st century and beyond.

The research will develop methods for assessing:

- The effectiveness of technical measures and policy instruments to reduce flood risks
- The implications of their implementation for urban and countryside environments
- The robustness (resilience and resistance)of comprehensive FRM strategies in view of uncertainties

In addition guidelines are provided for the design of long-term Flood Risk Management alternatives and individual measures based on effectiveness (flood risk reduction), robustness and their contribution to the development of entire regions (multi-functional use, natural values and spatial quality)

Research subjects include flexible flood defence infrastructures in a setting of river branches, management of coastal dunes and beaches, economic damage potentials. Special attention is paid to the Rijnmond area and the Wadden Sea and its hinterland. International comparisons are made with the Thames estuary (London) and the Elbe estuary (Hamburg).

Development in Flood risk & adaptation costs

CcSP Project IC03: Historical (1900-2000) and projected land use (2000-2100) in the flood prone area of the Rhine catchment has been combined with detailed information on the maximum flooding depth in order to illustrate how urban developments over time relate to flood hazards. Furthermore, changes in potential flood damage are estimated throughout the 20th and 21st century, taking the effect of future sea-level rise and soil subsidence into account. The insights gained from this study may serve as a reference for other urbanized deltas that are expected to grow considerably during this century. We show that urban developments are not disproportionately more located in the flood-prone area (Figure 4.2), but that the total urban surface area has increased six-fold during the 20th century, and may double during the 21st century.

Moreover, these developments took, and will take, place in areas with progressively deeper potential inundation (Figure 4.2). Potential flood damages have tripled from 1900 to 2000 due to socio-economic developments and are projected to increase 2% to 10% per decade in the 21st century, depending on the scenario[5].

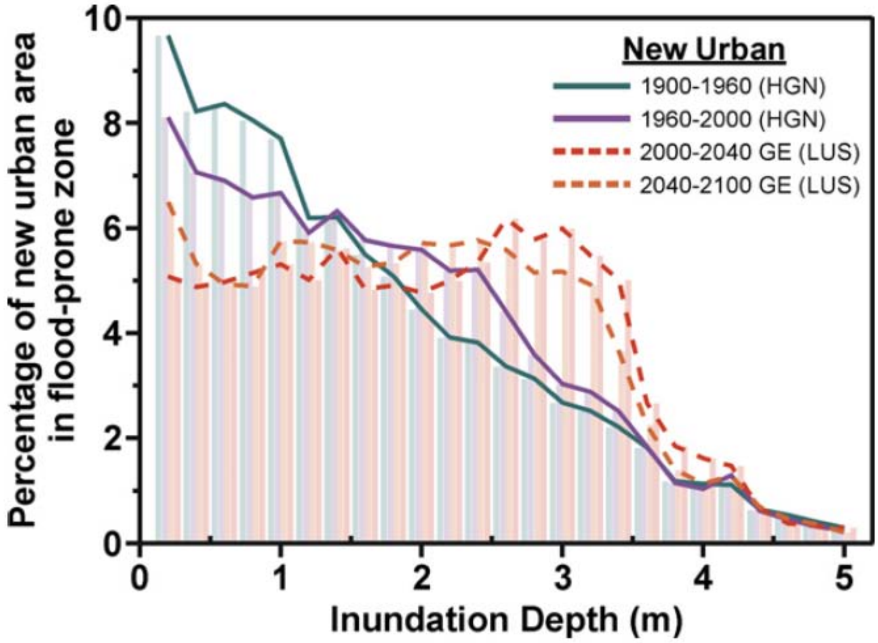


Figure 4.2: Percentage of the newly added urban area in flood-prone area for different inundation depths. HGN refers to the historical land use database and LUS to land use projections from the Land Use Scanner (Koomen & Loonen, 2007) with GE being the ' global economy ' scenario

Sea-level rise adds another 10-15% on top of this increase in potential flood damage. While there are substantial differences between future projections of potential flood damage between different scenarios (from a very moderate increase to more than doubling in 2100), potential damages per capita are projected to increase considerably (+35 to +60% in 2100) regardless of the future scenario. This indicates that the social burden of floods is likely to increase in the future.

CcSP Project A09: In an international comparative study, effects of climate change versus socio economic effect on flood risk were analyzed. It appeared that the increasing impact of natural disasters over recent decades has been well documented, especially the direct economic losses and losses that were insured. Claims are made by some that climate change has caused more losses, but others assert that increasing exposure due to population and economic

[5] CcSP projects use a socio-economic scenario approach that have 'value' (Self-Interest versus solidarity) and 'governance' (global versus regional) as two main dimensions of socio-economic uncertainty in long term projections. Those socio-economic dimensions of uncertainty are combined with the KNMI climate scenarios. All future damage cost estimates are based upon the price level of 2000 as a reference.

growth has been a much more important driver. By analyzing 40 international studies, it can be concluded that – although economic losses from weather related hazards have increased – anthropogenic climate change so far did not have a significant impact on losses from natural disasters. The observed loss increase is caused primarily by increasing exposure and value of capital at risk. This finding is of direct importance for studies on impacts from extreme weather and for disaster policy. Studies that project future losses may give a better indication of the potential impact of climate change on disaster losses and needs for adaptation, than the analysis of historical losses.

CcSP Project A13: The costs of the adaptation to climate change in flood management in the Netherlands are estimated between 6-30 billion Euro depending on the sea level rise scenario and maximum river discharges (table 4.2). A Business as Usual solution includes river widening, the raising of embankments and sand nourishment of the coast. In addition, for an extreme scenario of 5m sea level rise cost would be more than 80 billion Euros.

Table 4.2: Absolute costs of the Business As Usual Solution trajectory in billions of euro in case of various sea level and river discharge scenarios (excl. VAT) (Aerts, et al., 2008)

	Scenarios				
	2040	**2100**	**2100**	**2100**	**Far future**
Sea level rise (cm)	24	60	85	150	500
Max. Rhine discharge (m^3/s)	16,800	18,000	18,000	18,000	18,000
Max. Meuse discharge (m^3/s)	4,200	4,600	4,600	4,600	4,600
	Euro costs (billions)				
Inland waters					
Rhine river widening	2.7	5.5	5.5	5.5	5.5
Meuse river widening	1.3	4.2	4.2	4.2	4.2
Raising dyke levels	0.2	1.8	2.6	6.1	36
Rhine river widening	2.7	5.5	5.5	5.5	5.5
Coast and Estuaries					
Sandy coast	1.9	6.4	9.1	16.0	25
Wadden Sea supplementation	1.1	3.8	5.4	9.6	?
Westerschelde supplementation	0.1	0.4	0.6	1.1	?
Raising dyke levels	1.9	2.3	2.6	3.4	8
Total	**9**	**24**	**30**	**46**	**>80**

Upstream Developments

Project A07: Using a combination of hydrological and hydrodynamic models, developments in future flood water levels in upstream area in the Rhine basin were analyzed until the year 2050. The effects were assessed of measures planned in the multi billion Euro project Rhine Action Plan on Floods (APF) and of several additional measures, which include the restoration of abandoned meanders, a bypass around Cologne, the implementation of additional retention polders and land-use change to forest in the catchment. The modelling method includes the sampling and recombination of meteorological data and a hydrological model to simulate long discharge series (10,000 years). This can be considered as a process-based approach to better estimate peak discharges of low-probability flood events. It was found that flooding upstream in Germany causes a significant peak attenuation, which lowers the maximum discharge and peak water levels further downstream in the Netherlands. This upstream flooding is likely because flood defences in Germany provide a lower protection level than those in The Netherlands. Measures currently implemented and proposed in the APF, as well as most additional measures, appear insufficient to counteract the increase of flood probabilities caused by climate change (cf. also (Hooijer, et al., 2004).

Project A07: the effect of land use change in the Rhine floodplains on flood risk was simulated in a modelling exercise. The change in value at risk was based on land-use projections applying two different socio-economic scenarios, and flood probabilities were derived from two different climate scenarios. The results were aggregated for seven sections along the Rhine River. It was found that the annual expected damage in the Rhine basin may increase by between 54% and 230%, of which the major part (three-quarters) can be accounted for by climate change. The highest current potential damage can be found in the Netherlands (110 billion euro), whereas the second (80 billion euro) and third (62 billion euro) highest values result for two areas in Germany. Results further show that the area with the highest fluvial flood risk (in terms of mean annual damage) is located along the Lower Rhine (Nordrhein- Westfalen) in Germany, and not in the Netherlands, as often perceived. This is mainly due to the higher flood protection level in the Netherlands as compared to Germany.

Flood insurance

CcSP Project A09: It is questioned whether the currently dominant role of the Dutch government in providing flood protection is justified from an economic efficiency perspective. (Botzen & Van den Bergh, 2008) propose to insure flood risk in the Netherlands with a public-private partnership in the form of a ‘three-layered insurance programme’. A first layer of small losses is paid by households, as ‘own risk’. In the second layer (between ~1-2 Billion euro) the losses will be covered by private insurance companies. The government covers the third layer of very large losses in order to prevent problems with the insurability of highly correlated risks, and to account for the limited financial capacity of the Dutch insurance sector. From a survey among 1300 households, it appears that 55% of the respondents would consider purchasing such an insurance policy.

CcSP Project A09: pays attention to the role insurances can play in mitigating damage by providing incentives to policy-holders to undertake damage-reducing measures. The results of the survey indicate that many homeowners are willing to undertake investments in mitigation. In particular, approximately two-third is willing to invest in water barriers in exchange for a premium reduction and about a fifth would consider replacing vulnerable floor types by water-proof floors. Furthermore, about a quarter is willing to move central heating installations to levels safe from flooding in return for a reduction in the insurance premium.

4.1.3 Research Highlights

- Currently implemented and proposed measures in the Action Plan for the river Rhine (APF), nor most additional measures, can counteract the increase of flood probabilities resulting form climate change.
- There has been a large increase in urban area in the flood-prone area of the Rhine catchment during the 20th century, increasing six-fold from 1900 to 2000 (from ~20,000 ha to ~120,000 ha).
- Estimates for the 21st century show an increase of potential flood damage of about 2% per decade (RC scenario) to 10% per decade (GE scenario).
- Damages per capita, which did not increase too much over the 20th century, are expected to increase considerably during the 21st century, regardless of the socio-economic scenario considered.
- Natural flooding upstream in Germany causes peak attenuation resulting in lower flood levels in the Netherlands. Consequently, improved flood protection in Germany may increase flood discharges which must be coped with in the Netherlands.
- A public-private flood insurance programme may be feasible in the Netherlands if 'three-layered'. A survey revealed that 55% responded that they may consider purchasing such a policy.
- The costs for flood risk management adaptation for the entire country of the Netherlands in the 21st century are estimated to be between 6 and 30 billion Euro for the current KNMI 06 scenarios. When expressed as a per-

centage of the GNP (2007), the additional costs are expected to be 0.1-0.2% for the Business as Usual policy.

4.1.4 Suggestions for further reading: key publications and websites

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(River Meuse, northwest Europe). Climatic Change, in press. doi:10.1007/s10584-010-9926-2.

4.2 Climate adaptation and fresh water resources management

***Authors:** E. van Beek (Deltares/ Twente University), A.B.M. Jeuken (Deltares), A.C. de Vries (ACACIA-Water)*

Table 4.3: Facts and figures about research theme 'Fresh water resources management'.

Involved research institutes	
Deltares Wageningen UR (Alterra, Wageningen University) ACACIA-Water VU University Amsterdam	TNO Utrecht University KWR Water Research TU Delft Twente University
Selection of key researchers	
E. van Beek (Deltares/TU Twente), S. van der Zee (WU), A.C. de Vries (ACACIA-Water), A.C. Jeuken (Deltares), J.Rozema (VU-Amsterdam), J.A. Veraart (Alterra), W.Thissen (TU-Delft), J.P. Van der Sluijs (Utrecht University), A. van der Veen (TU-Twente), P.Stuyfzand (VU-Amsterdam/KWR-Water research), G.J. Zwolsman (KWR-Water Research)	
Projects (only the project numbers, see appendix for full titles)	
Finished A01, A21, COM25, MSZD01, A06	**On-going** A23, HSHL08, HSOV01A, HSOV)1B, HSZD01, HSZD02, Thema 2

4.2.1 The societal relevance of the research theme

Climate change will affect the supply of fresh water to the population and to economic sectors in many deltas around the world. Also the Netherlands will have to adapt to a growing mismatch between freshwater demand and fresh water supply. The central issue is: what are opportunities and adaptation strategies for fresh water supply in the Netherlands, given the changing physical boundary conditions in evaporation, precipitation, river discharges, sea level rise and salt water intrusion?

The focus within this research theme is on regional and local solutions within the low lying parts of the Netherlands. In this area, in addition to droughts, the main threat to freshwater availability is salinisation. The salt load from internal seepage leads in dry periods to high concentrations of salt in the surface water system, making this water unfit for agriculture and threatening for nature. The water boards manage the salt concentration of the surface water system by flushing the system with fresh water. Fresh water is also needed to maintain the surface water level in the system. Keeping the surface water above a certain minimum level is required for safety (e.g. to stabilize peat dikes), to prevent foundation problems of buildings and to minimize soil subsidence by oxidation. Most of the needed fresh water supply in the low lying areas is used for level control and flushing. The actual demand for fresh water by 'consumers' such as agriculture, drinking water companies and industries is small compared to the requirements for surface water level control and for flushing. In principle the objectives of level control can also be achieved by using brackish or salt water (which is abundant in the low lying parts of the Netherlands, even in very dry summers) but if that is done the surface water cannot be used anymore for consumption and it will have consequences for the ecosystem. In this case the challenge will be to find solutions that make the users independent of the quality of the surface water and/or to adapt the system to more salty conditions. Hence, a primary focus of the present research is on how these regions can become more self reliant.

A second challenge for the research is to further develop the comparative advantage of the Netherlands to deal with increased drought compared to other countries in Europe. The high groundwater table in the Netherlands and the relative ease to distribute and allocate supplementary fresh water to irrigate crops make that the Netherlands is less sensitive to drought than our neighbouring countries. This was clearly shown in the dry summer of 2003 where the reduced crop yield by drought was more than compensated for the farmers in the Netherlands as the price they got for their (somewhat reduced) crops was much higher due to the much lower production in the remainder of Europe. As a major part of our agricultural production is exported this was an economic gain for the Netherlands. Climate change might make that this will happen more frequently and the Netherlands should develop this opportunity by further improving the fresh water supply situation for agriculture.

4.2.2 The scientific approach and the research questions

The aim of the proposed research is to develop robust, flexible and long-term solutions, from a local to regional perspective, to bridge the growing mismatch between demand and supply of fresh water (quantity and salinity) in the changing Dutch Delta. Based on this aim the following main research questions are formulated:

- What range of conditions should be taken into account to assess the severity of an inadequate fresh water supply (evaporation, precipitation, river discharges, sea level rise and related salt water intrusion, international economic changes)

- How will fresh water availability within the coupled groundwater-surface water system change due to climate change and how can the self-reliance of water users be increased?
- To what extent can tolerance levels of different types of land use be stretched? What opportunities for the reduction of the fresh water demand are possible?
- What is the potential of water technology for providing solutions for regional self-sufficiency in the fresh water supply?
- What approach should be used to build robust and flexible adaptation strategies, given the uncertainties in the long-term prediction of future climate change effects, and of other relevant socio-economic developments?
- How can knowledge about specific adaptation measures, perspectives of different stakeholders, available approaches for tackling uncertainty, be integrated to build strategies for selected pilot areas?

These six main research questions are addressed by the six work-packages of this KfC research theme. The three application oriented pilot areas (cases) of work-package 6 are guiding for the theoretical research being carried out in the first five work-packages and the researchers of these other work-packages are actively involved in the pilots.

A specific feature of the research approach is to link the various spatial levels. Although the CcSP and KfC research has an ultimate focus at a local level (the hotspots/pilots), work-packages 1 and 5 of theme 2 of KfC address the link between these levels. The results of other KfC/CcSP research projects will be taken into account. CcSP research carried out in other areas in the Netherlands (e.g. in North Netherlands) can be considered as additional cases for KfC.

4.2.3 Research Highlights

The research projects focus on strategies on how to adapt to a growing mismatch between water demand and supply under climate change and contribute to the social discussion on salinity. The studies focus on both the regional and local hydrological and institutional systems. This is imperative both from a scientific and from a social perspective. Although the projects have not been finalised a number of first observations can be made about viable strategies and knowledge gaps.

Viable strategies

Past studies about fresh water supply in the Netherlands clearly show a low conveyance efficiency[6] with respect to the fresh water use (A. De Vries, et al., 2009; I. De Vries, et al., 2010). It has been shown that only a small percentage of the total fresh water intake is actually used for irrigation or drinking water. The largest part of the intake is used for flushing out the salt from the system and for sustaining the water levels. In other words, a huge volume of fresh water is used to keep the system fresh, while only a small percentage is used for irrigation or potable water. With climate change and further increase of demand it is apparent that a strategy is required for those areas with a large dependency on external fresh water supply. This leads to two possible strategies:

Table 4.4: Two strategies to cope with increased fresh water demand

Resistance strategy
Given the small demand with respect to the total intake, it seems logical to look at measures that limit the volume of water required for flushing out and sustaining the water levels. The dependency on external supply will decrease while the self-sufficiency will increase.
Adaptation strategy
For this strategy the salt water intrusion is no longer controlled. The system is no longer maintained fresh, implying that that the intake of fresh water is no longer required. It does imply that the fresh water supply is separated from the natural system.

The research has clearly shown that in order to develop strategies to cope with climate change in areas sensitive to salinization it is essential to understand the water balance both in terms of quality and quantity. It has been illustrated that in some areas the inefficient fresh water use is the major challenge while other areas can be made climate proof with only limited interventions.

The current studies focus on optimising the self-reliance through measures in the field of water management, governance, economics, stakeholder involvement and technology. The challenge is to select the most viable strategy, whereby the preference mainly depends on the characteristics of the area, and

[6] Conveyance efficiency concerns the efficiency of the distribution and transport of water towards the users (water supply perspective), while the field application efficiency concerns the efficiency of water use for irrigation (water demand perspective).

the inefficiency in particular. These characteristics would include the sensitivity to salinization but also the type of agricultural practices.

Scientific insights

In low lying areas, fresh groundwater lenses are found in the upper part of the sub-soil. These lenses float on deeper regional saline groundwater systems, and are fed by local precipitation. The local system is more dynamic than the regional system, while the interaction between both systems depends on the seasonal variance of the water balance. Hence, for developing relevant adaptation options and optimisation of the self-reliance one needs to understand the hydrological system at all scales and also the coupling of surface- and groundwater. Figure 4.3 illustrates both the spatial and temporal dynamics of the shallow fresh water lenses. Is these processes are not fully understood it will be difficult to develop a regional strategy towards self-reliance.

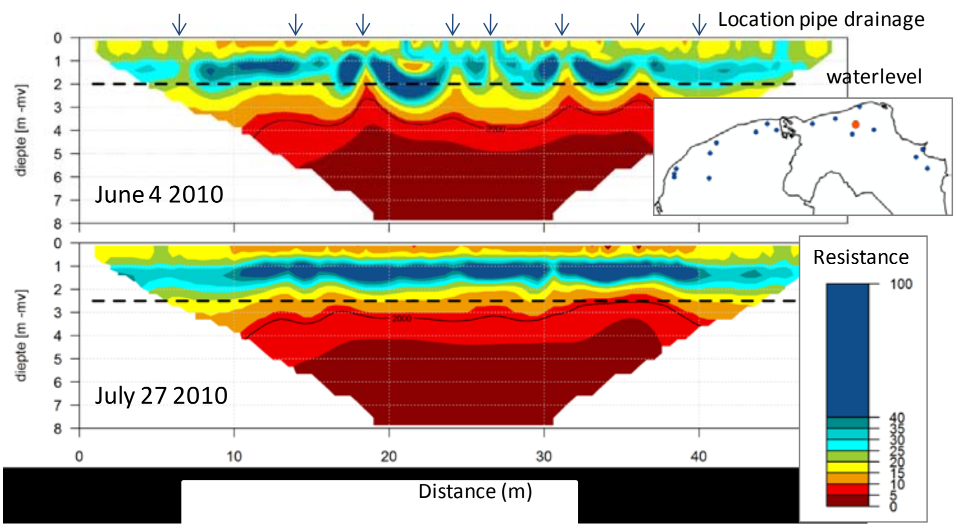

Figure 4.3: Electric resistance (or conductivity) of a typical agricultural plot (Velstra & De Jong, 2011).

The figure shows the electric resistance (or conductivity) of a typical agricultural plot, with drainage pipes at -1.5m, in a low lying area in the North of the Netherlands. The resistance is an indicator for salinity levels, where low values represent brackish to salt water and high values represent fresh water. The top section present the situation after a wet period (June 2010), with relatively large fresh water lenses. The lower section presents the situation at the end of a dry period (July 2010), where the fresh water lenses have diminished. Note that salt is present above the groundwater table (Velstra & De Jong, 2011).

The projects contribute to the social discussion on the changing freshwater availability under climate change, by identifying the perceptions and illustrating the facts. These facts include the processes of salinization and the possible impacts on especially agriculture. Also insight is gained in what areas are the most vulnerable and which viable options to deal with salinization in the future can be considered. These insights create a sense of ownership and commitment from the stakeholders and help to develop and implement options to deal with the changing climate.

Knowledge gaps

Through the research major achievements have been realised on understanding the mismatch between freshwater supply and demand and developing strategies to deal with these. The ultimate aim is to achieve a climate proof freshwater supply. However knowledge gaps remain and some of these are addressed in the current KfC research theme, at a practical level in particular through the case studies that focus on actual implementation of adaptation strategies and related measures.

Examples of knowledge gaps that are being addressed in theme 2 of KfC:

- Which water technology options are available to contribute to the self-reliance?
- Given the uncertainties in the long-term prediction of future climate change effects and of other relevant socio-economic developments, how can we develop strategies that are both robust and flexible?
- How should the decision making process be organized? Is a top down policy approach required or are there opportunities for local initiatives and how can they be combined?
- What are the opportunities, challenges and benefits of a participative approach in formulating regional options in policy strategies?
- How to consider the required fresh water supply in relation to other water issues, such as safety (flooding), saltwater intrusion, and external storage (e.g. in the Ijssel lake).

4.2.4 Suggestions for further reading: key publications and websites

Peer reviewed

De Louw P.G.B., GHP Oude Essink, PJ Stuyfzand, SEATM van der Zee, 2010. Upward groundwater flow in boils as the dominant mechanism of salinisation in deep polders, the Netherlands, J. Hydrol. 394, 494-506.

Oude Essink GHP, Van Baaren ES, De Louw PGB, 2010. Effects of climate change on coastal groundwater systems: a modeling study in the Netherlands, Water Resour. Res., 46, W00F04, doi:10.1029/2009WR008719.

Veraart, J.A., Van Ierland, E.C., Werners, S.E., Verhagen, A., De Groot, R.S., Kuikman, P.J., et al. 2010. Climate Change Impacts on Water Management and Adaptation Strategies in The Netherlands: Stakeholder and Scientific Expert Judgments. Journal of Environmental Policy & Planning, 12(2), 179-200.

Goes, BJM, Oude Essink, GHP, Vernes, RW and Sergi, F, 2009. Estimating the depth of fresh and brackish groundwater in a predominantly saline region using geophysical and hydrological methods, Zeeland, the Netherlands, Near Surface Geophysics 401-412.

Other

De Vries A., Veraart, J.A., De Vries I., Oude Essink G., Zwolsman G., Creusen R., Buijtenhek H., 2009. Vraag en aanbod van zoetwater in de Zuidwestelijke Delta, een verkenning. Kennis voor Klimaat rapport (KvK 017/09). ISBN 978-94-90070-15-1

Oude Essink, GHP, Louw, de, PGB, Stevens, S, de Veen, B, de, Prevo, C, Marconi, V and Goes, BJM, 2009, Monitoring campaign in the occurrence of freshwater lenses in the Province of Zeeland (in Dutch), 2007-U-R0925/A, 132p.

Oude Essink GHP, Van Baaren ES, De Louw PGB, 2010, Salinisation and freshening of phreatic groundwaters in Zeeland, The Netherlands: a modeling study, Proceedings 21st Salt Water Intrusion Meeting, Azores, Portugal, July 2010

Verkaik, J, Van Baaren ES, Delsman, J, Oude Essink GHP, 2010, Netherlands Hydrological modelling Instrument for fresh and saline groundwater in the Dutch coastal zone, Proceedings 21st Salt Water Intrusion Meeting, Azores, Portugal, July 2010.

Velstra, J. and De Jong, K. (2011). The impact of climate change on salinization of groundwater in coastal regions and how to respond: a case study in the north of Groningen and Friesland. Proc. of 25th ICID European Regional Conference, Groningen.

Websites

KvR verziltingsonderzoek in Noord-Nederland: www.verzilting.nl
Salinisation research wiki Deltares: zoetzout.deltares.nl and freshsalt.deltares.nl

4.3 Climate adaptation in rural areas

Authors: A. Van den Brink (Wageningen University), C. Vos (Alterra), J.P.M. Witte (KWR-Water Research), M. Van Ittersum (Wageningen University), J. Verhagen (Plant Research International) and M. Bakker (Wageningen University)

Table 4.5: Facts and figures about research theme 'Rural Areas'.

Involved research institutes	
Wageningen UR (Wageningen University, Alterra, Plant Research International and LEI) KWR-Water Research VU University Amsterdam Deltares Utrecht University Leiden University	University of Edinburgh Grontmij LTO-Noord PBL SOVON Vlinderstichting
Selection of key researchers	
A. van den Brink (WUR), C. Vos (WUR), J.P.M. Witte (VUA), M. van Ittersum (WUR), J.Verhagen (WUR), M.Bakker (WUR), R. Aerts (VUA), P. van Bodegom (VUA), M.J.Wassen (Utrecht University), Dr. M. Bierkens (Utrecht University), E. van Leeuwen (VU-Amsterdam), P. Opdam (WUR), M. Rounsewell (University of Edingburgh), P. Prins (LTO-Noord), A.J. Reinhard (WUR).	
Projects (only the project numbers, see appendix for full titles)	
Finished A01, A02, A12, A21, A18, COM06, ME06	**On-going** A19, HSDR01, HSDR02, HSOV1B, HSOV01C, Thema 3

4.3.1 The societal relevance of the research theme

Rural areas play an important role with respect to climate change. On the one hand climate change will impact on rural areas, as hazardous weather events such as droughts, heat waves, torrential rainfall and subsequent floods are likely to become more frequent. On the other hand, the rural area has the potential to provide services that can relieve the pressure of climate change, such as water buffering, prevention of soil subsidence, carbon storage and facilitating a northward migration of species. In order to do so, rural areas have to adapt to the changing environment, so as to mitigate pressures and capitalize on opportunities. In this respect, a broad view is necessary. Besides nature and agriculture more land use functions need to be taken into account, such as recreation and heritage.

This KfC research theme is based on the concept of the metropolitan landscape (M. A. Jacobs & Tress, 2004). This concept aims to avoid oppositional and negative connotations between urban and rural, because this distinction has lost most of its relevance in a densely populated country such as the Netherlands.

Climate Adaptation will happen – both planned and autonomously – at various levels and with different aims. Most land in the Netherlands is privately owned, and farmers and resource managers are autonomous decision makers with different goals. The challenge is to combine certain governmental and societal demands (e.g. storing water surpluses, meeting EU nature conservation standards, maintaining strong and competitive agriculture, preserving cultural and natural heritage, etc.) with the individual objectives of the land owners (farmers and nature organizations) as much as possible.

In spite of considerable research effort, we still have insufficient knowledge about how the biophysical system, institutions and people will respond to climate change. What is particularly lacking is interdisciplinary research about the interactions and trade-offs between different sectors and across adaptation options. Vegetation responses to new hydrological circumstances are insufficiently known, and current models do not allow such assessments. Whether or not particular nature targets – obligatory by law – are realistic for the future is not clear. Also, little is known about the effects of extreme weather events on the survival of species in ecological networks, and the adaptation required of such networks to make them climate-proof.

Moreover, whilst there has been much research on the impacts of climate change and other environmental change drivers on rural systems, the assessment of *human adaptation* to change is much less developed. Better understanding of adaptation is urgently needed for society to be able to cope with the consequences of climate change. Human adaptation strategies are essential processes for all societies to consider, but the large uncertainties associated with the behavioural aspects of adaptation strategies make research in this area difficult.

4.3.2 The scientific approach and the and research questions

The **KfC research programme** aims to assess the effects of climate change and adaptive strategies (i.e. sets of concrete adaptation measures) on agriculture, nature and other land-use functions in the rural landscape of the Netherlands. To reach this objective, we focus on two climate scenarios and a selection of regional to local case study areas. For EU-policy, demography, and market two plausible existing scenarios will be defined and integrated into the contrasting climate change scenarios. In addition to these exogenous scenarios we will investigate, in a case-study specific setting and in close co-operation with the stakeholders, the feasibility and effectiveness of adaptation strategies. These strategies are meant to:

- Achieve a climate-versatile ecological structure that allows meeting high-standard, climate-adjusted nature targets;

- Achieve good prospects for agriculture, the drinking water sector and other land-use functions;
- Whereby the overall functionality of the landscape, in terms of water management, biodiversity, agriculture, drinking water and recreation is optimized.

Central research questions in the **CcSP programme,** were, among others:

- What are the effects of climate change – i.e. changes in temperature, precipitation and potential evapotranspiration – on the spatial distribution of vegetation and its functional diversity within ecosystems in the Netherlands?
- What are the impacts of climate change on biodiversity, especially focusing on the interaction with habitat fragmentation?
- What could be the relevant impact of climate change for Dutch farming systems, with specific relevance to the four northern Provinces (Friesland, Groningen, Drenthe and Flevoland).
- What is the impact of extreme events vis a vis average changes in the climate and what are possible adaptation measures against these extreme events?
- What is the relative importance of climate change in the context of other drivers of change in agriculture towards 2050?

The CcSP research has provided important answers to these questions (Section 4.3.3). Nevertheless, several questions remain, for example questions about feedbacks between soil and vegetation and about the impacts of extreme weather events. Moreover, it was found that a better quantitative prediction of local gradients in soil nutrients is the bottleneck for a reliable assessment of vegetation biodiversity (Witte, et al., 2007). Furthermore, there is a need to quantify the importance of extreme events and to assess adaptation measures in terms of their inputs and outputs and compatibility with farming systems. Another question is to what extent farmers will adapt autonomously, and where and how they would need extra incentives from the government. These and other questions are addressed in the KfC research programme.

Our assumption is that adaptation policies to climate change in rural landscapes are probably most effective when the autonomous response of the hydrological system to climate change is taken into account. Policy should facilitate favourable developments and, where necessary, intervene locally to prevent negative impacts. Therefore, we aim to predict the autonomous developments of hydrology, nature and agriculture under a range of future conditions.

These conditions will comprise two contrasting exogenous scenarios (i.e. integrating a high temperature increase with a 'global economy' and a moderate temperature increase with a 'regional economy'). Furthermore, the conditions are defined by a number of region-specific policy options (concerning spatial planning, drainage, water prices, etc., to be defined together with stakeholders). Policy recommendations will be formulated, following an integrated impact assessment of the autonomous adaptation strategies under the various policy options. Central research questions are:

- Which adaptive measures in water management, nature and agriculture are feasible options to help eliminate potential climate change threats and create opportunities for nature restoration? Where and how should the National Ecological Network be strengthened? Do nature targets have to be adjusted, and how? What is the attitude of resource managers towards these options?
- How are different types of farms and farmers distributed over the rural area, currently and in the future, and what is their attitude towards different adaptation strategies? What are promising adaptation strategies, what are their effects, and what will be the trade-offs with other functions?
- What are the cross-sectoral effects of adaptation? How do adaptation strategies within the agricultural sector and the drinking water sector affect ecosystem functioning and water management, and how does adaptation of ecosystems and water management affect agriculture? Can the exploitation of new ecosystem services attenuate the possible detrimental impacts of one sector's adaptation on another sector?
- Which adaptation strategies have the highest potential to serve society, agriculture, nature and water management in multifunctional landscapes in an effective manner? What is their viability in terms of support from local decision makers?

The spatial and abiotic requirements for adaptation measures will be quantified and attitudes of nature managers and farmers towards adaptation options will be explored. Making innovative use of Agent Based Modelling (ABM)[7] (Bonabeau, 2002) we aim to generate understanding of where land managers

[7] In agent-based modeling (ABM), a system is modeled as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules.

are willing to provide ecosystem services and thus where opportunities for adaptation will occur. The ABM approach will also be used to explore how policy options and (spatial) incentives might improve adaptation opportunities. Furthermore, we will generate, in close cooperation with the relevant stakeholders, design options for the optimal allocation of adaptation measures for landscapes in a broader context including e.g. recreation, heritage, land subsidence and carbon storage. The synthesis of the project outputs will include a comparison of the efficacy of alternative adaptation options within different biophysical and socio-economic contexts and future environmental change scenarios.

4.3.3 Research Highlights

In this Section we focus on key results of CcSP only, as the KfC research programme has just begun.

Nature

- It is unlikely that current empirical relations, as currently often used in ecohydrological models, between environmental conditions and vegetation characteristics will hold in a changing climate. Therefore, research focused on developing climate-versatile measures of environmental conditions. Nitrogen mineralization, as driven by temperature and hydrology, was used to quantify soil fertility conditions. Likewise, spring groundwater levels were replaced by variables for oxygen stress and drought stress in these models. The analyses showed that both stresses will increase in a future climate and that they will increasingly coincide, i.e. both stresses will occur more often within the same vegetation. The simulations also showed that increased oxygen and drought stress will particularly affect endangered species. This pleads for a general consideration of endangered species and habitats within the Netherlands (CcSP A01).
- A new conceptual framework was developed to link climate to vegetation through plant traits. The use of plant traits links to new developments within ecology over the past two decades (i.e. within functional ecology and community ecology), but more importantly, it describes how vegetation is functionally affected by global change and how the vegetation will respond to climate change. The predicted traits were linked to smart statistical tools to compute vegetation responses, including uncertainty bandwidths, in terms of species composition (CcSP A01).

- Based on model simulations and a literature survey, we created a sketch of predicted vegetation changes under influence of climate change. The sketch consists of a map (Figure 4.4) and an accompanying text (Witte, et al., 2009). The aim of this map was to not only show the predicted change for nature in the Netherlands, but also to start a discussion on these consequences of climate change to enlarge the knowledge on the eco-hydrological effects of climate change. This sketch map thus provides policy makers with first critical insights (CcSP A01).

- It was shown that habitat fragmentation increases the negative effects of climate change. It slows down or even blocks the colonization process that is an essential component of range expansion. A refinement on this general conclusion should be made for butterflies, which were found to become more active and hence more successful colonizers under warm conditions (CcSP A02).
- A general formula was developed that predicts which species are most vulnerable to climate-induced range shifts. Survival time depends on:
  - species' range size (the larger the better),
  - the observed northward species' expansion (the faster the better), which is an interplay of species traits (large dispersal and growth capacity) and landscape characteristics (good spatial cohesion),
  - the speed of climate change (the slower the better).

This general formula is potentially a powerful indicator to identify those species that are most at risk and identify those areas where the landscape cohesion is insufficient (CcSP A02).

Knowledge for Climate

climate changes spatial planning

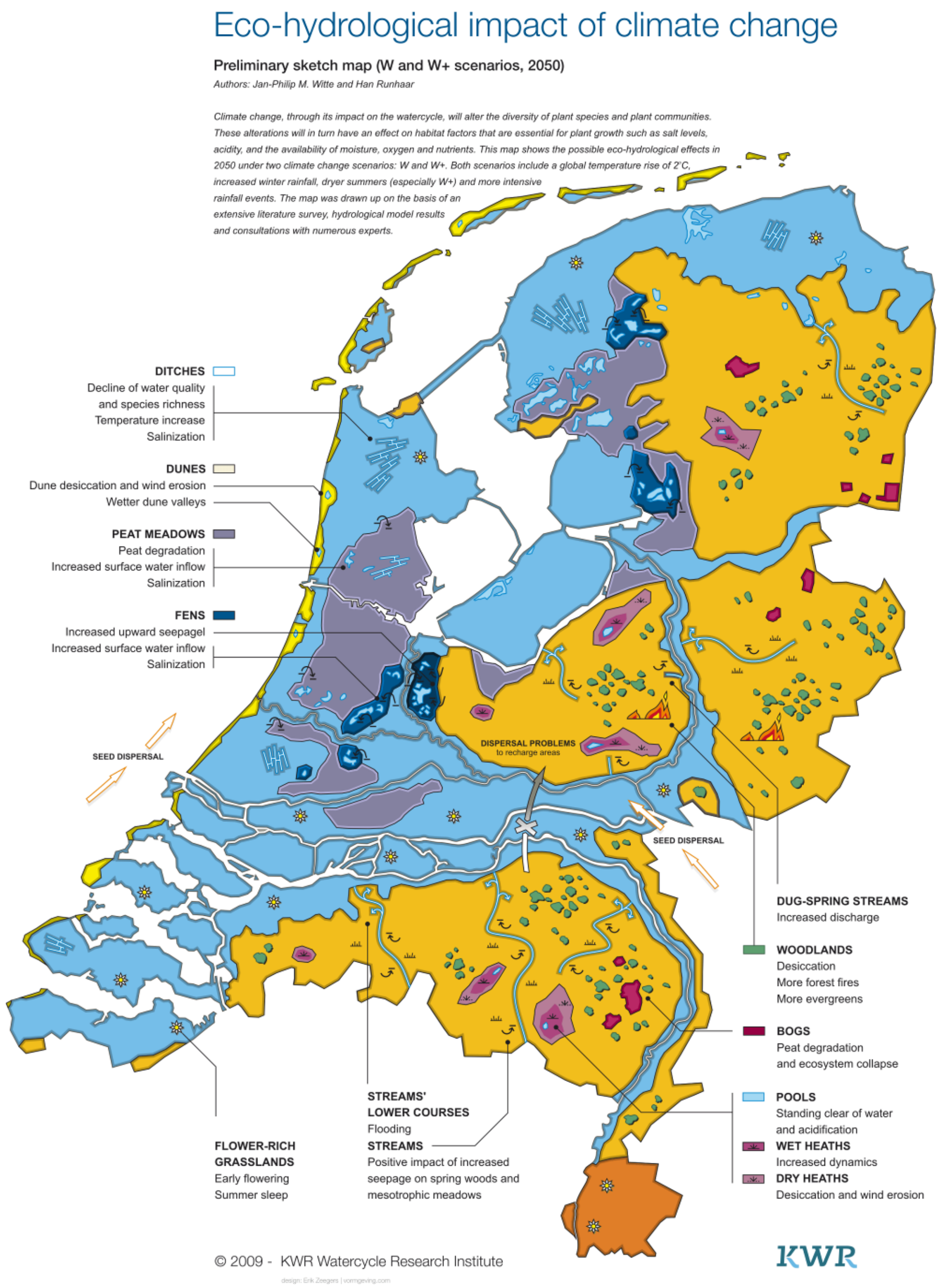

Figure 4.4: Sketch map of vulnerable vegetation as affected by climate change (Witte, et al., 2009)

Agriculture

- An agricultural climate impact assessment method of extreme events and the so-called adaptation ateliers with stakeholders in the North of the Netherlands were developed and well received in the scientific and applied domain. This work made clear that extreme events will probably be much more important for Dutch agriculture than the gradual changes in the climate. Farmers and scientists can come up with adaptation measures for several of the extreme events, while for others good measures are currently lacking. A clear limitation in the assessment of extreme events is that they are very hard to predict (also their frequency) from current climate models (CcSP A21)
- Extreme events related to drought and flooding are relativity easy to address, as technologies and institutions exist to deal with these impacts. Heat waves, pest and diseases are more difficult not only because the scientific knowledge is lacking but also because response mechanisms are not yet well defined. The interaction with farmers was essential to understand the farming systems and context in which farmers operate so linking adaptation measures to current practices and identify relevant research questions (CcSP A21).
- The methodology for integrated assessment of climate change uses a global agricultural market model CAPRI (University of Bonn, 2011) and uses information from a cropping system model (APES-ACE) to assess impacts of climate change on European agriculture and prices. This information provides a context for detailed assessment of the province of Flevoland (NL) (CcSP A19): the relative importance of climate change was assessed vis a vis other drivers of change. A method was developed to derive future images of farms and for these farms the importance of the different factors are currently assessed using a bio-economic farm model (FSSIM). Results indicate that effects of markets, policies and technological progress are generally much larger than effects of climate change (apart from some extreme events that more occur more often under scenarios of climate change. This research is inspired by and builds upon the SEAMLESS approach. Future scenarios for climate, demography, technology and global demand for agricultural commodities were used to assess the competitiveness of European agriculture. Climate change impacts and technological development were used to determine changes in productivity. Regional economic competitiveness was determined by combining indicators

for the economic strength of farms in a region and population pressure on agricultural land, and subsequently used to determine where agricultural production is likely to sustain under the market scenarios. The method is illustrated for the 27 EU member state countries for three commodities: wheat, potato and milk (relying on grass) (CcSP A12).

- Although regional differences exist the results show that technological development has an overriding impact on changes in productivity; climate change only has a minor effect. Due to increased agricultural productivity, less agricultural land will be needed to supply the European demand for food and feed. In addition, production will concentrate in those regions, which have a comparative advantage. This potentially leads to a strong polarization between north-western Europe and southern Europe, which faces negative impacts of climate change and central and northern Europe where agricultural businesses lag in economic strength and farm size (CcSP A12).

4.3.4 Suggestions for further reading: key publications and websites

Some of the peer reviewed publications:

Hermans, C. M. L., I. R. Geijzendorffer, F. Ewert, M.J. Metzger, P.H. Vereijken, G.B. Woltjer, A. Verhagen (2010). Exploring the future of European crop production in a liberalised market, with specific consideration of climate change and the regional competitiveness. *Ecological Modelling* 221(18): 2177-2187.

Vos, C.C., P. Berry, P. Opdam, H. Baveco, B. Nijhof, J. O'Hanley, C. Bell, H. Kuipers (2008). Adapting landscapes to climate change: examples of climate-proof ecosystem networks and priority adaptation zones. *Journal of Applied Ecology* 45: 1722-1731.

Witte, J.P.M., R. Wójcik, P.J.J.F. Torfs, M.W.H. de Haan, S. Hennekens (2007). Bayesian classification of vegetation types with Gaussian mixture density fitting to indicator values. *Journal of Vegetation Science* 18: 605-612.

Websites:

http://www.klimaatenlandbouw.wur.nl/NL/

http://www.ltonoord.nl/nl/25223008-Klimaat.html?path=

http://www.pbl.nl/en/publications/2010/Adaptation-strategy-for-climate-proofing-biodiversity

http://www.kwrwater.nl/page.asp?id=4654

4.4 Climate adaptation in urban areas

Authors: *P. Bosch (TNO), A.A.M Holtslag (Wageningen University)*

Table 4.6: Facts and figures about research theme 'Urban Areas'.

Involved research institutes	
Dutch Building Research Foundation (SBR) TU-Delft Deltares	TNO Wageningen UR (Wageningen University, Alterra) TU-Eindhoven
Selection of key researchers	
R.A.W. Albers (TNO), P. van Oppen (SBR), F. van de Ven (Deltares/TU Delft), A.M.M. Holtslag (WU), B. Blocken (TU-Delft), H.A.M. Daanen (TNO), P.Bosch (TNO), L.W.A. Van Hove (WU)	
Projects (only the project numbers, see appendix for full titles)	
Finished A14, A16, A22, COM22, COM23, COM29, COM34	**On-going** HSRR01, HSRR02, HSRR05, HSRR09, Thema 4

4.4.1 The societal relevance of the research theme

Urban environments seem particularly vulnerable to the consequences of climate change: increased risk of flooding, droughts and heat waves. How can cities as dynamic systems, where most people live and work, prepare for such changes in climate? In order to strengthen the adaptive capacity and to reduce the vulnerability of the urban system against climate change and support the development of strategies and policy instruments for adapting our cities and buildings, a series of questions need to be answered:

- How, and to which extent, do Dutch cities influence local climate?
- How vulnerable are Dutch cities to climate change and what will be the impacts of future climate change?
- Which effective measures and strategies are available to improve the adaptive capacity of cities?
- How to implement adaptive measures in urban areas?

As cities are a focal point for all kinds of societal and urban design issues, successful implementation of climate adaptation policies will require integration with other policy and spatial planning questions in the urban area.

When the CcSP programme started, little was known about the existence of the urban heat island (UHI) in the Netherlands, effects of increased precipitation, the impacts of climate change on Dutch cities and the effectiveness of adaptation options.

4.4.2 The scientific approach and the and research questions

In contrast to many countries in the world, where urban meteorology has been studied for more than 3 decades, urban meteorology was not a common field of research in the Netherlands until recently. This changed after the heat waves in 2003 and 2006, which made many people realize that also Dutch cities are vulnerable to heat waves. As a result the societal support grew for the design of adaptation measures in order to cope with future climate threats on the liveability in cities and conducting supporting research.

Within the CcSP programme a start was made with data collection and this data was explored to assess the characteristics of urban meteorology and climatatology in the Netherlands (Van Hove, et al., 2010). As such, an inventory has been made of internationally available data sources and the possibility to utilize datasets provided by hobby meteorologists has been explored. The underlying question is whether or not thermal comfort will be a critical issue considering urbanization and climate change in the next decades. The assessment is based on results from meteorological observations reported in the literature with particular focus on assessed relationships between maximum nocturnal UHI intensity (UHImax) and city features, such as and city size and urban configuration and structure. Also results from recent meteorological observations in the urban canopy in Rotterdam and Arnhem have been used. Furthermore, historical datasets provided by hobby meteorologists have been analyzed to obtain a more nationwide coverage. In addition, models for the urban canopy have been reviewed and the performance of these models has been evaluated as part of the Urban Surface Energy Balance Land Surface Scheme Comparison project (PILPS URBAN; (Grimmond, et al., 2010). However, it is clear that many issues remain open and that more knowledge is needed on the impacts of land use and material use in (and around) urban areas on local weather and climate.

When we will have better knowledge about the development of climate related variables, the next question is: And does that matter? To answer that question, additional information is needed on the sensitivity of cities to the various influencing factors and on the possible impacts. A wide range of effects need to be considered. Sometimes impacts cause damage (for instance to building materials or properties in case of flooding), some impacts influence health and well-being of the population (for instance in heat waves and smog episodes). Another question is how neighbourhoods and business parks can maintain their attractiveness under changed climatic conditions.

A quantification of sensitivity, the impacts and the resulting vulnerability is necessary for providing guidelines for adaptation strategies, for the mapping of vulnerability of neighbourhoods and prioritization of measures. As impacts differ, such quantification needs to be made on various scales: from buildings, in terms of heat and moisture impact, to the level of neighbourhoods and cities for impacts of flooding and heat waves.

A typology of cities and neighbourhoods according to their vulnerability to climate change is a useful tool to enable policy makers to judge the urgency of action and to prioritise between areas and possible measures.

Research on adaptation options is closely linked with the quantification of impacts, as this provides the priority setting and the requirements to the respective solutions. Research on adaptation options will need to focus on buildings and street-level components that will be able to cope with changed heat stress, more precipitation extremes and salinisation. In addition attention should be paid to reduction of energy use, indoor air quality, climate proof urban water infrastructure and measures to improve the living environments of the neighbourhoods (providing design guidelines for layout, use of materials, green spaces and water. The motivation to pay special attention to linking water and energy is that measures to absorb excess water, from rainfall or from other sources, offer opportunities for synergies with decentralized energy provision and closing of water cycles, two other topics for making cities more sustainable. The assessment of costs and benefits (for local climate), and co-benefits (for climate change mitigation and other urban issues) is part of all research on adaptation measures.

When we know “why” (impacts) and “what” (options) to do, the remaining question is “how”. There is factually no experience in the Netherlands and hardly any in the developed world with adaptation policy in cities. Science can, however, support the development of strategies and policies with insights in the necessary cooperation between governmental agencies, business society and civic organizations (NGOs). Three areas stand out where improved knowledge can support adaptive policies. One is the building sector, where many of the measures will have to be taken, but where also many problems can be expected (as they are apparent with climate mitigation policies now). The others are the restructuring of post-World War II estates including the policy aim to construct more new houses in cities, and the redevelopment of business parks. These are large-scale ongoing developments in which adaptation elements can be introduced. The main issue will be to integrate adaptation in other policies and programmes. As adaptation can have spatial consequences, special attention will be required for the physical planning. Linked to the governance aspect (the ‘how to’ questions) is the issue of adaptive capacity. This links the knowledge base on impacts and adaptation measures with the capacities of societal actors to bring about changes. For complex urban systems with multiple stakeholders it is important to study the various stakeholders in the decision-making process and determine the capacities needed to implement adaptation policies. According to (Carter, 2011), the KfC consortium Climate Proof Cities “highlights the potential value of developing interdisciplinary, cross sector adaptation strategies that are reflective of the nature of the challenges associated with a changing climate.”

Finally all the information resulting from the research outlined above needs to be integrated and made useful for actual policy making. For different scenarios for the future, adaptation strategies will need to be developed together with the stakeholders. Integrating the knowledge of the research programmes then comes down to providing information to policy makers on the costs of inaction, the priorities for action, the different options for adaptation measures, their costs and the governance needed, for each of the scenarios.

4.4.3 Research Highlights

In the CcSP and the first phase of the KfC programme several exploratory studies have been executed, such as on impacts of climate change on urban water systems in Rotterdam and possible adaptation options for heat in the city.

In depth studies focused on observing and modelling of the urban climate in the Netherlands. At present, no systematic meteorological data records for towns and cities in the Netherlands are available yet. A preliminary analysis of the data from hobby meteorologists obtained in 19 towns and cities in the Netherlands showed that the UHI is clearly present in the Netherlands as well.

Preliminary in-situ measurements in Rotterdam and Arnhem show a large consistency with the observations of the hobby meteorologists. All point to the existence of a considerable UHI-max in densely built areas in the Netherlands under favourable meteorological conditions, i.e. under calm and clear (cloudless) conditions, with 95 percentile values ranging from 3 to 10 K. The UHI-max values in Dutch urban areas, are comparable with those found for other cities in Europe. However, no clear effect of city size, defined as the logarithmic value of the number of inhabitants, on UHI intensity could be assessed suggesting that other factors such as population density and/or city district or neighbourhood characteristics may be more important in determining the magnitude of the UHI intensity. Considering future developments in climate and urbanization, thermal comfort and heat stress will likely become a critical issue in many urban areas in the Netherlands.

Many different urban canopy models have been considered. These models vary in complexity from simple schemes that represent the city as a concrete slab, to those which incorporate detailed representations of momentum and energy fluxes distributed within the atmospheric boundary layer. Results from the international PILPS project (Lettenmaier, 2003) shows that generally the models perform well with respect to net radiation and worse with respect to evapotranspiration (order net radiation, storage in the UCL, sensible heat flux, latent heat flux). No model performs best or worst for all fluxes. Relatively simple models may perform equally well or better as very detailed models. Different results for the diurnal variation and maximum value for UHI intensity are obtained with the non calibrated UCM versions of WRF and RAMS[8]. Comparison of the grid-box-averaged temperatures with local observations suggests that both models tend to underestimate the actual average UHI effect. In the case of RAMS the timing of the UHI clearly needs improvement. Both modelling studies show a significant influence of urban areas on their neighbouring rural areas (the effect of the urban plume). With RAMS it has been demonstrated that it is possible to quantify the effect of a change in city configuration on both the magnitude of the UHI intensity and its influence on the neighbouring rural area.

Studies have also explored some of the adaptation options in more detail. Rotterdam, for instance, is facing a significant task with regard to high water protection, and the existing dikes are unable to provide the required safety for future scenarios. The traditional reinforcement of dikes is becoming more and more of a problem in densely built areas. By making levees that guarantee our safety, as well as meet urban development and spatial planning targets, a new approach to flood protection arises: a dike that is suitable for various applications, the ‘multi-functional dike’.

Also options have been explored for a durable flood-proofing strategy for the areas outside the dikes. Improving the adaptive capacity of an area by, amongst other things, applying adaptive construction, is an important component of such a strategy.

Figure 4.5: Floating Pavilion in Rotterdam the perfect show case of adaptive building

[8] WRF and RAMS (Regional Atmospheric Modeling System; more info http://atmet.com) are regional climate models (RCM). A regional climate model is used to downscale Global Climate Model results (GCM) to address physical phenomena at a greater detail that is possible with GCM.

4.4.4 Key publications and websites

Heusinkveld, B.G., Hove, L.W.J. van, Jacobs, C., M.J., Elbers, J.A., Moors, E.J., Holtslag, A.A.M. (2010). Use of a mobile platform for assessing urban heat stress in Rotterdam. In Proceedings of the 7th Conference on Biometeorology – Berichte des Meteorologischen Insituts der Albert Ludwigs Universität Freibourg 20- ISSN 1435-618X- p433-438

Ven, F.H.M. van de, B. Gersonius, R. de Graaf, E. Luijendijk, C. Zevenbergen, E. Tromp, L.A. Valkenburg (2010). Water Robust Building, A three step approach for the Netherlands linking planning, design, construction and exploitation. CcSP016/2010.

Van Hove, L. W. A., Steeneveld, G. J., Jacobs, C., Ter Maat, H., Heusinkveld, B., ELbers, J., Moors, E., & Holtslag, B. (2010). *Modelling and Observing urban climate in the Netherlands.* (No. ISBN 978-90-8815-020-3).

4.5 Climate adaptation and Infrastructure and networks

Authors: *P. Rietveld (VU University Amsterdam), L.A. Tavasszy (TU Delft)*

Table 4.7: Facts and figures about research theme 'Infrastructure and networks'.

Involved partners	
VU University Amsterdam Deltares TNO KWR Water research TU-Delft Havenbedrijf Rotterdam Kantoor Binnenvaart	Australian Commonwealth Scientific and Industrial Research Organisation Southern Cross University, Tweed Heads, Australia Purdue University School of Aeronautics & Astronautics, U.S.A. Louvain School of Management, FUCam (Mons Campus), Belgium Massachusetts Institute of Technology and US Geological Survey, U.S.A. University of Michigan Center for Sustainable Systems, U.S.A. Tottori University and Arid Land Research Center, Japan Swedish Geotechnical institute, Linköping, Sweden Fraunhofer Institute for Systems and Innovation Research ISI, Germany
Selection of key researchers	
P. Rietveld (VU Amsterdam), L.A. Tavasszy (TU-Delft), O. Jonkeren (VUA), F. Barends (TU-Delft), E.J.M. Blokker (Deltares), D. Danciu (KWR)	
Projects (only the project numbers, see appendix for full titles)	
Finished A08, IC05	**On-going** HSMS01, HSMS03, HSRS01, Thema 5

4.5.1 The societal relevance of the research theme

There are still substantial gaps in our knowledge on how to make the Netherlands 'climate proof'. An international review (Koetse & Rietveld, 2009) reveals that in particular in the fields of transport networks and other infrastructures, research on adaptation to climate change has been lagging behind. The research theme focuses on two hotspot regions in the Netherlands: Schiphol-Haarlemmermeer and Rotterdam-Rijnmond. Given the open economy of the

Netherlands, its specialization on trade and its position as hub in international energy and transport networks these mainport regions are of significant economic relevance within the Netherlands and in international transport networks. Large investments of a spatial (public) and industrial (private) character are expected in those regions in the next decades.

Of special relevance is the uncertainty of climate change effects, both concerning their location as well as their magnitude: our climate is a system that exhibits chaotic behaviour. Weather patterns and temperature change during a long time period. One way of dealing with inherent uncertainty is by making use of scenarios. However, probabilities of occurrence cannot easily be attached to scenarios. This calls for adaptive approaches to infrastructure investments where flexibility is an important element. It is this type of adaptive approaches that will be considered in the present programme. Such approaches are relevant to avoid two major potential problems: 1) a waste of resources in the form of overinvestment and 2) a lack of proactive measures to be prepared in case rapid climate change would take place e.g. due to tipping of the complex, chaotic climate system. This not only requires technical and infrastructure system innovation and new network concepts, but also concerns the governance of infrastructure: the institutional environment should be prepared in time for climate change in order to be able to act quickly in case of rapid climate change.

This research theme involves stakeholders from planning, design, maintenance, and operation of infrastructures, both on national and on regional levels. It aims to provide them with a better understanding of infrastructure vulnerability related to climate change, through:

- Qualitative and quantitative information on climate based threats and risks that infrastructural systems are facing.
- A focused and justified awareness at public, private and policy levels, including an assessment of the urgency of adaptation measures.

Combined with a comprehensive set of short-term and long-term policy measures, adaptation strategies need to be formulated and a roadmap for actions and timing developed, which will help policy makers to set priorities.

Stakeholders involved that co-finance programmes in this theme include the municipality of Rotterdam and the following infrastructure providers:

- Rijkswaterstaat, the roads agency of the Ministry of Infrastructure and the Environment
- ProRail, the national rail provider
- Waternet, provincial water management

- Tennet, a national electricity provider.

Other stakeholders involved include other local governments, sectoral organizations such as the inland waterways organization CBRB, the safety research institute SWOV and the Port Authority Rotterdam.

4.5.2 The scientific approach and the and research questions

Central questions addressed are:

- What are relevant effects of climate change on infrastructures and their interconnected networks?
- To what extent do these effects threaten the safe, sound, reliable operation of infrastructures, their availability and socio-economic productivity?
- How can we avoid congestion, service interruption, system breakdown or even systemic crisis through reinforcing effects rippling through interconnected infrastructures?
- Through what policies, strategies and governance can we adapt infrastructure networks and make our economic hotspots robust and resilient to climate change?

To address the research questions in concert, the theme requires a systemic approach including modeling of infrastructure operation and development, including complete models on transport, energy, ICT and water infrastructure networks in the hotspot Rotterdam-Rijnmond and, for road and rail networks, at a national scale.

The research questions require a multidisciplinary approach that brings together knowledge of engineering, economics and system analysis. The three disciplines develop their own research and are joined in a fourth stream of work that integrates the research results during the programme into adaptation strategies for climate change, together with the stakeholders in the mainport region.

From the engineering research dimension, we aim to provide a scientific basis to a risk based analysis of the effects of climate changes on sub soils and physical infrastructures supported by sub soils. By quantifying subsoil settlements due to changing groundwater tables the effects on pipelines, embankments and surrounding foundation elements can accurately be determined. The main focus will be on clay and peaty soils; as such the project results are suited for the subsoil conditions in the western part of the Netherlands where both hotspots are situated. The work will focuses on existing as well as new roads and railways, including tunnels. For existing roads and railways, the main importance is to quantify the effects of climate change for the use and maintenance thereof and to develop measures to limit the consequences thereof. Special attention goes out to concealed faults that, under influence of changing circumstances, gradually develop, after which they suddenly develop into large damages followed by large reconstructions.

An additional focus is on vulnerable structures in the shallow subsoil especially drinking water infrastructure. With a changing temperature due to climate change, the temperature in the subsoil will change accordingly. This can have a tremendous effect on the quality of the water in the pipes. Drinking water is most vulnerable in its direct effect on public health, but also sewerage water will experience an increased micro-biological activity with increased temperature. This might lead to uncontrolled release of greenhouse gasses from sewerage systems. Finally the recovery of energy from the water caused by the increased temperature might contribute to more energy efficiency and to cooling down the water to stop unwanted processes.

The main problem in terms of economics is a lack of knowledge on the size of the damages that may occur as a result of the impact of climate change on infrastructures. Our analysis concerns a monetization of the impacts of climate change on the physical networks (transport and electricity) and on the reliability and usability of these networks, given uncertain futures.

CcSP research has focused on inland water transport as a crucial transport sector for freight transport in the Netherlands and its neighbour countries. It appears that low and high water periods have a large impact on the functioning of this market, which implies a clear climate vulnerability theme is most visible here. In the next phase of the research ample attention will be paid to other infrastructures including for example rail, road and electricity. Based on research questions formulated by the hotspots we foresee analysis of socioeconomic effects in three separate projects:

In the **first project** we will assess the economic impact of changes in reliability and usability of land side transport infrastructures in the hotspot regions due to climate change. This also includes studying the costs associated with changes in behaviour of decision making actors (passengers, freight forwarders, shippers). The project entails analysis of revealed preference data on those changes in reliability/ usability and behaviour. Survey-based stated preference data and network economic loss analysis to assess the impact on the broader economy will complete the project.

A **second project** will focus on changes in reliability and usability of electricity infrastructure in the hotspot regions due to climate change. This entails the theme of how firms and residents will react to changes in the quality of this infrastructure service. Similar research approaches as in the first project will be used.

The **third project** will study flexibility oriented adaptation approaches. Given various long run uncertainties, adaptation strategies involve taking preventive measures to increase flexibility of infrastructure; an example being spatial reservations for zoning schemes around the Schiphol airport to cope with future uncertainty on wind directions.

Adopting a socio-technical perspective, the impact assessment of climate change will be used to develop network models to analyze and design network robustness and test short-term adaptation strategies for the hotspots. Quantitative Agent-Based models (ABM) will be developed to simulate the infrastructure development over 50 years. Therein infrastructure assets are modeled as technical objects; the stakeholders are represented by social agents. The networks grown will be assessed for resilience to network failure using a failure mode propagation model. Building on asset management and risk knowledge, we will explore how we can incorporate robustness and resilience to climate change into the (re)design of our (physical) infrastructures while maintaining the reliability and quality of operation of current infrastructure. The ABM's can then be used to explore the combined effect of policy, strategy, innovation and climate change and to test institutional arrangements and possible transition strategies towards climate change.

4.5.3 Research Highlights

Climate change is likely to affect inland waterway transport through variation in the water level of rivers in North West Europe. Low water levels imply restrictions on the load factor of inland ships, reducing effective supply in the market. Climate scenarios for Western Europe for 2050 show that years with extremely low water (such as 2003) having large impacts on this transport sector may well represent the average water level within four decades, implying that what is an exceptional year now becomes business as usual in the future when no adaptive measures are taken. The low water levels lead to low load factors which means that the price per ton transported will go up substantially.

Knowing to what extent transport prices for inland waterway transport rise due to the occurrence of low water levels, a welfare analysis can be carried out. We find that, in an average year (for the period 1987 – 2004), the annual welfare loss due to low water levels in the Kaub-related Rhine market is equal to € 28 million. For the year 2003, which was characterized by a very dry summer and can be seen as a typical year in the most extreme climate scenario (W+), the welfare loss was € 91 million (Jonkeren, Rietveld, et al., 2007; Jonkeren, Van Ommeren, et al., 2007). Extending the estimation to the total Rhine market plus the Moselle market, the welfare loss is estimated to lie between € 194 million and € 263 million. As it is plausible that dry years like 2003 will happen more often as a result of climate change, annual welfare losses via the inland waterway transport sector will be substantial.

Adaptation strategies take place within the inland water transport sector itself, though to a limited extent. It appears that opportunities to reduce transport volumes are limited. An in-depth analysis of modal shift away from water transport to rail and road reveals that this indeed might take place, but again to a limited extent for a number of reasons having to do with the relatively high cost of road transport and also because capacities in the rail and road network are limited. Besides, from a transport policy point of view, and from an environmental perspective, the reverse modal shift and the increase in CO_2 emissions are highly undesirable (Jonkeren, et al., 2009).

It appears that the transport price per tonne may increase by 74 per cent at extreme low water levels, compared with a situation with water levels at which inland ships are not restricted in their load factor. This percentage applies to an inland ship of average size. For larger ships, the transport price per tonne increases even more (Jonkeren, Rietveld, et al., 2007; Jonkeren, Van Ommeren, et al., 2007).

Future adaptation strategies in the inland water transport sector involve both the adjustment of ship size (a private sector action) and the intensification of water management (a public sector responsibility). A thorough analysis reveals that public sector adaptation is more efficient from a cost benefit viewpoint compared with private sector adaptation, but that a combined effort of private and public sector is even more efficient.

Road transport is rather strongly affected by weather conditions. This holds true for demand for transport as such, for accidents, and for congestion. For example, we find that travelling through congested areas reduces car speed by about 7 percent. Car commuters' welfare costs due to rain are rather substantial during the evening peak in congested areas (and up to 12 percent of the overall commuting costs). This shows that in metropolitan areas the disturbances of adverse weather conditions are substantial, and with climate change these adverse effects might well be expected to increase.

4.5.4 Suggestions for further reading: key publications and websites

Demirel, E., J. van Ommeren & P. Rietveld 2010b. Climate change and inland navigation between the Netherlands and Germany: An economic analysis, in P. Martens and C. Chang (eds). The Social and Behavioural Aspects of Climate Change: Linking Vulnerability, Adaptation and Mitigation, Greenleaf Publishing, Sheffield, pp. 121-138

Jonkeren, O., P. Rietveld & J. van Ommeren 2007a. Climate change and inland waterway transport; welfare effects of low water levels on the river Rhine, Journal of Transport Economics and Policy, 41 (3), 387-411.

Jonkeren, O., B. Jourquin, P. Rietveld 2009. Modal-split effects of climate change: The effect of low water levels on the competitive position of inland waterway transport in the River Rhine area, Transportation Research Part A, doi: 10.1016/j.tra.2009.01.004.

Koetse, M.J & P. Rietveld 2009. The impact of climate change and weather on transport: An overview of empirical findings. Transportation Research Part D, 14, 205-221 (most downloaded paper of this journal in 2009).

4.6 Climate projections, scenarios and observations

Progress booked and dilemma's encountered in scenario research

Authors: *B. Van den Hurk (KNMI), A. Feijt (KNMI) and J.Bessembinder (KNMI)*

Table 4.8: Facts and figures about research theme 'Climate projections, scenarios and observations'.

Involved research institutes	
ECN, Energieonderzoek Centrum Nederland Futurewater KNMI, Royal Netherlands Meterological Institute NIOZ, Royal Netherlands Institute for Sea Research Deltares KWR Water Research Deutsche Wetter Dienst (DWD) SMHI	RIVM SRON Delft University of technology Utrecht University VU Amsterdam University Wageningen UR (Alterra, Wageningen University) TNO University of Exeter
Selection of key researchers	
B. van den Hurk (KNMI), H. van Aken (NIOZ), H. Russchenberg (TU-Delft), J. van Dam (WU), H. ten Brink (ECN), F. Selten (KNMI), E. van Meijgaard (KNMI), J. Bessembinder (KNMI), Th. Brandsma (KNMI), J. Vandenberghe (VUA), P.M. van Bodegom (VUA), S.R. Dessai (University of Exeter), T. Fuchs (DWD), R.W.A. Hutjes (Alterra), M. van Ittersum (WU), R.S.W. Van der Wal (Utrecht University), E.Koomen (VUA)	
Projects (only the project numbers, see appendix for full titles)	
Finished CS01, CS02, CS03, CS04, CS05, CS06, CS08, CS09, COM21, COM27, COM01	**On-going** CS07, HSHL05, HSRR04, HSHL06, HSHL12, HSMS02, KKF01a, KKF01b, KKF01c, Thema 6

4.6.1 Climate scenario research and the society relevance

The combination of the unpredictable nature of many future developments on one hand, and the significant benefits of being well prepared for this future on the other, generates a well-known dilemma. Definition and evaluation of scenarios of possible future evolutions are a widespread means to cope with this dilemma. Also in the CcSP and KfC programmes this scenario approach is widely adopted. In the strategy followed in these programmes, climate change scenarios are used as a starting point for impact and vulnerability assessments. Requirements of these climate change scenarios include *plausibility*, *internal consistence* and *relevance*. Plausibility excludes future evolutions that are extremely unlikely or physically impossible. Internal consistence acknowledges the need to assess multiple variables, time scales and regions at one. And relevance excludes scenarios that are either very similar (indistinguishable), or have a very limited societal impact.

The future climate of the world, and certainly of a region surrounding the Netherlands, is subject to a wide collection of processes, drivers and feedbacks, many of them being largely unknown or at least very uncertain. Global and regional climate models are, together with a high quality observational reference and theoretical understanding of the climate system, imperfect but valuable tools for generating future climate outlooks. These models have developed into a shape where it nowadays is fairly easy to generate or download a future projection and analyze the modelled changes in key climate indicators for the area, time slice and application considered. However, frequent confrontation of models with verification data, comparison between model projections, and understanding of the natural variability of any climate variable at any spatial and temporal scale impose the need to carefully address the reliability of these models and the plausibility of the outcomes. Apart from providing the society with estimates of future climate conditions guided by expert judgment, it is necessary to remain alert about the many unknowns in the models, in the observations, and in the generated scenarios. To give expression to this awareness, CcSP (and to a smaller extent also KfC) follows a dual-course strategy in climate scenario research: one track aimed at generating tailored climate scenarios for a wide range of users, and one track focusing on an increased understanding of the system and improved observational records, adequately merged into a new generation of (regional) climate models.

The CcSP programme attempts to bridge the long trajectory between fundamental insights in climate processes and feedbacks to the specific knowledge needs in practical applications has been partially successful. Earth system scientists were encouraged to communicate their findings in non-scientific media (papers, conferences) and these reports were generally positively received by the public. The core project **"Tailoring climate scenarios for impact assessment"** (CS7) has been very successful in providing climate change information and its guidance to a vast variety of users. However, in the communication around climate research results and the scenarios produced continues to be affected by a different perspective from climate scientists on one hand and users of the scenarios on the other. While climate scientists tend to focus on the many unknowns in the system, climate information users continue to formulate requests for an increasing amount of detail and hope for a decreasing degree of uncertainty of the structure of future climate. To respond to these needs, both fundamental research into the limitations of climate predictability at all relevant temporal and spatial scales, and a thorough understanding of the perceptions of the scientific value of the climate information provided continue to be necessary after finishing CcSP.

4.6.2 Scientific approach and research questions

The theme "Climate Scenarios" of CcSP has been designed to allow further development of scientific expertise in a number of areas where Dutch research groups have a good (international) reputation: Atlantic Ocean, atmospheric profiling, regional climate modeling & physical parameterizations, and assessment of regional climate variability. In addition, a new project was formed devoted to the generation and guidance of tailored climate scenarios for impact assessment. Activities in this project were synchronized with the development of a new set of climate change scenarios for The Netherlands, issued by KNMI in 2006 (Van den Hurk, et al., 2006) . A continuation of the process of tailoring climate scenarios and additional stakeholder dialogue is taking place in KfC (see below).

In CcSP research questions were primarily formulated at the project level. At the theme level the research questions and aim can be formulated as:

- The delivery of information about climate and climate change relevant for a wide group of users in society and for other projects in the research programme: this is mainly achieved by executing case studies with specific stakeholders in the tailoring project (CS7), but also by generating and publishing updates of national climate data (CS8), analyzing drivers of changes in the hydrology of major rivers (CS9, A7), and participating in stakeholder driven projects like the climate effect atlas (COM21 and COM27) and the data delivery project for CCsP projects (COM28).
- The improvement of our knowledge on the climate system by improving the quality of climate system models, supported by observations and process studies: this is organized around two types of climate models. A regional climate project (CS6) actively cooperated with specialized disciplinary projects dealing with soil processes (CS3), aerosol (CS4) and clouds (CS2) and implemented and tested model updates. A global modeling project (CS5) addressed natural and anthropogenic climate variability in Western Europe and devoted several case studies to reveal mechanisms of heavy storms and extensive droughts.
- To contribute to the climate monitoring and to specific multiyear observation programmes: this work was embedded by adding oceanic monitoring devices to the global archive (CS1), performing highly specialized continuous atmospheric profile measurements at Cabauw (CS2) and digitizing and publishing ancient weather data (CS8).

Links between CcSP and KfC

The climate scenario themes in both CcSP and KfC are designed to cover the entire pathway between basic climate research, the condensation of this research into specific information products for a wide range of users, and guidance of these products in a communication service. However, CcSP used a combination of Dutch expertise and urgent research needs to formulate research projects in the areas of ocean monitoring, modeling and observing physical components of the climate system, and data base building. In KfC this somewhat scattered portfolio of research topics was avoided by a clear focus on research and information on high impact climate events, and a central role for stakeholders organized in hotspots. WP1 in KfC's theme 6 addresses model development to allow for instance simulations with extreme North Sea surface temperatures, WP2 analyses the propagation of uncertainties about high impact events from science to stakeholders, WP3 formulates relevant climate information for a range of sectoral stakeholders, and WP4 provides the necessary guidance. Research in KfC is ongoing, and only preliminary results are available.

4.6.3 Selected research highlights

Regionalized climate change scenarios

During the formation of the CcSP programme KNMI initiated the preparation of a new generation of climate change scenarios for The Netherlands, labelled KNMI'06 (Van den Hurk, et al., 2006). This synchronous process turned out to be very successful for both CcSP and KNMI'06. The scenarios – published in 2006 – were used as a reference for (almost) all CcSP projects addressing impacts of climate change, and the CcSP contribution allowed the development of a professional user dialogue interface, including a set of case studies demonstrating the interpretation and tailoring of KNMI'06, a large volume of oral presentations and website visits, and a strong network of scenario developers and users. KNMI'06 was updated in 2009 (Klein Tank & Lenderink, 2009) with scientific and popular publications addressing intense precipitation, SST-effects on coastal precipitation, non-local circulation effects of widespread droughts, observed versus modeled continental temperature trends, and gravity effects on regional sea level rise (see textbox). A new sea level scenario was created in 2008/2009 for the Second Dutch Delta committee (Deltacommissie, 2008; Katsman, et al., 2011 (accepted); Vellinga, et al., 2008).

The user network is being used extensively for the design of again a new generation of scenarios (labelled KNMI next, expected in 2013). Users and interested parties express their desire for a similar 4-scenario structure as in KNMI'06, but with considerably more information on (a) a wider range of climate variables, (b) the probability of occurrence of each scenario, (c) natural variability in space and time within each scenario, and (d) a set of representative case studies consistent with the scenarios ("future weather").

Lenderink et al (2008) found that intense precipitation increases stronger with temperature than Clausius Clapeyron, probably due to thermodynamic effects in tall showers. **Katsman et al (2011)** showed that the contrasting gravity effects from Greenland and West Antarctica result in a net small impact of sea level near the Dutch coast. (**Haarsma, et al., 2009)** demonstrated effects of Mediterranean drying on atmospheric circulation at higher latitudes, giving non-local effects on temperature and precipitation.

Development of a new version of the Regional Climate Model RACMO

A new version of the Regional Atmospheric Climate Model RACMO has been developed and tested, giving rise to improved performance in a number of key climate variables. In international comparison experiments carried out in the context of e.g. the ENSEMBLES project this RACMO version is often one of the better models in the participating ensemble. The developments are carried over to follow-on projects. In the Dutch National Model and Data Centre (NMDC), the coupling between RACMO and the aerosol chemistry model LOTOS is implemented for operational application. The global climate model EC-Earth, co-developed by KNMI and Dutch research institutes, has copied some of the revisions tested in RACMO.

Climate models tested with new observations

As part of the Atlantic Ocean project (CS1), a systematic confrontation of climate models with existing and new observations of deep ocean mixing in the North Atlantic sector has shown large difficulties in reproducing the vertical redistribution of heat and salt (De Jong, 2010). Given the wide current interest in decadal climate predictions – heavily relying on an adequate representation of the thermal time scales of ocean models – the results have given insights in the necessary direction of further progress in the development of model quality before significant prediction skill can be expected.

4.6.4 Suggestions for further reading

A good overview of the KNMI'06 climate scenarios and the associated tailoring process can be found in the original brochure[9] and the 2009-update[10]. The KNMI scenario website[11] gives a comprehensive overview of the many cooperation projects with stakeholders that have been modulated by CcSP. Many scientific results of CcSP are documented in scientific papers. The scientific highlights presented above are described in detail in the references below, also accessible via the CcSP website.

Key literature

Haarsma, R.J., F.M. Selten, B.J.J.M. van den Hurk, W. Hazeleger and X. Wang, Drier Mediterranean Soils due to Greenhouse Warming bring easterly Winds over Summertime Central Europe; Geophys. Res. Lett., 2009, 36, L04705, doi:10.1029/2008GL036617.

Hurk, B. van den, E. van Meijgaard and G. Lenderink, Climate Research Netherlands - Research Highlights; CcSP international newsletter, 2009, 6-12.

Jong, F. de, S.S. Drijfhout, W. Hazeleger, H.M. van Aken en C.A. Severijns, Simulations of hydrographic properties in the north western North Atlantic Ocean in Coupled Climate Models; J. Climate, 2009, 22, 7, 1767-1786, doi:10.1175/ 2008JCLI2448.1.

Katsman, C.A., W. Hazeleger, S.S. Drijfhout, G.J. van Oldenborgh and G.J.H. Burgers, Climate scenarios of sea level rise for the northeast Atlantic Ocean: a study including the effects of ocean dynamics and gravity changes induced by ice melt; Climatic Change, 2008, doi:10.1007/s10584-008-9442-9.

Lenderink, G., E. van Meijgaard and F. Selten, Intense coastal rainfall in the Netherlands in response to high sea surface temperatures: analysis of the event of August 2006 from the perspective of a changing climate; Clim. Dyn., 2009, 32, 19-33, doi:10.1007/s00382-008-0366-x.

Lenderink, G. and E. van Meijgaard, Increase in hourly precipitation extremes beyond expectations from temperature changes; Nature Geoscience, 2008, 1, 8, 511-514, doi:10.1038/ngeo262.

Linde, A.H. te, J.C.J.H. Aerts, A.M.R. Bakker and J.C.J. Kwadijk, Simulating low-probability peak discharges for the Rhine basin using resampled climate modeling data; Water Resour. Res., 2010, 46, doi:10.1029/2009WR007707.

[9] http://www.knmi.nl/publications/fulltexts/knmi_eng_lr.pdf
[10] http://www.knmi.nl/climatescenarios/documents/KNMI_2009_EN.pdf
[11] http://www.knmi.nl/climatescenarios

4.7 Governance of climate adaptation

Authors: *C.J.A.M. Termeer (Wageningen University) and J. Gupta (VU University Amsterdam)*

Table 4.9: Facts and figures about research theme 'Governance of climate adaptation'.

Involved research institutes	
Utrecht University VU IVM VU University Amsterdam Wageningen UR (Alterra, Wageningen University) Radboud University Nijmegen	Twente University DHV Erasmus University Rotterdam University of East Anglia (UEA) Carl von Ossietzky University Stockholm University
Selection of key researchers	
C.J.A.M. Termeer (WU), J.Gupta (VUA), J.E.M. Klostermann (Alterra), J. De Boer (VUA), M. Hisschemöller (VUA), S.V. Meijerink (Radboud University Nijmegen), E. Bergsma (VUA), S. Nooteboom (Erasmus University Rotterdam), M.W. Van Buuren (Erasmus University Rotterdam), P. Leroy (Radboud University Nijmegen), D. van Soest (VUA), G. Teisman (Erasmus University Rotterdam), M. van Rijswijck (Utrecht University)	
Projects (only the project numbers, see appendix for full titles)	
Finished A11, COM30, IC08, IC10, IC12	**On-going** Thema7

4.7.1 The societal relevance of the research theme

There is increasing recognition of the need for society to adapt to the potential impacts of climate change (IPCC, 2007). Adaptation involves both infrastructural adjustments, like enhancing dikes or creating water-storage capacity, and broader processes of societal change, such as adjusting land-use planning, more efficient water use, or agricultural transitions. Because of the many uncertainties surrounding climate change issues, actors must not only develop and implement these adjustments and transitions, but must also increase the adaptive capacity of society (Gupta, et al., 2010; Huitema, et al., 2009; Jordan, et al., 2010). Many adaptive measures will be the result of autonomous or planned actions of individual actors (Berkhout, et al., 2006; Stern, 2006). However, many aspects of adaptation have public-good characteristics, requiring collective action. Most people expect or hope that governments will safeguard them from floods, droughts, and the other effects of climate change. This makes adaptation to climate change not only a complex technical issue, but also a continuous political challenge and will make many demands from governance.

Three general challenges will affect the governance of adaptation. First, important changes in local, national, European and global governance systems are unfolding. Governance today includes a variety of actors operating in different for at different scale levels (Teisman, et al., 2009). This multi-actor, multi-sector and multi-level governance world within the context of governance gaps (fragmentation) and overlaps (pluralism) forms the inescapable context for climate adaptation. Although these changes may imply lack of coordination and delays, they also provide the social capital to enable climate adaptation. Governance actors search for ways to combine the benefits of bottom-up approaches with the benefits of hierarchical arrangements; and to synergise the diverse horizontal approaches within a common goal.

Second, climate adaptation lacks a well-structured policy domain and practice. Adaptation is an emerging policy field with, at least for the time being, only weakly-defined ambitions, responsibilities, procedures, routines and solutions. As a result, governance actors face basic dilemmas, that have to be (re)addressed in developing the governance of adaptation, for instance: who is responsible; which forums are the most appropriate, what levels to act at; how to act and which instruments to use; when and in what sequence to act; who wins and who loses; and how to deliver policy results (Haug, et al., 2010).

Third, decision-making in relation to climate change is knowledge-intensive. Without systematic observations and mathematical models, awareness of climate change would be limited (Siebenhüner, 2002a, 2002b). But important uncertainties about the nature and scale of risks and the effectiveness of solutions will persist (Arvai, et al., 2006). Furthermore, information is needed regarding the institutional framework of societies and how they may be further developed to promote adaptation. In addition, the many actors involved bring with them a variety of perceptions leading to fundamental controversies. In spite of these inherent uncertainties, governance actors face the problem that decisions about adaptation strategies need to be taken or prepared now (Burton, et al., 2007). However, short-term interventions based on a long-term vision demand a specific commitment by taxpayers, politicians, and/or residents.

In the academic realm, there has been a sizeable growth in the number of publications on the governance of adaptation to climate change (see for an overview (De Gier, et al., 2009; Van Nieuwaal, et al., 2009). This literature has dealt with a plethora of topics, including but not limited to general legal aspects, innovative governance concepts ranging from adaptive governance to social learning, assessment tools, adaptive policies and strategies, science-policy relations, and examples of adaptation in case studies (Adger, et al., 2009; Arvai, et al., 2006; Burton, et al., 2007; Dessai & Hulme, 2007; Folke, et al., 2005; Gupta, et al., 2010; Olsson, et al., 2006. ; Pahl-Wostl, et al., 2007; Siebenhüner, 2002a, 2002b; Tompkins & Adger, 2005).

In the Netherlands, regional and local governments have often taken the lead in regional climate mitigation initiatives and are now facing the practical challenges of developing the new policy field of climate adaptation. Within these regional governance practices there is an urgent need for translating theoretical concepts into practical governance arrangements. They have to cope with vested interests of industries, farmers and individual citizens, and the complexity of existing (inter)national regulations. Climate adaptation considerations cut across developments and decisions in a number of other domains like water management, urban development or nature conservation. How can the necessary connections be established between these policy fields, when faced with long-term uncertainties and a public opinion divided between climate optimists and pessimists? How can one deal with the future need for water storage when redeveloping an urban area? How can one achieve conservation targets or develop new nature areas when the future habitats for certain species are moving North? Climate adaptation challenges also raise questions about how to (re-)allocate the costs, benefits and risks of climate impacts. Can public-private partnerships be useful in domains like water storage or flood protection, which are now largely administered by public actors? Developing adaptation policies that work, that are acceptable to society and that do not get in the way of future adaptation efforts, and that will not be undermined by other social activities are practical but daunting challenges for local and regional governments today.

The national government has already started many initiatives and infrastructural investments and faces similar questions regarding the roles, tasks and responsibilities of government, civil society and the market in realizing climate adaptation. When should the national government undertake actions, and which actions could be taken by (organized) citizens and private actors when it comes to – for example – the availability of freshwater? Should the public authorities take the final responsibility for damage by flooding, for example, or can private parties be encouraged to manage the risks by themselves through new forms of insurance? Another key question the national government faces is which level of government should take the lead for which adaptation issues? How should cooperation between the levels of government be organized to maximise economies of scale and policy coherence and minimize unnecessary centralisation and red tape? In complex areas such as the South-Western Delta or the Wadden Sea this type of question is highly relevant and has not yet been answered effectively. Finally, the national government faces the challenge of designing multi-level governance processes to implement the national adaptation strategy or the recommendations of the second Delta Commission(Delta programme Commissioner, 2011; Deltacommissie, 2008; Werners, 2009).

4.7.2 The scientific approach and the and research questions

In this programme, we define governance as the interactions between public and/or private entities ultimately aiming at the realization of collective goals. This broad definition comprises governing activities of government, businesses and civil society actors; and encompasses economic, communicative and juridical steering mechanisms. A governance arrangement is defined as the ensemble of rules, processes and instruments that structure interactions between actors for a specific domain or issue (Leroy & Arts, 2006). This concept will be used for both analysing existing and designing new arrangements. We define institutions as: *'systems of rules, decision-making procedures, and programmes that give rise to social practices, assign roles to the participants in these practices, and guide interactions among the occupants of the relevant roles'* (IDGEC, 1999).

Capacity of institutions to adapt

Institutions are expected to provide a certain degree of stability and predictability to society (March & Olsen, 1989; Pollitt & Bouckaert, 2000), and thus both enable and constrain the opportunities for society to respond to climate changes (Giddens, 1984; Scharpf, 1997). Since most institutions are the product of times in which the climate issue was hardly of any importance, the *first key question* is - To what extent do our evolving institutions allow and encourage society to adapt to complex and uncertain climate change impacts? In order to answer this question, the Adaptive Capacity Wheel has been developed by our team of researchers[12] as a method to assess the adaptive capacity of institutions (For details see(Gupta, et al., 2010)).

Governance arrangements

The second question aims to develop and test governance arrangements that will contribute to (1) developing and implementing adaptation options; and (2) increasing the adaptive capacity of society so that future climate changes can be confronted. It will do so by addressing the following key questions:

- How can we organise connectivity within the existing structures through innovative experiments, leadership approaches and process designs?
- Which economic instruments and governance structures to allocate risks and responsibilities between the public and the private are promising, and how can they be implemented in the Dutch situation?
- What are the consequences of uncertainties, stakeholders' perceptions and contested knowledge, and which methods help to cope with them in decision-making processes?

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[12] Including Judith Klostermann, Emmy Bergsma, Sander Meijerink, Margot van den Brink, Pieter Jonge, and Siebout Nooteboom.

- How can the principles of legitimacy, effectiveness and resilience be elaborated and what are the implications for the governance of adaptation?

A conceptual framework has been designed to develop and assess governance arrangements. It has analytical, design, normative, and methodological components, and addresses the following questions: (1) What are the distinct challenges for the governance of climate adaptation? (2) Which concepts can guide the design of new governance arrangements and strategies? (3) What are the normative shifts that regional adaptation governance would require? And, (4) what research methods are best to develop and test governance arrangements and strategies?

Frames

Climate change communication, decision-making and governance are heavily dependent on frames. Frames are organizing principles that enable a particular interpretation of a phenomenon by highlighting some potentially relevant aspects. This is particularly important for climate change, because its multitude of aspects cannot be captured in their entirety in any one frame. For instance, certain frames may highlight the role of climate science, but others are necessary to capture the moral issues that are involved, or changes in the incentive structure for stakeholders, or spatial relationships between areas. A third question is to identify different climate frames and to explain the role of frames for the target group of members of a decision unit who have the task to make decisions on climate change adaptation.

International comparison

With the growing awareness of climate change impacts over the past decade, some governance research and practical learning has occurred in Europe. New research findings and practical experience are now becoming available across a number of countries, regions and sectors that are highly relevant to the Dutch case. The third research topic aims to learn across regions and countries. The Adaptive Capacity Wheel (ACW, Figure 4.6) is being applied in many western and developing countries. An international comparison of adaptation efforts between Netherlands, Sweden, Germany and UK will provide in-depth insights on governance arrangements.

4.7.3 Research Highlights

A first result is the Adaptive Capacity Wheel (ACW) and associated research protocol. Presentations of and workshops with the ACW have shown its ability to provoke discussion, about the strengths and weaknesses of current institutions in promoting the adaptive capacity of society as well as about the needed institutional reforms.

The ACW has been applied to assess the adaptive capacity of formal and informal Dutch institutions in the adaptation sector in general and in four sectors in particular: agriculture, nature, water and spatial planning, by examining 23 policy and related documents out of a total of 93 inventoried documents and four in-depth case studies of climate adaptation practices as they are unfolding in the Netherlands.

The results show that (a) the nature institutions are the weakest in adaptive capacity since there are few interactions with non-nature institutions, they strive towards recreating situations that existed in the past, and there are rigid regulatory approaches focusing on protected areas, spatial borders and rare species; (b) the water safety institutions are strong on dynamic aspects such as variety and learning, and on the more traditional aspects such as fair governance and resources; and (c) agriculture and spatial planning institutions have an intermediate position, being enabling and flexible in character, even though climate change is not yet explicitly taken into account.

More general weaknesses across the sectors are: (a) redundancy is given less priority than efficiency in most sectors; (b) because government remains the dominant actor in adaptation to climate change the room for autonomous change for social actors is still relatively low; (c) where Netherlands is still a high-trust society, climate change is a source of mistrust; (d) many processes stagnate due to a lack of active involvement of formal leaders; (e) long-term resources may be in short supply (the Wadden fund and the Delta fund are first attempts to build a financial reserve for the future); (f) there is a path dependency and institutional lock-in to continue the focus on 'hard' technical measures and building in vulnerable areas; and (g) although climate change adaptation is likely to have major equity implications within the country, and will probably raise new questions of responsibility for dealing with the impacts of climate change, this has not so far been taken into account.

The most striking general institutional strengths are that (a) Dutch policy makers are aware of the importance of variety, but they are constrained by available resources; (b) the skill to organize search processes that do not jump to conclusions by framing problems and solutions is widely increasing; (c) developments in all sectors are increasingly geared toward a search process for tailor-made solutions; (d) experimentation with new ideas such as individual responsibility and Room for the River are stimulated, but create new problems as well; (e) although fair governance increases complexity, it is passionately supported.

However, the adaptive capacity of Dutch institutions is under pressure. The research concludes that the adaptive processes in the Netherlands, although having a head start of 800 years, are too incremental and too much subject to alteration. The research recommends adaptive processes in the Netherlands to be accelerated by institutions enabling 'governance in the shadow of hierarchy'.

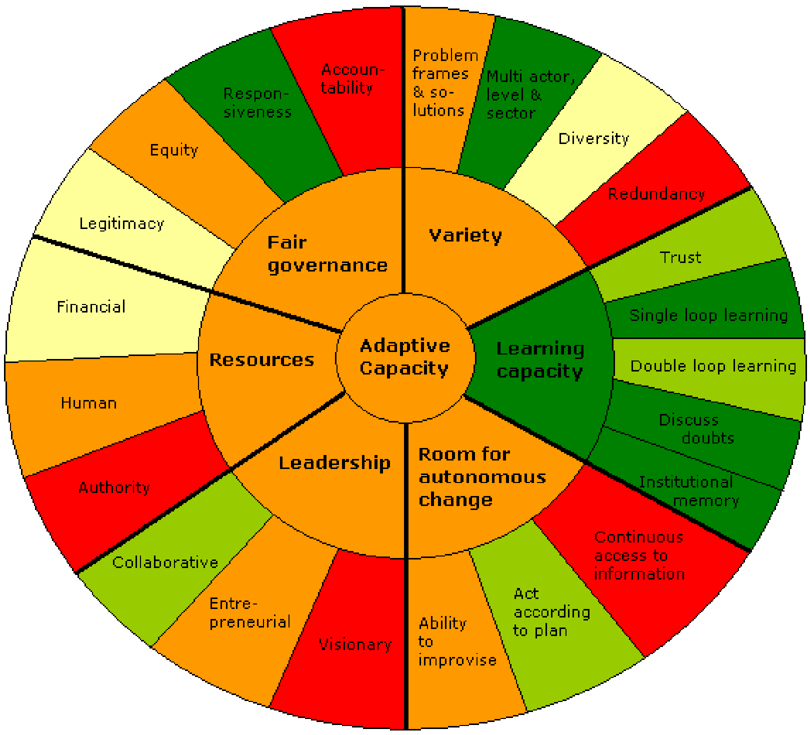

Figure 4.6: The adaptive Capacity Wheel completed for the question: To which extent is nature legislation an opportunity or a bottleneck for mainstreaming climate adaptation into policies (source: Gupta et al., 2010).

A second result is the overview of different frames that may underlie discussions on science-related issues (table 4.10). Table 4.10's upper right cell represents a distal approach (long-term, broad categories) to prevention-orientation. Prevention-oriented frames aim to avoid errors in dealing with, for example, the earth's atmosphere or with climate change adaptation. This may be combined with broad categories of thinking about moral aspects of climate change. Al Gore's movie "An Inconvenient Truth" fits well into this pattern, calling for precaution in the face of potentially catastrophic impacts. The work of the Intergovernmental Panel on Climate Change (IPCC) and the national report of the second Dutch Delta Committee on Flood Safety in the Netherlands take a more proximal view of prevention-orientation (lower right cell of Table 4.10). The Delta Committee report (Deltacommissie, 2008) aimed to develop an integrated vision for the Netherlands for centuries to come. Despite the report's long time horizon, it has a narrow, specific, concrete focus, for example, on specific sea-level scenarios.

Both prevention-oriented frames contrast with two promotion-oriented frames. Promotion-oriented frames highlight the possible gains that climate-related issues can entail for society. A proximal example of this is the notion of a "climate-proof city" such as expressed in the city of Rotterdam, the Netherlands (lower left cell of Table 4.10). Rotterdam is expected to face numerous challenges due to climate change. However, the municipality aims to establish a strong economy and attractive city. Being (and clearly appearing) well-prepared for climate change is considered to be an important factor in promoting these aims.

Taken together the four cells of Table 4.10 can improve our understanding of the various ways in which climate issues may be framed. In addition, the contrasting features of the four cells indicate that none of the frames is a stand-alone guide to an adaptive choice. Each frame has its strengths and weaknesses in articulating the specifics of a situation. Prevention may have to be complemented with promotion (or vice versa), and the distal view of broad strategic planning needs a more implementation-oriented, proximal way of thinking about how measures can be organized. Hence, introducing a contrasting frame may be used to open-up the process of decision-making.

Table 4.10: Science-related frames grouped into 4 strategic contrasts, with examples about climate issues.

Perceptual distance	**Goal orientation and focus**	
	Promotion orientation (highlight the possible gains)	Prevention orientation (aim to avoid errors)
Distal view (long-term, broad categories)	***Social progress frame*** Defines the issue as improving quality of life or harmony with nature ***Middle way frame*** Puts the emphasis on finding a possible compromise position between polarized views *Example*: Plan to reconcile adaptation and mitigation	***Morality/ethics frame*** Defines the issue in terms of right or wrong; respecting or crossing limits; divides rights and responsibilities between actors ***Pandora's box frame*** Defines the issue as a call for precaution in face of possible impacts or catastrophe *Example*: Al Gore's movie, An inconvenient truth

Proximal view (short-term, narrow categories)	***Economic development frame*** Defines the issue as investment that improves competitiveness ***Conflict/strategy frame*** Defines the issue as a game among elites, a battle of personalities or groups *Example*: Climate Proof City	***Scientific uncertainty frame*** Defines the issue as a matter of what is known versus unknown; can both justify action or delay ***Public accountability frame*** Defines the issue as responsible use or abuse of science in decision-making *Example*: Sea level discussion

4.7.4 Suggestions for further reading: key publications and websites

De Boer, J., Wardekker, J. A., & van der Sluijs, J. P. (2010). Frame-based guide to situated decision-making on climate change. Global Environmental Change, 20, 502-510.

Gupta, J. Termeer, C. , Klostermann, J. Meijerink, S.,van den Brink, M., Jonge, P., Nooteboom, S., Bergsma, E. (2010), The Adaptive Capacity Wheel: A Method To Assess the Inherent Characteristics of Institutions to Enable the Adaptive Capacity of Society. Environmental Science & Policy (13) pp.459-471

Wardekker, J. A., de Jong, A., Knoop, J. M., & van der Sluijs, J. P. (2010). Operationalising a resilience approach to adapting an urban delta to uncertain climate changes. Technological Forecasting & Social Change, 77, 987-998.

Termeer, C., Meijerink S., Nooteboom S., 2009. Klimaatneutrale of klimaatbestendige bestuurskunde? Bestuurskunde 2009, nr.4

Driessen P., Van Nieuwaal, K., Spit T., Termeer C., 2009. Bestuurskundig onderzoek naar klimaatvraagstukken. Bestuurskunde 2009, nr.4

Klostermann, J.E.M., Gupta J., Biesbroek R., 2009. Multilevel klimaatbeleid in Nederland: mitigatie en adaptatie. Bestuurskunde 2009, nr.4

Breeman G., Pot W., Timmermans A., 2009. Evolutie van het klimaatvraagstuk: Agendadynamiek en framing van het klimaatprobleem in de media. Bestuurskunde 2009, nr.4

Huitema, D., Meijerink S.,2009. Adaptitivteit van beleid em de rol van beleidentrepeneurs. Bestuurskunde 2009, nr.4

Teisman G., Nooteboom S., 2009. Slotbeschouwing: Bestuurskundigen laten kansen liggen. Bestuurskunde 2009, nr.4

Nieuwaal, K. van, P. Driessen, T. Spit and K. Termeer, (2009), A state of the art of governance literature on adaptation to climate change: Towards a research agenda. IOP Conference Series: Earth and Environmental Science, Volume 6, 2009, 362019.

Termeer, C.J.A.M. G.R. Biesbroek and M.A. van den Brink. (accepted oktober 2010). Institutions for Adaptation to Climate Change: Comparing National Adaptation Strategies in Europe. European Political Science (EPS).

4.8 Decision support tools for adaptation

***Authors:** E.C. Van Ierland (Wageningen University), M. Kuijpers-Linde (Geodan-Next)*

Table 4.11: Facts and figures about research theme 'Decision support tools for adaptation'.

Involved research institutes	
Wageningen UR (Alterra, Wageningen University) VU University Amsterdam TNO Deltares PBL TU-Delft Geodan-Next	Arcadis DHV TAUW-BV BuildDesk IPO Loasys Novio Consult
Key researchers	
E.C. van Ierland (Wageningen University), A.K. Bregt (Wageningen University), R. Swart (Alterra), H. Goosen (Alterra), M. Hofkes (IVM-VU), R. Brouwer, R. Janssen, Piet Rietveld, O. Ivanova (TNO), A. Jeuken (Deltares), N. Pietersen (PBL), E. Koomen (VU-Amsterdam), G. S. Stelling, T.Kram (PBL), M. Kuijpers-Linde (Geodan), J. van den Berg (DHV), A.Leusink (Loasys)	
Projects (only the project numbers, see appendix for full titles)	
Finished COM35, ME06, IC05, COM15, COM21, COM26, COM30, COM31, IC03, IC11	**On-going** HSHL01A, HSHL05, HSRR04, HSHL06, HSHL12, Thema 8

4.8.1 The societal relevance of the research theme

The programme aims at improving tools for design and evaluation of adaptation strategies with a special focus on spatial planning and cross cutting issues. The programme focuses on three core elements:

- Tools for formulation of the adaptation task, based on climate scenarios and economic development;
- Tools for development and visualization of adaptation strategies in general and in particular related to hotspots and case study areas of KfC;
- Evaluation and monitoring tools for assessing adaptation strategies in terms of various indicators such as costs and benefits; side effects; equity issues; efficiency and temporal and spatial scales.

The programme elaborates on results of previous research (NOP, BSIK, EU programmes) and extends the analysis in order to make further progress in the scientific domain and in order to apply the results in the context of the case studies and hotspots of KfC in close consultation and collaboration with stakeholders. The programme contributes to the ongoing planning process in the Netherlands at various levels, such as Delta programme and current Regional Strategic Visions (Structuurvisies), the National Adaptation Strategy (NAS) and the execution of national policies.

The relevance of the programme at the national and international level is threefold. Firstly the programme produces new methods and results that are relevant for the international scientific community and that will be published in the international literature. For WP1 this includes the innovative approaches for land use modelling; For WP2 the CGE modelling approach (Bergman, 2005) for assessing secondary impacts of flooding; For WP3 the stakeholder analysis based on several layers of GIS maps in an interactive manner. For WP4 the international relevance is the fundamental innovative approaches in visualization through integrated hydrological modelling and visualization in 3D, a method that can be used for assessing the impacts of heavy precipitation in many international case studies. For WP5 the fundamental innovation relevant to the international community is the integrated hydrological and economic approach for assessing fresh water allocation under different climate scenarios. The Dutch scientific expertise in this domain is highly relevant for other countries facing similar water resource allocation policy questions within and outside the EU. For WP6 the innovation is on the analysis of the optimal timing of measure for climate adaptation. So far little research has been explicitly focusing on the optimal timing under uncertainty and learning for adaptation. Most studies on optimal timing focused on mitigation. WP7 is very innovative because monitoring of adaptation measures is just in its infancy and we still have to decide about what appropriate indicators are and how good monitoring systems can be designed.

Secondly the programme, by focusing in detail on the case studies in the Dutch contexts, provides examples and results of typical case studies that can be compared with results in other European or international case studies. Other researchers can then follow similar approaches or adjust the approach according to the local circumstances. Typical innovative case studies are the application of the GIS design table studies on the peat meadow area, the fresh water allocation in the Netherlands, and modeling of hydrology and visualization for polders in Hotspot Haaglanden.

Thirdly the results of the programme can be integrated in meta analyses and integrated in European assessments of climate change impacts and adaptation options in the European context, in order to contribute to a European strategy for adaptation. Through publication in international journals, presentation at conferences, international exchange and participation of several consortium members in EU programmes such as Mediation the innovation can be shared with European partners.

4.8.2 The scientific approach and the and research questions

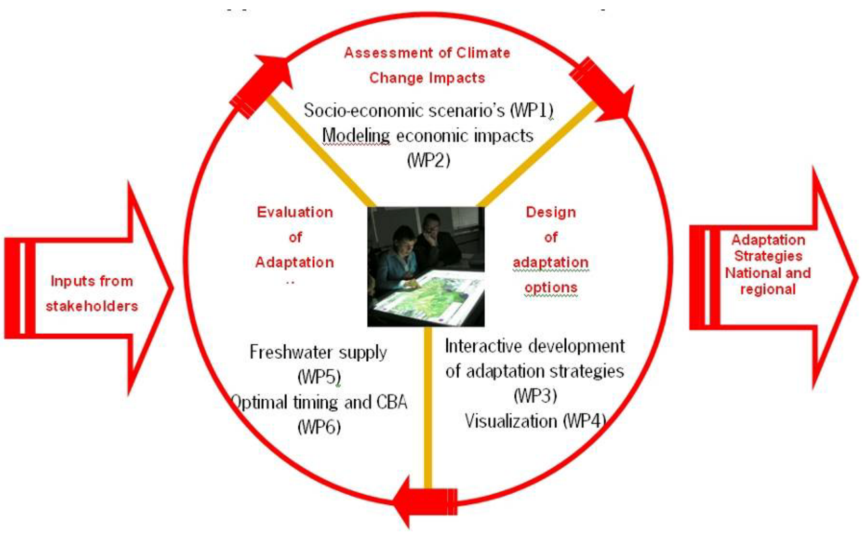

Figure 4.7: Evaluation of adaptation strategies

The main research questions for the overall programme can be summarized as:

- How can - in a dynamic context and given the uncertainties related to climate change- the targets be identified for adaptation in the various sectors and the various regions of the Netherlands and what will be the desired timing?
- How can a consistent adaptation strategy and alternative and innovative adaptation options are generated, both in terms of changes in infrastructure and changes in behaviour and society, in order to cope with climate change and to make the Netherlands climate proof?
- How can assessment and evaluation tools be developed and applied for adaptation in the various regions in the Netherlands and for the various sectors and hotspots, including crosscutting issues?

The research questions are elaborated in the various work packages:

Integrating and downscaling national socio-economic scenarios

- How can the existing land-use modeling framework be improved in order to facilitate the preparation and evaluation of spatially explicit adaptation measures?

Assessing the economic impacts of flood risks

- What are the impacts of flood event and flood risk on (adaptive) behaviour of firms and households?
- How do regions recover from flood events?
- What is the role of governmental policy in an economic recovery of the flooded region?
- What are the economic modeling instruments, which can help policy makers and researchers to predict the future development of the flooded region as well as to choose the most optimal policy to promote its recovery?

Interactive development of spatial adaptation strategies

- How effective are map based decision support tools for interactive design of special adaptation strategies?

Visualization and simulation of climate change impacts

- How can interactive visualization and simulation systems for various types of target group directed protection measures contribute to the use of climate change information in planning for regional and local adaptation strategies?

Economic modelling and assessment of the impacts of climate change on freshwater resources

- How efficient are current freshwater resources allocation decision rules across sectors and regions in the Netherlands from an economic point of view?

- What are the economic implications of future climate change scenarios on the freshwater resources allocation across sectors and regions in the Netherlands?
- How can economic efficiency of freshwater resources allocation be improved across sectors and regions in the Netherlands given future climate change through cost-effective adaptation strategies?
- What role is there for economic markets to improve freshwater resource allocation efficiency across sectors and regions in the Netherlands given future climate change?
- How to design efficient economic markets to improve freshwater resource allocation efficiency across sectors and regions in the Netherlands given future climate change?

Optimal timing, cost benefit analysis and evaluation tools for adaptation options

- How can optimal timing of adaptation measures be determined in a setting of decision making under uncertainty and what are the implications for developing an adaptation strategy for climate change at the regional level?

Monitoring and indicators

- Which evaluation methods and associated indicators are available or can be developed to monitor and evaluate the implementation of adaptation measures and the climate-robustness of plans, programmes and projects?
- How does the choice of methods and indicators depend on the scale of application, on time, and on the specific policy objectives?
- What is a coherent framework to structure evaluation methods and indicators in the broader context of sustainability?
- How can monitoring and evaluation methods and indicators of climate change adaptation and climate resilience best be integrated into existing monitoring programmes?
- How can indicators be communicated and visualized, taking into account uncertainties?

Reflection:

The research questions have been defined on the basis of a detailed assessment of the knowledge gaps at the time of writing the proposals. It has been shown that the topics were very timely and well-chosen and at the edge of scientific knowledge. The need for adaptation is now widely recognized and many governments and stakeholders are struggling to find the best adaptation strategies and measures. Also at the European level these issues are programmed in for instance the ADAM project, Mediation and Climsave. The CcSP and KfC programmes enabled the researchers to fine-tune activities with the European programmes and also to take the lead in a number of them.

It is impossible to obtain sufficient insight without the stakeholder consultation and participation process. In that respect, the stakeholder approach has been accepted as very useful.

The visualization methods are extremely useful in this process and stakeholders at the regional level show great interest in the visualization for instance of the processes of flooding as results of extreme weather events.

The focus on the economics of decision making under uncertainty is extremely useful because in many cases further progress needs to be made in the translation of highly complex methods of decision making under uncertainty to the practicalities of making decision on very expensive measures for protection against flooding. Over-investment easily occurs and billions of Euros are at stake. At the same time serious underinvestment and inadequate assessment of the risks at stake may lead to very serious damages of flooding.

Our early focus on monitoring and indicators for adaptation to climate change show how much we are aware that systematic monitoring of the need for adaptation and the actual implementation of policies is needed in order to avoid excessive future damages. Which indicators to be used to assess the appropriateness of adaptation policy in various domains of society is an urgent scientific question with high social relevance.

4.8.3 Research Highlights

Integrating and downscaling national socio-economic scenarios

- In preceding CcSP projects much research effort was focussed on improving the existing Land Use Scanner model in such a way that it could be applied in the context of climate adaptation. This resulted in a range of scientific publications (various book chapters and papers in, for example, Annals of Regional Science, Applied Spatial Analysis and Policy, Global Environmental Change). In addition, this revised modelling framework was applied in strategic planning projects for different regional authorities providing a novel approach in Strategic Environmental Assessment (SEA).

Spatial planning and climate change in practice

In the Netherlands, provinces (regions) play an important role in spatial planning policy and this role will increase in the near future. Each province develops a strategic plan (structural vision) for the region in order to provide a framework for interaction between the province and other parties involved in spatial planning activities (national and local government, private partners, NGOs and residents). A large amount of knowledge is needed to develop these provincial strategic plans: knowledge about actual and potential spatial developments (related to social, economic, political developments and effects of climate changes in the long term). Adaptation to climate changes is one of the actual themes in spatial planning in the Netherlands. Spatial planning law provides instruments that are very useful for transferring climate change knowledge to the regional spatial planning policy. These instruments, the environmental impact assessment for planning and digital plan sharing provide multiple opportunities for organizing the knowledge management system during the different steps in the planning process.

In two case studies (province Overijssel and province Zuid-Holland), knowledge on climate change was used in a strategic impact assessment.

In 2008, the Province of Overijssel wanted to update the strategic plan for the physical environment because new themes had become important, such as climate change and demographic shrinkage, while at the same time the new national spatial planning act had been enacted. This new Regional Spatial Strategy (Omgevingsvisie Overijssel) has a highly integral character and serves as the spatial structural vision, regional water management plan, environmental policy plan, provincial mobility plan and soil-management plan. Knowledge from different CcSP/KfC projects (COM30, IC03) was used. The province developed its strategic plan in three phases. The first phase involved setting the policy agenda. In this stage indicators for the environmental impact assessment were selected. Sustainability of the physical environment was broken down into different themes like:

- Climate change: flood risks and water damage;
- biodiversity (diversity of plant and animal life): connectivity and quality of the National Ecological Network and Natura 2000 areas;
- traffic and transport: accessibility of cities (car, public transport and bike) and congestion on roads

- Attractive living environments: shortage of quantitative and qualitative housing (particularly location: green space in urban areas, rural living), and noise and external safety;
- Attractiveness for business location: availability of easily accessible business parks and availability of land for commercial agriculture;
- Cluttering of the landscape.

In the second phase policy choices were worked out for the main themes. In this phase various new spatial policy alternatives were simulated with help of the Land Use Scanner (IC03). This land use model makes it possible to combine climate change scenarios and land use change at a regional scale. One of the examples was a stronger discouragement of urbanisation in flood-prone and water-retention areas through restrictive policies, and in the national ecological network, which was spatially redefined and replaced an older version. In the third phase (political commitment round), the planning EIA report was written. Besides modeling exercises (flooding) workshops (expert judgement) were organised in which researchers of both research programmes were invited to discuss the potential effects of new provincial policies.

In the Province Zuid-Holland a similar process took place. In this province the adaptation policy is more urgent (lower part of the Netherlands). In several decision-making processes (such as de Voorloper Groene Hart: scenario for the Green Heart; Climate and environment action programme and the province's strategic plan) knowledge about qualitative (salinisation, water shortages in agriculture) and quantitative aspects (flood risk, water damage and drought) from the programme CcSP/KfC was used. Since the field of policy-oriented research was very dynamic during the policy-convergent phase, this resulted in a lot of new knowledge input. Many difficult choices about the future of the Green Heart and agriculture in the South western islands of the provinces were not made. The strategic plan contains an important research agenda.

This type of research contributed to different components for a national knowledge infrastructure:

- DSS for scenario building (combination of Land use scanner and Climate scenario's)
- Development of Indicator databases based on in depth research (risk modeling, modelling the effects of climate change on biodiversity, etc.)
- Development of stepwise assessment method which combines quantitative (GIS-based) modeling and expert judgement
- These experiences show that linking digital maps to text clarifies policy choices. It forces people to think about the details and the effects in the long term of a policy concept. This research approach makes it also possible to link spatial images of ambitions to spatial data from monitors. New techniques like interactive map tables may strengthen the use of this type

of DSS tools in spatial planning practice. This is a new topic in follow up of this research programme.

Assessing the economic impacts of flood risks: Valuation of immaterial damages due to flooding

Under CcSP we studied the VOSL related to flood risks by means of choice experiments and we compared these values with VOSL in other domains of society. The new VOSL numbers have been directly communicated with the Ministries in the Netherlands and are being considered in the analysis of the future safety standards for the Netherlands. This is a clear illustration of the direct policy relevance of the research.

Focus of the study: Valuation of immaterial damages in the context of flood risk as measures of benefit of avoided human victims, injuries and evacuations (respective indicators: VOSL - value of statistical life, VOSI - value of statistical injury and VOSE - value of statistical evacuation).

Methodology: Stated preferences for non-market goods (Contingent valuation and Discrete choice modelling). Data gathered through an internet-based survey (2008) among a 1,000 sample of representative respondents from TNS NIPO panel covering 4 dike-ring areas (Riverside and Coast).

Main results:

- New estimates of VOSI and VOSE obtained in the context of flood risk provide concrete values for avoided injuries and evacuations that can be directly used in CBA
- Importance of spatially differentiated approach in accounting for immaterial damages in CBA: composition of immaterial damages in monetary terms (consisting of VOSL, VOSI and VOSE[13]) may significantly differ across the regions (for example, for riverside dike-rings, monetary value of evacuation per one fatality may be 1 to 10 times higher than VOSL, while for the coastal areas it makes 15% to 80% of VOSL).

Visualization and simulation of climate change impacts

[13] Value of statistical life (VOSL), Injury (VOSI) and evacuation (VOSE)

The Climate Adaptation Atlas14 (CAA) discloses spatial information on climate change impacts to a wider audience. The Atlas is a discussion/decision support tool. The easily accessible database - or geoportal – with an emphasis of visualizing information by means of G.I.S. makes the information comprehensible for a wider public and allows local governments to work towards a climate-proof future. The CAA has been developed for the Netherlands. Its methodology has proven to be successful in supporting governments to develop adaptation strategies. Its methodology can also be applied outside the Netherlands. The atlas is being developed by a consortium consisting of knowledge institutes (Alterra-Wageningen UR, Deltares, KNMI) and consultants (DHV Group, Geodan Next) in close collaboration with regional stakeholders and governments. The CAA contains information about projected impacts of regionalized climate change scenarios, including flooding, ecosystem shifts, urban heat island effect and agricultural production. The Atlas is accessible online through a Geoportal: http://klimaateffectatlas.wur.nl and is successfully being applied in numerous workshops and design sessions with different groups of stakeholders.

The Climate Adaptation Atlas discloses and visualizes scientific information on climate change to support spatial planning and decision making. The Dutch Climate Adaptation Atlas consists of a large number of maps disclosed via an online Geoportal (http://klimaateffectatlas.wur.nl). The development of adaptation strategies requires more than the 'predict-optimize-act' approach. Adaptation problems cannot be resolved only through downscaling of climate information. Developing robust adaptation strategies or climate-proofing plans or projects requires a bottom-up process involving also non-climate objectives. In the Netherlands, the Climate Adaptation Atlas has proven itself to be an important discussion/decision support tool for climate adaptation at the regional level. Using the atlas provided a wealth of information and experience working bottom up. This approach can be an important tool in bridging science, policy and private sector around the world.

The atlas contains a wealth of information on climate change impacts, e.g. flood modeling, urban heat island effect, crop drought sensitivity and sensitivity of nature types to droughts. This Climate Adaptation Scan helps users to

[14] **Acknowledgements:** The CAA is developed in close cooperation with the 12 provinces of the Netherlands, supported by the BSIK programme "Climate changes Spatial Planning", RGI and Knowledge for Climate, the ministry of Agriculture, Nature and Food Quality (LNV) and the ministry of Transport, public works and water management (V&W).

identify key adaptation challenges in their areas of interest. The Atlas combines the effects and visualizes the main conclusions in an adaptation map, highlighting areas where adaptation is more urgent. This map addresses policy makers and highlights areas where proposed investment policies may face future damage or opportunities due to climate change. The impact and adaptation maps are used in several interactive and multidisciplinary workshops between scientist, policy makers and spatial planners. Together the participants design adaptation options based on the local impacts of climate change. The adaption options are evaluated on their effectivity and social costs and benefits. These workshops proved to be very helpful in investigating robust adaptation strategies, leading to an increased political support for action.

The CAA offers easy access to regionalized state-of-the-art knowledge on the impacts of climate change. Its methodology has proven to be effective in supporting local and regional governments to develop adaptation strategies. The methodology can easily be applied elsewhere in the world. The consortium has the knowledge and expertise as well as the experience with facilitating adaptation planning processes.

Interactive simulation and 3D visualization for water protection policy development

This project is conducted, together with project 4.2, as a part of the project "3Di Water Management", in cooperation with the Water boards of Delfland and Hollands Noorderkwartier, Deltares, Delft University Civil Engineering, Waterkader Haaglanden, and Nelen and Schuurmans consultants. The aim of this project is to make fast and effective simulation and visualization tools for integrated water management policy development and planning. Within this project, the results of the investigation can be evaluated on the basis of practical problems, and usability of the tools can be examined.

As a first result of this project, a prototype software system has been developed for interactive 3D visualization of very large 3D geographic data sets. Raw laser scan data and photographs from the new "Actual Height Database of the Netherlands" (AHN2) are used, in which both the landscape and structures such as vegetation and buildings are included in great detail. Without the need for manual 3D modelling, the visualization shows a realistic and complete picture of the landscape in 3D. The specific data and software structure can guarantee a smooth image on the screen, which allows interactive navigation through the 3D landscape. An initial integration with numerical flooding models such as Sobek produces 3D images of static water levels, e.g. due to extreme rainfall.

The software system is suitable for large-screen stereo projection for increased the visual impact and spatial insight. Also, a mobile stereo projection setup was built for demonstrations and case studies. The first results of static flooding scenarios have been frequently demonstrated, including the 'Deltas in Times of Climate Change' conference held in Rotterdam. Also, a first evaluation of the system and visualization was performed in an emergency exercise with the Water board of Delfland, the City of Delft, and local emergency services, in November 2010.

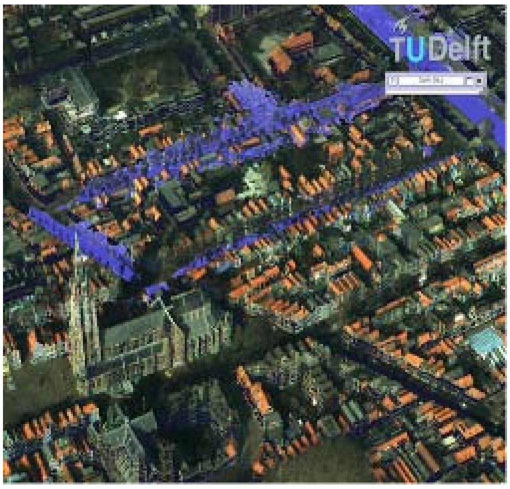

Figure 4.8: Visualization of a flooding scenario in the central part of Delft. Lanscapdata: AHN2; flooding data: SOBEK simulation (Gerwin de Haan, November 2010)

Optimal timing, cost benefit analysis and evaluation tools for adaption options

- Under CcSP we have made in inventory of adaptation options and made a ranking of the most important options based on a variety of criteria, including importance, urgency, no regret, and ancillary benefits. We showed that for the Netherlands water policies and integrated nature management would be very important. Also climate proof infrastructure and spatial planning turned out to be high on the list of priorities. Retreat was considered to be unimportant and not urgent.
- We have studied how optimal adaptation in the Zuidplaspolder could be implemented. We studied by means of cost benefit analysis a number of alternative options for spatial planning and climate proofing of new housing infrastructure. The study showed that the potentially negative impacts of climate change could be reduced by creating more water storage capacity, and by climate proofing new houses.
- We have also studied in an advanced economic model the economic aspects of selecting structural or non-structural measures for coastal defence. Structural measures are characterised by high initial costs and low

annual costs, whereas non-structural measures are characterised by low initial costs but higher annual costs. The analysis shows that the selection depends on the discount rate used and the hazard rate, which indicates how quickly uncertainty on sea level rise is resolved.

- Currently we are investigating how optimal adaptation to sea level rise can be implemented on the basis of assessing the uncertainties of future sea level rise, based on KNMI scenarios, and the costs related to implementing new infrastructure by means of structural measures or by non-structural options, such as beach nourishment along the coast. Depending on the best "guess" of the probability distribution of sea level rise the optimal level of new coastal defence infrastructure can be determined, where a trade-off is made between the costs of overinvesting and the costs of underinvesting. Results will be published in international journals and are directly communicated to the Delta commissioner in the Netherlands.

4.8.4 Suggestions for further reading: key publications and websites

Peer reviewed key publications:

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Jonkman, S.N., Bočkarjova, M., Kok, M., Bernardini, P. Integrated hydrodynamic and economic modelling of flood damage in the Netherlands (2008) Ecological Economics, 66 (1), pp. 77-90.

Koomen, E., Koekoek, A. and Dijk, E. (2011) Simulating land-use change in a regional planning context. Applied Spatial Analysis and Planning, doi: 10.1007/s12061-010-9053-5.

Koomen, E., Rietveld, P. and De Nijs, T. (2008) Modelling land-use change for spatial planning support, Annals of Regional Science 42 (1): 1-10.

Koomen, E., Stillwell, J.C.H., Bakema, A. and Scholten, H.J. (2007) Modelling land-use change; progress and applications, GeoJournal Library Vol. 90, Springer, Dordrecht.

Veraart, J.A., van Ierland, E.C., Werners, S.E., Verhagen, A., de Groot, R.S., Kuikman, P.J., Kabat, P. Climate change impacts on water management and adaptation strategies in The Netherlands: Stakeholder and scientific expert judgements (2010) Journal of Environmental Policy and Planning, 12 (2), pp. 179-200.

Other publications

Bočkarjova, M., P. Rietveld, E.T. Verhoef (2010) "*Valuation of immaterial damages in flooding in the Netherlands: fatalities, injuries and evacuations*" ESRA newsletter, september 2010.

Bočkarjova, M., P. Rietveld, E.T. Verhoef (2010) "*Monetary valuation of immaterial damages in the context of flood risk: value of statistical life, value of injury, value of evacuation*" NVRB newsletter, juni 2010.

Websites

Klimaateffectatlas: http://klimaateffectatlas.wur.nl/

4.9 Monitoring and mitigation of land based greenhouse gas emissions

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Table 4.12: Facts and figures about research theme 'Mitigation'.

Involved research institutes	
Wageningen UR (Wageningen University, Alterra, AT&V) ECN VU University Amsterdam VU IVM TNO	Utrecht University KEMA University Groningen National Institute for Space Research (SRON) TU Delft RIVM
Selection of key researchers	
R.W.A. Hutjes (Alterra), E.C. Moors (Alterra), H. Dolman (VUA), R. de Waal, J.Sanders (AT&V), B.Annevelink (AT&V), J. Vermaat (IVM), R.Janssen (IVM), C. Jacobs (Alterra), I.Aben (SRON), A. Apituley (RIVM), F. Bosveld (KNMI), G. Nabuurs (European Forsest Institute), R.E.M. Neubert (RUG), R.M.A. Timmermans (TNO), P.J.A. Builtjes (TNO)	
Projects (only the project numbers, see appendix for full titles)	
Finished ME01, ME02, ME03, ME04, ME05, ME06	**On-going**

4.9.1 The societal relevance of the research theme

To mitigate climate change, demanding greenhouse gas emission reduction targets are being negotiated. Meeting these targets requires effective implementation of a broad and integrated range of reduction options, including those related to land use. To merit the reduction achievements by motivated stakeholders in all sectors and to prevent leakage to less committed players requires a form of full carbon accounting.

This applies equally to the emissions and reduction options associated with the use of fossil fuels in power generation, industry and transport, and to emissions associated with biomass production and consumption in managed and natural ecosystems. However, the first category basically comprises the uni-directional input of greenhouse gases (GHGs) to the atmosphere through heterogeneous, but largely man-controlled conversion processes of fossil carbon, extracted at a limited number of sites, i.e. coal mines, oil/gas wells. Contrastingly, biogenic emissions are the small, net result of large, spatially diffuse fluxes into and out of the atmosphere, only rudimentary controlled by humans and characterized by a strong temporal asymmetry ('slow in, fast out').

Thus big challenges arise on two aspects of land based emissions. On one hand the development of truly effective land based options that maximise the mitigation potentials demands consideration of the full production chain: GHG in- and outputs associated with the primary production, on-site effects on above and below ground stocks, any emissions related to transport and processing, and the use and lifetime of the final product, be it energy or some bio based product. Since net fluxes of natural or agricultural ecosystems are small, land based mitigation policies affect large areas and need to be maintained for long time spans (multiple decades). Therefore, they need to be closely integrated in spatial planning processes and taking into account a variety of sustainability criteria (with ecological, economic and social dimensions).

On the other hand an appropriate accounting system for land based emissions needs to be developed, that prevents or at least shows leakage in space and time. However, quantifying the effects of mitigation efforts against the large natural background variability is a demanding task, in which scientific complexity and manageable, transparent accounting systems have difficulty to meet. More over, the diffuse and variable nature of land based emissions and their mitigation also increases the need for independent verification of reduction claims.

In addition, biogenic emissions are important from an earth system perspective. It is increasingly being recognised that important feedbacks may occur between climate and land based emissions. Climate change may turn current carbon sinks in to sources (e.g. tropical forests) and may destabilise large carbon stores (e.g. boreal peat lands). From that perspective knowledge of processes involved in biogenic emissions is highly needed to further constrain uncertainties in our knowledge of these feedbacks and to be timely warned of their imminence.

The knowledge that is being generated in response to these societal challenges, is relevant at both international and (sub)national scales. It is partly generic in nature, but of course the relative importances of certain land use types and their associated GHG emissions vary by country. On a global scale the small area of the Netherlands makes its biogenic emissions irrelevant at first sight (though the agricultural footprint is at least six times larger). Thus, the approaches, methodologies and tools developed in the current programme are of international interest, but the context in which we developed them and the data that went into implementations are highly specific for the Netherlands. Nevertheless, utilizing Dutch biomass has a clear mitigation potential that may be of considerable national relevance. However, at the regional level understanding about biomass potentials and biomass utilisation systems often still needs to be developed. Regional stakeholders need support develop optimal regional biomass delivery chains and other land based mitigation options. National stakeholders will need policy advice to assess different (bio-energy) options, performance and (spatial) impacts under different (national and supranational) scenarios.

4.9.2 The scientific approach and the and research questions

To tackle some of these challenges, in 2005 we started an ambitious, integrated, combined modelling and monitoring programme (four projects ME1, 2, 3 and 5). This programme aims, then and now, to build a knowledge and data base serving as a fundament for the development of *and* viable mitigation options *and* fool-proof reporting systems *and* ways to independently verify emission reduction claims, focusing on biogenic emissions. Somewhat later, two additional projects started addressing the incorporation of mitigation options in spatial planning processes, one (ME4) assisting this community with expertise and tools to optimise regional biomass delivery chains and the second (ME6) to reduce emissions from the large, often drained fen meadow (peat) areas found in the Netherlands.

Central to the monitoring and modelling programme is the concept of developing multiple quantitative constraints on GHG budgets at a given scale. To do so we developed a measurement programme that addresses the quantification of magnitude and variability of *fluxes* of carbon dioxide, methane and nitrous oxide in various ecosystems. Addressing the three gases simultaneously provides direct insight in drivers and mutual interactions. Also we worked on quantification of carbon stocks, mostly on the more permanent below ground soil carbon, as these integrate long term processes and are closest to current accounting concepts based on changes in stocks. Both C-stocks and GHG fluxes are being studied along gradients of land management or in manipulative experiments in order to study potential mitigation options. At the regional scale tall towers provide high precision GHG measurements that can be used to constrain regional to national scale fluxes using inverse methods, complemented by aircraft observed fluxes along transects covering representative Dutch Landscapes. Measurements at all these scales were complemented by modelling efforts, both at process level and at aggregated activity level. The latter resulted in direct information flows in support of the further development of our national reporting system and in DSS tools facilitating the evaluation of mitigation options in Dutch agriculture. The research was and is strongly embedded in international, especially European programmes like CarboEurope, NitroEurope, GHGEurope. On an infrastructural level long term continuity of monitoring activities is essential; we played a strong conceptual role in the design of ICOS-EU but unfortunately have not been able to secure national funding yet. This part of the programme can be characterised as policy relevant rather than policy supporting and stakeholder involvement as been limited to a number of sessions aimed at two way information exchange.

The ME4 biomass project aimed to develop an integrated framework to assess and analyse the spatial implications and related opportunities and consequences of an increased implementation of biomass delivery chains for energy, bio fuels and biochemical's at different geographical levels. It included both the actual design of sustainable regional biomass delivery chains, and the assessment of their spatial implications including their effects on land use, social and economic development and environment. The emphasis was put on a number of Dutch regional case studies, but European cases have been studied in cooperation with the REFUEL project.

The ME6 fen meadow project aimed to design, evaluate and compare various (long term) development scenarios for the Dutch fen meadow area, with a focus on policy targets related to water retention and carbon sequestration in agriculture and nature development. It focused on the use of maps projected on touch tables in multi stakeholder workshops to support spatial analysis and design and facilitated negotiations with visual feedbacks.

Both spatial planning projects aimed to play a role much more in support of regional policy development and implementation and as such very actively engaged with stakeholders in more participatory design and planning processes. Each used a systematic methodology to articulate and analyze the different perspectives that underlie the views of a broad variety of public and private Dutch stakeholders. We learnt from this process that a focus on specific options and topics rather than on general values or framing issues encourages an exchange of views and information.

4.9.3 Research Highlights

- Having completed a number of years of sometimes technically advanced measurements using flux towers and chamber measurements, jointly operated between several groups, allowed compilation of annual GHG budgets for many land cover types and revealed a number of dependencies of the emissions of each CO_2, CH_4 and N_2O on local water and land management conditions (Hendriks & et al., 2007; C. M. J. Jacobs & et al., 2007; van Beek & et al.) as well as strong relations between vegetation composition and (CH_4) fluxes. Several process based models have been parameterised, from stand-specific to spatially explicit national scale, using these observations.

- Previously unknown carbon stocks of Dutch soils have been quantified and could be related to the spatial distribution of natural factors in the landscape, but also to past and present land use. Tree species, age of the stand as well as management proved to be a an important source of variability on both the SOM as the FFC in forests (C.J.E. Schulp & et al., 2008). Historical land use proved to explain a larger part of the SOM variability then the present land use (C.J.E. Schulp & Veldkamp, 2008). The effect of management trends in dairy farming on SOM in grassland soils and total GHG emissions at farm level have been quantified. Results have been incorporated in the Dutch NIR methodology.
- Considerable progress has been made in relation to the development of the required monitoring network, the atmospheric transport models and inversion algorithms for the assessment of large scale GHG emissions. At sub continental scales the model based Carbontracker framework provides unprecedented spatial and temporal resolution of CO2 fluxes more consistent than ever before with bottom up approaches (Peters & et al., 2010). Relatively simple event-based data inversions provided realistic emission estimates at national scales(van der Laan & et al., 2009). Further progress towards sub national scales seems feasible in the near future, though accuracy levels useful for verification may be more difficult to achieve.
- At present the development and implementation of bio energy chains is hindered by insufficient knowledge among stakeholders of (the potential of) new technological concepts, and of perceived associated (noise, emission, odour and other) nuisances. Also, markets of both feed stocks (wood, by-products, waste) and products (heat, CO_2) are underdeveloped and sometimes problems are experienced in relation to suitable location or necessary permits. Large variations exists in biomass production potential and costs between European regions; high potential and low costs regions are large parts of Poland, the Baltic States, Romania, Bulgaria and Ukraine; moderately attractive are parts of France, Spain and Italy (Fischer & et al., 2009). In consultation with stakeholders an integrated DSS framework for biomass delivery chain assessment has been developed(Cuppen, et al., 2010; Van der Hilst & et al., 2010).

4.9.4 Suggestions for further reading: key publications and websites

Peer reviewed

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Fischer, G, et al., 2009. Biofuel production potentials in Europe: Sustainable use of cultivated land and pastures. Part I: Land productivity potentials. Biomass and Bioenergy 34 (2): 159-172

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Appendix A: Overview of research projects

Climate adaptation, flood risk and coastal zone management

Code	Project Title	View
HSGR02	Assesment of upstream flood risk in the Rhine Basin	
HSGR06	Adaptation to Meuse flood risk	
HSHL01A	Klimaat in ruimtelijke keuzes	
HSRR01	Urban developement - Urban water systems / Impact van klimaatsverande-ringen op stedelijke watersystemen (oppervlakte, grond-, en riool) en beno-digde adaptatiestrategieën	
HSRR02	Definitiestudie 'Waterveiligheid buitendijks gebied'	
HSRR03b	Afsluitbaar open Rijnmond - Waterfront Rijnmond	
HSRR06	Veilige en goed ingepaste hoofdwaterkeringen	
HSRR09	Adaptief bouwen in het buitendijks gebied in de hotspot regio Rotterdam	
HSZD01	Negotiating uncertainties: defining climate proofing and assessing asso-ciated uncertainties in the Southwest Delta Region of the Netherlands	
Thema 1	Water safety at national and regional level	
A07	Adaptations to extreme events in transboundary river basins / Aanpassing aan weersextremen ingrensoverschrijdende stroomgebieden	
A09	Financial arrangements for disaster losses under climate change / Financiële arrangementen voor rampschade bij klimaatverandering	
A11	Routeplanner 2010-2050	
A13	The Coastal Zone Definition phase / Definitiefase Aandacht voor Veiligheid	
A14	Hotspot Zuidplaspolder	
A20	Attention for Safety II / Aandacht Voor Veiligheid II	
COM11	Deltas in times of climate change / Delta's in tijden van klimaatverandering	

Climate adaptation and fresh water resources management

Code	Project Title	View
HSHL08	Demonstratieproject meervoudig ruimtegebruik voor waterberging in glastuinbouw	
HSOV01A	Climate effects on decomposition in drained peat meadows: implications for peat subsidence and water quality	
HSOV01B	Climate influence on water quality: which trends are already apparent?	
HSZD01	Negotiating uncertainties: defining climate proofing and assessing associated uncertainties in the Southwest Delta Region of the Netherlands	
HSZD02	Climate change effects on restoration of estuarine dynamics within the Delta region	
MSZD01	Verkenning zoetwatervoorziening Zuidwestelijke Delta	
Thema 2	Fresh water supply and water quality at national and regional scale	
A01	Biodiversity in a changing environment: predicting spatio-temporal dynamics of vegetation / Biodiversiteit in een veranderende wereld voorspellingen van vegetatiedynamiek	
A21	Hotspot Climate change and agriculture in Northern Netherlands / Hotspot Klimaat en Landbouw in Noord Nederland	
COM25	Definition study Biesbosch in times of Climate Change / Definitiestudie De Biesbosch in tijden van klimaatverandering	

Climate adaptation in rural areas

Code	Project Title	View
HSDR01	An inventory of strategies to cope with climate change in dry rural sandy areas with a temperate climate: a case study in the Province of Gelderland	
HSDR02	Combining spatial claims of land use functions and adaptive strategies to climate change in densely populated rural areas	
HSOV01A	Climate effects on decomposition in drained peat meadows: implications for peat subsidence and water quality	
HSOV01B	Climate influence on water quality: which trends are already apparent?	
HSOV01C	Managing climate effects in peat meadows and shallow lakes	
Thema 3	Exploring the Potential for Climate Change Adaptation Stategies in Rural Areas	
A01	Biodiversity in a changing environment: predicting spatio-temporal dynamics of vegetation / Biodiversiteit in een veranderende wereld voor-	

	spellingen van vegetatiedynamiek	
A02	Strategies for optimizing the nature conservation potential of the Dutch Ecological Network and the surrounding multifunctional farm landscape under predicted climate change scenarios / Adaptatie van de Ecologische Hoofd Structuur EHS	
A12	How can agriculture adept to changes of both climate and market; NL-North as a pilot region / Definitiestudie landbouw	
A18	Hotspot Groningen	
A19	Assessing the adaptive capacity of Agriculture in the Netherlands to the impacts of climate change under different market and policy scenarios	
A21	Hotspot Climate change and agriculture in Northern Netherlands / Hotspot Klimaat en Landbouw in Noord Nederland	
ME06	Spatial decision support for management of Dutch fen meadows / Hulpmiddelen voor het maken van ruimtelijke keuzes voor de toekomst van de Veenweidegebieden	

Climate adaptation in urban areas

Code	Project Title	View
HSRR01	Urban developement - Urban water systems / Impact van klimaatsveranderingen op stedelijke watersystemen (oppervlakte, grond-, en riool) en benodigde adaptatiestrategieën	
HSRR02	Definitiestudie 'Waterveiligheid buitendijks gebied'	
HSRR05	Heat stress in the city of Rotterdam	
HSRR09	Adaptief bouwen in het buitendijks gebied in de hotspot regio Rotterdam	
Thema 4	Climate proofing urban areas	
A16	Hotspot Tilburg	
A22	hotspot Rijnenburg	
COM22	Heat in the city, definition study / Definitiestudie Hitte in de stad	
COM23	Water resilient building / Definitiestudie Waterrobuust bouwen	
COM29	Climate in the urban environment	
COM34	CROW - Adaptation public space to climate change / CROW - Adaptatie openbare ruimte aan klimaatverandering	

Climate adaptation and Infrastructure and networks

Code	Project Title	
HSMS01	WindVisions: an airport Wind and Visibility Monitoring System for critical weather conditions in a changing climate	
HSMS03	"The impact of climate change on the critical weather conditions at Schiphol airport" (Impact)	
HSRS01	Verkenning adaptatievraagstukken Schiphol Regio en opbouw hotspot	
Thema 5	Infrastructure and networks	

Climate projections, scenarios and observations

Code	Project Title	View
HSHL05/HSRR04	Regiospecifieke klimaatinformatie voor Haagland en regio Rotterdam	
HSHL06/HSHL12	Brede, gebiedsspecifieke verkenning van effecten van klimaatverandering in samenhang met toekomstscenario's en trendmatige ontwikkeling	
HSMS02	Climatology and climate scenarios Mainport Schiphol	
Thema 6	Improving climate projections and modelling instruments used for modelling	
KKF01a	Modelplatform - Future Weather Phase 1	
KKF01b	Modelplatform - Coupling	
KKF01c	Modelplatform - Tailoring	
COM01	A virtual data portal for CcSP projects / Databeheer Bsik-KvR projecten	
COM21	Climate change sketchbooks / Klimaatschetsboeken en eerste generatie geodatabase	
CS01	North Atlantic Ocean Monitoring and Modelling / Monitoring en modellering van de Noord-Atlantische oceaan	
CS02	The CESAR Observatory climate monitoring en processtudies / Het CESAR Observatorium klimaatmonitoring en processtudies	
CS03	Representation of soil moisture and root water uptake in climate models / Weergave van verdamping van bodemvocht door vegetatie in klimaatmodellen	
CS04	The regional climate impact of aerosols / De invloed van aerosolen op het regionale klimaat	
CS05	Remote influences on European climate / Invloeden vanuit ver weg gelegen gebieden op het Europese klimaat	

CS06	Refinement and application of a regional atmospheric model for climate scenario calculations of Western Europe / Verfijning en toepassing van een regionaal atmosferisch klimaatmodel voor klimaat-scenarioberekeningen van West-Europa	
CS07	Tailoring climate information for impact assessment / Op maat maken van klimaatscenario's - tailoring	
CS08	Time series information / Informatie in tijdseries	
CS09	Modeling and reconstructing precipitation and flood frequency in the Meuse catchment during the late Holocene / Klimaatreconstructies op basis van paleoklimatologische gegevens uit het stroomgebied van de Maas	

Governance and economics of adaptation

Code	Project Title	
Thema 7	Governance of climate adaptation	
COM30	Integrating climate change knowledge in regional planning processes / PlanMERs, structuurvisies en kennis uit het KvR programma	
IC08	PROFILES - PRObing an method to Facilitate the Interactive Linking of Expert knowledge to Stakeholder assessment / Onderzoek naar methodes om op interactieve wijze kennis van experts en stakeholders bij elkaar te brengen - PROFILES	
IC10	Communicating climate change: tools for framing climate risks and benefits / Communiceren over klimaatverandering methoden om risico's en kansen inzichtelijk te maken	
IC12	The Dutch institutional framework and governance of adaptation strategies / Instituties voor adaptatie Is de Nederlandse institutionele structuur in staat zich aan te passen aan klimaatverandering	

Decision support tools for adaptation

Code	Project Title	View
HSHL01A	Klimaat in ruimtelijke keuzes	
HSHL05/HSRR04	Regiospecifieke klimaatinformatie voor Haagland en regio Rotterdam	
HSHL06/HSHL12	Brede, gebiedsspecifieke verkenning van effecten van klimaatverandering in samenhang met toekomstscenario's en trendmatige ontwikkeling	
Thema 8	Tools for adaptation strategies	
A11	Routeplanner 2010-2050	

A14	Hotspot Zuidplaspolder	
COM21	Climate change sketchbooks / Klimaatschetsboeken en eerste generatie geodatabase	
COM26	Scoping study comparative assessment / Definitiestudie afwegingskader Ruimte en Klimaat	
COM30	Integrating climate change knowledge in regional planning processes / PlanMERs, structuurvisies en kennis uit het KvR programma	
IC02	A tool for integrated analysis of emission reductions over regions, sectors, sources and greenhouse gases / Integrale analyse van vermindering van uitstoot voor regio's, sectoren, bronnen en broeikasgassen	
IC03	Designing national land use adaptation and mitigation strategies under changing climate conditions (VU) / Landgebruiksontwikkelingen in een veranderend klimaat - LANDS	
IC05	Cost-Benefit analysis of adaptation and mitigation options for climate change: methods and applications / Kosten-baten analyse van adaptatie en mitigatie mogelijkheden voor klimaat-veranderingen - methoden en toepassingen	
IC11	Socio-economic scenarios for climate change assessments / Socio-economische scenarios voor klimaatstudies	

Mitigation and land use

Code	Project Title	View
ME01	Integrated observations and modelling of greenhouse gas budgets at the ecosystem level in The Netherlands / De broeikasgasbalans van Nederlandse natuurlijke- en landbouwecosystemen	
ME02	Integrated observations and modelling of greenhouse gas budgets at the national level in the Netherlands / Geïntegreerde observatie en modellering van broeikasgas budgetten op nationaal niveau	
ME03	Soil carbon dynamics and variability at the landscape scale: its relation to aspects of spatial distribution in national emission databases / Invloed van landgebruik, landgebruik-geschiedenis en management op de koolstofvoorraad in de bodem in Nederland	
ME04	Integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains / Geïntegreerd raamwerk voor de beoordeling van ruimtelijke en gerelateerde gevolgen van een verhoogde implementatie van biomassaketens	
ME05	The effect of the spatial arrangement of wetlands on water quality improvement and carbon sequestration in a multifunctional land-use setting / Het effect van de ruimtelijke rangschikking van moerassen op waterkwaliteit en koolstofvastlegging in veenweide	
ME06	Spatial decision support for management of Dutch fen meadows / Hulpmiddelen voor het maken van ruimtelijke keuzes voor de toekomst van de Veenweidegebieden	

Appendix B: Organisation structure of the programmes

Organisation Climate changes Spatial Planning (September 2010)

Programme Council
Strategic cooperation, confinancing

Knowledge institutes
Prof.dr. P. Kabat (chair) WUR
Prof.dr. F.G.H. Berkhout VU, FALW
Prof.dr. P.P.J. Driessen, UU
Prof.dr. E.C. van Ierland, WUR

Research institutes
Msc. J.R. Ybema, ECN
Msc. D.F. Sijmons, H+N+S Landschapsarchitecten
Dr. B.F. van Tooren, Ver. Natuurmonumenten
Dr. M. Kuijpers-Linde, Geodan Next
Msc.. A.G.A. Schellekens, Arcadis

Civil service
Msc. R. Roggema Provincie Groningen
Msc. B. Verboom Provincie Gelderland
Msc. R.H. van Waveren RWS Waterdienst

Theme coordinators

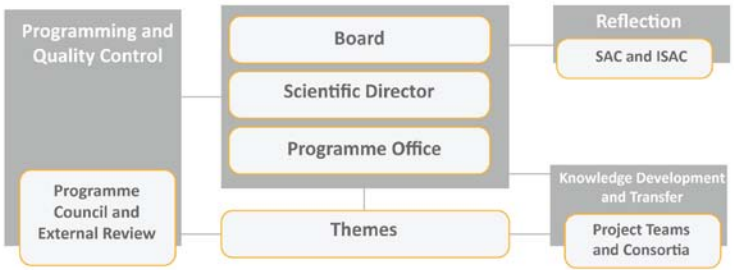
External review
Judging the quality of research proposals by a inerna-tional scientific panel

Board
Verification, approval, advice

Prof.dr. W. van Vierssen (chair)
Prof.dr. P. Vellinga
Dr. A.C.J. Bullens
Msc. J.G.A. Coppes
Msc. M.A. van der Gaag
Mcs. J.A. Oude Lohuis (observer)
Msc.. S. Schöne
Dr. F.J.J. Brouwer (observer)

Scientific Director
Daily management of the programme

Prof.dr. P. Kabat



Theme coordinators
Relation themes
Adaptatation — Prof.dr. J.C.J.H Aerts, Vrije Universiteit Amsterdam, FALW
Climate scenarios — Prof.dr. B.J.J.M. van den Hurk, KNMI
Mitigation — Dr. R.W.A. Hutjes, Wageningen UR
Integration — Msc. T. Kram, Planbureau voor de Leefomgeving
Communication — Msc. F. de Pater, Programmabureau Klimaat voor Ruimte

International Scientific Advisory Council
Prof. Leen Hordijk (chair), Italy
Prof. Neil Adger, United Kingdom
Prof. Guy Brasseur, USA
Prof. Fu Congbin, PRC
Prof. Jim Hall, United Kingdom
Dr. David Major, USA
Prof. Wolfram Mauser, Germany
Prof. Carlos Nobre, Brasil
Prof. Judith Rees, United Kingdom
Prof. Karen O'Brien, Norway
Prof. Tsezuo Yasuanari, Japan

Societal Advisory Council
Mrs. Msc K.M.H. Peijs, Provincie Zeeland
Dr. H. van Liempt, BMBF, Germany
Mw.ir. M. Demmers, DHV
Msc. J.J. de Graeff, Natuurmonumenten
Mrs. Msc. J.M.P. Moons, Waterschap Vallei en Eem
Msc. R.W.W. Nijs, Rabobank Nederland
Msc. W.M. de Jong, Provincie Utrecht

Projectteams and consortia
Project execution, reporting (content and financial)

Organisation Knowledge for Climate (September 2010)

Executive Advisory Board
Stratigic cooperation, cofinancing

Msc. C.B.F. Kuijpers, VROM, DG Ruimte (chair)
Msc. R.J. Schoonman, VROM (secretary)
Msc. J.H. de Groene, EZ
Mrs. Msc.. A.N. Wouters, LNV
Mrs. Msc.. A.G. Nijhof, VenW

Msc. A.J. Baayen, Deltares
Prof.dr. F. Berkhout, TNO
Dr. H.W. Haak, KNMI
Msc. C.T. Slingerland, ESG, WUR
Prof.dr.ir. W. van Vierssen, KWR
Prof.dr. G.J. van der Zwaan, UU

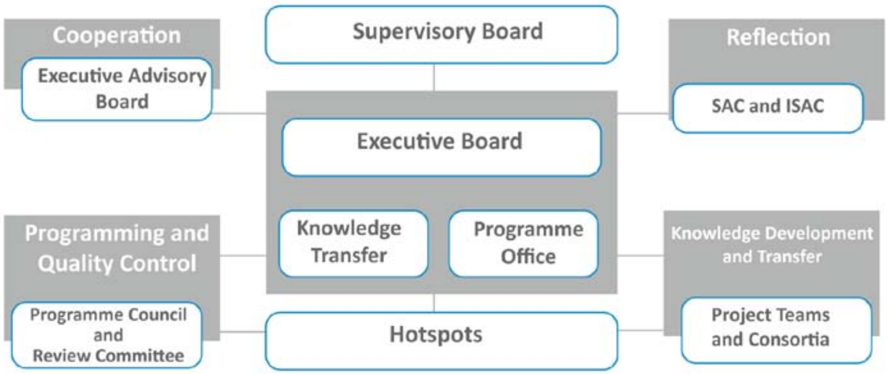
Supervisory Board
Supervise, approval, advice
Prof.dr. C.P. Veerman (*chairman*)
Prof. G.J. Cerfontaine
Mrs. S.M. Dekker
Mrs. M.M. Kool
Dr. G.W. Noomen
Prof.dr. L.C. Zachariasse

Board
Board foundation KvK

Prof.dr. P. Vellinga (chair, scientifc director)
Msc. C.L. van Deelen (business director)
Prof.dr. P.P.J. Driessen (social science director)

International Scientific Advisory Council
Prof. Leen Hordijk (chair), Italy
Prof. Neil Adger, United Kingdom
Prof. Guy Brasseur, USA
Prof. Fu Congbin, PRC
Prof. Jim Hall, United Kingdom
Dr. David Major, USA
Prof. Wolfram Mauser, Germany
Prof. Carlos Nobre, Brasil
Prof. Judith Rees, United Kingdom
Prof. Karen O'Brien, Norway
Prof. Tsezuo Yasuanari, Japan

Societal Advisory Council
Mrs. Msc K.M.H. Peijs, Provincie Zeeland
Dr. H. van Liempt, BMBF, Germany
Mw.ir. M. Demmers, DHV
Msc. J.J. de Graeff, Natuurmonumenten
Mrs. Msc. J.M.P. Moons, Waterschap Vallei en Eem
Msc. R.W.W. Nijs, Rabobank Nederland
Msc. W.M. de Jong, Provincie Utrecht



Programme Council
Advise on research programming and research proposals, cohesion programme

Knowledge institutes:
Prof.dr. M.J. Dijst, UU
Dr. R.F. van Oss, KNMI
Msc. A.S. Hassoldt, TNO
Dr. J.C.J. Kwadijk, Deltares
Prof.dr. F.G.H. Berkhout, VU Amsterdam
Prof.dr. A.A.M. Holtslag, WUR
Ministry
Msc. R.J. Schoonman, VROM

Hotspots and coordinators
Generation of research questions, tuning of research results and development of options for regional adaptation strategies

Projectteams and consortia
Project execution, reporting (content and financial)

Programme office
General and daily coordination and facilitation of reserach programme, including secretary, controlling and communication
Project coordinators
Controllers
Communication
Secretariat

Knowledge transfer

Hotspot coördinators, Board			Communication, publications, masterclasses, dissemination and implementation of research results
Review committee Assessment of research proposals on scientific and societal criteria by national and international high-profile reviewers.	Waddensea Schiphol Mainport Major rivers Haaglanden Region South-west Netherlands Delta Dry rural areas Rotterdam Region Shallow waters and peat meadow areas International	Dr. M. Engelmoer, Provincie Fryslân Msc. P. van den Brink, Schiphol Msc. R.H.van Waveren, Rijkswaterstaat Msc. C.S.J. Paauwe, Waterkader Haaglanden Msc. N. Landsman, Provincie Zeeland Msc. F.B.A.van Lamoen, Provincie N-Brabant A. Molenaar, Gemeentewerken Rotterdam Prof.dr. J.T.A. Verhoeven, Universiteit Utrecht Msc..P. Oortwijn, ONRI	

To develop the scientific and applied knowledge required for Climate-proofing the Netherlands and to create a sustainable Knowledge infrastructure for managing climate change

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