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Knowledge for Climate is a research programme in which knowledge, tools and services for *climate-proofing* the Netherlands are designed. A series of nine books show, at a glance, what research has revealed and how this knowledge can be applied in practice.

Part nine of the series is **Climate adaptation in the Netherlands**. This book describes the highlights of the programme, looks back on lessons learned, and forward into the future of the Netherlands in times of climate change. Policy makers and practitioners explain what Knowledge for Climate has meant for the Netherlands.

Innovation in Climate Adaptation

Knowledge for Climate

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Innovation in Climate Adaptation

Scientists, policy makers and entrepreneurs worked together in the Knowledge for Climate programme to research ways in which the Netherlands can be climate proofed. A book is published for each of the eight research themes within the programme. This book discusses the overall design of the programme, highlights some remarkable results and discusses lessons learned.

01 Innovative and taboo-breaking

The book you have in your hands presents the results of the Dutch 'Knowledge for Climate' research programme on climate change and adaption. The programme will conclude at the end of 2014. Nine books have been published, covering a cross-section of all the results attained by hundreds of researchers and practitioners in the field. Eight of these focus on the main themes of the programme, for example urban environments, flood safety, infrastructure, fresh water, and governance; the ninth, the present book, gives an overview of the entire programme.

The topic of climate change has become unpopular in some circles in recent years. A few errors in the IPCC's fourth report were grist to the mill of climate sceptics. Indeed, there were many local and regional governments considering the subject of 'climate change' taboo during the initial years of the Knowledge for Climate Programme. All this made cooperation problematic at times. But it was precisely in the wake of this debate that innovative research was carried out, leading to results that are proving to be useful now. For example, the programme managed to break a number of taboos in water management and flood safety. It also promoted the idea of regional and local self-sufficiency with respect to fresh water. In addition, it overturned the dogma of 'absolute' flood safety. 'Unbreachable' dikes ensure the highest level of safety for every euro spent. These are insights that the Dutch Delta Programme will be adopting in its implementation stage.

The Knowledge for Climate Programme brought together researchers, public officials and consultants in new ways. It trained more than sixty PhD candidates and post-doctoral researchers in new skills, for example how to develop and conduct research in partnership with public authorities and businesses. In addition, it became a launch pad to international research and the private sector. The programme participants collaborated with foreign researchers and much of the research keyed into European research projects. The international conferences organised (or co-organised) under the aegis of the Knowledge for Climate Programme have led to a tight-knit international research network.

"The dogma of absolute flood safety has been overturned."

Sybilla Dekker

At the heart of the research programme was collaboration with practitioners in the field and co-creation. Provincial and municipal authorities, water boards and businesses asked the questions and assisted in implementation, leading to custom-made solutions. Climate adaptation issues require this – after all, adaptation is tied to local circumstances and the local context. The Knowledge for Climate Programme has also demonstrated that three concepts are vital in a cost-effective adaptation strategy: innovation, new governance combinations, and linkage to the approach taken to existing problems.

I am delighted to present this final book of the Knowledge for Climate Programme: *Innovation in Climate Adaptation*.

On behalf of all those who have collaborated on this programme and on behalf of the Supervisory Board, I hope you enjoy reading it.

Sybilla Dekker,
Supervisory Board Chair

02 Leaving room for the unexpected

The Knowledge for Climate Programme started with a ‘blind date’ between three researchers. The programme has run for seven years and has a budget of more than eighty million euros. Now that it is drawing to a close, Executive Board members Pier Vellinga, Peter Driessen and Kees van Deelen feel modest pride as they look back – and ahead.

The three men – an engineer, a social scientist and a climate researcher – had never met before. The Dutch Ministry of Infrastructure & Environment asked them to set up a research programme aimed at making the Netherlands climate-proof. This was in 2007. In 2008, the threesome – Kees van Deelen, Peter Driessen and Pier Vellinga – accepted their appointments as business director, social science director and scientific director, respectively.

They have spent a lot of time scouring the field for research questions. The questions came from all over: from water boards, provincial authorities, the Foundation for Applied Water Research (STOWA), and the hotspots set up for the Climate Changes Spatial Planning Programme. “We wanted to embed stakeholder involvement and come up with questions of scientific merit,” says Peter Driessen. “A number of the hotspots supplied good research questions, for example Haaglanden region, Rotterdam region, South-West Netherlands Delta and, later on, Schiphol Mainport. Some of the questions – often those supplied by policymakers – were practical in nature and outsourced to consultants. It led to many good things, but the results were not always equally scientific.”

Photo Peter Driessen, Pier Vellinga and Kees van Deelen

Off the beaten track

The questions served as inspiration for setting up eight research themes that constitute the backbone of the programme, along with the hotspots. “We used the questions we received from practitioners to develop more scientifically abstract problems and outsourced these to the market,” explains Vellinga. “That gave rise to the consortia.” They included researchers at differing institutes who worked together to answer the practical research questions. This approach led to a demand-driven programme staffed by users and researchers. “The consortia delivered the knowledge that the hotspots used to develop climate adaptation strategies,” continues Van Deelen. “The work is based on co-creation, in the sense that hotspot stakeholders and consortium members, for example municipal and provincial authorities and STOWA, invested their own money in the research. That generated a huge sense of ownership, and co-owners always work just a little harder.”

> “It’s not technology that’s the bottleneck for adaptation, it’s having the courage to work together to test new solutions and strike out in new directions.”
>
> **Pier Vellinga**

When asked whether the Knowledge for Climate Programme had made a difference to climate research in the Netherlands, all three men reply with a resounding 'Absolutely!'. "There was very little social science content in the original proposal," says Driessen. "We were able to increase that to a little more than half. In the end, the programme included economic and spatial planning research, and we addressed legal and governance issues. Much of the research explores how to deal with the uncertainties of climate change." "We got parties working together that weren't used to doing so," adds Van Deelen. "By collaborating, scientists and policymakers came to understand each other better. We also encouraged a lot of people to continue working in the field of climate change. We trained 61 PhDs and 26 post-doctoral researchers. We also set up a Climate Adaptation Business Challenge to encourage entrepreneurship in the field of climate adaptation."

New ways of thinking

The programme's innovative approach led to new and taboo-breaking insights and solutions. "One of those insights is that dikes don't necessarily have to be taller to manage flood risks," says Vellinga. "If we use smarter designs to fit dikes into the landscape and make them broader and stronger, they will offer protection and serve other purposes at the same time. Another example is the many forms of underground water storage. The Delta Programme, the water boards and businesses have recognised this as a good solution for mitigating flooding and drought. They are investigating whether innovations like storage under greenhouses and in saline soil can be applied elsewhere. These are great knock-on effects, with knowledge being applied in actual practice. I think that another mark of our success is that we've been asked to perform the scientific review of all Delta Programme sub-programmes."

"We drew attention to some unexpected issues," says Peter Driessen. "When Hurricane Sandy ravaged the East Coast of the United States in 2012, there was a sudden demand for information about the climate-robustness of infrastructures and networks. Few people were interested in that topic before then. The Infrastructure and Networks consortium had already completed a few years of research on how networks are interconnected and how they can be made more robust. So we were able to answer a number of questions immediately."

Other themes that the programme put on the map were climate-proof cities and fresh water supply. "We covered the full spectrum of climate adaptation and went beyond looking merely at flood safety, as is customary in the Netherlands," says Driessen. "For example, the impact of climate change on Dutch cities will be huge. This is where most of our population lives and where most of our capital is invested." The programme reveals the effects of heat and flooding on cities. It came up with solutions for peak downpours, for example underground water storage. In residential areas of Rotterdam that are not protected by dikes, the programme explored new partnerships for coping with the impact of high water levels on new buildings. It also linked heat effects to demographic trends, for example the ageing of the population, making it possible to investigate whether neighbourhoods that retain a lot of heat during heat waves have a high elderly population. Guidelines have been made available offering suggestions for alleviating heat stress. But the research also led to various eye-openers, for example the discovery that a body of water will not always have a cooling effect on a city, but can also retain heat.

> "Because we were independent, we were able to tackle less obvious issues and be more innovative in our approach."
>
> **Kees van Deelen**

More about the *business challenge* on **page 28**

More about the *scientific review* on **page 23**

Courage and independence

Vellinga, who has been active in the field of climate change since the late 1980s, suggests that climate adaptation involves two things: "Innovation and governance. Innovative governance allows us to create new connections between water boards, the national government, the provincial authorities and the municipal authorities, but also between these public authorities and private businesses. It's not technology that's the bottleneck for adaptation, it's having the courage to work together to test new solutions and strike out in new directions. The leeway for adaptation will arise if land management bodies, water boards and municipal authorities enter into smart arrangements with one another."

The programme is drawing to a close, but the work of making the Netherlands climate-proof is far from finished. The follow-up to the Knowledge and Climate Programme is the Water & Climate Programme, initiated by the Ministry of Infrastructure and Environment, the Netherlands Organisation for Scientific Research (NWO), the Delta Programme and one of the government-designated top economic sectors, 'Water'. Alongside basic scientific research, the new programme will also be working on policymaking experiments and policy-driven research. "It's important for the Water & Climate Programme to operate at arm's length from politics, so that it can act independently," says Driessen. "The new programme is supposed to focus more on knowledge implementation – and that's something I support wholeheartedly."

Partners and financing
Wageningen University and Research Centre, Utrecht University, VU University Amsterdam, the Royal Netherlands Meteorological Institute (KNMI), TNO and Deltares joined forces to generate the necessary applied knowledge. Other knowledge centres, the business community and public authorities cooperated in the many research projects. The Dutch Government provided 50 million euros in funding from the Economic Structure Enhancing Fund (FES). Other parties, for example the Foundation for Applied Water Research (STOWA), contributed another 30 million euros to the budget.

More about the *Hotspots see the figure* on **page 11**

Kees van Deelen believes that the Knowledge for Climate Programme sets a good example because it was able to maintain both financial and content independence. An independent foundation stood at the helm and monitored this model closely. “That meant that we were able to tackle less obvious issues and be more innovative in our approach,” says Van Deelen. “The Water & Climate Programme had closer ties to policymaking. I hope that doesn’t make it too susceptible to pressure.”

Vellinga emphasises the importance of independence as well. “The people involved in the Delta Programme have said themselves that it was extremely necessary, but also extremely difficult, to conduct independent research. Our operations were demand-driven and that pushed us to seek out institutes, consultants, knowledge centres and users. If you ask a water management institute to look at a problem, it will come up with a water-management solution. Other institutes might give you results aimed solely at agriculture, nature management or the economy. But climate adaptation requires broader and more integrated answers that embrace all of the disciplines. Spatial planning is a multi-sector matter, and the structure and methods of the Knowledge for Climate Programme meant that we could make all sorts of connections.”

Gaps

One of the subjects that the three directors believe was neglected in the Knowledge for Climate Programme is the impact of climate change on public health. The sector and the Ministry of Health, Welfare and Sport were not interested in setting up and co-financing research on this subject. The directors also felt that the financial and economic consequences of adaptation were given short shrift. “We looked at governance issues and partnership arrangements, but neglected the financing of adaptation,” says Peter Driessen. “We could have also explored the possibility of linking climate adaption to other policies, for example urban development.”

Van Deelen believes that more can be done to make climate knowledge less technical in nature. “A lot of climate research, for example modelling, is technical. We changed that, but we need even more research focusing on social and economic innovation.” “We’ve concentrated mainly on the Netherlands,” adds Pier Vellinga. “That was the intention, but looking back, I think we could have been more international in our approach.”

“Climate change is about people, about social transformation.”

Peter Driessen

Hotspots and themes
Scientists, polciymakers, entrepreneurs and other parties did research into specific themes, aimed at climate proofing different regions in the Netherlands. In the figure the themes are given in the outer ring, in the inner ring the hotspots are shown; specific regions in the Netherlands vulnerable for the effects of climate change. In these hotspots science and practice are brought together. For each hotspot ‘Options for a regional Adaptation strategy’ are designed.

In Driessen’s view, climate change is not about carbon dioxide. “CO_2 is merely a measure. Climate change is about people, about social transformation. That’s what we should invest in. That means, for example, that we should redesign the transport sector so that emissions are lower on the one hand and so that the sector is less vulnerable to the consequences of climate change on the other. That’s how we should examine every sector. It’s important to come up with plans for adapting sectors and regions to climate change, but the trick is to actually integrate those plans into processes.”

Figure Hotspots and themes

03 Facts & Figures

Knowledge for Climate.

Over **75** active partners.

61 PhD's and **26** postdocs.

1200 Participants in the 2010'Deltas in Times of Climate change' conference.

Short films on www.youtube.com/ ClimateNL have been viewed over **17000** times.

Over **800** scientific publications.

The most popular publication is about heat stress (over **5700** downloads).

700 Website visitors each week.

Over **2800** followers on Twitter and over **800** LinkedIn group members.

04 Co-creation links theory and practice

Knowledge generation can only contribute to making the Netherlands climate-proof if the knowledge accrued is actually applied in practice. Co-creation is the ideal way to achieve this aim.

Hans van der Vlist, the former Secretary-General for the Ministry of Transport, Public Works and Water Management (now the Ministry of Infrastructure and Environment), was a staunch advocate of co-creation from the very start of the Knowledge for Climate research programme. He thought that climate adaptation methods should be developed from the ground up, with the smallest possible gap between researchers and users. According to Florrie de Pater at the programme office, the Knowledge for Climate Programme more than achieved that aim. “People out in the field were brought in at every stage,” she says, “in partnerships that ranged from traditional to radically innovative.” By traditional, she means the customary procedure of inviting parties in the field to help guide the research by participating in a steering committee or liaison group. Co-creation is the most radical form of partnership. Here, practitioners in the field come up with the research questions; they are also involved in guiding the research and cooperate in carrying it out. “The emphasis in the Knowledge for Climate Programme was on co-creation because it was the best way to ensure that the knowledge generated by the programme would be applied in practice. We call that knowledge uptake.”

Pilots in the hotspots

The underpinnings for such co-creation were established during the initial years of the Knowledge for Climate Programme, when scientists and a wide range of different stakeholders collaborated in eight ‘hotspots’, i.e. specific locations in the Netherlands that are particularly vulnerable to the consequences of climate change. “The hotspots functioned as real-life laboratories for generating knowledge and putting it into practice,” says De Pater. “The research questions addressed what was needed out in the field at that point, but they were less scientific in nature because they focused mainly on short-term solutions. That’s why in the follow-up, we emphasised in-depth research and worked with eight different themes, each with its own consortium.” In the third part of the Knowledge for Climate Programme, the accrued knowledge was used to develop options for regional adaptation strategies (ORAS) for all the hotspots.

Vital links

Co-creation can only succeed if the necessary linchpins are present, i.e. people who understand the mores of both sci-

Photo Florrie de Pater, Knowledge for Climate

“Discussion drives knowledge forward.”

Florrie de Pater, Knowledge for Climate

ence and actual practice. De Pater knows a number of these go-betweens. “They might be scientists who understand the rhythms of policymaking and speak the language of policymakers. But they might also be people working in the field who have mastered the language of science.” De Pater gives the example of urban planning expert Florian Boer, who spent two intensive days studying flood defence theory specifically for the project ‘Safe and multifunctional urban levees’ and used that knowledge to work with water boards. The result was a book that presented technically sound and generally accepted spatial planning designs.

Another vital link in co-creation consists of visualisation tools. These are tools that present scientific knowledge in a manner that is easy to digest for the people who work with it. Examples are the lifelike 3Di flood modelling platform, the interactive Touch Table that reveals the impact of an adaptation measure, and the Climate Effect Atlas. The third vital link consists of the meetings with stakeholders, says De Pater. “They might be workshops, meetings at conferences or a dedicated conference like Deltas in Times of Climate Change. Whatever the case, it pays to invest time and money in communicating with parties. It was a good lesson for us – create enough financial scope for that communication, because it’s indispensable. Discussion drives knowledge forward.”

Doubling the benefits

De Pater believes that co-creation doubles the benefits: the knowledge generated by scientists is applied immediately in practice; the scientists, in turn, can use the application to generate new scientific knowledge. One example is the study carried out in the ‘Shallow waters and peat meadow areas’ hotspot. One of the researchers surveyed participants about their experiences before and after working with the interactive Touch Table tool and published the results of the survey in an article. “The university system rewards cooperation with field practitioners only if it leads to publication in a recognised scientific journal,” explains De Pater. “It would be better if they recognised it without imposing an obligation to publish. That would be genuine appreciation of the importance of co-creation.”

Climate effect atlas
The atlas consists of digital maps with meteorological data which are linked to the spatial planning of an area. If the user wants to know more about precipitation or temperature in his/her region under a specific climate scenario, the atlas shows a user friendly map with this information. Will there be sufficient fresh water in times of drought? Will extreme precipitation lead to inundations? Is this a suitable spot te develop new nature?

05 How Knowledge for Climate measures up

Has the Knowledge for Climate Programme managed to adequately explain the complex issue of climate change to the public? The Rathenau Institute wanted to know how the programme measures up. “The public impact of the projects was felt in many different ways.”

The national government gave the Knowledge for Climate Programme a fifty million euro budget to study climate adaptation in the Netherlands. Funding bodies – in this case the Ministry of Infrastructure and Environment – obviously want to know whether their money is well spent. The Ministry thus asked the programme to contract the Rathenau Institute to review its working methods and public impact. The Institute studies the impact of science and technology on society and analyses major research programmes.

Edwin Horlings of the Science System Analysis Department investigated the Knowledge for Climate projects. “The purpose of this programme was not merely to conduct scientific research but above all to generate solutions for people who have to deal with the consequences of climate change. The question is whether the programme actually produced anything for policymakers and public administrators who need to take real-world decisions that make allowance for the consequences of climate change.”

“How will this research help you?”

Edwin Horlings and PhD candidate Tjerk Wardenaar surveyed the project supervisors and participants. The question they

The Rathenau Institute
The Rathenau Institute studies how science and technology impact our daily lives. It analyses the dynamics of that process by conducting independent research and organising debates. The Institute is part of the Royal Netherlands Academy of Arts And Sciences.

asked them was “How will this research help you?” They compared the Knowledge for Climate Programme with climate programmes elsewhere, for example in Germany (Klimzug) or the United States (NOA RISA).

“What we noted was that while Klimzug and NOA RISA both involved collaboration with stakeholders, it was nowhere near as intensive as in the Knowledge for Climate Programme,” says Horlings. “There, stakeholders could submit problems in advance to help determine the agenda, and they were given the opportunity to provide feedback later. But they were not actively involved in any interim decision-making, and they did not actually participate in the project. In the Knowledge for Climate Programme, stakeholders played a wide variety of different roles, from hotspot coordinator to liaison group member or project reviewer.” The Rathenau Institute’s analysts found that stakeholders had in fact played a total of seven different roles throughout the various phases of the projects. In that sense, practitioners in the field had a clear impact on the programme’s research and its results.

Unlike Klimzug and NOA RISA, stakeholders played a key role on the programme board. The board produced a series of documents indicating how the money was to be divided between the research proposals. “It’s difficult to say precisely what influence the non-scientists had,” says Tjerk Wardenaar. “What we can say is that the practical input trickles down to the entire programme. It has led to more demand-driven research than in the US or German programmes. In those programmes, the research questions often focused on a single stakeholder’s specific problem. The Knowledge for Climate approach meant that solutions and results were scalable and could be used by other parties as well.”

Societal impact

But what has been the programme’s impact on society? “The usual response to that kind of question is a formula showing economic yield,” says Horlings. “In the case of Knowledge for Climate, we identified five types of societal impact, from encouraging public debate to applying results in the field and influencing decision-making about major investments.” The level of impact on society depended on how the relevant project was organised. In those projects that sparked off public debate, there were many different stakeholders involved. The project staff focused not only on writing reports but also in disseminating information through the media, in newsletters

> “In the Knowledge for Climate Programme, stakeholders played a wide variety of different roles.”
>
> **Edwin Horlings**, Rathenau Institute

Photo Results of Knowledge for Climate have contributed to decisions about investments.

and at meetings. If the project involved introducing a technical innovation in the field, project staff sought out specialist stakeholders who could make a very obvious contribution.

The consortia and the hotspots in particular invested in cooperating with stakeholders. Horlings believes that partnerships between practitioners and researchers are a much more common feature of Dutch research culture than elsewhere. “Although we’re used to it in the Netherlands, it remains exceptionally difficult to organise. This programme was no exception. One of the pitfalls was that the people who collaborated in a hotspot or consortium came from different types of organisations and were accountable to their own employers first. Firm agreements had to be made in advance to prevent the participants from holding back. It’s also tricky to find the right people in an organisation to contribute. Each project is different and each case required us to take a unique approach to assembling an effective team to lend support at programme level and get results.”

What will last?

“This programme managed to establish a solid knowledge infrastructure in just a few years’ time,” says Horlings – but the question is whether that infrastructure will survive. There is no clear problem owner when it comes to climate change. Who should take on that role? Government? Economic sectors in the Netherlands?” Whatever the case, the legacy of the Knowledge for Climate Programme includes the large number of PhD candidates and post-doctoral climate researchers who carried out the research. Horlings and Wardenaar examined whether they differed from other research assistants in climate studies. One clear distinction is that the Knowledge for Climate PhD candidates cooperated more with practitioners than PhD candidates in academia. “We don’t know what impact that will have on their skills and experiences,” says Horlings. “What’s clear, however, is that more than half of the PhD candidates, like most university research assistants, end up in careers outside the world of academia. The future will show what the Knowledge for Climate Programme, with its emphasis on co-creation, has taught all those people who will be working all across society.”

Stakeholders were given a role in the programme leadership.

Knowledge for Climate PhD candidates

Tjerk Wardenaar compared the sixty Knowledge for Climate PhD candidates with those of the Netherlands Organisation for Scientific Research (NWO). The former group did more than just conduct scientific research. “Even so, the quality of their academic publications matched that of the ‘traditiona’ research assistants. They published in relevant academic journals. The Knowledge for Climate Programme also gave them the chance to participate in group processes and to get deeply involved in communicating with non-scientists.” They helped author policy documents, organised practical workshops and gave lectures geared to non-scientists. Their work was more interdisciplinary and transdisciplinary than that of ‘normal’ research assistants.

06 Knowledge for a climate-proof Delta

The Delta Programme is helping to make the Netherlands safer, both now and in the future, and to secure a sufficient supply of fresh water. Researchers involved in the Knowledge for Climate Programme’s hotspots and themes collaborated closely with the Delta Programme in an effort to climate-proof this vulnerable country.

Since the construction of the Delta Works, the Netherlands has been renowned as the world champion of flood defence structures. Today, the country’s Delta Programme is continuing that tradition, with national government collaborating closely with regions to keep the Netherlands safe, beautiful and economically robust, and to prevent disaster. The Delta Programme is divided into nine regional programmes that had close links with the Knowledge for Climate Programme’s themes and hotspots, enabling scientists, policymakers and regional experts to join forces and pool their ideas.

That sounds much easier than it actually is, however. The Knowledge for Climate Programme, with its focus on knowledge, and the Delta Programme, with its focus on strategy and policy, faced the challenge of linking science and policymaking. This didn’t make communication and coordination any simpler. Decision-makers have trouble dealing with the long-term nature and uncertainties of climate change. They need to know which effects will be felt where and how likely they are. They require information about applying adaptation measures in practical policymaking.

“We worked hard to bring theory and practice together,” says Delta Commissioner Wim Kuijken. “We invested a lot of energy in turning theoretical knowledge into practical methods for the

“Knowledge for Climate played an important role in ensuring the quality of the 2015 Delta Programme.”

Wim Kuijken, Delta Commissioner

people working in the Delta subprogrammes. The Climate for Knowledge researchers conducted in-depth studies, collected information, made it available, and developed decision support tools and systems. They participated in the project teams and were involved in carrying out the practical pilot projects. Practice and theory also encountered each other at the 'learning tables' for governance issues." The learning tables were set up by Knowledge for Climate's Governance of Adaptation consortium. The participating scientists and policymakers developed ideas for coping with the consequences of climate change, for example drought or flooding. Their proposals will enable residents and stakeholders to take more responsibility and grow more self-sufficient, and they offer new and existing partnerships more leeway to introduce new initiatives for coping with the impact of climate change. The processes made possible by their proposals are described in the publication *Governance van klimaatadaptatie* [Governance of climate adaptation].

Specific solutions

The Knowledge for Climate hotspots and Delta Programme subprogrammes overlapped to some extent. The Knowledge for Climate Programme generated both theoretical and practical knowledge about flood safety, fresh water supply, climate-proof spatial planning and governance in the hotspots. One good example of the sort of practical knowledge it generated is the wide-ranging package of solutions proposed under the Climate-Proof Fresh Water Supply theme, meant to ensure the supply of enough fresh water in the Netherlands' south-west delta. "The projects in the south-west delta region illustrate the added value of co-creation for all regional parties," says Kuijken. "Farmers working the saline soil of the delta do not always have access to good quality fresh water. In our pilot projects, researchers, local businesses and water management bodies worked together on new forms of water storage that we tried out in practice at various locations. This way the region can create a fresh water buffer to fall back on during periods of drought." Thanks to innovations such as underground water storage and saline agriculture, farmers have more effective ways of coping with the consequences of climate change. A series of tools can help them choose the best solution in specific situations.

Practical knowledge

Products that turn new theoretical knowledge into practical applications offer good examples of the way the Delta and Knowledge for Climate programmes complemented each other,

Thanks to the Knowledge for Climate Programme, we have accrued knowledge in areas that are crucial to our continuing to live in the delta.

Photo Wim Kuijken, Delta Commissioner

says Kuijken. "These include the climate projections for the delta scenarios, the Climate Effect Atlas for climate-proof spatial planning, the studies focusing on multifunctional dikes and on building outside dike protection zones. But they also include area-specific adaptation studies, for example robust spatial planning in the IJssel Valley, or decision support instruments such as the design tool *Kust* [Coast]."

Quite apart from practical collaboration and knowledge-sharing, the Knowledge for Climate Programme also played a key role in ensuring the quality of the 2015 Delta Programme. Researchers involved in the Knowledge for Climate Programme reviewed the Delta subprogrammes. According to the researchers, the scientific quality of the Delta Programme is up to par, but the programme could do more to substantiate the choices made somewhat further down the road, for example eventually taking a more flexible approach to the water levels in Lake IJsselmeer. The new Water & Climate research programme, which will also help answer some of the Delta Programme's knowledge-driven questions, should look more specifically at the governance and knowledge-generation aspects of these choices.

Even after its subprogrammes have been completed in 2014, the Delta Programme will need a method for taking and implementing decisions in the delta. Under the Delta Act, the Delta Commissioner draws up the annual Delta Programme and monitors its integrity and progress. In the report *Samen verder werken aan de Delta, de governance van het Nationaal Deltaprogramma na 2014* [Working together on the Delta: the governance of the National Delta Programme after 2014], governance experts Geert Teisman and Arwin van Buuren of Erasmus University Rotterdam recommend that all the parties remain closely involved in the follow-up to the Delta Programme.

"All things considered, the synergy between the Delta Programme and the Knowledge for Climate Programme was good," says Kuijken. "The research of the various knowledge centres is of practical use to policymakers, water management bodies and businesses. Perhaps individual researchers can continue to benefit by keying into the questions that need to be addressed during the Delta Programme's implementation phase. One example is to study the dynamics of the sand along the Dutch coastline. The results obtained by the Knowledge for Climate Programme can serve as the basis. Thanks to the programme, we have accrued knowledge in areas that are crucial to our continuing to live in the delta."

07 Did Knowledge for Climate make a difference?

Hundreds of research results, 250,000 publication downloads in 2013, adaptation strategies and new business ventures: these are the tangible legacy of the Knowledge for Climate Programme. Less tangible but equally valuable are the unanticipated partnerships and innovations generated by the programme.

People want their tax euros to be put to good use. What did society gain from seven years of climate research carried out according to the Knowledge for Climate Programme's methods? It is not always easy for research programmes to demonstrate a return on the taxpayer's investment. Although practical projects such as the multifunctional dike in Streefkerk and subsurface fresh water buffering in the south-west delta may appeal to the imagination, they are not as impressive as massive storm surge barriers. How have all the millions of euros spent made the Netherlands more climate-proof?

For Deltares director Ron Thiemann, the programme's main contribution is that it created closer links between multiple disciplines. "Both in science and in policymaking, people still work (too much, I feel) according to fixed patterns and routine thinking. The Knowledge for Climate Programme has really shaken things up. It joined up different disciplines, created links between water management and construction, between flood safety and infrastructure, between hydrological modelling, design research and spatial planning. Scientists and technicians sat down with public administrators and economists. And that is really essential, because climate change, adaptation and flood safety are typically multidisciplinary issues."

More about *multifunctional dikes in Streefkerk* on **page 49**

More about *buffering fresh water* on **page 40**

Photo Knowledge for Climate educated more than 60 PhD Students.

Building bridges

Marjolein Demmers, director of Corporate Social Responsibility at Royal Haskoning DHV, adds that the research and knowledge generation were especially valuable owing to the interaction with questions posed out in the field. "That interaction wasn't a one-way street. The Knowledge for Climate Programme kept its sights set on this idea and elaborated on it by pushing the idea of co-creation." In Demmers' view, co-creation played a huge role in the innovations produced during the programme. "It has focused and streamlined the research. For example, climate scenarios are a good way of

Collaboration leading to innovation: Water storage under greenhouse

In the Westland region, the centre of greenhouse horticulture in the Netherlands, researchers and growers worked on buffering water in the subsurface beneath greenhouses. Four tomato growers and an orchid grower took part in the fresh water buffer trial. KWR Watercycle Research Institute carried out the research. The Waterbuffer Foundation will focus on supporting the application of underground fresh water storage. Businesses, knowledge centres and the authorities are working together in the foundation. **www.waterbuffer.net**

Read more about this project in *Hotspot Haaglanden* on **page 34**

showing the potential consequences of climate change. In actual practice, however, governments and businesses are looking for a *modus operandi*: what can they do with this information? What does a particular change mean for a region or a city? What are the specific consequences? And what measures can regional or municipal authorities put into place to adapt to those changes? What will it cost? It is pure co-creation to build a bridge between a scenario and possible adaptation options – between abstract and concrete. That generates value for society. The Knowledge for Climate Programme has done this by linking scientists to policymakers and business people. In that way, the scientists came to understand how science actually works down on the ground. The two groups developed the research questions together."

One good example is the Climate Effect Atlas. The first steps were taken in the Climate *Changes* Spatial Planning Programme, part of which ran parallel to the Knowledge for Climate Programme. Provincial authorities wanted an overview of climate change impacts on different regions. The High-Quality Climate Projections and Decision Support Tools consortia collaborated with stakeholders and scientists on improving the Atlas and the climate scenarios. The questions raised in the field produced information that policymakers in the Province of Zuid-Holland, for example, can use to ensure a sufficient supply of fresh water for all future users.

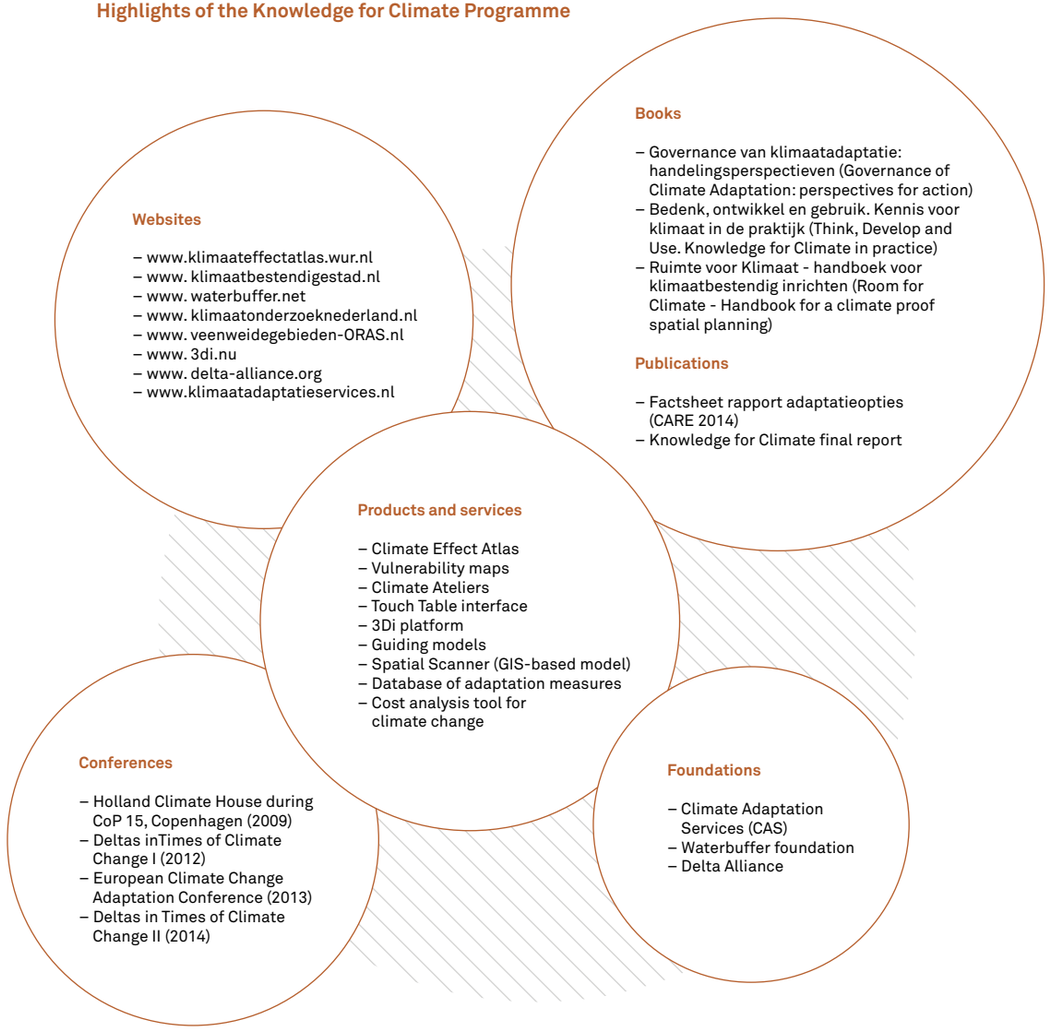
Promising

Collaboration in the hotspots and consortia has given rise to a broad spectrum of innovations that can be used more widely throughout the Netherlands. Perhaps more important still is the insight that adaptation is not a question of building taller, stronger dikes. Both directors believe that the Knowledge for Climate Programme has made a major contribution to putting the issue of climate adaptation on the map in the Netherlands. "Climate adaptation supports short-term action, for example by answering practical policy-driven questions" says Demmers. "At the same time, it keeps us focused on the longer term, on the future. It takes uncertainties into account, for example about the climate, but also socio-economic trends. It forges a link in the area of tension between short term and long term." "The new partnerships – some of them unanticipated – have led to innovative approaches," adds Thiemann. One example is the 3Di platform, which visualises how flood waters can spread through the streets of a city. Questions raised in the hotspot and consortium projects have been tackled by different disciplines, leading to integrated solutions. That's extremely valuable!"

Bridging science and practice
The Climate Adaptation for Rural Areas consortium joined stakeholders and policymakers in the Province of Gelderland to develop a set of adaptation measures. By working together using the Touch Table interface, farmers and nature management organisations drew closer together and gained a better understanding of each other's viewpoints. One of the results is coordination on retaining natural banks and hedgerows so that flora and fauna can migrate with shifting climate zones.

More about *Climate Adaptation Services* on **page 31**

Highlights of the Knowledge for Climate Programme



08 A different climate adaptation story

Frank Sinatra said it best: ‘And now, the end is near…’ The Supervisory Board, senior officials at the Ministry of Infrastructure and Environment, researchers and consultants are all busy looking for a follow-up to the Knowledge for Climate Programme.

The Knowledge for Climate Programme was a success, but success does not guarantee survival. Politics dictates otherwise; politicians make more of a splash by setting up new projects. And new programmes may also bring new opportunities. But there is no uniform answer to the question of how to continue. “Just look at the Climate Adaptation Business Challenge,” says business director Kees van Deelen. “The first national meeting took place in November 2013 and had more than one hundred participants. It was the first climate adaptation business competition in the world. We organised the international version in 2014 and received 78 submissions from 28 different countries, each one proposing how to turn climate adaptation into a business. We can’t stop now!” One of the winners of the first competition was Arjan Vos, who developed a potato that grows in saline soil. Another winner was the Magic Mitad, a glass sheet for baking *injera*, a type of pancake that is part of the basic diet in Ethiopia. The Magic Mitad consumes much less fuel than customary baking sheets. The winners of the second business challenge had not been announced at the time of publication.

Social science director Peter Driessen believes that the Knowledge for Climate Programme should be linked to an investment programme like the Multi-year Plan for Infrastructure, Spatial Planning and Transport (MIRT). “We want to optimise climate-robustness and apply adaptation strategies in the field. That requires setting up MIRT-type funding structures, or being able to use existing ones.” In the MIRT plan, the State and the regions both invest in spatial planning. Co-funding means sharing responsibility and supporting practice-based research. Driessen points out how powerful co-funding is. “You invest in research which produces results that are interesting for your own organisation. We then want you to actually do something with those results. The incentive comes from tying budgets to follow-up research.”

More than 100 people participated in the dirst Climate Adaptation Business Challenge.

Trials and applications

Imagine that the unlikely happens, and another 50 million euros are made available. How should the money be spent?

Knowledge for Climate’s scientific director Pier Vellinga would spend three-quarters of that amount on evidence-based trials in order to put new insights into practice and optimise them.

Photo Tools like the Touch Table bring scientists and practitioners closer together.

"In the Netherlands, research is still too far removed from implementation when it comes to major public works. But it's precisely when researchers collaborate on implementation that we get innovation. New knowledge is needed every step of the way in all the major climate adaptation issues. Progress means monitoring, producing smarter innovations, streamlining implementation, making things less expensive and more robust."

In many cases, the researchers that generate the theoretical knowledge are not the ones who have to apply it in the field. As a result, existing knowledge may be overlooked and practitioners may embark on a new round of research covering the same subject. "Knowledge and implementation should belong to the same cycle," says Kees van Deelen. "In follow-up programmes, we have to continue trying to incorporate the latest insights into applications."

Vellinga would like to spend a quarter of the imaginary 50 million euros on promoting the ideas that emerge from the programme. "We see a lot of good ideas fade away after one or two pilots, often because implementation requires a party that does not own the idea. Don't let a good idea die in the pilot project stage; instead, promote it so you can find parties that will take it a step further." Vellinga wants to see more customised approaches to flood safety and fresh water supply. Get local residents involved, he recommends. "For example, I'd like to advise water boards and municipal authorities to experiment with offering tax breaks to people who remove hard paving from their gardens. I mean taking up the paving stones so that heavy rainfall doesn't lead to flooding, but instead supplements the groundwater. That touches directly on governance, on experimenting with water-related and property taxes. Water management and, in particular, climate change adaptation offer many opportunities to involve local residents in solutions. Social and tax-related experiments can help secure their engagement in the longer term."

Adaptation fund

The three directors believe it may be possible to set up an adaptation fund similar to the Netherlands' energy funds. There is nothing unusual anymore about investing in renewable energy; examples include the solar panels installed on the Amsterdam Arena stadium or offshore wind farms. Such projects have a transparent revenue model and offer environmental advantages. The same trend could be extended to climate adaptation measures. Such principles as multilevel flood safety are just as likely to produce win-win situations: if local residents know what to do and we can control the flow of flood water into an area, there will be much less damage than if a dike is suddenly breached. An adaptation fund could thus be used to invest in communicating with local residents and authorities and in building innovative, broad dikes. It will cost less than constructing complex flood defence systems and much taller dikes. It will also produce a more attractive landscape and mitigate the consequences of flooding.

> "Adaptation creates win-win situations and saves costs in the long run through integrated projects that fit nicely in their surroundings."
>
> **Hasse Goossen**, Climate Adaptation Services

Appoint a chief scientist

The work of the Knowledge for Climate Programme will continue in various spin-off initiatives, for example the Waterbuffer Foundation and the Climate Adaptation Services Foundation (CAS). CAS presents practical projects and tools on the website www.ruimtelijkeadaptatie.nl.

CAS project supervisor Hasse Goossen says that, after so many years of climate adaptation research, the time has come to find a new way of communicating about the subject. "We spent a lot of time and effort working on the reports and models. What sorts of calculations can we perform? What data is available? That's shifted more towards the practical side of things: what can we do with this information? Now the professionals have to get swept along in the story. Ultimately, climate change is only one of the many issues on the agenda of policymakers and public administrators. So it's up to us climate researchers to tell our story as transparently as possible and to make the added value of climate adaptation measures clear. If we don't take climate change seriously now, we'll simply be shifting the burden onto future generations. But an even better tactic would be seduction: adaptation can create win-win situations that deliver long-term cost savings, combined with all-round projects sympathetic to their surroundings. We need to give examples of where this has already happened. So we work with visualisations to make all of the knowledge we've built up in CAS accessible. Then it becomes useful to the people down on the ground."

The Water & Climate research programme will continue conducting climate adaptation research to some degree. Pier Vellinga would also like to see a foundation that reports to the public on the extent to which the Netherlands is climate-proof. "A chief scientist who is unaffiliated with any of the parties could provide unbiased advice based on all the knowledge generated about climate adaptation."

1 HOTSPOT 1 Mainport Schiphol

A safe airport

Climate change will mean extreme precipitation and drought at Schiphol Airport as well, along with subsidence and rising sea levels at the North Sea. Mainport Schiphol Hotspot looked at how climate-proof the airport really is.

“We developed a number of good projects,” says Peter van den Brink, hotspot coordinator. “Various studies showed that Schiphol is already well prepared for climate change. The projects were beneficial mainly because the new operational system developed by the Royal Netherlands Meteorological Institute (KNMI) gives us more detailed, accurate meteorological forecasts.”

Schiphol has collaborated with the KNMI, Wageningen University and Research Centre and a consultant in a number of studies on crosswinds, visibility and other weather conditions important to aviation. The partners also surveyed and evaluated the possible effects of climate change on airport operations.

Collaboration between theory and practice was not always easy. Schiphol Airport wanted very concrete projects. For example, the prospect of more extreme weather conditions pointed up the need for a system that can measure crosswind and visibility across an airplane’s entire flight path. “It was hard to fit a specific request like this into the research programme at first. Fortunately, the programme office helped us make it happen,” says Peter. “I also saw that researchers were much more interested in theoretical questions, whereas as a business, we were more much focused on practical results that we can use. Whole periods would pass without our hearing anything. That’s when the researchers were studying, calculating and performing tests.”

Has the hotspot programme made Schiphol Airport any safer? “Of course. More precise meteorological information improves aviation safety,” says Peter. “And that, in turn, benefits the Dutch economy.”

Regional adaptation strategy for Mainport Schiphol

What is the impact of climate change on airport operations and to what extent is Schiphol Airport prepared for it?

This study brings together recent research into the influence of climate change on the safety and operational reliability of Schiphol Airport. The study covers changing weather conditions, hydrology, and flood safety at the airport. It also indicates which potential changes should be closely monitored and where additional research will be needed once the contours of climate change become clearer. The wind is one example. Imagine that the prevailing wind direction changes in future. What impact will that have on existing runway alignment and on noise pollution?

HARMONIE: weather forecasts on a 2 kilometre scale

Extreme precipitation (in winter), mist, wind or storms can lead to delays at Schiphol Airport or put safety at risk. It is important to have reliable weather data on a local scale.

The project explored the influence of climate change on weather conditions at Schiphol Airport and the impact of various weather variables on airport operations. As part of this project, the KNMI cooperated with users of weather data at the airport on developing a high-resolution weather model, called HARMONIE, that can be used to make accurate weather forecasts on a scale of approximately 2 kilometres.

2 HOTSPOT 2 Haaglanden region

Climate change is not a big problem

If we don't do something now, climate adaptation will cost us a lot of money later on. Now is the time to adapt streets, squares and infrastructure to climate change by keying into existing spatial planning programmes. That way, climate change doesn't have to be a big problem. That is the main message of The Haaglanden Region Hotspot's adaptation strategy.

The Haaglanden Region Hotspot has produced an adaptation strategy that has the backing of all the municipal authorities and water boards involved. The results of the Knowledge for Climate projects played an important role in marshalling their support. "At first, we were going to outsource the job of developing the adaptation strategy to a consultant," says Arno Lammers, hotspot coordinator. "But that turned out be harder than we thought. So the municipal authorities and water boards took over. After all, they had all the knowledge gained through the Knowledge for Climate projects and wanted to put it into practice for themselves."

The most important message of the adaptation strategy is that climate change need not be a big problem if we start adapting systems now. "If we can manage to link climate adaptation to spatial planning processes, then it won't cost anything, or very little," says Lammers. "For example, when it comes time to redevelop a street or square, why not see whether it's possible to create a water buffer or plant trees to shade public spaces in heat waves."

The strategy has been underpinned by a thorough examination of the effects of climate change. The research considered the economic and spatial options in different climate scenarios.

Water buffering under a greenhouse

The Waalblok Polder needed to be able to buffer 11,000 cubic metres of water to avoid flooding. But land is expensive in the polder, where greenhouse horticulture dominates. Could water be stored in cellars beneath greenhouses?

Market gardeners wanted to keep the amount of land set aside for water buffering to a minimum. They wondered whether it would be possible to buffer water underneath a greenhouse. And so they came up with a new concept that involved rainwater retention, drainage water buffering, irrigation water preparation and crop irrigation. One of the market gardeners was willing to make his greenhouse available for the trial; the cellar underneath the greenhouse could hold 5,000 cubic metres of water. It was technically feasible, but would it be possible to store irrigation water while temporarily buffering rainwater from a heavy downpour? There were many organisational and legal questions involved, and the answers came thanks to a hotspot project. The greenhouse horticulture sector has gained an innovation and the water board is more understanding of market gardeners' needs.

My 3Di

Thanks to a smart calculation system and visualisation technology, it's now possible to see whether your street will flood in the event of a heavy downpour.

Smart visualisation technologies allow water management bodies to come up with better methods for coping with heavy rainfall and flooding. The 3Di platform shows precisely what happens at street level if there's a downpour or if a dike is breached. You see your own block being flooded and discover where to go to stay dry. What makes this all possible is a rapid calculation technique. The delta commissioner believes that this has huge potential for the process of developing and implementing Delta Programme decisions. The Haaglanden Region Hotspot played a key role in acquiring funding for this sizeable project. The Knowledge for Climate Programme assisted with the project and also made a financial contribution.

3 HOTSPOT 3 Rotterdam region

Rotterdam, innovative delta city

The City of Rotterdam aims to be climate proof by 2025. The hotspot projects carried out within the Knowledge for Climate Programme have helped accelerate that process.

"The hotspot has increased our understanding of the effects of climate change and made us more aware of the implications for the city," says Arnoud Molenaar, hotspot coordinator. "It also resulted in the Rotterdam Adaptation Strategy, a unique set of guidelines that will help stakeholders tackle urban heat, flooding and a robust water supply."
The city would like to buffer more water on the surface, for example public squares that act as overflow basins when necessary, 'green roofs' (i.e. covered with vegetation), and micro-scale gardens created by removing paving stones from kerbs. This would be in addition to maintaining the city's oldest canals, according to the Strategy. "The idea is for spatial planners to incorporate these types of measures into their designs," says Molenaar. "We're also taking a road show to housing corporations, utility companies and the Port of Rotterdam Authority to talk about what they can do to make their operations and the city of Rotterdam more climate proof."

The hotspot has also compiled an adaptation strategy for the Rotterdam Region. "A lot of our knowledge about Rotterdam's climate also applies for other municipalities in the region. We provide not only technical but also ecological solutions, for example planting more vegetation in the riparian zone," says Molenaar.

Rotterdam's image as an innovative delta city has been reinforced by the hotspot project. "We've really started taking advantage of Rotterdam's reputation in that respect," says Molenaar. "We welcome about twenty-five delegations a year that want to see how we're tackling climate adaptation. We're also asked to participate in many pilot projects, and our knowledge of climate adaptation has become one of our export products. For example, Grontmij adapted our Rotterdam Adaptation Strategy for Ho Chi Minh City, and the designers of the floating exhibition pavilion in Rijnhaven Harbour have also designed a floating community in California."

Heat stress in Rotterdam

The urban heat island effect is a serious problem for vulnerable groups of people, such as the elderly. In airless summer periods, cities hold on to heat and the elderly may suffer heat stress or even die of heat-related causes.

Researchers explored the causes of the urban heat island effect by heading off into Rotterdam on cargo bikes loaded down with instruments. They fitted trams with temperature sensors, inspected satellite images, and even studied the sleep patterns of Rotterdam's inhabitants on hot summer nights. It turned out that the city could be as much as 8 degrees Celsius warmer than nearby rural areas. Molenaar hopes that Rotterdam will make allowance for heat waves in the years ahead by planting vegetation all around the city. The research project has been given the name 'Hotterdam'.

Costs and benefits of adaptation measures

What will climate adaptation measures cost, and who will enjoy the benefits? Rotterdam wants to perform the necessary calculations on a district-by-district basis.

The City of Rotterdam and the Rebel Group have developed a unique social cost-benefit tool that allows the municipal authorities to estimate which adaptation measures are useful and cost-effective in each climate scenario. It has analysed a whole list of adaptation measures for two districts in Rotterdam. The calculations show that constructing public squares that act as catchment basins raises property prices in residential areas. They also show that small-scale implementation of green roofs does not have a cooling effect, but if a whole district or city were to construct green roofs, temperatures would indeed be lower in hot summers.

4 HOTSPOT 4 Major rivers

Robust safety

The Major Rivers Hotspot calculated the discharge of an entire branch of the river IJssel and analysed the best strategy for limiting the damage and the number of victims in the event of flooding. The result was multilevel safety put into practice.

What does robustness mean in practical terms when it comes to flood safety? The Knowledge for Climate Programme answered that question for the river IJssel. Several different configurations were calculated. Harold van Waveren, hotspot coordinator, explains. “How large will the peak discharge be in the IJssel if the climate changes? And what can we do to minimise the damage and the number of victims in the event of extreme discharge? This is the first time an entire branch of the river has been analysed. We looked at the effect of traditional dike reinforcement and what multilevel safety can do. In the latter case, we considered unbreachable dikes and leaving more room for the river.” As a basis for the preferred strategy for the Delta Programme, the most robust solution turned out to be ‘far-reaching interaction between dike reinforcement and river enlargement’.

The hotspot mainly produced technical knowledge. For example, one of the studies involved cross-border research into how much climate change and economic development had increased the flood risk in the Rhine and Meuse basin. “These studies gave us interesting insights. Unfortunately, the international dimension has been somewhat neglected in the Delta Programme,” says Van Waveren.

The Knowledge for Climate Programme will provide other options for adaptation strategies in the Netherlands’ Major Rivers Region. ‘The building blocks are there, but the structure has yet to be completed. That will be the icing on the cake of the Delta Programme,” Van Waveren promises.

Rhine flood risk

In thirty years’ time, the Rhine could cause between 50 and 230 per cent more damage than today if it were to flood its banks. These are startling figures, especially since the damage would already be immense today.

More than ten million people live in flood-sensitive regions along the Rhine. How much will the flood risk increase as a result of climate change and shifts in land use? That was the main question addressed in the hotspot project ‘Evaluation of flooding risk in the Rhine basin’. Flooding will cause between 50 to 230 percent more damage in thirty years’ time than today, depending on how much the climate changes and whether these regions see a great deal of social and economic development or only a little. Climate change, it turns out, would account for fifty percent of the rise in the level of damage. Another conclusion is that creating water buffering areas in Germany will do nothing to reduce the risk of flooding in the Netherlands.

Quick calculation of Meuse flood risk

It was an unintentional result of one of the studies on flood risk along the Meuse: a quick method for calculating future risk.

The hotspot project ‘Adaptation to Meuse flood risk’ also explored future changes in that flood risk. Based on the insights gained, we may be able to avoid doing things that will greatly increase the risk of flooding. The project also looked into which measures can be introduced to reduce future flood risk. This led to an interesting insight: in terms of average annual damage, the flood risk is more sensitive to damage caused by high-frequency events (i.e. every 10 to 100 years) than to low-frequency ones (every 1,000 to 2,000 years). At the same time, the project gave rise to a quick method for calculating future flood risk.

5 HOTSPOT 5 South-West Delta

Gardening in the delta

Ensuring fresh water supply in the south-west delta requires carefully selected measures. There are advantages to flexible designs that take the varied landscape into account.

There are many questions in the south-west delta concerning salinity and fresh-water shortages. “We’re working on pilot projects and using them to shape our approach to water supply in the future,” says Thecla Westerhof, coordinator of the South-West Delta Hotspot. “For example, we’ve studied the underground storage of fresh water in creek ridges in the hotspot. Another option involves pricing the supply of fresh water, for example by taking out a subscription for fresh water from elsewhere. And of course, there’s saline agriculture, i.e. the cultivation of crops that are saline-tolerant, so that we don’t require as much fresh water. Right now we’re looking at economies of scale. What opportunities are there for which type of measure?” The provincial authorities of Zeeland hope to take decisions in a few years’ time.

An adaptation strategy has been developed for the south-west delta. Westerhof finds the underlying principles appealing. “One of these is to think in terms of systems and integration, but to keep your actions flexible and small scale. This means we can take the varied landscape of the Province of Zeeland into account and maintain close ties with the region. For example, the fresh water situation is slightly different at every location. There are major advantages to selecting measures that reflect those differences.” Think of it as gardening in the delta, which is precisely one of the underlying principles of the adaptation strategy.

Go Fresh

It seems so obvious: drain away saline water under farmland so that there is more room for fresh-water buffers. Thanks to the Knowledge for Climate Programme, that is precisely what is happening in the Province of Zeeland for the first time.

The Freshmaker is a new way of storing fresh water underground. The system serves to boost the fresh-water aquifer under farmland in winter so that more water is available in summer for irrigation. Brackish or saline water that lies below the fresh-water lens (fresh water is always closer to the surface than the deeper saline water) is drained away, leaving more space for fresh water. Excess precipitation in winter is infiltrated (artificially) into that space. The Freshmaker system was first tested in Ovezande in the Province of Zeeland, giving a fruit grower enough fresh irrigation water to get through dry summer periods. Infiltration, storage and recovery of water are being monitored closely so that the Freshmaker’s potential becomes clear.

Climate change as a business opportunity

Tourists are happy with the changing climate of the Netherlands’ south-west delta, but not so farmers, whose crops cannot cope with the extreme weather conditions.

Business owners in the Zeeland Flanders region are aware of climate change, but have not really thought about what it means for their business. HZ University of Applied Sciences and the Agricultural Economics Research Institute (LEI) explored two questions: What are the local effects of climate change, and what can businesses do about it? The researchers spoke to farmers and business owners in the leisure sector, but also to banks and insurance companies. The results show that climate change has more serious implications for the agriculture sector than for tourism. The latter can benefit from the hotter weather. Many common crops, however, cannot cope with extreme weather conditions such as heat waves and heavy downpours – both of which are set to increase.

6 HOTSPOT 6 Shallow Waters and Peat Meadow Areas

Can we save our peat meadows?

The Shallow Waters and Peat Meadow Areas Hotspot has scientists, policymakers and stakeholders cooperating on research and plans to save a very Dutch natural environment from extinction.

“Which results am I most proud of?,” asks Jos Verhoeven, ecologist at Utrecht University and hotspot coordinator. “That would be our website about adaptation strategies for peat meadow areas. The site brings together all the research that we carried out in our hotspot.”

The hotspot participants explored how to prevent water stress and subsidence in peat meadow areas and how to combat the growth of algae and botulism in lakes and ponds. For example, researchers looked at the influence that temperature and precipitation have had on water quality over the past few decades. Researchers and stakeholders also attended workshops in which they used interactive touch tables with digital maps to develop and evaluate adaptation strategies. This allowed farmers to see what would happen to their land if the water level were to be increased.

“The entire hotspot project taught me how scientific knowledge can be used to inform policymaking,” says Verhoeven. “For example, I noticed that we gained the most from knowledge workers employed by regional government who were in close touch with public administrators. That’s when our knowledge was put to best use. Coincidence also played a huge role. The Province of Friesland happened to be working on a strategic policy agenda for peat meadow areas. They heard about us at precisely the right time and we were able to send them demand-driven information. Unusually, public administrators actually took that information out into the field.”

Has the hotspot saved the peat meadows? “Time will tell,” laughs Verhoeven. “We delivered a lot of information and did our best to take all the parties’ interests into account. So I’m pretty confident that the peat meadows will be saved.”

Manual for peat meadow areas

Models show that if we make no changes to our management approach, almost all of the Netherlands’ peat meadow areas will disappear by 2100. The website www.veenweidegebieden-oras.nl was developed to prevent that from happening.

This online manual surveys state-of-the-art adaptation measures and adaptation strategies for peat meadow areas. It also provides information on the features of different peat meadow areas and the challenges that have arisen in nature conservation and agricultural areas, for example. The short texts make it easy to get to the heart of the problem, but readers can also learn more about the science involved. The website has now been online for six months. Visitors tend to come from regions that are struggling with this issue.

A fresh look at warmer water

Changes in temperature and precipitation have led to massive blooms of cyanobacteria in lakes and ponds. Botulism has increased, killing birds and making swimmers sick.

The Netherlands has invested a considerable amount of money and effort in cleaning up its surface waters in recent years, but climate change threatens to undo all this good work. In *Een frisse blik op warmer water* [A fresh look at warmer water], published by the Foundation for Applied Water Research (STOWA), ecologist Sarian Kosten (then employed by Wageningen University and Research Centre) surveys recent research on water quality and nutrification and how to prevent the growth of harmful bacteria and algae. One way is to remove all phosphates from purified waste water; another is to have farmers practise more balanced fertilisation. It is a handy, well-written manual that has become popular in water management circles.

7 HOTSPOT 7 Dry Rural Areas

Out of their comfort zone

The Dry Rural Areas Hotspot brought practitioners and scientists together. Their collaboration took them out of their comfort zone and generated fresh and feasible ideas.

“Because we have scientists participating in an area-specific project, there are experiments,” says hotspot coordinator Frank van Lamoen. “That has taken the provincial and water board employees out of their comfort zone and forced the scientists to generate knowledge that can be used in actual practice. That collaboration is really valuable.”

In the Baakse Beek area, scientists and practitioners studied how the National Ecological Network can be combined more effectively with present-day land use. Doing so would make it easier to build the network and would also promote nature conservation. That means letting go of the idea that things can be manipulated, and going along with developments as they unfold – something that is not always easy for public authorities.

The Delta Plan for High-Lying Sandy Areas focused on fresh-water supply and is quite technical in nature. “We worked on an adaptation strategy within the context of the Knowledge for Climate Programme,” relates Van Lamoen. “That ensured that other aspects also came in for more attention, for example the link between fresh-water supply, land use and active groundwater management: How can we store more water in the subsoil? Finally, the adaptation strategy devoted quite a lot of attention to governance: How can we implement a plan successfully? What combination of tools is best? What types of partnerships are suitable? The adaptation strategy is a kind of toolbox that we gave the water boards as input for their water management plans. That’s very handy given that they’ll be working on a new round of plans shortly.”

Water storage in Stippelberg Nature Conservation Area

Stippelberg Nature Conservation Area has water shortages in summer and excess rain in winter. Can the excess wintertime water be stored for use in the summer?

Stippelberg Nature Conservation Area in the Province of Noord-Brabant provided a good opportunity for a field experiment in which excess winter rainwater was stored and used in summer. In a trial, 100 cubic metres of water held in storage tanks were poured into an infiltration ditch. At the same time, researchers started keeping track of changes in the water table. If the water table changes and does not quickly return to its old level, then infiltrating water would be a good strategy for building a supply. This is the first time that an infiltration experiment of this kind has been carried out in the high-lying sandy subsoil of the southern Netherlands. If it proves successful, it could be a good method for alleviating summer water shortages in the high-lying areas of the Netherlands.

Flexibility in adaptation arrangements

What the future demands is flexibility during implementation. But how can we be flexible when implementing plans aimed at climate change adaptation?

The people charged with implementing adaptation plans often run into barriers such as shrinking budgets and conflicting interests. Parties involved in implementing adaptation strategies try to minimise risk and maximise guarantees by drawing up ironclad contracts. The cases analysed in this project show that adaptation measures are in fact not very flexible, even though flexibility is an important principle in adaptation policy. Monitoring also receives little attention. Scientists and policymakers have joined forces in developing guidelines for implementing adaptation strategies flexibly and engaging in reflexive monitoring. Their method consists of a questionnaire, a serious game and the ‘policy arrangement canvas’. It also includes descriptions of possible arrangements that can be used flexibly to a greater or lesser extent.

8 HOTSPOT 8 Wadden Sea

A helicopter view of Wadden Sea research

The Wadden Sea Region is already the subject of a considerable amount of research. It was a challenge for the Wadden Sea Hotspot to find a niche where it might still make a difference. Ultimately, the question researchers tried to answer was: Can natural solutions provide the basis for dealing with rising sea levels in the Wadden Sea Region?

“We got a consultant to interview the experts for us,” says Kim van Nieuwaal of the Knowledge for Climate Programme. “We also consulted scientific publications. We believed that combination would lead to an all-round, long-term adaptation strategy for the Wadden Sea Region.”

“Sometimes, it’s a good idea to ask very basic questions and then try to get a helicopter view of all the answers,” continues Van Nieuwaal. That occasionally led to resistance because some specialists felt that the Knowledge for Climate Programme was encroaching on their territory. “Our aim was not to generate new knowledge,” continues Van Nieuwaal. “We wanted to amass existing knowledge. The specialists sometimes forgot that.”

The Wadden Sea Region is a battleground for many different organisations with many different interests. On the one hand, it is an important international nature conservation area; on the other, it is home to gas extraction activities and, in the Eems region, to coal-fired power stations. Van Nieuwaal finds the tension between these interests fascinating. “There is much to be gained by getting the various parties to work together on protecting the Wadden Sea Region in the longer term.” He hopes that the hotspot research results will be an eye-opener for public administrators, giving them the chance to work quietly on investing in climate adaptation, for example by setting up a pilot project or a monitoring programme.

Adaptation strategy for the Wadden Sea

The Knowledge for Climate Programme interpreted sea-level rise scenarios for the Wadden Sea Region and the effect of such a rise on the Wadden Sea’s sedimentation system.

The study stressed that sea level rise is not linear, but progressive. In other words, we aren’t seeing much of a difference now, but the rate of sea level rise will accelerate in the future. Sand and sediment will play an important role in the survival of the Wadden Islands. After all, sand and sediment are what create and maintain the islands and sand flats. But the source of that sand and sediment, which lies in the outer delta, can suddenly be exhausted. Eventually, the islands and sand flats could deteriorate or be engulfed by water as a result. For a better understanding of the situation, the study suggests setting up a monitoring programme so that sand can be replenished in good time.

Salt marshes for flood safety

How can innovative dikes and the ‘building with nature’ principle guarantee flood safety in the Wadden Sea Region?

Jantsje van Loon (Wageningen University and Research Centre) concluded that it would be interesting from a climate adaptation perspective to integrate salt marshes into the dike protection zone along various sections of the dike. Combining salt marshes with a broad, ‘green’ dike is particularly interesting in areas where the marshes occur naturally; the combination is safe, it is sympathetic to the landscape of the Wadden Sea Region, and it will also contribute to the ecological quality of that region. Because the research is state-of-the-art and socially relevant, there was close collaboration with the Delta Programme and the Programme towards a Rich Wadden Sea.

Complete safety is an unrealistic aim

The Climate Proof Flood Risk Management consortium was the gadfly of the Delta Programme. Innovative research combined with a fresh way of thinking produced remarkable results.

Consortium leader Frans Klijn prefers the term ‘flood risk’ to ‘flood safety’. As he puts it, “Safety refers only to victims, but floods also cause social upheaval and economic damage. And complete safety is an unrealistic aim anyway.” That is why the consortium conducted extensive research into robustness. “The point of the Delta Programme is to reduce risk and the associated costs,” says Klijn. “We asked additional questions, for example: How serious is it if things go wrong? Can we limit the impact so that recovery is faster? The research we carried out on robustness shows that that is indeed the case.”

Klijn believes that unbreachable dikes are the best example of how his consortium explored the impact of climate change on flood risk. “Our ideas are making the rounds, and so we’ve had some influence on the preferred strategies that were selected within the Delta subprogrammes,” says Klijn. He describes this influence as ‘an ant trying to move a rubber tree plant’. However, “it does show that the Dutch are slowly starting to rethink flood safety and that it’s become more generally acceptable to live with a certain amount of risk.”

Book 1 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/waterveiligheid

Jacking up existing buildings

Sometimes innovation means looking at a centuries-old problem from a new perspective.

The waters are rising, so we need to raise the dikes. But that’s easier said than done in old city centres. In the case of Dordrecht, the city’s most important flood barrier is also one of its oldest streets, Voorstraat. It would be impossible to raise the elevation of this street, which is lined with 17th and 18th-century buildings. Delft University of Technology student Joost Polman looked at the problem from a different angle. If you can’t keep the water away from the buildings, then how about lifting the buildings out of the water? After all, there are old techniques for raising buildings, known as ‘jacking up’. Polman’s research shows that all the buildings along a 1.4-kilometre stretch of street can probably be jacked up for less than 30 million euros. Major interventions in the environs – some of which could take years to complete – would then be unnecessary.

River Lek experiment

The Rivierenland Water Board had to reinforce the dikes along the river Lek in the village of Streefkerk. But space was limited. A broad dike is the solution.

A carpentry workshop abutted the dike, a property developer wanted to build housing on the same spot, and the municipal authorities did not want the village to be cut off from the river by a taller dike. The various parties involved sat down with a landscape architect and came up with a design that offers flood safety while taking all interests into account. The new design for the dike spares a number of historic buildings that would have been demolished otherwise. The municipality can also build new housing on the new, broad dike. Last but not least, Streefkerk will gain a lovely village conservation area with a view of the river. The work will be completed in 2017.

2 THEME 2 Fresh Water Supply

Knowledge is the foundation for smart water management

Much of the Netherlands is permeated by saline water, so ensuring access to sufficient good quality fresh water will be quite a challenge in the face of climate change. Local, customised solutions can make a big difference.

"This is precisely the time to explore small-scale solutions to fresh water shortages," says consortium leader Ad Jeuken. "The growing trend is for government to share responsibility for fresh water availability with users. Users themselves want this." Large-scale consumers of fresh water are under pressure, not only because of drought caused by climate change but also because of changes in regulations. For example, in a few years' time they will no longer be allowed to inject desalinisation residue into the subsoil.

The consortium has busted a number of myths. For example, fresh-water flushing – using fresh water to reduce the salinity of surface waters – is not always wholly effective. And a number of crops can handle saline water better than was previously assumed. "The knowledge that we've generated can help improve facilities and make smart water management possible," says Jeuken. "When water management bodies know which solutions are available in a certain area, they can adapt their policy accordingly."

Book 2 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/zoetwater

Wide-ranging combination of solutions

Maps of potential fresh-water measures show all the measures that can be applied in the event of a fresh water shortage. Water management bodies can see at a glance whether a particular measure is feasible.

The consortium studied various types of local measures: technology (underground water storage, desalinisation techniques, recycling of waste water), saline-tolerant crops and robustness. The detailed maps show the most effective way to use fresh water in a certain region. They indicate water availability, soil composition, water table levels and groundwater flows. The maps can be combined effectively with the Climate Effect Atlas developed by the Decision Support Tools consortium.

Fresh-water flushing not always effective

Thanks to a new technique for measuring the effectiveness of fresh-water flushing, not a drop of fresh water need be wasted.

Along the Dutch coast, saline seepage leads to high concentrations of chloride in surface water, something that is disadvantageous to farmers as it can harm crops. One of the methods used to combat salinisation is fresh-water flushing. This involves using fresh water to dilute saline surface water. Fresh-water flushing accounts for about twenty percent of the Netherlands' national water demand every year. PhD candidate Joost Delsman developed a technique for measuring just how effective this method is. He concluded that the influence of fresh-water flushing varies from one location to the next. Delsman's technique makes it possible to make smarter use of precious fresh water so that not a single drop is wasted.

3 THEME 3 Rural Areas

Better idea of future land use

Climate change will affect ways in which the countryside is used in future. Researchers are investigating what the effects will be and how they are interrelated. “We’ve brought the future a step closer,” says consortium leader Adri van den Brink.

Because climate change happens at a slow pace, it is feasible to look into the future. Which land will still be valuable agricultural property in twenty years’ time? How will climate change affect the suitability of the soil? Armed with the answers to these questions, policymakers in the agriculture and nature conservation sectors can begin preparing for the future.

The consortium developed a new spatial planning model, RULEX, that reveals changes in land use by land owners, for example because nature conservation organisations purchase land or because farmers sell off plots that have poor crop yields. Consortium leader Adri van den Brink thinks that the new model is one of his consortium’s most important products, especially because it is being used in combination with existing ecological models and a new vegetation model. “Knowing in advance which land use trends are most likely allows us to take conscious decisions that ensure that an area is well prepared.” Combining all these models offers farmers and nature conservationists the best chance of adapting to the consequences of climate change.

Book 3 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/ruralegebieden

Solidarity in the Baakse Beek basin

The Baakse Beek and Veengoot river basin can look forward to a climate-proof future, at least on paper. Thanks to the consortium’s research, well-informed decisions have been taken about the area’s future.

The knowledge and information that the consortium offered about future ecological and agricultural trends may lead to greater mutual understanding and, subsequently, to a solution. One good example is the Aaltense Goor nature conservation area, which is located in the Baakse Beek basin. Local businesses and residents were unhappy with the water board’s plans at first. After discussion and a joint visit to the site, however, things changed. “They got to see things from the same point of view and trust was rebuilt,” says process manager Arno Gosselink. “Now the parties aren’t on opposite sides anymore – they’re working together on solutions.”

Evapotranspiration can be measured

Plant and tree transpiration means a loss of fresh water. With summers becoming hotter, we need to know more about the cycle of evapotranspiration. Thanks to research, we can measure it precisely.

The high-lying sandy areas such as the Veluwe heathlands and the Salland and Utrecht Ridges, push-moraines and dunes are important areas for drinking water supply and nature conservation. But they are also vulnerable to drought because the nutrient-poor soil loses much of its moisture to evaporation. Evapotranspiration data were collected in a number of testbeds involving bare soil, moss, grass and low-lying shrub. A pinewood forest populated with Douglas Firs loses eighty percent of precipitation to evapotranspiration, and an oak forest sixty per cent. Bare sand loses only twenty-five per cent – a huge difference. Mosses are the thriftiest with water, even more so than bare sandy soil.

4 THEME 4 Climate Proof Cities

Climate adaptation in cities requires a customised approach

Climate adaptation in cities requires a customised approach. The research carried out by the Climate Proof Cities consortium has generated a vast number of new insights.

"For a long time, climate adaptation was mainly about flood safety and fresh water supply," says consortium leader Ronald Albers. "In terms of adaptation, the city was the great unknown in the Netherlands, even though most people live in urban areas, where the biggest long-term investments are also made. Heat, drought and flooding are already leading to problems in cities, and climate change will only make things worse."

The adaptation measures investigated by the consortium ranged from very small ones, for example awnings for housing, to very big ones, such as green spaces for urban communities. The measures required to tackle the heat problem depend on local circumstances, says Albers. It is further important for policymakers and urban planners to exploit the city as a dynamic system. "A city is a living entity. The trick is to interweave climate adaptation with the evolution that a city is already undergoing and to find smart methods for linking the two. When that happens, the necessary adaptation to climate change doesn't have to be expensive."

Book 4 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/stad

Bergpolder Zuid Climate Atelier

The municipal authorities of Rotterdam looked for ways to apply adaptation measures while the the 19th century Bergpolder Zuid district is being redeveloped. It was an ideal experimental setting for the Climate Proof Cities consortium.

The Bergpolder Zuid district is popular among first-time home owners and students because of its inexpensive housing. Because the district has very little vegetation and the houses are closely spaced, temperatures in summer can skyrocket. The district also suffers flooding. Researchers and local stakeholders explored which measures would be suitable for Bergpolder Zuid in various 'Climate Ateliers' One solution was to develop more parks; vegetation has a cooling effect and parks can absorb a lot of water during heavy rainfall. The many subsurface cables and pipes made this option a difficult one, however. Instead, the municipal authorities could encourage private parties to plant more vegetation, for example by replacing hard surfacing in their gardens with soil and plants, or by creating roof gardens.

Climate Adaptation App & Support Tool

The interrelated nature of the adaptation measures is made very clear by the Climate Adaptation App (CAPP), a digital application that indicates which measures could be successful in a given situation.

"The aim of the CAPP is to inspire users," says its co-designer, Frans van der Ven of Deltares. "The CAPP doesn't provide a ready-made solution for heat, drought or flooding, because the effectiveness of the measures still has to be calculated." Another tool has been developed for this purpose: the Adaptation Support Tool, which will be available in the course of 2015. This tool, an electronic design table, will allow urban planners to input adaptation measures and calculate their effectiveness. That way the ideal combination for a specific area can be found.

To use the *app*, go to :
www.climateapp.nl

5 THEME 5 Infrastructure and Networks

Networks are more inter-connected than we realised

The failure of one infrastructure network can have a knock-on effect on other networks. This cascade effect can occur in the case of flooding or extreme weather conditions. ‘Everything is interconnected.’

The consortium investigated the impact of climate change on the physical infrastructure and utility networks. There had been little research on this subject before, even abroad, says consortium leader Lori Tavasszy. “We studied the vulnerability of infrastructures and networks from different angles – for example technical and economic – and compared the outcomes.” One technical study involved a measurement method that can predict when and where a dike will be breached or a water supply pipe will fail. One of the economic studies focused on the cost to the economy of lost travel time when a motorway floods. The consortium also addressed governance issues: a role-playing game for decision-makers showing how policymakers deal with uncertainty in spatial planning.

“Our studies made stakeholders aware of the vulnerability of the infrastructure and networks and how they are interconnected.”

Book 5 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/infrastructuur

Vulnerability of the drinking water network

The water supply grid is vulnerable to climate change; subsidence caused by drought can damage pipes.

Bas Wols of KWR Watercycle Research Institute studied the risk of pipe failure caused by drought. “Certain types of pipe materials are sensitive to drought. These materials predate PVC, which has been used for pipelines since the 1960s and 1970s.” Wols believes that climate change will not lead to excessive pipe damage. “At most, we’ll see an increase in damage to the grid of ten per cent a year compared with the normal rate of failure.” The results produced valuable information for drinking water supply companies, he says. “It means they can schedule earlier replacement of pipes in vulnerable spots, and make the entire water supply grid more robust.”

Analysing weak peat dikes

Will the Netherlands’ 3500 kilometres of peat dikes stand firm in extreme weather conditions? A new computational model calculates the stability of the dikes for various national climate scenarios.

The model calculates whether the area in which the peat dike is located will become wetter or drier. The researchers also look at other factors, such as the dimensions and structure of the dike and the water table. “That will make it possible to reinforce the dikes in order to avoid a breach like the one in Wilnis in 2003”, says Deltares researcher John van Esch. “We can also use the model to analyse the stability of a peat dike based on a weather forecast.” Strikingly, the biggest problems would only arise after the water recedes. The waterlogged substrate could destabilise the dike. The risk of subsidence also increases when there is a ditch or canal alongside a body of soil. Drainage ditches should therefore be situated further away from dikes than is now customary.

6 THEME 6 High-Quality Climate Projections

We've narrowed the gap between theory and practice

There is a lot of uncertainty about what our weather will be like in future. On top of everything else, the data are often highly technical. Thanks to collaboration with stakeholders and visualisation methods, researchers managed to turn climate data into information for practical use.

The Royal Netherlands Meteorological Institute (KNMI) develops scenarios that depict how the climate will change in future. The latest set of projections was published in 2014, known as the KNMI'14 scenarios. The High-Quality Climate Projections consortium made an important contribution to the new scenarios, for one thing by talking to many different users in order to discover which information they actually need. Consortium leader Arnout Feijt is proud that the climate scenarios are being used as the basis for the Dutch climate adaptation policy. "We're trying to make the climate data as consistent as possible. That's very important in our crowded polder landscape."

Thanks to the many conversations with users, the gap between theory and practice has become narrower, says Feijt. "We've developed tools that make climate data comprehensible, despite all the related uncertainties. The Future Weather project is a good example in that respect. Its colourful animations show what the weather may be like in future. The visualisations make an enormous impression, because they bring to life what the consequences of climate change could be."

Book 6 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/klimaatprojecties

Future Weather

The inevitable question after extreme weather incidents is: Is this a sign of climate change? Can we expect this to happen more often in future?

Caravans sent flying through the air by gale-force winds in Vethuizen. Farmers who are forced to evacuate their cattle when a flood hits Noorderzijlvest in the Province of Groningen. A heavy downpour in the village of Hupsel brought about by tropical air currents. The Future Weather project has tried to explain the changes by looking at a number of different variables, i.e. extreme rainfall of short duration, precipitation on the coast, and high water levels in rivers combined with a storm surge. "Future Weather involves high-resolution 3D visualisations of weather conditions that have yet to occur or that we have yet to experience," says Bart van den Hurk of the KNMI. "These are situations that may have huge consequences for society. The visualisations help local stakeholders prepare for extreme situations like the ones depicted."

Climate information in a handy atlas

Climate adaptation professionals want to know what impact climate change will have on their sector or region. The Climate Effect Atlas consists of a set of maps showing the potential consequences.

The maps that make up the Climate Effect Atlas show precipitation, temperature, flooding, flood safety, drought, heat in urban areas, and the consequences for agricultural and nature conservation areas. The Atlas helps climate adaptation, water management, spatial planning and environmental professionals answer climate-related questions and draw up adaptation strategies. The Atlas can be used as a basis for developing regional adaptation strategies. Municipal authorities can attend Climate Ateliers in which they work with the Atlas at district or street level.

klimaateffectatlas.wur.nl

7 THEME 7 Governance of Adaptation

No shine without friction

Knowledge for Climate was the first major climate research programme in which governance was given a prominent place. “We wanted to show the governance side of climate adaptation.”

Climate adaptation benefits from close cooperation between the parties involved. But governance is more than that, says consortium leader Katrien Termeer. “It also means linking decision-making and research, developing smart tools and designing funding structures. Governance also involves dividing responsibilities between public and private parties and it covers normative principles such as solidarity, types of leadership and keeping climate change on the political agenda. In the international context, governance is about cooperating with neighbouring countries and harmonising with EU legislation.”

Practitioners, for example policy makers, often ask us whether it’s at all possible to research governance. “What we do lies close to their daily work, but we look at the topic with a broader perspective. We include international examples and experiences from other policy fields. Moreover, we look at governance from a range of disciplines, such as legislative, economics, spatial planning, administration and politics.

Conflicts are sometimes a necessary part of the policymaking process, says the consortium leader, and it also happens that parties need to be excluded on purpose to actually achieve a result. “Governance doesn’t mean getting everyone together in the hope that things will work out. That’s a naïve idea.” She quotes the title of a thesis authored by her colleague Arienne van Staveren: “No shine without friction.”

Book 7 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/governance

Multilevel safety

Dikes are not the only way to combat flooding. Flood safety is a multilevel affair and can best be tackled in cooperation with all the parties in vulnerable areas. Sometimes it’s even cheaper that way.

The Island of Dordrecht will be facing more floods in future unless the authorities invest heavily in new flood barriers. One alternative to building expensive flood barriers is multilevel safety, which involves three elements: flood protection (first level), sustainable spatial planning to limit the impact of flooding (second level) and disaster control (third level). Multilevel safety can be achieved by governments working together on disaster plans and coordinating their spatial planning agendas. It is also important to inform the local community. By communicating with local residents about the risks, the authorities can make them aware of their responsibility and get them to take steps themselves.

Coercion is more effective than incentives

Green roofs are welcome newcomers in cityscapes. But the spread of green roofs will never take off without government intervention. Examples from abroad show that coercion works.

‘Coercion’ has become almost a dirty word in the Netherlands, but sometimes it is the best way to get things done. That became clear in a comparative study conducted by Heleen Mees of Utrecht University on encouraging green roofs in urban environments. Mees compared how the cities of Stuttgart, Basel, Chicago, London and Rotterdam supported the construction of green roofs. Basel and Stuttgart have gone the furthest in terms of intervention by the authorities, whereas Chicago, London and Rotterdam have left much of the initiative to the private market. Green roofs cover twenty-five times as much surface area in Basel and Stuttgart than in the other cities. “Starting out with non-coercive measures, for example a subsidy for green roof construction, and effective communication draws in the innovators. After a trial period, it isn’t a problem to scale up implementation by introducing mandatory requirements.”

8 THEME 8 Decision Support Tools

The most cutting-edge tools imaginable

Which climate adaptation measure is best? Thanks to advanced tools and methods, policymakers are now able to answer this question and even calculate the degree of uncertainty involved.

The Decision Support Tools consortium has worked to make the consequences of climate change obvious and clear. The tools and methods that the researchers developed or improved can be used by anyone involved in decision-making about climate adaptation. “We have equipped professionals with the most cutting-edge tools imaginable,” says consortium leader Ekko van Ierland. “The Netherlands is setting the pace in that regard. In fact, we’ve had a lot of interest from abroad in some of the tools we developed, for example the *Climate Effect Atlas* and 3Di.”

Climate models, methods and tools are often fairly abstract in nature and hard for non-scientists to understand. The consortium has succeeded in making climate change real. Tools such as the *Climate Effect Atlas* and the Touch Table visualise the consequences of climate change. “Some of the visualisations are accurate down to the hectare,” says Van Ierland. “These tools are very useful for the authorities and other users who need to know whether they have to prepare for climate change.”

Book 8 (in Dutch) is available for download at
www.kennisvoorklimaat.nl/oogst/instrumenten

Sitting down at the Touch Table

Where do policymakers turn when they want to start developing a climate adaptation strategy for their area? How do they make sense of all the available scientific information when so much of it is difficult to comprehend? The Touch Table is one solution.

The Touch Table and its interactive maps provide striking images of the consequences of a climate adaptation measure. The stakeholders explore the future of their area in question during interactive sessions. Potential adaptation measures can be sketched out immediately. “The images on the screen can be real eye-openers,” says ecologist and emeritus professor Jos Verhoeven. According to project leader Ron Janssen, what is innovative about the Touch Table is that it encourages interaction between scientific techniques and the people who use them. “It’s very important to provide scientific information incrementally. People may get overloaded if you give them too much information at once.”

Flood damage

Flooding not only causes damage; it can also lead to public unrest. The social media can aggravate the situation. Research has revealed what happens in a population and the economy after a flood.

The level of unrest influences the extent to which the Government intervenes with new measures. “People today communicate with one another in all sorts of ways, and all that communication can aggravate the sense of unrest,” says Trond Husby, PhD candidate at the Institute for Environmental Studies. “Television and the social media feed the worry.” The consequences of public unrest aren’t counted as damaging effects of floods at the moment. When we take indirect damage of this kind into account, the cost of a flood suddenly becomes much higher. Knowing this can help the authorities decide which measures should be taken to protect areas. The higher cost of flooding owing to indirect damage justifies investing more money in flood control.

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