



Knowledge
for Climate

Climate Change in Water Management



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Climate Change in Water Mangement

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Netherlands Commission for
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This project was co-financed by MER and CPWC

KfC report number

KfC KfC 027/2010

Dit onderzoekproject (KKF02A.; NAS development and implementation support) was carried out in the framework of the Dutch National Research Programme Knowledge for Climate (www.knowledgeforclimate.org). This research programme is co-financed by the Ministry of Housing, Spatial Planning and the Environment (VROM).



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Executive Summary

This report summarizes an inventory of methods and tools for assessing climate change impacts, vulnerability and adaptation options, focusing on the water sector. Two questions are central: What are the opportunities for international applications of Dutch methods and tools? And: Which methods and tools available abroad are suitable for application in The Netherlands? Our main conclusions are:

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1. *Many tools assisting in climate change adaptation are available but most of them with limited applicability.* The process of adapting to climate change can be roughly divided into three steps: impact assessment, selection and design of adaptation options, and evaluation of these options. Especially for assessment of climate change impacts and vulnerability a large range of tools is available. Only a very limited amount of tools, mostly datasets are available for the selection and design of adaptation options. There is a number of guidelines available covering the complete adaptation cycle but for a thorough assessment these guidelines are usually not sufficient and/or they guide you to additional tools.
2. *Integration of climate change into broader decision making is a major challenge.* Climate change is only one of the many issues policy makers need to cope with and therefore climate change adaptation should be integrated into broader current policy making tools, such as Strategic Environmental Assessments (SEA) or Integrated Water Resources Management (IWRM). This requires more attention to participatory and other “bottom-up” approaches in addition to the currently dominant natural-science centered top-down approaches.
3. *Existing Dutch capacity has to be further mobilized for international applications.* All steps of the adaptation development cycle are covered in the Netherlands in principle, but not in practice. While much knowledge is available on climate change impacts and adaptation in The Netherlands, it is not yet widely mobilized for application abroad. Hence, the challenge is to increase the ability and interest to get involved in international climate proofing exercises in practice. Opportunities for this include the “hot spots” under KvK/Delta Alliance, “Water Mondiaal”, and the Connecting Delta Cities programme, as well as the expected market to apply the capacity at transboundary (EU Water Framework Directive, UN ECE), national (UNFCCC – NAPA implementation) and local level (municipalities, regional, sectoral). Knowledge for Climate research projects could increase attention to the international transferability of produced knowledge in its current and future national projects.
4. *Integration and packaging rather than new tools.* Integration, packaging and visualization of knowledge existing in Dutch knowledge institu-



tions may provide better opportunities for international application than developing new tools. The toolbox would have to include a diverse set of not only top-down, but also resilience-oriented bottom-up tools to be able to match specific adaptation and climate-proofing questions, while components of the toolbox would have to be strengthened by incorporating a larger set of specific, practical, hard and soft adaptation options. Partnerships with the private sector to amplify applications are as yet underdeveloped in The Netherlands.

5. *Foreign tools can be integrated into the toolbox and can form inspiration for local applications.* Not all tools in the toolbox have to be fully Dutch-made. Especially in the area of climate scenarios and impacts modeling, foreign tools and datasets are available that can be used for free or for a small license fee. For research purposes, e.g. in KvK, foreign methods and tools can provide very useful new insights and inspiration for strengthening Dutch approaches. Guidance for practitioners coupling specific methods and tools to specific policy questions and adaptation problem types at different temporal and spatial scales would facilitate application.



1 Background, objectives and introduction

Background

As the evidence of climatic changes accumulates and impacts are increasingly observed, countries around the world have started to develop adaptation plans. The Intergovernmental Panel on Climate Change (IPCC) has identified the developing world as the most vulnerable to the impacts of climate change and the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC) urges the need for capacity development in particular in countries vulnerable to climate change. The European Union in its White Paper lays out a timeline for the preparation of a European Adaptation strategy. In response, many methods, tools and guidance documents for assessing impacts, vulnerability and climate adaptation have been developed for local, national and regional application.

This report was prepared at the request of the research programme Knowledge for Climate (KvK), the Co-operative Programme on Water and Climate (CPWC) and the Netherlands Commission for Environmental Assessment (MER). It presents a framework for adaptation and presents methodologies, methods and tools that are available internationally to assess potential climate change impacts, vulnerability and adaptation options. Then, it discusses the capacity of Dutch knowledge and tools to support climate change adaptation planning internationally, and the opportunities of tools available elsewhere to strengthen Dutch adaptation research and policy.

KvK aims not only at supporting the development of adaptation strategies in a number of national vulnerable hotspots by providing targeted scientific and technical knowledge, but to a limited extent also supports adaptation strategy development abroad, in particular in delta regions, in the context of the Delta Alliance. CPWC aims at improving the capacity in water resources management to cope with the impacts of increasing variability of the world's climate by building bridges between different scientific disciplines and stakeholders, enhancing the development of coping strategies for climate change and variability in general, but also with a focus on application in the five delta countries of the "Water Mondiaal" programme. The MER Commission is an independent advisory body that on request advises authorities on Strategic Environmental Assessment (SEA) for strategic policy-making. Since 2007 the Commission incorporates climate change considerations in its advisory reports, for example for coastal development in Mozambique or for a provincial land use plan in Vietnam. SEA has already a legal basis in about fifty countries and the number of countries is growing rapidly. SEA provides a very good approach to assess the vulnerability for climate change impacts, identify, design and evaluate adaptation options for sector and provincial plans and policies.



For all the above institutions it is important to understand the potential of methods and tools for supporting adaptation to climate change, which are available in The Netherlands, for application in other countries, particularly in developing countries. For Knowledge for Climate, it is also relevant to understand which methods and tools that are available elsewhere may be applied or adopted in The Netherlands, to avoid starting the development of such methods and tools from scratch in The Netherlands.

This results into two main questions, which are both addressed in this report:

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- What are the opportunities for international applications of Dutch methods and tools?
- Which methods and tools available abroad are suitable for application in The Netherlands?

These questions were addressed via the following four steps:

1. An inventory of available methodologies, methods and tools for assessing climate change impacts, vulnerability and adaptation, including climate-proofing of plans;
2. The selection of a framework for structuring and evaluating the methodologies, methods and tools;
3. The assessment of opportunities for Dutch methods and tools to assist with adaptation and climate proofing abroad;
4. The assessment of opportunities provided by methods, tools and methodologies available abroad for strengthening Dutch adaptation research and policy.

In evaluating the methods and tools, we used a number of criteria. Dutch methods may be candidates for application abroad, if they fill a niche because no or few competing methods and tools are available, or if the Dutch methods and tools clearly have an added value over those available elsewhere. In addition, their developers should have an interest in expanding the scope of application and the ability to do so (e.g. KNMI has legal constraints with respect to commercial applications), and it should take relatively little resources to make these Dutch methods and tools suitable for such applications in a foreign context. We consider those foreign methods and tools to be interesting for application in the Netherlands if they can be easily adjusted to match Dutch circumstances, if they are scientifically up-to-date, readily available, and if there are no, or inadequate Dutch equivalents. Because of the enormous variety in methods and tools, and uneven information about the various aspects covered by the criteria above, in practice it appeared difficult to apply these criteria systematically, and they were used more loosely to arrive at our conclusions. Also, the usefulness of a tool often depends on the specific question to be addressed and the area



of application. Therefore a very detailed analysis of each individual tool that was identified was not considered useful for the purpose of this report..

The questions relate to two separate subprojects of the KvK project “Building Blocks National Adaptation Strategy”, the terms of reference of which are attached to this report as Annexes 1 and 2 (in Dutch). Since the two questions are closely related and the sources of information similar, this report addresses both questions and thus integrates both subprojects. The initiative for this project was taken by the three partners, with the intention to present the outcomes to and follow up with relevant parties, including representatives of Water Mondiaal, capacity building institutions (UNESCO-IHE and others), consultants, and researchers involved in the KvK programme.

In this report, first we will discuss the definition of key terms, determine the scope of the inventory, present a framework for the development of adaptation policies or climate-proofing options, present criteria for evaluating relevant methods and tools, and describe the methodology used for the inventory. Then we will present and discuss the inventory of available methods and tools, and finally critically evaluate the usefulness in the context of the two above questions.





2 Methodology and framework

2.1 Methodology

The search for methodologies, methods and tools included a literature review, internet search, team members networks, and the results of meetings with an advisory committee. In addition to the search for individual methodologies, methods and tools, the report also draws upon a number of other inventories that were recently compiled, with usually a slightly different context and focus, such as Dickenson (2007), Garg et al. (2007), Kay and Travers (2008), Takama et al. (2008), and UNFCCC (2008). At the start of the project, the objectives, scope, initial inventory and work plan were discussed on the basis of an annotated outline of the report with the Advisory Committee (see Table 1). Halfway through the project, a 2nd meeting was held with the Advisory Committee with a more detailed assessment of promising methods and tools, an overview of policy needs to be addressed with the tools and methods, and a discussion on a framework for adaptation and climate proofing. A final draft was presented to a broader group of stakeholders and their recommendations were taken into account in the current report. Figure 1 presents the project steps and advisory meetings.

Table 1: Project Advisory Committee

Project Advisory Committee	
Arend Kolhoff	MER Commission
Raimond Hafkenscheid	CPWC
Henk van Schaik	CPWC
Cees van de Guchte/Dick van den Berg	Deltares



2.2 Definitions

This inventory focuses on methods and tools. How can these be defined? The UNFCCC (2008) uses the following definitions:

- *Methodology/approach*: complete framework that prescribes an entire process for the assessment of vulnerability and adaptation and offers a broad strategic approach. An approach in some instances assembles certain methods and toolkits to support this process. Examples include: IPCC Technical guidelines (1994), NAPAs guidelines (2002), Adaptation Policy Framework (2004).
- *Method*: A set or sequence of steps that should be followed in order to accomplish a specific task within a larger framework. Method can be implemented through using a number of tools. Examples include: Methods for development and use of scenario data in the vulnerability and adaptation assessment, e.g. those presented in the UNEP Handbook (1998) and IPCC-TGCIAGuidelines on the Use of Scenario Data for Climate Impact and Adaptation Assessment (1999).
- *Tool*: A means or instrument by which a specific task is accomplished. Examples include: regional climate models (RCMs), impact models, decision (support) tools, stakeholder tools.

According to the terms of reference of this project and using the above definitions, the emphasis would be on the last two categories. However, “methodologies” or generic “approaches” applied elsewhere can be quite different from those applied in The Netherlands, or the other way around, offering interesting opportunities for application of different approaches and knowledge exchange. In consultation with the Advisory Board of the project it was decided to include key examples of all three categories in the assessment, rather than attempting to comprehensively cover all methods and tools available around the world for only the latter two categories.

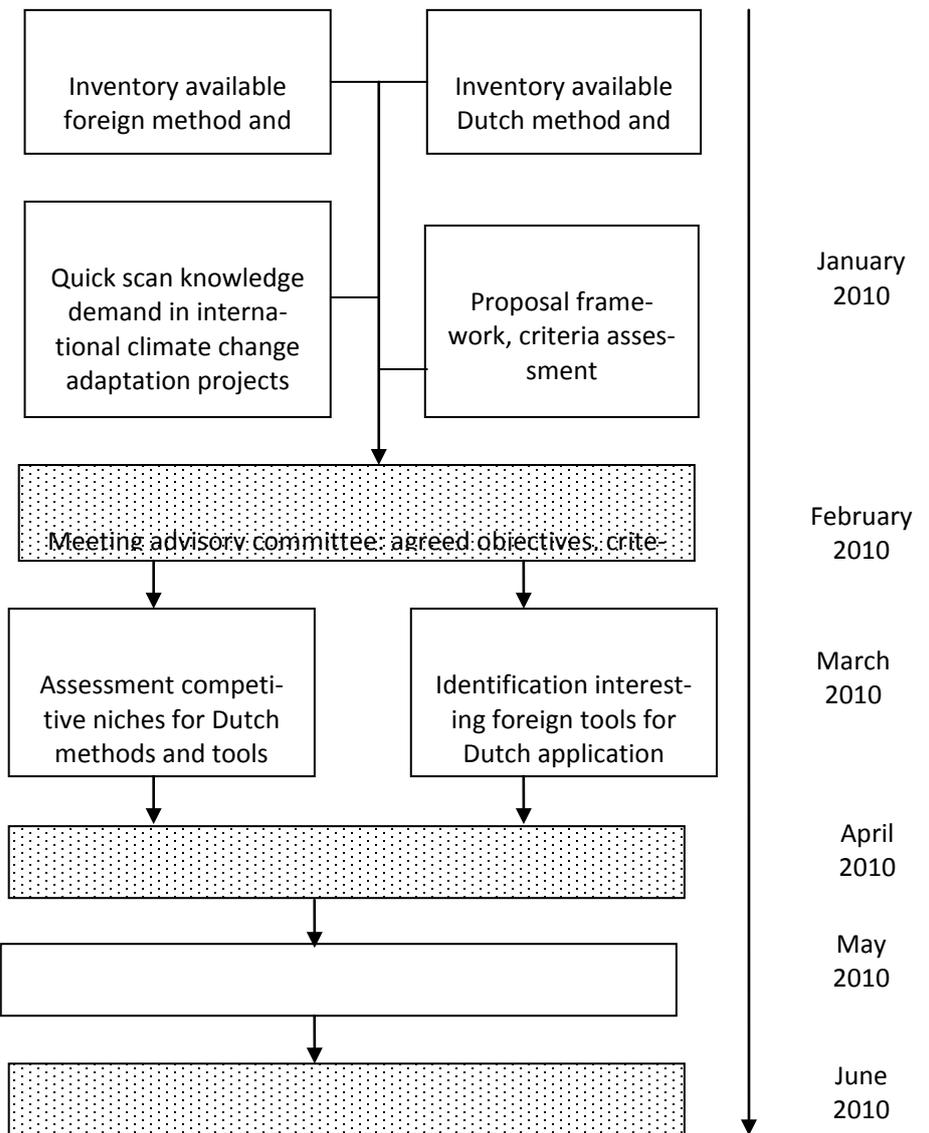


Figure 1: Project schedule international inventory project

2.3 Scope

2.3.1 What does this inventory include and what not

Following the terms of reference, we included methodologies, methods and tools that can be used to assess potential climate change impacts, vulnerability and adaptation options. This implies that we do generally NOT include methodologies, methods and tools that do not specifically address climate



change, such as hydrological models that do not take into account climate change.

We followed the recommendation of the Advisory Committee to focus on methods and tools available in the English language, because in general Dutch researchers, experts and consultants operate in networks which do not focus on regions where English is not understood. While our inventory did not per se exclude methods and tools in other languages, we did not identify interesting ones during this study.

The emphasis is on sectors which were identified as of particular importance for KvK, CPWC and the MER Commission: water management (safety, fresh water supply), spatial planning and land use at the regional level in low lying coastal areas in general and in urbanized deltas in particular. Hence NOT included are methodologies, methods or tools in the area of agriculture, health, ecosystems, urban management and other sectors, unless they were identified in the margin of the above mentioned focus, e.g. if there is a clear relation with water management or spatial adaptation: no comprehensiveness has been pursued for these sectors. The same applies to methods and tools that specifically target local applications (e.g. level of communities, citizens).

According to the terms of reference, the inventory would focus on methodologies, methods and tools which should have been applied successfully in real-world situations to support adaptation action. Already in the initial stages of the work it was found that particularly for methods and tools related to adaptation, still very little experience exists, and hence this constraint was relaxed a bit and also interesting methods and tools without practical application as yet were included.

2.3.2 Different types of impacts/adaptation models

In the gradual development of climate science and climate policy, the focuses shifted from questions about the reality and the causes of climate change to mitigation questions, and to local impacts. Only recently the attention moved to adaptation, with the obvious consequence that adaptation centered models, which are the most relevant for the current project, are not yet widely available. Most adaptation models available now are either integrated assessment models which sometimes incorporate adaptation options in a rather aggregate manner, or tools that can be applied to evaluate the characteristics of specific adaptation options.

Using the broad definitions above, types of methodologies, methods and tools can include integrated assessment models, cost-benefit analysis, scenario analysis, downscaling of climate projections, guidelines for adaptation



planning, evaluation frameworks, participatory methods, analytical tools such as climate- and impact models, and GIS-applications.

2.3.3 Two complementary, different approaches

In terms of scope it is important to recognize that there are two very different ways in which the issue of climate change adaptation can be approached. Because climate change has been framed from the perspective of a global problem that can have regional and local effects, in the area of climate change research and policy a “top-down” approach is usually followed, in which global climate projections are downscaled and used as input for the assessment of regional or local physical vulnerability (water scarcity, flood risk, etc.). Adaptation options are then generated that most efficiently or effectively reduce the vulnerability (Figure 2). This classical approach has been called the “predict-optimize-act” approach and can be regarded as framing the problem through a “climate lense”. The popular figure 3 (adapted from the EEA), followed from the top to the bottom, is an example of this top-down approach. At the same time this framework does acknowledge that vulnerability can be reduced by directly increasing the adaptive capacity and improving capacity which are key factors in a bottom up process. However, in most applications of this framework for evaluation of vulnerability and adaptation options, adaptive capacity is not included in practice because commonly agreed methods to quantify adaptive capacity do not exist.



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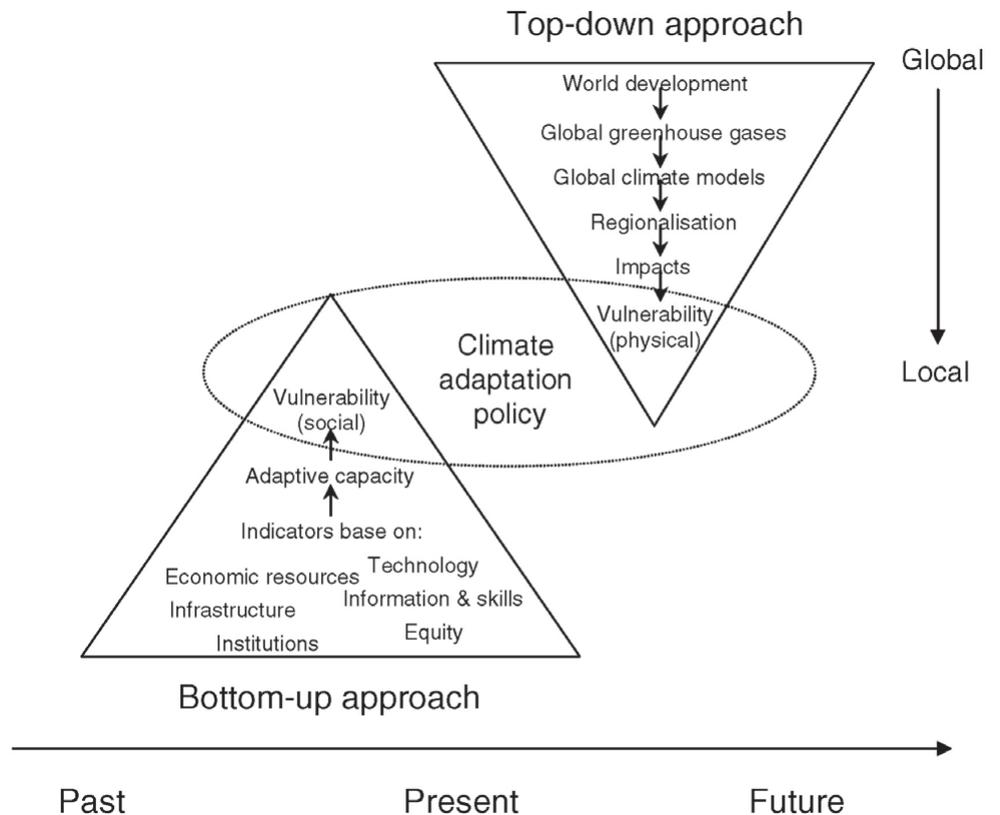


Figure 2: Bottom-up and top down approaches to climate change adaptation (Dessai and Hulme, 2003)

From a different perspective, at the local level, or in particular sectors, development plans are being developed on which climate change could have an impact. Especially sectors or regions which are already vulnerable to current climate variability do take climate change into account, sometimes well before specific adaptation plans were developed. This “bottom-up” approach departs from socio-economic developments, adding climate change concerns as one out of many possible stress factors (“assess-risk-of-policy” approach, approaching the problems through a “development policy lense”). In the area of climate change adaptation, the emphasis in developing and applying methods and tools has largely been concentrated in the top-down category. Because this is not necessarily the most appropriate method to address all relevant adaptation-related questions, we also explored the availability of bottom-up methods and tools.

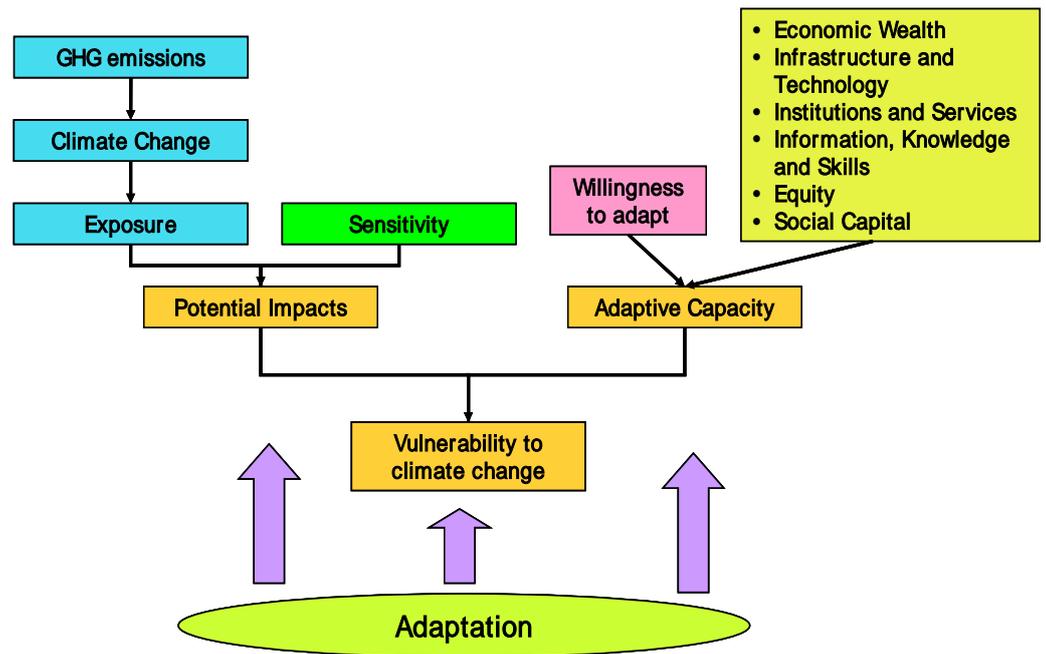


Figure 3. Conceptual diagram showing the interaction between climate change impacts, vulnerability and adaptation. Important in this framework is that vulnerability is determined by both potential climate change impacts and adaptive capacity. Adaptation strategies or measures can focus on directly reducing the impacts or sensitivity or by improving the adaptive capacity. (adapted from Isoard et al.,2008)

In real life, climate adaptation measures and policies are not limited to the interaction-zone between the ‘top-down’ and ‘bottom up’ triangles. Interaction exists at all levels also in early stages. Adaptation measures and policy decisions have existed for centuries. For example, irrigation systems have existed for more than thousands of years. Climate adaptation can often be seen as incremental ‘add-on’ to the existing policy making process. In some regions and sectors, tipping points can exist above which impacts of climate change are so severe that such incremental changes are insufficient. We therefore argue that both approaches should be used in a complementary fashion in support of climate change adaptation action and “climate proofing” of projects and plans. The classical top down approach is primarily based upon scientific information from the natural sciences (climate and impacts data, models and scenarios), sometimes complemented by socio-economic and governance information to assess vulnerability and sometimes adaptive capacity. The bottom up approach for developing adaptation options and making choices can be considered as a guided societal consultation process between stakeholders, in order to arrive at preferred and socially accepted risk management policies, strategies and adaptation actions. Limited, contradicting or inconclusive information about the direction or magnitude of climate change does not necessarily prevent the development of adaptation strategies in a bottom-up manner. At the same



time, such information is very useful when available, and we note that many methods and tools which are traditionally applied in the top-down approach (e.g., from IPCC, EEA, KNMI) can also be applied to support decision-making in the bottom-up mode.

2.3.4 Climate adaptation and climate proofing

There is quite some confusion about “adaptation” and “climate proofing”. As we have observed above, full “climate proofing” against all possible climatic changes is not realistic, and we define “climate-proofing” as increasing the resilience of policies, programmes, and investment projects against a wide range of possible climate change scenarios. The term is often used in a Dutch water safety context (e.g., Kabat et al., 2005), but as yet not much beyond that. According to Kabat et al. (2005), “climate proofing does not mean reducing climate-based risks to zero — an unrealistic goal for any country. The idea is to use hard infrastructure to reduce risks to a quantified level, accepted by the society or economy. This risk can be further combated by ‘softer’ measures, such as insurance schemes or, as a last resort, evacuation plans. Such climate proofing should be driven by opportunities for technological, institutional and societal innovations, rather than purely by fear of the negative effects of climate change”. In this sense, it is very close to “adaptation”, defined by the IPCC as “initiatives and measures to reduce the vulnerability of natural and human systems

against actual or expected climate change effects.” Because the term “climate-proofing” is not widely accepted internationally, but is defined very similar to adaptation, we use both interchangeably.

2.3.5 Different tools for different stages in the adaptation cycle

Methodologies, methods and tools can be applied in different phases of climate adaptation policy development and implementation. The cycle of vulnerability/impact assessment – development of options and evaluation and review has been structured in the literature in many ways, usually based on the environmental policy cycle framing developed in the 1970s. One of the early frameworks to structure adaptation policy development was designed for the UK Climate Impacts Programme, and widely used in the United Kingdom (Figure 4a). For the project “Building Blocks National Adaptation Strategy”, a three-step cycle was applied (Figure 4b, Goosen, 2009). The three steps identified are assessment of impact, design of adaptation options and evaluation of strategies, and reflect the steps 3, 4, and 5 of the UKCIP framework. Like in the other projects of “Building Blocks National Adaptation Strategy” we focus on these three steps, because this is the part of the full cycle on which current policy questions and methods and tools focus. Most of the current methods and tools are applied after



the problems have been recognized and the political objectives have been set, and criteria established (steps 1 and 2 of the UKCIP cycle). We did also not specifically focus on steps 6-7 of the UKCIP cycle, because methods and tools required for the actual implementation (like policy instruments) and monitoring and evaluation of policies and adaptation action, have as yet been poorly developed in the current early stages of adaptation policy development. We have evaluated in our inventory in which of the three categories the tools would fit best.

In addition to developing tools specifically for climate change adaptation, another approach is to include climate change adaptation into existing tools and/or decision frameworks. As discussed above, in many cases climate change is only one the many issues governments need to deal and as such integrating climate change adaptation into existing policy cycles could be more efficient. For example, climate change adaptation could be integrated into Strategic Environmental Assessments (SEA) or Integrated Water Resources Management (IWRM).

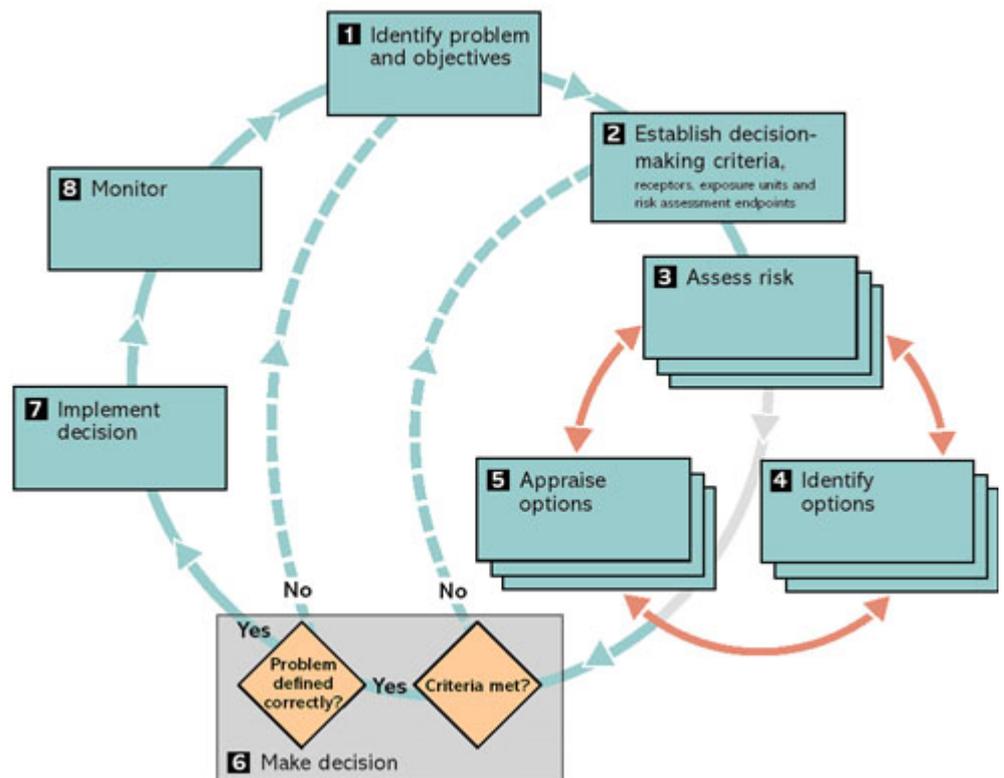


Figure 4a Policy cycle according to the UKCIP adaptation wizard (<http://www.ukcip.org.uk/>)

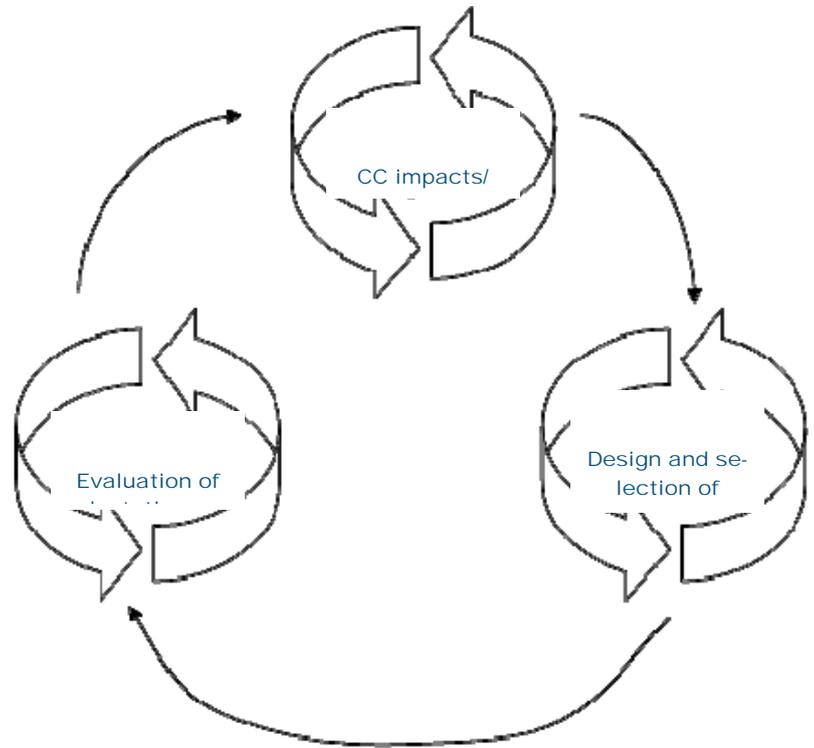


Figure 4b. The three important stages in the process of developing adaptation strategies following a top-down approach: assessment of (regional/local) impacts of CC, designing possible adaptation options, and evaluation of strategies (adapted from Goosen, 2009)

2.3.6 Integrating climate change adaptation into policy-making tools

In addition to the “tools” that provide information specifically for climate change adaptation, climate change information needs to be used in water management decision making processes such as IWRM or SEA (See Figure 4a). In many cases climate change is only one the many issues for water managers (whether in government, civil society, or private sector). Other factors include population growth, economic development and land use change all implying changing demands for water resources. Strategic Integrated Water Resources Management (IWRM) and Strategic Environmental Assessment (SEA) are approaches available to support the integration of climate change adaptation in basin/country/locally specific sectoral plans and policies. These approaches are complementary and can be applied simultaneously in order to benefit from each others strengths as stipulated by the 5th World Water Forum, Istanbul 2009:



IWRM, with special focus on adaptive management, provides an obvious framework for climate change adaptation, and should be considered in combination with strategic environmental assessment (SEA)

Because of the water focus of this report, below we elaborate on this point.

Strategic Environmental Assessment (SEA)

SEA is an approach that identifies and addresses the environmental consequences and stakeholder concerns in the development of policies, plans and programmes. The definition of environment depends on the scope of the SEA, and ranges from the sole biophysical environment to encompassing biophysical, social, economic and institutional environments. Although the latter broader definition may lead to more effective results, lack of knowledge or of agreed methods and tools on socio-economic and institutional dimensions often limit applications to biophysical factors. SEA aims at better strategies, ranging from legislation and countrywide development policies to more concrete sectoral and spatial plans. SEA assists in identifying, assessing and comparing the different ways in which a policy, plan or programme can achieve its objectives.

The strength of SEA is that in the European Union and in a growing number of countries it is a legally embedded tool, with clearly demarcated roles and responsibilities (EU – SEA directive 2001/42/EC) figure 5). Furthermore, there is a strong common understanding of what good SEA practice is. Transparency and stakeholder participation are core values, supported by an increasing evidence base of good practices. The main weakness of SEA lies in the contents. SEA in itself has relatively little content, but provides the procedural umbrella under which a variety of tools have to be used. Other tools described in the report can be used as part of the SEA to identify climate change vulnerabilities and potential adaptation measures.

Ideally these adaptation measures are building blocks for the alternatives that are assessed and compared in the SEA. Climate change adaptation is only one of the interests that needs to be balanced with the costs and benefits of other interests, SEA providing therefore an opportunity for a balanced and well-informed decision. Experience shows that SEA for sub-national spatial plans provides the best opportunity to identify and select the necessary adaptation measures (OECD-DAC SEA, 2008).

Integrated Water Resources Management (IWRM)

IWRM has been the accepted management paradigm for efficient, equitable and sustainable management of water resource since the early 1990s. The WSSD (2002, Johannesburg) agreed that all countries should have an IWRM plan by 2015. IWRM is a process that promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner, without compromising the sustainability of vital ecosystems.



IWRM could potentially be used to implement climate change adaptation in the water sector. Guidance from the Global Water Partnership considers the IWRM as suitable to include climate change in particular for trans-boundary water resources management, but does not provide specific guidance on how to incorporate climate change into the IWRM process (GWP, 2007). The strength of IWRM is its well-developed and highly structured approach, capable to cope with the multi-functionality of water, based on quantified data. Its weakness is a lack of formal procedural requirements to implement IWRM and, consequently, weakly implemented process aspects, such as public participation. A further disadvantage is that other sectors are unaware of the principles of IWRM.

Linking SEA and IWRM

According to the Perspective Document “Integrated Water Resources Management and Strategic Environmental Assessment - joining forces for climate proofing” (Slootweg, 2009), it is apparent that IWRM and SEA share the same principles, but both instruments have a complementary scope of work. IWRM provides in-depth sector knowledge and a comprehensive framework to develop relevant knowledge, SEA, because of its legal status, is best equipped to facilitate a process to influence decision-making (Slootweg, 2009). The legal backing of SEA provides the necessary entry point in a planning process to get the IWRM message on water management across. A national climate change policy can facilitate the integration of adaptation to climate change in IWRM and SEA. This policy ideally contains information concerning:

- Expected climate changes for the medium and long term;
- Risks to the society (population and economy);
- Vulnerability of the different areas and land use types;
- Objectives such as safety levels that need to be achieved;
- An identification of possible adaptation options.

In conclusion, there is clear scope to further elaborate the added value of bringing IWRM and SEA together when discussing the implementation of climate change adaptation. Because SEA and IWRM come from different disciplinary backgrounds (and are “owned” by different Ministries), there is a need to bridge their separate, but overlapping perspectives, terminologies and communities. Several of the tools described in the report can be used to feed support this bridging process and make the required information available for the associated policy process.



tegrating activities, and creating a network of dedicated individuals and organizations.” As a starting point, KVK specifically initiates projects with partners in California, Indonesia (see Box 1), and Vietnam. The information in this report can help developing the basis for further work in the Alliance.

Box 1: Demand for methods and tools for water-related adaptation to climate change and climate proofing in Indonesia

In March 2010, an international workshop in Indonesia on methods and tools marked the start of the development of a toolbox on adaptation for use in Indonesia and other countries. Elements of this toolbox would be:

- Advanced modeling capacity of the climate-hydrology system (includes data analysis; concentrates on extreme events; includes scenario and down scaling; with attention for the boundary condition: (joint?) computing facilities).
- Monitoring and assessment (including combinations of remote sensing and field observations; from rainfall to impacts of climate change in the water sector: drought, morphology etc.).
- Development of tools for management of water and land (including carbon stocks and flows; including interaction natural-social science).
- Development of communication for science, policy and public (including training at various levels: academic - general public/NGO; through master classes, workshops, seminars, dedicated training on e.g. GIS, measurement techniques, using data and models in daily practice of farmers, etc.; and increased stakeholder involvement in projects).
- Share experiences (with methods) in adaptation between countries on a regular basis through seminars, networking (e.g. Delta Alliance), joint research, etc

Source:CPWC, 2010

- *Strategic Environmental Assessment (SEA)*. As discussed in section 2.3, SEA and Environmental Impact Assessment are rapidly gaining ground as a legal mechanism for integrating environmental considerations into policies, plans and programmes and evaluate their linkages with economic and social considerations (Figure 5). This offers immediate opportunities to include climate consideration when developing climate-proof policies, plans and programmes.
- *Climate and Development Knowledge Network (DFID, 2010)*. The UK Department for International Development (DFID) is initiating the establishment of a Climate (and Development Knowledge) Network, “a facility to improve developing countries’ access to world-class exper-



tise, helping them build climate-resilient economies and societies. The Climate Network will enable developing countries to access, interpret and use the latest research, science and other relevant information. It will support their policy-making and practice on adaptation and low carbon development, and help build their own (developing country) research capacity. “ (DFID, 2010). A group of Dutch institutions are interested to build a capacity building consortium on “Water and Land related Climate proofing” that may be linked to this DFID supported Climate and Development network.

2.4.2 Adaptation in Europe:

- *Adaptation White Paper.* As part of the EU White Paper on Adapting to Climate Change, the European knowledge base will be strengthened with a European Clearinghouse on Impacts, Vulnerability and Adaptation as a centre piece. Our inventory can be used as a basis to consider Dutch contributions to these activities. Alterra has recently been awarded the contract for implementing the Clearinghouse and is partner in the new European Topic Centre on Climate Change Impacts, Vulnerability and Adaptation of the European Environment Agency that will probably support its management and maintenance.
- *Mainstreaming in EU legislation.* In the context of the Framework Water Directive, climate change adaptation has been suggested as a major component of the 2nd round of River Basin Management Plans, for which a Guidance document was recently published (European Commission, 2009). The Floods Directive requires Member States to coordinate their flood risk management practices in shared river basins, and to avoid taking measures that would increase the flood risk in neighbouring countries. In the context of EU policy development on droughts, a review of the strategy for water scarcity and droughts is planned for 2012.
- *European Water Partnership.* The Netherlands also plays an active role in the European Water Partnership, which is currently setting up a European Dialogue on Climate Change Adaptation and Water, focusing on raising awareness, exchanging experiences and best practices between all stakeholders.
- *Climate Knowledge and Innovation Community.* A number of Dutch organizations is involved in the development of the Randstad Collocation Center of the new Knowledge and Innovation Community (KIC-Climate next to KIC-Energy and KIC-ICT), aiming at innovation in mitigation and adaptation in public-private-academic partnerships in 4 work areas, of which primarily “Assessing and Managing Climate Drivers” and “Adaptive Water Management” are relevant in the context of this study.
- *UN ECE Guidelines on climate adaptation in trans-boundary context.* The Guidance aims at supporting decision makers from the local to the international level. It puts a special emphasis on the specificities and



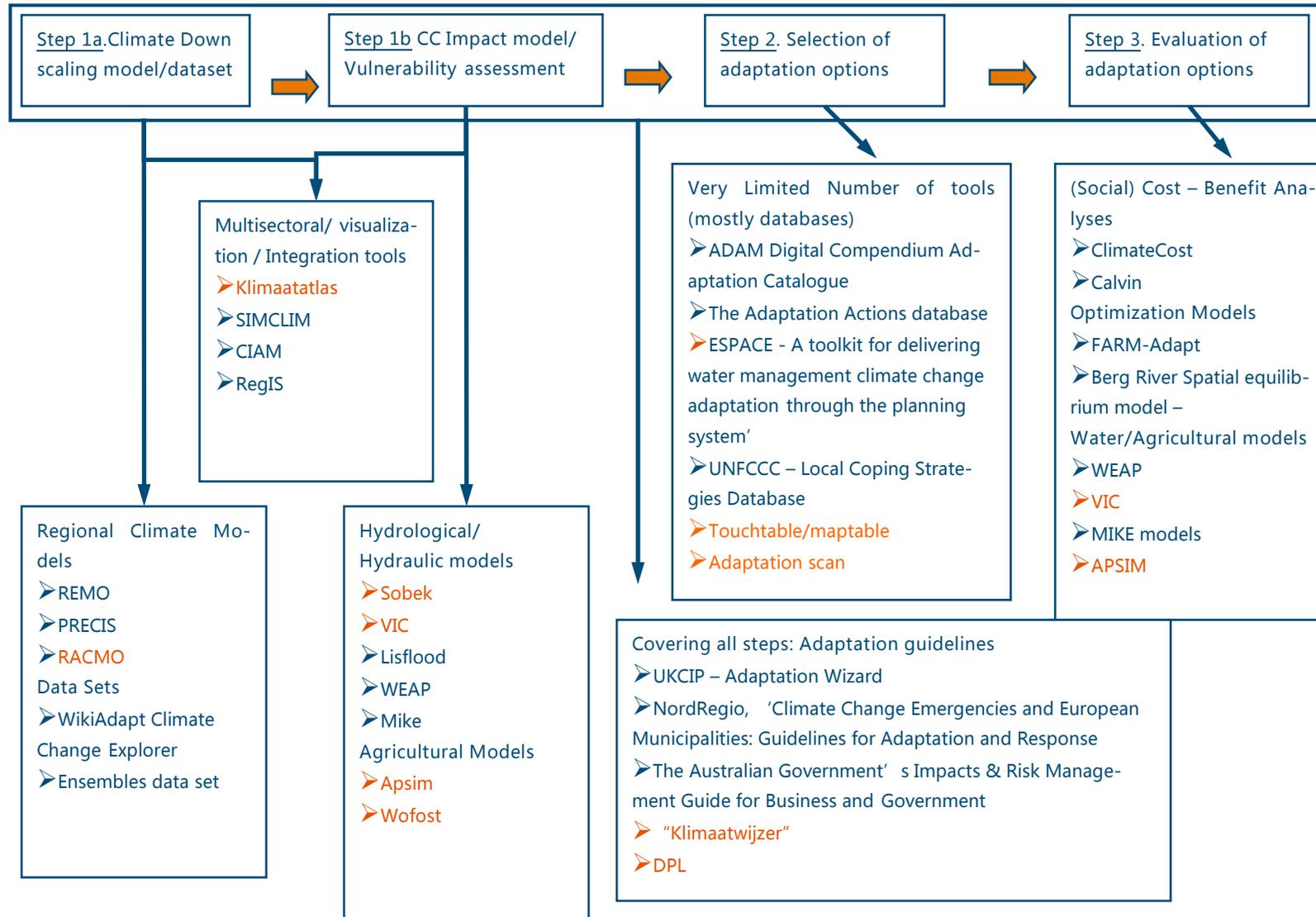
- requirements of transboundary basins, with the objective of preventing, controlling and reducing transboundary impacts of national adaptation measures. A process has started to implement the Guidelines.
- *Climate services.* The 2009 World Climate Conference gave a boost to the development of global, national and European “climate services”. In Europe, a number of FP7 research projects (IS-ENES, EURO4M and EUC-LISE), as well as the network of European meteorological institutes (EUMETNET), in most of which KNMI, WUR and other Dutch institutions have a leading role, have stepped up efforts to define and develop climate services. These services will probably mostly focus on delivering the climate data needed for impact assessment.
 - *Research collaboration.* Various EU FP7 research projects as well as the ERA Network CIRCLE deal with methods and tools in the area of climate change adaptation. A EU Joint Programming Initiative “Connecting Climate Knowledge for Europe” (Clik’EU) has been developed by Austria, Finland, France, Germany, Italy and the Netherlands, which next to decadal predictions, climate services, and understanding of societal transformations also includes “decision-making tools” as a key programme area.

2.4.3 National adaptation:

- *The Delta Action Programme (Delta Plan)* The Delta Programme consists of a series of concrete projects. These projects are intended to ensure that our country is protected against flooding and in addition, that the supply of freshwater is secure. The Delta Act constitutes the legal foundation for the programme. This Act will be submitted to the Lower House in 2010. The Delta Act and the Delta Programme arose from the recommendations entitled “Working with Water Together” by the Delta Commission and the National Water Plan. The integrated structure of the Delta Programme means that in addition to the government (with the Ministries of Housing, Spatial Planning and the Environment (VROM), Agriculture, Nature and Food Quality (LNV) and Transport, Public Works and Water Management (VenW) as the initiating ministries) other authorities like the provinces, municipalities and water boards are also involved in the programme. Knowledge institutes and the business community are also playing an important role in the implementation of the Delta Programme.
- *The Knowledge for Climate research programme.* The findings of this inventory can be useful for the researchers involved in the 2nd tranche projects that will start in 2010, drawing inspiration from development of methods and tools noted in this inventory. Also, they can inform the debate about the 3rd tranche, and the discussion about a permanent climate change adaptation support mechanism in The Netherlands.
- *Bilateral collaboration.* In other (EU and other) countries (UK, Germany, Scandinavian countries, Canada, Australia) also activities in this area are



developed at the national level. The level of international collaboration and knowledge exchange in the area of impacts and adaptation is much poorer than for example in the climate modeling community. The ERA network CIRCLE brings together research managers and funders, but much less researchers and practitioners. The establishment of a new mechanism and network to facilitate such exchange in a more structured way would be useful.



Figuur 6. Example of adaptation tools for different steps in the adaptation cycle. Most tools have been developed for one individual step within the adaptation cycle. For step 1 (the impact assessment) usually two individual tools are necessary (a downscaling tool and an impact model), although some tools exist which integrate both. In addition there are guidelines which cover all steps. The tools in orange have (partly) been developed in The Netherlands.



3 Available methods and tools in the adaptation cycle

3.1 Tools in the adaptation cycle

Most of the tools available have been developed to support a particular step in the adaptation cycle (Figure 6). For the grouping of the tools we used the three steps in the adaptation cycle as shown in Figure 4b and 6.

- *Climate change impact and risk assessment:* Firstly, the potential impacts of climate change and/or the vulnerability has to be assessed. For this step in most cases first climate change scenarios are derived with downscaling tools. In a second step these climate change scenarios are used to drive impact models, for example a hydrological or an agricultural model. The result of the impact model can finally be presented using different visualization/GIS/mapping techniques.
- *Selection of adaptation options:* Secondly, from the huge number of possibilities, a limited number of promising adaptation options needs to be selected and designed, ideally requiring some systematic, structured approach. For this step not many tools have been developed yet. Some databases with adaptation options are available and some toolkits and sets of guidelines also include a list of possible options.
- *Evaluation of adaptation options:* Thirdly, after selecting and specifying a number of promising adaptation options, or investment projects, plans, or programmes, they need to be evaluated to make definite choices and design the implementation details. For this step a range of methods and tools are available. First of all there is group of tools based on (social) cost benefit analyses through which the pros and cons of individual measures are strategies can be evaluated.

An overview of all methodologies, methods and tools evaluated for this report is given in the annex to this report. They are grouped in categories, *e.g.*, evaluation frameworks, guidelines for adaptation planning, downscaling techniques for climate projections, cost-benefit methods, adaptation option catalogues. The impact models are grouped based on the sector/area of application: *e.g.* hydrological models (flooding and water supply), water quality models, land-use and agricultural models, coastal zone management, spatial planning. For each model a basic description is given, a link to a relevant website (if available) and the organization which has developed the tool. In addition we have given an initial indication if Dutch tools would be suitable for use in international applications by Dutch institutions and if a foreign tool would be useful for application or inspiration in the Netherlands.



3.1.1 Step 1a: Downscaling/regional climate models

For climate change impact and risk assessment, usually two different tools are needed. First there is a need for downscaled and/or bias-corrected climate change scenarios. This can be done by using either statistical or numerical approaches (Jacob and Van der Hurk 2009). Statistical downscaling techniques use a relation between large-scale climate variables, which are well represented in GCMs, and observed local variables like daily precipitation or temperature. This relation is subsequently applied to GCM output to obtain local and regional climate change signals. The advantage of this method is that series of climate variables can be obtained for a particular location (e.g. meteorological station). Therefore, using these statistical tools, the same analyses can be applied to future and historical droughts, implicitly assuming unchanged relationships (stationarity) under future climate conditions (Jacob and Van den Hurk, 2009). As statistical downscaling is based on historical records, the quality of the climate scenarios strongly depends on the quality of the local climate data. For example, the WikiAdapt Climate Change Explorer Tool (see Box below) contains a statistically downscaled dataset for many stations in developing countries in Africa and Asia. This dataset can be very useful as a first impression of the expected climate changes for local project in developing countries.

Box 3. WikiAdapt Climate Change Explorer Tool

The Climate Change Explorer (CCE) is developed by the Stockholm Environment Institute (SEI) and the Climate System Analysis Group of the University of Cape Town to facilitate the use climate change information and its application to adaptation strategies and actions. The CCE can be downloaded to any computer and then packages data access routines with guidance and customized analytical and visualization procedures. It is designed to make the analyses of climate change data much simpler and user friendly. The tool is linked to a rich database with statistically downscaled climate change data for many sites in Africa and Asia. For local project this a very useful tool for an initial evaluation of how local climate is expected to change. The tool is linked to the WikiAdapt website and is accompanied by an excellent manual. Through the WikiAdapt site also SEI's Water Evaluation and Planning System (WEAP) is offered as a complementary tool to evaluate water impacts. The tool will be upgraded in the near future to a Climate Information Portal (CIP).

Reference:

http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool



A more physically based downscaling method, also referred to as dynamical downscaling, is the use of high-resolution regional climate models (RCMs) nested into Global Circulation Models (GCMs). These models add detailed information on land use, coastlines, topographical structures and better-resolved spatial gradients. GCM large-scale boundary conditions are used to constrain the RCM simulation. The use of RCMs allow for an improved representation of local feedback processes such as snow-albedo/temperature or soil moisture/temperature feedbacks (Jacob and Van der Hurk 2009). These local feedbacks may be important for drought development. The major disadvantage of RCMs is their large demand on computer resources and the complexity of their operation, which requires trained staff. There are many regional climate models available and for some regions output from these models is publically available. For example, through the EU-ENSEMBLES project output for a range of RCMs is available Europe and West Africa for the A1B emission scenario. The REMO model, developed by the Max Planck Institute, has been used in regions across the globe. Also the PRECIS model of the UK Met Office has been used worldwide. Both the REMO and PRECIS results have been used in projects focusing on climate change adaptation.

For most climate change impact studies it is important to have both historic and future climate data. Historic data usually comes from local station data or a national/global data base. The climate KNMI Climate Explorer developed by Geert Jan van Oldenborgh gives an excellent overview of the available databases (<http://climexp.knmi.nl/start.cgi?someone@somewhere>). Within the Netherlands, KNMI is using the RACMO model, which was also included in ENSEMBLES. As far as we are aware there is limited use of this model for projects outside Europe beyond ad hoc projects. In general some know how on downscaling especially for developing countries is available but much more limited in the Netherlands compared to other countries. This is partly due to the limited mandate and capacity of KNMI, which is limited to knowledge development and communication, but does not allow for extensive consultancy work for specific circumstances abroad. KNMI can collaborate in projects in European or developing countries if this would imply the development of new tools or making available existing supporting tools (such as their weather generator) and climate databases (such as those developed in EU projects like ENSEMBLES or IS-ENES, global data for further dynamic downscaling). KNMI cannot provide more tailored support to commercial projects such as those of consultancy firms in developing countries. For such purposes other ways should be explored: the consultants could develop their own expertise in this area, they could establish strategic alliances with foreign parties specialized in those areas, or there may even be room for a new public or private institution specialized in supporting climate change impacts and adaptation projects in other industrialized and developing countries.



3.1.2 Step 1b: Impact models

The “local/regional” climate change scenarios discussed above are then used to drive impact models. These impact models are usually hydrological, agricultural or ecological models. There is a large range of these impact models/tools available, ranging from local to global scale. Most of the models have not specifically been developed as climate change impact or adaptation models but are used for analysis of water resources, flooding, or irrigation assessment. When originally developed, historic climate data were used to drive these models. To use these models for climate change impact studies future climate change scenarios are used instead of historic climate data,.

Box 4. Selected examples of impact models

VIC: The Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model is a large-scale, semi-distributed hydrologic model which was originally developed by the University of Washington. Currently it is further developed by Wageningen UR to study the impact of climate change on hydropower production, water temperatures and changes in discharge. VIC can be used for application at global, regional and river basin level. It is an open source model with an active user community.

APSIM: APSIM is a farming systems model which was originally developed in Australia but is currently also used at Wageningen UR. It can be used to study the impacts of climate change on crop production in a wide range of environments for several different crops. It can also be used to assess different adaptation options such as planting dates, using different varieties and nutrient management. APSIM was originally developed by ASPRU, and is now transforming to an APSIM Community Source Framework (a modified ‘Open Source Framework’). APSIM is freely available for non-commercial use.

Spatial Tools for River Basins and Environment and Analysis of Management Options (STREAM): STREAM can be used to study the impacts of climate change, climate variability and land use changes (including dams and reservoirs) on water resources in river basins. For these issues, STREAM enables calculation of the impacts of changes in temperature and precipitation on the regional hydrology. Based on these impacts, different management strategies can be assessed by providing a quantitative assessment of water availability under various scenarios. Stream has been developed by IVM.

Mike: Mike by DHI is one of the climate-relevant software packages developed by DHI in Denmark (<http://www.dhigroup.com/>). The different Mike models can be used for water resources and coastal applications. For a study in Bangladesh the Mike model was used to study the climate change impact and adaptation options related to urban flooding in Khulna, the third largest city in Bangladesh. Mike software can be downloaded from the DHI website.



3.1.3 Step 1a+b: Integrating climate downscaling and impacts

Some tools are available that integrate climate downscaling and impact assessment. These are usually (multi-sectoral) tools that integrate the results of a range of models. These tools are usually much more user-friendly than the impact models mentioned above. Because these tools usually visualize their input and output in an attractive way they are also very useful for stakeholder consultation processes and/or to stimulate science – policy interactions. The disadvantage of these tools is that they are less flexible and it is more difficult to apply them for very specific impact questions.

Integration can be done in one system, such as SIMCLIM: (<http://www.climsystems.com/simclim/>), developed in New Zealand and made available for a license fee by CLIMsystems Ltd. It can also be done in a more distributed way, like the Community Integrated Assessment System (CIAS, see Warren et al., 2009), developed jointly by the Tyndall centre and PIK for broad impact assessment at a global to continental scale. CIAM represents a new approach to integrated modeling for climate change policy, which combines a number of models (from climate downscaling to hydrological and vegetation impacts) in an innovative way, maintaining the models at their original location in the United Kingdom and Germany.

Another attractive example is the Regional Impact Simulator (ReGIS-2), an integrated assessment tool that was developed with stakeholders in the UK (East Anglia and North West England) to support adaptation planning (Holman et al., 2007). It contains a suite of computer models and datasets with a user-friendly interface that allows the user to rapidly identify the sensitivity of an indicator to climate and/or socio-economic change; to investigate the effects of uncertainty in the future scenarios; and to investigate regional adaptive response to future change. While ReGIS was specifically developed for specific regions in the UK. These tools could be potentially interesting for the Netherlands as a source of inspiration for supporting regional development planning.

A Dutch example of this kind of tools is the “Climate Adaptation Atlas” project which combines climate and impacts information for all Dutch provinces. In this tool the results of different climate and impact models are combined to create integrated impact and vulnerability maps at the regional scale, developed in collaboration with a number of knowledge institutions and consultants and in consultation with various regional stakeholders.

We note that in step 1 the available tools focus on potential impacts rather than on vulnerability, which would require to include the assessment of adaptive capacity. There is a large literature basis for vulnerability in general, but no generally accepted methodology in the context of climate change



adaptation (see Box 6). Hence, we did not include the vulnerability literature in our inventory.

Box 5. Example of integrated assessment model: SIMCLIM

SimCLIM is an integrated computer model system developed over more than 15 years by Dick Warrick and colleagues in New Zealand to evaluate the effects of climate variability and change over time and space, including extremes, and also covering sea level rise. Users can customise the model for their own region and preferred spatial resolution and can attach their own impact models. Baseline climate scenarios are described using the MAGICC model that was also used by the IPCC. The system is tied to the DHI suite of models such as Mike, perturbing precipitation, temperature and sea level data and in some locations, wind data that can be input into the DHI models. Adaptation measures can be tested for present day conditions and under future scenarios of climate change and variability. The system has a very easy user interface, designed to support decision making and climate proofing in a wide range of situations. Attention is paid to uncertainties and sensitivity analyses can be performed. The “open framework” character allowing for specific new applications led to widespread use, e.g. in 2009 new versions were developed for India, Ghana, Nigeria, Pakistan, the United Kingdom, Ireland, Mexico, Malaysia, and an updated version for New Zealand. SimClim has different sets of license fees for academic institutions and NGOs, for personal non-commercial use, for non-profit research institutes and government entities, and for commercial private sector consultants and corporations.

Reference: www.climsystems.com/simclim

Box 6: Assessment of vulnerable hotspots

One element of step 1 of the adaptation assessment cycle is often the establishment of specifically vulnerable hotspots, using vulnerability indicators. The establishment of vulnerability indicators has a long history, but there is no generally accepted definition, as it is usually based on other vaguely defined concepts and includes normative aspects (see Figure). As a consequence, no generally accepted methods and tools exist to identify vulnerable hotspots. Many definitions following the top-down approach see vulnerability as a function of exposure to climatic changes (e.g. temperature increase), sensitivity to those changes (e.g. damage per degree centigrade) and adaptive capacity. Because the latter cannot be easily quantified, often this factor is ignored in practice. While in the top down approach vulnerability is a function of adaptive capacity (“outcome vulnerability”), in a bottom-up approach vulnerability is determined by contextual factors and determines adaptive capacity (contextual vulnerability”, Füssel, 2009).



In a comparison of different definitions of vulnerability, Eriksen and Kelly (2007) conclude that definitions may appear similar, but results in terms of ranking different countries according to vulnerability very much depend on choices of indicators and data availability: “agreement is more often a result of data availability than of convergence of insights”. Another extensive literature analysis in the context of the ADAM project concluded that the conceptual literature offers little guidance on how to make the concept of vulnerability operational. A definition more precise than “vulnerability is a measure of possible future harm” could not be provided. Hence, the development of methodologies for assessing vulnerability (including indicators) should rather be informed by spelling out the specific research question or policy objective addressed, acknowledging that vulnerability is very context specific (Hinkel et al., 2008).

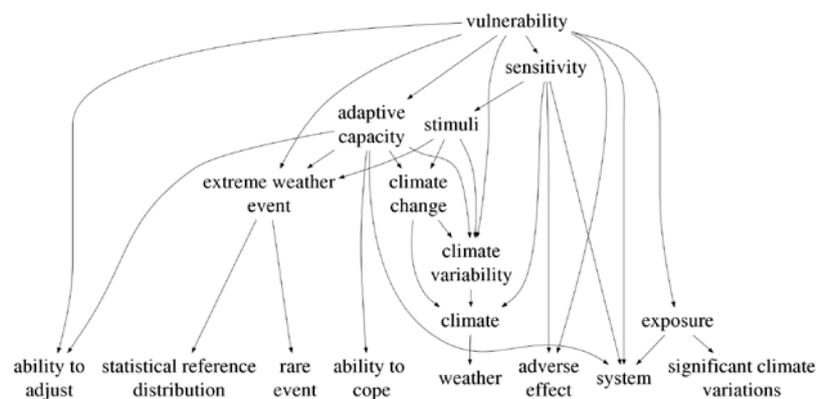


Figure 7: Vulnerability is based on other vaguely defined concepts (Hinkel, 2009)

3.1.4 Step 2: Tools for policy development and option assessment

For the selection and design of adaptation options much fewer tools are available than for the impact assessment and evaluation steps. Usually adaptation options are selected from available lists of options (e.g. in Guidance documents) and/or during expert/stakeholder meetings. The risk of these approaches is that novel adaptation options are left out. Engineers tend to choose for engineering options where social scientists or development workers tend to go for behavioral or institutional changes. For example in the ADB funded project “Strengthening the Resilience of the Water Sector in Khulna to Climate Change”, most people involved had an engineering background and the adaptation options preferred were all engineering options such as building new drains, pumps and levees. Other options were neglected or seen as “add-on” options.

The most useful database we have come across is the adaptation catalogue hosted by PIK in Germany and developed as part of the EU ADAM project.



In the Netherlands new electronic tools have been used such as a Touch-table which allows policy makers and stakeholders to interactively visualize the effects of different adaptation options. In the context of the Climate changes Spatial Planning programme, the Dutch consultant Builddesk developed the so-called Adaptation Scan, a tool helping policy makers at local and regional level to link different adaptation options to specific policy questions. At the time of writing this report, the tool was not yet sufficiently well developed to be considered for international applications, although potential future work could take international transferability into account.

3.1.5 Step 3: Tools and methods for evaluation of policies and options

For the third step in the adaptation cycle, again a range of tools is available. These mostly focus on ex-ante evaluation of possible options or investment decisions. As discussed above, we did not consider tools to evaluate (ex-post) the effectiveness of adaptation strategies during or after their implementation, because we did not identify any specifically for adaptation purposes. In general three different kinds of evaluation methods are available.

- *Methods based on (social) cost benefit analyses (CBA).* These tools can usually evaluate a large range of options depending on the details needed for both the costs and the benefits. These CBA tools can be applied to a range of sectors at very different spatial scales.
- *Tools focusing on optimization.* These tools are usually developed for individual businesses or farms (e.g. FARM-Adapt) or for distribution of water resources within a basin (e.g. Berg River Spatial equilibrium model).
- *Impact-focused models.* These impacts models can sometimes be used to study the effectiveness of different adaptation options, for example the impact of additional drains or levees on future flood frequency.

3.1.6 Climate Change Adaptation Guidelines

Guidelines are available covering the full adaptation cycle. In many cases these guidelines can be used as a first step toward climate change adaptation for businesses and local governments but they are usually insufficient for designing and implementing an effective adaptation strategy. Sometimes these guidelines “guide” people to individual tools as those described above. The first guidelines were developed in the 1990s in response to the growing demand for support in assessing impacts and developing adaptation. Early guidance documents by the IPCC (Carter et al, 1994) and UNDP (Lim, 2004), which were primarily directed towards developing countries, were followed by a long series of more targeted guidelines, e.g. for regional



adaptation policies (Ribeiro et al., 2009), adaptation in the water sector (UNECE, 2010; EC, 2009), or in urban areas (Snover et al., 2007). One of the best sources of practical information about climate impacts and adaptation for developed countries (specifically the United Kingdom) since 1997 is UK-CIP (<http://www.ukcip.org.uk/>). This includes the UKCIP Adaptation wizard. This tool uses a “ 5-step process assisting in assessing the vulnerability to current climate and future climate change, identify options to address key climate risks, and support the development of a climate change adaptation strategy”. It is used as a way to structure the development of adaptation plans across a wide range of sectors and regions. Specifically aiming at developing countries and from a somewhat later date (so still partly under development) is the WikiAdapt programme and website offering a fully comprehensive set of guides for practically all aspects of climate change impacts and adaptation (http://wikiadapt.org/index.php?title=Main_Page). Australia developed The Australian Government’s Climate Change Impacts & Risk Management Guide for Business and Government (Australian Greenhouse Office, 2006).

The Netherlands was relatively slow in developing integrated, generally applicable guidelines. A recent development is the Klimaatwijzer, which has not yet been published. This Klimaatwijzer, as many adaptation strategies developed in the Netherlands, is very much government focused. In The Netherlands some guidance was developed for specific questions, such as water-robust building guidelines (van de Ven et al., 2009) and guidelines for climate change in sewerage and drainage systems (Rioned, 2008). There are not many initiatives which focus on the informing or assisting the business community . This is a gap in knowledge development in the Netherlands where lessons can be learned from the UK, Canada and Australia. Developing and testing similar guidelines for a wide range of actors in the Netherlands would be useful.

3.1.7 Bottom-up tools

Usually climate change is just one of many considerations to take into consideration when making investment decisions. A bottom-up approach may address the reality of decision-making at local, regional and sectoral levels more directly than the climate-centered top-down approach. At least the two approaches are complementary. For climate-proofing of plans, programmes and projects or mainstreaming climate change into sectoral policies a bottom-up approach may even be more effective, and hence preferable. However, since most of the supply of methods and tools comes from the traditional top-down way of looking at climate change, there is as yet little experience with bottom-up approaches.



Adaptation tipping points

Studies on the impact of climate change and sea level rise usually take climate scenarios as their starting point. To support the Netherlands long term water management planning, Deltares carried out a study that started at the opposite end of the effect chain. The Deltares approach examined whether, and for how long, current water management strategies will continue to be effective under different climate changes. This is done by adopting the concept of “adaptation tipping points”, reached if the magnitude of change is such that the current management strategy can no longer meet its objectives. Beyond the adaptation tipping points an alternative, adaptive, strategy is needed. By applying this approach the basic questions of decision makers are addressed related to the first problems that will be faced as a result of climate change and when can these be expected. The results show, for instance, that climate change and the rise in sea level are more likely to cause a threat to the fresh water supply in the West of the Netherlands than to cause a threat from flooding. Expressing uncertainty in terms of the period that the existing strategy is effective (when will a critical point be reached), appears more understandable for the policy maker/ water manager/stakeholder, than plots showing a certain percentage of change in a certain projection year. We consider therefore the approach as practical to facilitate the dialogue between scientific and water management world.

Resilience approach

A problem with top-down approaches is that they depend on the ability to project climate change and its impacts into the future with some degree of confidence. However, future climatic changes may be very uncertain (e.g., precipitation, extreme events), while climate may not change gradually, but could be instable and tipping points beyond which the climate may change fast are plausible (e.g., Scheffer, 2009). Please note that this definition differs from the adaptation tipping points mentioned above. If uncertainties as to the direction, magnitude and speeds of climate change are large, increasing resilience is may be the preferred option (Walker and Salt, 2006). However, few tools are as yet available to operationalize the concept of resilience. Enhancing resilience as an option to adapt to the threat of a changing climate is often associated with bottom-up approaches, including participatory process to identify specific actions together with vulnerable stakeholders.



3.2 Providers of tools and their availability

For the purpose of this project, an important criterion is the availability of methods and tools for usage by others. In this context it is important to note that the authors or “suppliers” of the methods and tools fall in different categories:

- *International organizations.* Several UN organizations (UNFCCC, UNDP, FAO, World Bank, UN-ECE) have developed activities to assist countries (particularly the most vulnerable developing countries) in assessing their vulnerability and develop adaptation plans. The European Commission is developing a Clearinghouse on assessing climate change impacts, vulnerability and adaptation which is planned for 2012 and is likely to include methods and tools. Already, the Commission published Guidelines for the development of regional adaptation strategies. Also non-UN-organizations (OECD, CGIAR, etc.) do work related to climate change impacts and adaptation, but did not yet make methods and tools available. Usually these organizations provide free guidance on how to develop plans, and refer to models and other tools available elsewhere for further work.
- *Governmental institutions.* In various countries government departments have subcontracted universities or consultants to develop methods and tools, which are subsequently made available publicly. Examples are Environment Ministries or Environmental Protection Agencies, development cooperation agencies, national agencies, or special project-like institutions such as UKCIP.
- *(Semi-) private institutions.* A number of methods and tools has been developed by and is available from (semi-)commercial firms, such as consultants. Since these tools determine their knowledge capital, they are usually not freely available. A number of institutions has a private legal status, but because of their specific activities make their tools available for free or for a limited license fee, e.g. if liaised to a University (CLIMsystems Ltd), or if the tools were developed with public funds (SEI).
- *Scientific organizations.* A significant part of the methods and tools have been developed in the context of academic research by universities. Often the methods and tools developed in this context have the limited lifetime of the associated development project, or of the attention of the main author. Such tools have not been developed with wider use as an explicit objective and are often not easily transferable, e.g. because they lack guidance for users.



It appears that there is no clear or common situation as to the availability of tools and intellectual property rights. In many cases tools have been developed in academic research projects funded with public money, which usually means that they are freely available, but that they lack user support. Tools developed and managed by private companies are either not available or for a license fee, which can be high in case of commercial use and low in case of non-profit organizations. As plans are being made to apply Dutch tools abroad, developed with private or public funds, it would be useful to consider the implications in terms of IPR.

3.3 Climate change and natural hazards

Climate change will not only change the average climate but will in many cases also increase climate variability and the number and severity of extremes. Depending on the region and the climate scenario this will change the frequency and magnitude of extreme events such as floods, storm surges, droughts and heat waves which in the end could cause human disaster. There is a large community focusing on disaster risk reduction which has developed a range of tools to evaluate and reduce the risks related to disasters. These tools can potentially be used for climate change adaptation. However, we have observed that the networks of those involved in climate change adaptation and those in disaster preparedness, prevention and control have only recently started to come together. At the same time, especially within the development NGO community there is a tendency to communicate to the public that climate change will increase the number drought and flood related disaster throughout the globe. In relation to this, all floods and drought in developing countries are increasingly suggested to be caused by climate change, especially in the popular media. The IPCC Special Report “Managing the Risk of Extreme Events and Disasters to Advance Climate Change Adaptation”, proposed jointly by the UN International Strategy for Disaster Reduction (UN/ISDR) and the Government of Norway (in response to the IPCC Fourth Assessment Report predictions that more frequent and severe extreme events were likely in a future warmer world) is currently under review. As stressed by the representative of the Red Cross Climate Change Centre during the stakeholder meeting of this project, also in The Netherlands better connecting the climate change and natural hazards communities would be useful.



4 Potential niches for Dutch methods and tools

The Netherlands has a long term tradition in international co-operation in the water sector. Dutch expertise on water management is widely appreciated and renowned both in developed and developing countries. However, especially technological knowledge is rapidly expanding also outside the Netherlands and more and more countries can build their “own dikes and bridges”. So, building on the current strong basis, the Netherlands needs to expand into new niches in order to maintain or increase international applications of Dutch expertise. One such a niche could be related to climate change adaptation. On the basis of our analysis, we propose three specific niches where opportunities exist for valorizing Dutch research and associated knowledge abroad: (1) integration of knowledge and tools across the adaptation cycle, (2) adding the design and evaluation of specific adaptation options to existing water management and other tools, and (3) further developing and applying bottom-up methodologies that recognize the importance of stakeholder participation and the fact that in many situations climate change adds pressure to a wide range of non-climate considerations. The Delta Programme, “Water Mondiaal”, the Delta Alliance, the globally expanding SEA applications and a possible contribution to the DFID Climate network are examples of concrete policy and knowledge frameworks in which these specific activities can be further developed and applied.

4.1 Integration of knowledge and tools covering the complete adaptation cycle

The challenge in climate change adaptation is not only related to the development and application of specific tools but to the integration of the different steps in the climate change adaptation cycle. This includes both the contents as well as the required partnerships. To develop and implement successful adaptation strategies and measures, increasingly a combination of technical, social and integrative skills is necessary, beyond traditional engineering or economic expertise. Technically a need exists to be able to interpret and manage climate data and impact models, while social and economic skills are necessary for policy and stakeholder interactions, needed to select and evaluate a broad range of hard and soft adaptation options. A credible information basis based on alpha, beta and gamma skills will not be sufficient, but should be complemented by an enhanced capacity to prepare, moderate and include stakeholder dialogues to arrive at broadly acceptable and implementable options.



To develop technical, scientific and social expertise, collaborating teams, applying and managing tools which cover the complete adaptation cycle could provide a promising niche in climate change adaptation. Within the Netherlands, such teams have not yet been well developed neither within the public and private sector individually, nor in public-private partnerships. Such teams can be developed further, either within a single institute or by combining people and expertise from different institutes. It seems relevant to encourage the development and usage of a toolbox which includes not an ad hoc combination of methods and tools that happen to be available now, but a dynamic set of targeted tools that represent evolving state-of-the-art knowledge. Application of outdated tools or databases or applying good tools with insufficient experience would not be good for the Netherlands image abroad, and some “good practice guidance” would be useful. It was beyond the scope of this inventory to evaluate the relative “quality” of the available tools that may fit in an integrated toolbox.

In addition, there is a need to train both the current and future generation to be able to work with a variable set of tools, combining alpha, beta and gamma related skills. To do this we need to develop more integrated Professional Masters and Masters of Science programmes at Dutch universities. The Master of Climate Studies which started two years ago at Wageningen University is an early example such a programme. In addition, special modules on climate change adaptation methods and tools could be developed not only for foreign students at the IHE/Unesco Institute for Water Education, but also courses can be designed for Dutch consultants applying Dutch climate knowledge abroad.

Given the rapid development of climate change adaptation sector we cannot wait for the next generation to take up the challenge of adaptation. There is a need to educate current professionals to be able to better understand and integrate the different steps within the adaptation cycle. Because application of knowledge in the very wide and diverse number of adaptation situations exceeds the capacity and mandate of the knowledge institutions, partnership with the private sector, notably consultants, is required. In The Netherlands, there is something to be learned from other countries, which have more intensively engaged the private sector, e.g Australia and Canada. In these and other countries various companies have started to respond to the market demand for adaptation knowledge. In order to make sure that Dutch (existing or new) companies apply the best available knowledge, more interaction between the academic, public and private communities would be useful.

In the coming years, opportunities should be sought to develop and test such integrated projects and teams. An adapted, flexible version of the UK-CIP adaptation wizard can provide a framework for this, including a user-friendly interface which links the different models covering the individual steps in the adaptation cycle. Recent initiatives in large deltas in both de-



veloping and developed countries provide starting points to develop this further. Deltas are interesting and challenging case studies for climate change adaptation. Collaboration between the major Dutch knowledge institutions in the National Modeling and Data Centre (NMDC) so far focuses on national applications, but could also be an asset in international markets, if organized appropriately. Developing the NMDC/KvK learning case “Coupling” focusing on climate change model integration could be expanded to include plans for international applications. Guidance on the coupling of specific available methods and tools to different types of problems and policy questions at different to temporal and spatial scales would be helpful.

4.2 Specific adaptation knowledge and tools

We have found that currently most methods and tools available internationally are limited to the evaluation of potential climate change impacts. If adaptation options can be addressed with these tools, it is usually only a limited number of options that can be evaluated, in particular only those that directly affect the variables that are included in the model, *e.g.* adding water retention areas in river basins in hydrological models. Conversely, several tools available to evaluate water management options appear not yet suitable for analysis of specific climate change adaptation options. At the same time, in various databases and guidance document extensive lists of adaptation options are included, which can be used to build a much wider set of options into the available tools, or to develop new methods to evaluate options that cannot be easily modeled. The addition of climate adaptation options into the DPL system that aims at sustainable design of urban areas is an example.

The lowest of number of tools was available for “step 2” of the adaptation cycle: “Selection and Design of Adaptation Options”. So in terms of developing tools there is an opportunity here. Until now only databases or very specific tools which are only applicable for one region are available. Such a tool could for example be developed for the water sector, focusing on delta regions. Dutch experiences such as water-robust building provide a basis for this.



4.3 Bottom-up approaches

It is increasingly recognized that rather than developing specific adaptation strategies, stakeholders are interested in the climate resilience of plans, programmes or projects that they are investing in. Climate change in those cases should be mainstreamed into processes in which non-climate factors are usually dominant. Since most available methods and tools have been designed for the classical top-down climate change impacts analysis, developing a methodology in which these tools can be applied in a different, “bottom-up” setting or developing tools specifically useful for such settings is likely to provide new opportunities for policy-relevant research and applications in The Netherlands and abroad. Deltares’ tipping points analysis is a good example. The expanding legal obligation for EIA/SEA offers opportunities for such new methods. Bottom-up approaches that combine participatory approaches, recognize that climate change is often an add-on to other issues, and take into account the uncertainties involved in climate change may also broaden the set of options to include both protective and resilience enhancing measures.

4.4 Future Opportunities

The amount of funding available internationally for climate change adaptation can be expected to increase rapidly, both through the Copenhagen UNFCCC commitments and bilateral programmes. In developing countries, the follow-up to the NAPA process will surely generate an increasing demand for practical adaptation knowledge. To be able to benefit from these adaptation funds when they become available and to contribute to the decrease of vulnerability and climate-proofing of plans and projects, it is important to further develop expertise, practical case studies and decision support tools as soon as possible.

Several programs now focus on water management, climate change and delta regions such as the Delta Programme, “Water Mondiaal”, the Delta Alliance, the Estuary Alliance and Connecting Delta Cities. These programs provide a unique opportunity for the development of the necessary multidisciplinary teams and projects which develop knowledge and tools covering the whole adaptation cycle. However to fully profit from this opportunity, a better integration is required between the different programs and institutes in the Netherlands. Also Dutch involvement in the activities of foreign institutions such as the Stockholm Resilience Centre¹ (for research)

¹ A collaboration between Stockholm University, Stockholm Environment Institute and the Beijer Institute



and the DFID Climate (and Development Knowledge) Network (for improving access to climate change research and information) can provide opportunities for applying and testing Dutch knowledge at the same time as for learning from these international networks.

Also in a European context opportunities may arise. For example, the Climate Knowledge and Innovation Community in which the Netherlands participates through a “Randstad node” provides opportunities to further develop and apply Dutch tools and develop public-private partnerships in collaboration with European partners for application in other European regions and beyond. The potential for international application of the methods and tools that are developed and improved in research projects in the 1st and 2nd tranche of KvK could be considered as well as specific new projects for the 3rd tranche. To fully benefit from the KvK work for the third tranche, the international work should be better integrated with the national work. For example applying tools and knowledge in the Netherlands could be applied/tested in some of the deltas selected by the Delta Alliance.





5 Potential relevance of foreign tools for The Netherlands

The Netherlands has an extensive knowledge base on climate change and associated impacts, based on a long history of research and development. However, our inventory suggests that this knowledge base is focusing primarily on the Netherlands and on international applications to support the international negotiations processes in Brussels and in the UNFCCC, but it has not yet been fully developed to support climate change adaptation at the local and regional level in other countries. A number of tools have been developed by academic as well as by commercial or semi-commercial institutions elsewhere that do focus on such applications, e.g. in the UK (e.g., PRECIS), Germany (REMO), Scandinavian countries (DHI, SEI), New Zealand (SimClim) and the United States (WEAP). In several cases, Dutch institutions are already using these tools, usually for applications in developing countries. This kind of usage of foreign tools can be continued or strengthened, e.g. in support of activities in the various delta programmes.

Due to the relatively advanced status of climate change, impacts and adaptation research in The Netherlands for national applications and the specific Dutch context, we did not identify tools elsewhere that can be directly applied in a Netherlands context because they would be better than available tools. However, Dutch work on climate change impacts and adaptation has focused mostly on the public sectors and compared to some other countries there is little work on assisting the private sector in adapting to climate change. In assisting the private sector the focus should be on long-term decisions and investments which are potentially vulnerable to climate change. For example, in the energy sector, insurance and banking, infrastructure and the water sector the longer climate change time scales are relevant. The companies in these sectors may have methods and tools that are not published in the open literature and are hence not included in our inventory. In terms of private-public-academic partnerships, the Netherlands could learn from experiences in the UK, Australia and Canada. Finally, the Netherlands could learn from the wide set of tools that has been developed by UKCIP over more than 12 years to assist regions and businesses with assessing their vulnerability and developing and implementing adaptation options. UKCIP has online tools and guidelines from both the public and private sector which provide an excellent starting point for climate change adaptation. The kind of tools and information provided by UKCIP is mostly also available in the Netherlands but it is fragmented over different institutions and not (yet) provided through a single entry point. Researchers and practitioners in Dutch universities (e.g. involved in KvK projects), knowledge institutions and consultants can build on those experiences for developing and adapting their own methods and tools.



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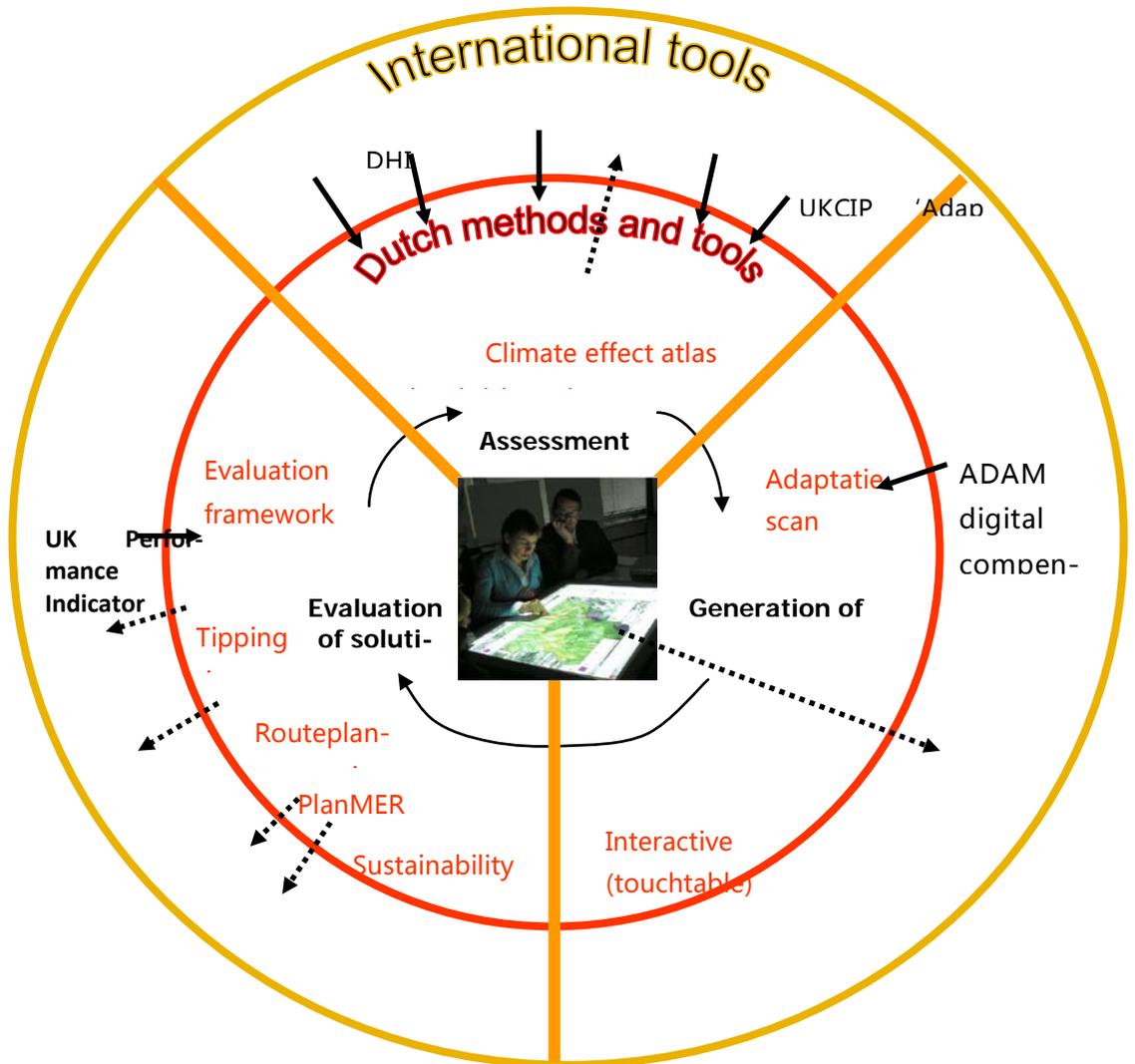


Figure 7: Dutch and selected foreign tools



6 Conclusions and recommendations

6.1 Available tools and methods

The process of adapting to climate change can be roughly divided into three steps: impact assessment, selection of adaptation options, and evaluation of these options. There is a large range of tools available with most tools available focusing on one of the three steps. Most methods and tools have been developed within the research and development domain and have only been used within universities and research institutes. Tools directly applicable in real world situations by governmental institutes and/or the private sector are in early state of development. Especially in industrialized countries, over the last decades the climate research and policy debate was dominated by questions about the reality and attribution of climate change and about costs and potential of mitigation. Vulnerability was perceived to be a problem primarily of developing countries. As a consequence, at the moment most tools available focus on the first step of the climate adaptation policy cycle: assessing climate change impacts and vulnerability. Much less specific tools are available to support the selection and design of adaptation methods, or to evaluate options and policies. Only a few tools are available for the step on the selection of adaptation options.

Especially for impact assessment, a large amount of tools, methods and instruments is available but the use by climate change adaptation policy and decision makers seems yet to be limited. Often the tools have originally been developed for goals other than climate change adaptation or climate-proofing. For future development of methods and tools it is crucial to find out what kind of information on climate adaptation is actually needed and what type of harmonization, integration and tailoring can be recommended to effectively support policy development.

Dutch expertise and capacity can in principle cover all three steps of this process to a varying degree, though the general capacity has to be tailored to specific conditions and applications, and in various areas strengthening of current capacity is required. We have not identified any specific tools which are developed in the Netherlands which are directly suitable for application abroad to support climate change adaptation. However, various methodologies and approaches can be adapted to usage in other, foreign contexts, with some additional effort. In terms of foreign tools to be used in the Netherlands, similarly those tools cannot be copied directly, but can serve as inspiration. We would specifically like to draw the attention to the approaches, methods and tools developed by UKCIP. Their web based guidelines linked to specific tools could be very useful for the Netherlands. In particular, there is a lack of information and tools in the Netherlands focusing on the private sector.



6.2 The competitive advantage of The Netherlands in relation to climate change adaptation

The amount of funding available and the demand for expertise on climate change adaptation is likely to rapidly increase in the coming decade. For example, in 44 developing countries, with UNDP/GEF support National Adaptation Plans of Action (NAPAs) have been developed, 8 EU member states have developed National Adaptation Strategies. These plans and strategies describe in general terms vulnerabilities and priority activities for adapting to the adverse impacts of climate change, putting adaptation on the national political agenda. Methods and tools are now urgently needed to support policy makers at the regional and local level to understand their specific vulnerabilities and adaptation options and start to implement the national plans. In addition, it is likely that both multi- and bi-lateral funding to adaptation will rapidly expand. These funds create a window of opportunity for the Dutch institutions (both private and (semi)-public).

The main challenge and opportunity for Dutch institutions is probably in developing multidisciplinary tools and expertise covering all steps of the adaptation cycle. This requires the combination of strong quantitative technical skills to analyze climate data and run and develop impact models in combination with the more socio-economic skills needed to select and evaluate adaptation options. For successful implementation of adaptation options, also skills to guide policy and stakeholder interactions are essential. These multidisciplinary teams could be developed within a single institute or by combining the strengths of different partners for example through private-public partnerships. The Netherlands has a proven track record for this kind of integration in water management and this should be further developed into skills for climate change adaptation. This in combination with being amongst the front runner countries in developing and applying methods and tools for supporting adaptation policy could provide the Netherlands with the essential competitive advantage in the international market.

Many tools are developed for specific research projects, with little or no incentives for their developers to expand the usage beyond their specific research interests. Valorization of climate change impacts and adaptation knowledge, bringing methods and tools to the marketplace is a challenge for Dutch knowledge institutions. There is a number of initiatives which could provide incentives to develop or strengthen the necessary expertise and partnerships needed to develop a further competitive advantage for The Netherlands, for example “Water Mondiaal”, “Delta Alliance”, “Connecting Delta Cities”, and the CWPC. These different programmes could join forces in developing projects in which multidisciplinary teams can work together on applying and testing climate change adaptation tools and further developing them for the different stages of the adaptation cycle. Further developing and applying existing tools to address the rapidly growing



demand for information about impacts, vulnerability and adaptation requires collaboration between knowledge institutions, public institutions, and consultants. This provides interesting new opportunities for partnerships between academic experts, consultants, and public bodies. How to go about IPR issues involving licensing and patenting rules should be further explored.

Dutch tools developed over the years to support water management projects in developing countries offer a good basis for expanding them for application in the international climate adaptation market, especially if the coverage of a wide variety of adaptation options would be strengthened. A possible niche would include the following three areas:

- *Integration and visualization of impacts, vulnerability and adaptation.* The competitive advantage of Dutch climate knowledge can be increased if water management methods and tools can be offered in conjunction with climate impact analysis tools, such as downscaling or regional climate models. This can require new forms of close collaboration between Dutch consultants in the water sector and public and private meteorological institutions. The concept of the Climate Adaptation Atlas, coupling different sources of information in a participatory process to actual policy problems in a spatial explicit manner could also be transferred to other countries in the EU (Climate KIC) and in other countries (Water Mondiaal, Delta Alliance), but it should be acknowledged that this is no easy task and would take a lot of effort and involves major data needs. Connecting the public and private sectors is a special point of attention.
- *Incorporating a wide variety of adaptation options in existing tools.* Currently existing tools cover the portfolio of adaptation options very poorly. Together with a small number of other countries, the Netherlands is one of the front runners in addressing climate change adaptation, and it can be attractive to position itself as an early mover in developing tools with a broad spectrum of different types of adaptation measures to support adaptation policy development.
- *Innovative, bottom-up approaches.* Like in The Netherlands, internationally climate change adaptation questions are often primarily addressed through the classical “predict-optimize-act” approach. Innovative approaches, such as the “tipping points” methodology to determine the level of climate-resilience of investments over time, offer opportunities for applications abroad. Also other bottom-up approaches, such as participatory activities focusing on enhancing resilience deserve attention.



6.3 Recommended follow up activities

A number of opportunities were identified that require further action:

- Foster connections between knowledge providers and stakeholders at different geographical scales to gradually expand the current “supply-driven” approaches by a more demand-driven approach to the development of new tools and methods.
- Evaluate the relative quality of the tools and methods that were identified in this project to assess if and how they can be integrated into the toolbox to be applied internationally.
- Improve the coverage of a much wider menu of hard and soft adaptation options in existing assessment tools, taking into account a broad range of scenarios including the possibility of both gradual and rapid climate change, and the synergies and trade-off with mitigation.
- Recognize the importance of changing frequency and intensity of extreme events, establishing closer contacts with the disaster management community.
- Further develop or establish new partnerships between academic and other knowledge institutions, government programmes, and consultants to be able to offer climate, impacts, vulnerability and adaptation expertise in one package.
- Explore the desirability and feasibility of standardizing risk assessment methodologies to facilitate quick expansion of applications.
- Analyze IPR dimensions of applying Dutch methods and tools abroad and the other way around.
- Make a concerted effort to explore the potential of the methods and tools developed in current national research programmes such as Knowledge for Climate (for regional, “hopspot” application in The Netherlands) for application in foreign contexts.
- Organize a workshop or course for experts from Dutch consultancy firms to ensure that up-to-date scientific knowledge and tools on climate change impacts, vulnerability and adaptation are used in advisory work in other countries.
- Develop an exchange programme with UKCIP and other relevant knowledge institutions abroad, e.g. for traineeships of students and visiting scientist positions for staff of knowledge institutions.
- Organize an inventory of international tools and methods covering agriculture and food security, and urban planning, following the experiences in the current water-oriented inventory.
- Develop a Guidance document helping practitioners to find the right methods, tools and databases for specific policy questions with their associated temporal and spatial scales in different phases of the policy cycle.



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8 Annex 1 List of Adaptation Tools

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
<p>approaches methodology</p> <p>Integrating CC-adaptation in policy-making</p>	Strategic Environmental Assessment (SEA)	il	Different sectors and national, provincial and local policies	<p>OECD DAC SEA Guidance note on climate change adaptation</p> <p>http://content.undp.org/go/cms-service/download/asset/?asset_id=2081168; (Netherlands Commission for environmental Assessment providing tailor made advice on integrating climate change adaptation in SEA www.eia.nl</p> <p>OECD-DAC: www.seataskteam.net</p> <p>IAIA SEA Performance criteria: www.iaia.org</p>	All steps	<p>Netherlands Commission for Environmental Assessment</p> <p>UK-EPA</p> <p>OECD-DAC</p>	
<p>Down-scaling of climate</p>	REMO – Regional Climate Model of MPI	Germany-Global	Regional climate model	<p>http://www.mpimet.mpg.de/wissenschaft/atmo_sphaere-im-erdsystem/arbeitsgruppen/regionale-klimamodellierung.html</p>	Assessment of impacts	MPI - Hamburg	As collaborative institute

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
projections	Providing Regional Climates for Impacts Studies (PRECIS).	UK – other regions	Regional climate model	http://precis.metoffice.com/	Assessment of impacts	UK MetOffice	
	RACMO - Regional Atmospheric Climate Model used by KNMI	Netherlands	Regional climate model		Assessment of impacts		Could be used but development and application behind other institutes
	WikiAdapt Climate Change Explorer	Asia/Africa/Latin America	Statistically downscaled climate scenarios	http://wikiadapt.org/index.php?title=The_Climate_Change_Explorer_Tool	Assessment of impacts		Useful to use in development projects
	Ensembles project data sets	Europe/Africa	Dynamically downscaled climate scenarios	http://ensembles-eu.metoffice.com/	Assessment of impacts	http://ensemblest3.dmi.dk/	

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	KNMI Climate Explorer – explorer for historic climate data	Global	Historical climate data	http://climexp.knmi.nl	Assessment of impacts	KNMI	Good source for data
Water/ hydrological models	STREAM (Spatial Tools for River basins and Environment and Analysis of Management options)	River basin, any spatial and temporal resolution	Runoff	http://ivm5.ivm.vu.nl/adaptation/project/stream	Assessment of impacts	IVM	Yes, as impact model
	RIBASIM (River Basin Planning and Management)	River basin	Water planning and management	http://www.wldelft.nl/soft/ribasim/int/index.html	Assessment of impacts	Deltares	Yes, as impact model
	SOBEK	River basin	Runoff, drainage, groundwater	http://delftsoftware.wldelft.nl/index.php?option=com_content&task=blogcategory&id=15&Itemid=35	Assessment of impacts	Deltares	Yes, as impact model
	HYMOS	River basin	water resources management	http://www.wldelft.nl/soft/hymos/int/index.html	Assessment of	Deltares	Yes, as impact model

Tool or method	Name	Country/region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
			ment		impacts		
	Rhineflow	Rhine basin, 10 days, 3 x 3 km	run-off	http://www.knmi.nl/onderzk/klimscen/swurve/RF2.html	Assessment of impacts	Deltares	Yes, as impact model
	WaterGAP	Global, Europe, 5 x 5 arc minutes (lat, long) (6 x 9 km)	Water resources	http://www.usf.uni-kassel.de/cesr/index.php?option=com_project&task=view_detail&agid=47&lang=en	Assessment of impacts	CESR/Kassel	No
	LISFLOOD	Europe, 1*1 km ²	Flooding, runoff	http://natural-hazards.jrc.ec.europa.eu/activities_lisflood.html	Assessment of impacts	JRC	No
	European Flood Alert System	Europe, 1*1 km ²	Flooding, runoff	http://efas.jrc.ec.europa.eu/	Assessment of impacts	JRC	No

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	WaterWare		water resources management	http://www.ess.co.at/WATERWARE/	Assessment of impacts	ESS/Austria	
	RiverWare	Non spatial	Water management	http://cadswes.colorado.edu/riverware/ .	Assessment of impacts	Colorado University	
	Interactive River and Aquifer Simulation (IRAS)		Water resources management	http://www.cfe.cornell.edu/research/urbanwater/project%20description/General/IRAS.HTM .	Assessment of impacts	Cornell University	
	Aquarius	Economic	Water allocation	http://www.fs.fed.us/rm/value/aquariusdwnld.html	Assessment of impacts	USDA	

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	MIKE BASIN/	Any basin	Water availability, Infrastructure planning, multi-sectoral demands, Ecosystem studies	http://www.dhigroup.com/Software/WaterResources/MIKEBASIN.aspx	Assessment of impacts	DHI Denmark	Is used globally
	Mike 11	Urban	Flooding drainage	www.dhigroup.com/Software (Bangladesh)	Assessment of impacts		Is used globally
	CALVIN (California Value Integrated Network)	Economic	Water management	http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/	Assessment of impacts	University California	Interesting approach
	WEAP Water Evaluation and Planning	Any basin	Integrated water resources	http://www.weap21.org/index.asp?doc=14&	Assessment of	SEI; Website has other tools/IHE-	Yes

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	System		management	cat=5	impacts	Unesco	
	VIC	River Basin, Continental, Global	Water resources availability/Hydropower	http://www.hydro.washington.edu/Lettenmaier/Models/VIC/ (Vietnam)	Assessment of impacts	Wageningen UR Princeton/ Uni of Washington	Yes, For impact modeling, but complicated
	OSWRM (Okanagan Sustainable Water Resources Model)	Okanaga, scenario development	Sustainable water use	http://www.forestry.ubc.ca/Portals/97/downloads/Okanagan_062a_April2007_Clean_000.zip	Assessment of impacts	UBC	
	DELWAQ					Deltares	Don't know
	Globio- aquatic/ Gloio3 – model focusing on biodiversity	River basin/global	Global / Regional /	http://www.globio.info/	Assessments of impacts	PBL	Yes for global and regional assessments

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
Water/quality	MONERIS	National, river basins in Europe	nutrients		Assessment of impacts	JRC, IGB Berlin	
	HBV-N	National, river basin	nutrients	http://www.smhi.se/sgn0106/if/hydrologi/hbv_np.htm	Assessment of impacts	SHMI	
	GREEN	Europe	Pressures on quality	???		JRC	
	EPIC	Europe	Ag impacts			JRC	
	FATE	Europe	nutrients			JRC	
Land use/ agricultural mod-	WOFOST	Europe, NUTS-2	Crop yields	http://mars.jrc.it/mars/Projects/WOFOST	Assessment of impacts	JRC/ Wageningen UR	Yes as impact model

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
els							
	CGMS	Europe, NUTS-2	Potential and actual crop-specific water consumption	http://mars.jrc.it/mars/About-us/AGRI4CAST/Crop-yield-forecast/The-Crop-Growth-Monitoring-System-CGMS	Assessment of impacts	JRC/Wageningen UR	Yes, but owned by JRC
	LPJmL	Global, 0.5 x 0.5 degree (lat., long.)	Crop yield/Water resources/irrigation	http://www.pik-potsdam.de/research/cooperations/lpjweb/	Assessment of impacts	PIK/Wageningen UR	Yes for global assessments
	LandSHIFT	Global, Europe, 1 x 1 km	Land use change	http://www.usf.uni-kassel.de/cesr/index.php?option=com_project&Itemid=143&task=view_detail&agid=27&lang=en	Assessment of impacts	CESR/Kassel	no
	IMAGE		Land cover	http://www.pbl.nl/en/themasites/image/index.	Assessment	PBL	Yes for global

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
			area	html			of impacts assessments
	The CLIMPACTS system is an integrated computer-based model developed to examine the sensitivity of New Zealand's climate, agricultural and horticultural sectors to climate change and variability.	New Zealand	Different sectors	http://www.waikato.ac.nz/igci/climpacts/System.htm	Assessment of impacts	Waikato university, NZ	Framework could be used for NL.
	Farm System Model: FARM-ADAPT – optimization model	UK	Agriculture	http://www.nottingham.ac.uk/environmental-modeling/Parsimony%20Case%20Study%20Models.htm	Evaluation of adaptation option	Univ of Nottingham	Maybe for application in the Netherlands
	CLUE-s	Many countries all over the world	Regional / National / Local	http://www.cluemodel.nl/	Assessment of impacts	Alterra / VU / Aidenvironment	Yes, for land use change issues
	Land Use Scanner	Netherlands (100m)	land use change	www.feweb.vu.nl/gis	Assessment of impacts/ Evaluation of adaptation strate-	Netherlands	Yes, focus on land use change not water

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
					gies		
	EU-CLueScanner	EU	Land use change	http://ec.europa.eu/environment/enveco/studies.htm#7	Assessment of impacts/ Evaluation of adaptation strategies	JRC	Interesting tool, focus on land use in the EU.
	APSIM	Local, around the globe	Farming systems	www.apsim.info	Assessment of impacts/ some evaluation options	APSRU, Australia/WUR	Yes, for impact modelling, in semi arid regions
Coastal management	Delft3D		hydrodynamics, sediment transport and morphology and water quality	http://delftsoftware.wldelft.nl/index.php?option=com_content&task=blogcategory&id=13&Itemid=34	Assessment of impacts	Deltares	Yes as impact model

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	SURVAS -> DIVA/DINAS-COAST	Global, regions	Coastal vulnerability	http://diva.demis.nl/	Assessment of impacts	PIK, EC	No
	MIKE-Info Coast	rivers, lakes, estuaries, bays, coastal areas and seas	flows, waves, sediments and ecology	http://www.dhigroup.com/Software/Marine.aspx	Assessment of impacts	DMI	Is used globally
Multi sector	SimClim	SLR scenarios	Different sectors	http://www.climsystems.com/	Assessment of impacts	ClimSystems Ltd.	Framework useful, model privately owned
	RegIS Project: Simulating the effects of future climate and socio-economic change in East Anglia and North West England		Water / biodiversity	http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=326&Itemid=9	Assessment of Impacts	UKCIP	Promising for use in NL, user friendly, probably data intensive, similar to Kli-

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
							maatatlas
	klimateffectatlas	Netherlands`	Water, agriculture, biodiversity	http://klimateffectatlas.wur.nl/bin/cmsclient.html	Assessment of impacts	WUR/IPO	Promising for export, data intensive, user friendly
Benefit Analyses	Routeplanner	Netherlands	Adaptation costing	http://www.narcis.info/publication/RecordID/oai%3Alibrary.wur.nl%3Awurpubs%2F383605/Language/en/?jsessionid=59m4nf2depiv	Evaluation of adaptation strategies		Yes as approach
	ClimateCost: economic costs of inaction, and the costs and benefits of adaptation	UK/PF7 project	EU	http://www.sei.se/programmes/risk-livelihoods-a-vulnerability/projects/1585-climatecost-the-full-costs-of-climate-change.html	Evaluation of adaptation strategies	Projected started in 2009	More a project than a tool
	Berg River Spatial equilibrium model – especially developed for cape region	South Africa	Water sector	No link -			Nice example. Could be useful

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	south Africa						for other regions
	University of California - Davis Statewide Economic-Engineering Water Model - CALVIN	California	Water Sector	http://cee.engr.ucdavis.edu/faculty/lund/CALVIN/	Evaluation of adaptation strategies	JC- Davis	useful for NL to simulate
Based Models	Climate Outlooks and Agent-Based Simulation of Adaptation in Africa –	Local farmers in Africa	Agriculture				No, project finished not much useful info available
	COBWEB (Complexity and Organized Behaviour Within Environmental Bounds) - The COBWEB project aims to computationally simulate the adaptation of autonomous agents in a changing environment.	local	Social/behavioral change	http://www.cobweb.ca/		<i>Selection of adaptation options</i>	Interesting for application in NL/ Not for export
	CRiSTAL (Community-based Risk Screening Tool - Adaptation and Livelihoods) is a tool designed to assist project	Local	Rural communities		Assessment of	unclear	Useful for rural adaptation in developing

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	planner and managers with integrating risk reduction and climate change adaptation into community-level projects.				impacts		countries
Databases	ADAM Digital Compendium Adaptation Catalogue	Germany/EU	EU	http://adam-digital-compendium.pik-potsdam.de/adaptation-catalogue/	Mainly Assessment of Impacts	PIK	Useful background document
	Data, Methods, and Synthesis Activity of the AIACC Program (Assessments of Impacts and Adaptations to Climate Change)	US/START	Selected developing regions	http://sedac.ciesin.columbia.edu/aiacc/	Mainly Assessment of Impacts	ended in 2006	No
	WikiAdapt			Wikiadapt.org			Useful website especially for local adaptation
	ADAM Digital Compendium Adaptation Catalogue – option database	Germany/EU	EU	http://adam-digital-compendium.pik-potsdam.de/adaptation-catalogue/option-database/drought.html	Selection of adaptation options	PIK	Useful database

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	UKCIP- Adaptation Actions database	UK	Different sectors	http://www.ukcip.org.uk/index.php?option=com_content&task=view&id=286&Itemid=423	Selection of adaptation options	UKCIP	Useful as an example to be developed elsewhere
	UNFCCC – Local Coping Strategies Database	Developing Countries	Global	http://maindb.unfccc.int/public/adaptation/	Selection of adaptation options	UNFCCC	
	AIACC-DMS Toolkit – Mainly a list of impact models			http://sedac.ciesin.columbia.edu/aiacc/toolkit.html			
Evaluation frameworks	Watertoets	Netherlands	local	http://www.helpdeskwater.nl/watertoets/		NL leeft met water	Probably too local process could be used internationally
	SEA	UK, anywhere	Guidance for Practitioners	http://www.epa.ie/downloads/advice/ea/epa_strategy_climate_change_guidance.pdf		UK EPA	Useful but brief guideline

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
			ners				for EIA
	Performance Indicator NI 188 as part of the Local Area Agreement process	UK	local	http://www.lga.gov.uk/lga/aio/1382855		UK CIP	
	Flood risk zone mapping (Overstromingsrisicozonering)	NL	Local	http://www.planbureauvoordeleefomgeving.nl/nl/publicaties/2010/Overstromingsrisicozonering-in-Nederland.html	Assessment of impacts	PBL	Usefull approach
	Routeplanner Ark						
Guidelines for adaptation planning	Klimaatwijzer	Nederland	Local/regional	ARK, still to be published		VROM	

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	USAID. Guidance manual for development planning: Adapting to Climate Variability and Change	United States	Developing countries	USAID. Guidance manual for development planning: Adapting to Climate Variability and Change		USAID	
	United Nations Development Programme (UNDP) guidance on 'Formulating an Adaptation Strategy'	UN	Developing countries	http://www.undp.org/climatechange/adapt/apf.html	All steps	UNDP	
	WikiAdapt Adaptation Decision explorer: evaluation of adaptation options under climate uncertainty with multiple decision approaches	UK	Developing countries	http://wikiadapt.org/index.php?title=Climate_Adaptation_Decision_explorer	Evaluation of strategies	Prototype, at SEI	
	Scottish Local Climate Impacts Profile (LCLIP) Guidance	UK	Local	http://www.sccip.org.uk/default.aspx?pid=1	Assessment of impacts	UKCIP	
	UK Climate Impacts Programme (UKCIP) 'Identifying Adaptation Options'		All levels	http://www.ukcip.org.uk/index.php?id=23&option=com_content&task=view	All steps	UKCIP	

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	UKCIP 'Adaptation Wizard'		All levels	http://www.ukcip.org.uk/index.php?Itemid=273&id=147&option=com_content&task=view	Impact assessment/ selection adaptation options	UKCIP	Useful approach could be used in NL
	ESPACE 'A toolkit for delivering water management climate change adaptation through the planning system'	UK	local, water	http://www.espace-pro-ject.org/publications/library/SEERA%20toolkit_1-5.pdf and http://www.espace-pro-ject.org/publications/library/SEERA%20toolkit_appendix_7.pdf	selection adaptation options (with some impacts)	Hampshire City Council	Useful approach could be used in NL
	Geological Survey of Finland 'Towards Climate Change Adaptation Strategies in	Baltic	Regional	Geological Survey of Finland 'Towards Climate Change Adaptation Strategies in the		GSF	No

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	the Baltic Sea Region'			Baltic Sea Region'			
	NordRegio, 'Climate Change Emergencies and European Municipalities: Guidelines for Adaptation and Response	Norway, Sweden, Finland	Regional	Nordregio (2009) Climate Change Emergencies and European Municipalities. Guidelines for adaptation and response. Page 3		Nordregio/ Sweden	No
	'Climate Change, Impacts and Adaptation Strategies in the Alpine Space'	Alps	Regional, mountains	http://www.climchalp.org/images/stories/documents-national_texts/climchalp_common_strategic_paper_en.pdf		ClimChalp	No
	United Nations Economic Commission for Europe (UNECE) 'Draft Guidance on Water and Climate Adaptation'	Europe	River basin, water	UNECE. Adaptation for Transboundary Watercourses		UNECE	Useful for export and NL
	International Council for Local Environmental Initiatives (ICLEI) guidance 'Preparing for Climate Change: A Guidebook for Local, Regional and State Governments'	Urban areas	All levels, urban areas	http://www.icleiusa.org/action-center/planning/guidebooks		ICLEI	

Tool or method	Name	Country/ region of Application	Level/sector of application	Weblink	Step in adaptation cycle	Available	Promising for Netherlands/ Export
	The Australian Government's Climate Change Impacts & Risk Management Guide for Business and Government	Australia	All levels	http://www.climatechange.gov.au/impacts/publications/risk-management.html		Australian government	Useful for NL
Visualisation tools	The ICLIPS Impacts Tool comprises a database of impact diagrams that result from climate impact simulations performed in the ICLIPS project and a graphical user interface for accessing and presenting these impact diagrams		Water/ ecosystems/ agriculture		Assessment of Impacts	PIK	No
	Touchable	Netherlands	Spatial Planning		Selection of adaptation options		Yes – but data & technology intensive



To develop the scientific and applied knowledge required for
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Knowledge infrastructure for managing climate change

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