Climate change in the Netherlands in a global and European perspective – our boundary conditions

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1 Description work package

1.1 Problem definition, aim and central research questions

What conditions can be expected (evaporation, precipitation, river discharges, sea level rise and consequent salt intrusion and other water quality issues) and what range of conditions should be taken into account to assess the severeness of an inadequate fresh water supply? But also what opportunities does Dutch society have under changed climate conditions? This Work Package will determine the boundary conditions for water management in the Netherlands and place climate change in the Netherlands in a global perspective, in particular in relation to the remainder of Europe and the Rhine/Meuse river basins.

The aim of the Work Package is to provide the water managers and the actual stakeholders with the boundary conditions in terms of *climate and hydrology* and corresponding *economic setting* in which they might have to operate under climate change. The boundary conditions for climate will be taken from KNMI (theme 6) and also the resulting hydrological situation (in particular the river discharges) will be determined in cooperation with theme 6. This will be done for the whole of Europe. The consequent economic effects of drought will be investigated for relevant European countries in general and the Netherlands in particular. Direct and indirect economic effects of increased drought by climate change will be reviewed. Meso- and macro data will be developed to sketch the importance of drought in Europe and the options the Netherlands has under these conditions. Next, and in cooperation with theme 6, building upon earlier national studies ("Klimaatbestendigheid Nederland Waterland", Netherlands Drought Study, ACER project) and European projects (e.g. WATCH, SCENES) consistent sets of boundary conditions for the fresh water use in the Netherlands will be developed, taking into account possible developments upstream in Germany and France with respect to demand and storage. What fresh water shortages will Germany, France and Belgium face and how may they react? What are possible consequences of upstream evelopments for the hydrology of the river Rhine? For this Work Package cooperation with the German policyresearch project KLIWAS will be established.

The central research questions for the Work Package are:

- What are the expected climate changes in Europe and are there differences in expected change between regions and countries?
- What threats and opportunities emerge from (the regional differences) of this change for economic sectors in the Netherlands?
- What will be the effects of climate change on the hydrology in the Rhine and Meuse basins (e.g. discharge, evaporation and precipitation?
- To what increase of salt intrusions will these changes lead?
- What kind of response can be expected from the upstream stakeholders and (regional) governments on the surface changed climatologically conditions?
- What will be the impacts of these possible upstream developments for the cross-boundary inflow of the Rhine and Meuse to the Netherlands?
- What are the perceptions of the stakeholders (farmers, firms, etc.) on drought (and possible increased drought) because of climate change and what will be their response action?

1.2 Interdisciplinarity and coherence between the projects

The two projects within this Work Package are closely related and will develop in parallel. The first project focuses on the (socio-)economic effects of climate change and related threats and opportunities on economic sectors and individuals. This project will be carried out by economists with experience in the water sector. The second project addresses the physical aspects involved in terms of hydrology (rainfall, river flow, etc.) but also the possible developments that upstream users and governments might consider and the impacts this will have on the water availability for the Netherlands. This second project will have a more physical science (hydrology) and engineering (water management) orientation.

The interaction between the two parallel projects is designed so as to establish in project 2 (scenario's for) meteorological consequences (temperature, rainfall, evaporation, etc.) of climate change and the resulting availability of water. Based on this information the economists of project 1 will determine the effects on economic sectors. The responses of the sectors in turn might lead to actions (e.g. different crops, water storage), which will result in hydrological impacts, in particular in terms of water availability. At the other hand, the actions that water managers might take will influence the performance of the economic sectors and the options these have to cope with the new situation. Consequent case study work will be developed in co-operation with Projects 6.1 and 6.3 in a common design for a survey.

1.3 Stakeholders

The stakeholders benefiting from the research of this Work Package are the national and regional water managers at policy and operational level (DGW, RWS, provincies, waterboards), sectoral representative organizations (Ministries, LTO, etc.) and the actual users of the water (agricultural and industrial companies). The research will contribute directly to (and cooperate with) the Fresh Water Supply component of the Deltaprogramme. It will provide also input to and boundary conditions (hydrological and economic) for some of the other Work Packages, in particular the cases of Work Package 6.

2 Project 1.1 Economic prospects under climate change in a global and European perspective

Project leader: prof. dr. A. (Anne) van der Veen

2.1 Problem definition, aim and central research questions

In recent reports of the IPCC (Easterling, et al., 2007) attention has been given to the effects of drought worldwide. The effects mainly focus on food security in developing countries. Drought as the consequence of extreme effects of climate change, however, also will affect developed countries: long periods of drought will influence vegetation, biodiversity, agriculture, fresh water quality, quantity of cooling water and consequently efficiency of industrial production.

In this project we will investigate literature on the economic effects of drought in Western European countries in general and the Netherlands in particular. The methodology to establish direct and indirect economic effects will be reviewed, incorporating the already established methodologies to compute the economic effects of disasters. Moreover we will come up with micro- and meso data to sketch the importance of the phenomenon. Within the literature on disasters a fierce discussion still takes place on the issue of vulnerability (Adger, 2006) and resiliency (Birkmann, 2006; Folke, 2006; Fussel, 2007). Matters of definitions shade however the urgent need to sketch how resilient societies are to disasters in general and drought in particular. Within the discipline of economics major steps are being made now especially on the meso level of economic sectors (Rose, 2004). In this project we want to extend this expertise to the level of individual firms (the micro level) in order to measure whether and how firms are able to cope with drought.

Consequently, the aim of this project is to develop a methodology that captures the economic effects of drought on a meso- and micro level, and to apply this methodology to our hotspots.

In the recent discussions in the Netherlands on how vulnerable the country is for flooding, the economic methodology to assess vulnerability focused more on mitigation than on adaptation strategies. Drought and increased salinity, as a new challenge for Dutch society, requires a clear spotlight on adaptation.

That implies a rethinking of our economic models that try to capture these effects: Not only on a meso level, where forward and backward chains multiply exogenous shocks, but also on a micro level. On this micro level, firms will adapt, e.g. through innovation, dependent on how they perceive the dangers of fresh water supply.

Therefore, the research questions for our project are the following:

1. What are the threats and emerging opportunities from climate change for economic sectors in the Netherlands?
2. How can we develop a new methodology that covers economic consequences of drought/salinity on a meso- and a micro level?
3. Is it possible to design policy measures of economic resiliency on both levels?
4. What are the outcomes of our analyses for some specific hotspots?

2.2 Approach and methodology

Drought in the Netherlands is a known issue, mainly researched by ecologists. For economists the issue becomes more and more important, because the functioning of the economy itself is at hand in case of dramatic changes in freshwater supply. Recently, several projects devoted (although rather scattered) attention to drought and consequences for Dutch economy: Sites like www.helpdeskwater.nl and www.droogtestudie.nl summarize research output. It is however apparent that most output is delivered by civil engineers. In Ecorys (2003) one of the few attempts to estimate damage to the Dutch economy is presented. Interestingly, on page 19, it is concluded that no detailed information for particular agricultural sectors was available to assess effects of drought. Ecorys applied a meso scale input-output model to estimate economic effects. Recently Agricom (see helpdeskwater.nl) was developed as a combined hydrological/economic model that enables to compute costs for the agricultural sector.

However, this model is not combined with the meso and macro economic scale. In the past economists devoted a lot of attention to flood damage to the macro economy and to the meso level of particular economic sectors (Bockarjova, Steenge and van der Veen, 2004a and 2004b). This damage estimation required a special methodology, dependent on input-output modeling. Specifically the point of resiliency got more and more attention with respect to the question how sectors and firms could cope with discontinuities in their production and in their demand and supply structures (Rose, 2002). Basically, it is important to estimate the redundancy in an economy in order to assess the vulnerability to a disaster (van der Veen and Logtmeijer, 2005).

Measuring economic effects of drought will contain major parts of the flooding methodology, but also differs in important respects. Floods are sudden shocks that create disruptions in production, and discontinuities in demand and supply of products. However, drought and salinity develop slowly and require water to be handled as a resource. That implies that attention should be given to behaviour of individual firms (the micro level) and their coping strategy in case of disruptions in the supply of fresh water.

In this project we will focus on the meso and micro level in order to research adaptation strategies on firm level and matters of redundancy on a sector level. Macro data will be handled exogenously. Collaboration will be established with Theme 7 and 8, with other economists. In Theme 8 a hydro-economic model is developed which, in our observation, is complementary to our micro approach.

In Theme 7 economic incentives are being investigated. These ideas and consequent results will be handled as input in our firm survey in order to test for resiliency.

An interesting corollary is to investigate behaviour of firms with respect to the risk of drought and/or salinity. A relation can be made with the literature on disaster management and risk communication on measuring intentions and motivations of individual firms to take adaptive measures (Maddux and Rogers, 1983; Martin, Bender and Raish, 2007). This concept has been applied in the recent BSIK project PROMO in Leven met Water, where the project leader participated. For the 2009 technical PROMO reports see http://www.itc.nl/Pub/Home/library/Academic_output/Working_papers_series.html. An important element will be to differentiate between individual measures and collective actions. In this Project we will question individual firms on attitudes, intentions, and on the role of, and trust in, government.

To research the economics around the problem of drought and salinity we will:

1. Investigate the literature on the economic effects of drought in Western European countries in general and the Netherlands in particular.
2. Outline the importance of the phenomenon of drought for the Dutch economy in relation to fresh water supply, based on available information for economic sectors in Dutch (CBS) statistics.
3. Pay attention, on a micro level, to the question how resilient individual actors are in coping with problems of drought. To do so we will in collaboration with Project 6.1 and 6.3 survey individual firms in order to research the role of fresh water in production, the possibilities to adapt to a change in the supply of fresh water, their perception of the risk involved and (technical and economic) strategies to deal with the issue.
4. Here a differentiation between measures of individual agents and the collective is made. TNS/NIPO will be asked to do the survey under our guidance and control; 75 firms will be questioned and asked to send in their forms.
5. Assess firm strategies to cope with drought and increased salinity on a meso level on basis of the methodology in Agricom.
6. Research redundancy on a sector level by extending the Agricom methodology.

2.3 Scientific deliverables and results

With respect to this project we expect to come up with the following results and deliverables:

1. A short literature survey on the economic effects of disasters in general and drought in particular.
2. An investigation of the importance of possible drought for the Dutch economic situation.

3. A methodology for computing damage to firms and economic sectors due to drought and decreasing amounts of fresh water.
4. Estimation on the meso economic level of redundancy by assessing direct and indirect economic effects of drought in the Western part of the Netherlands.
5. A survey design for investigating
    a) Technological and economic aspects of fresh water supply,
    b) Risk perceptions of drought and salinity, and
    c) Consequent economic behaviour.
6. Statistical analysis of a survey under 75 firms of economic aspects of fresh water supply, risk perceptions, motivations and intentions of economic behaviour.

2.4 Integration of general research questions with hotspot-specific questions

The project will increase our understanding of behaviour of individual firms in a more saline environment/ under heavier drought conditions. Consequently, the project will sketch the effects on a meso economic scale of these changing conditions. It is clear that changes in external conditions might have severe consequences for Fruit Cultivation and Horticulture, and therefore on production and employment as is also researched in Project 6.1 and 6.3.

2.5 Societal deliverables and results

There are a few apparent economic sectors that will suffer from drought; the obvious ones are agriculture and horticulture. This project is meant to sketch and research the vulnerability of these important sectors to the Dutch economy. We will establish how resilient firms within these sectors are in coping with alternatives.
However, there are other sectors in the Dutch economy that will be attached by future drought. Fresh water is used in some industries as cooling water (electricity production). Moreover, drought may also lead to transportation problems.
This project will deliver a general description on the consequences of drought for sectors in the Dutch economy and it will produce detailed micro results on basis of comprehensive surveys per firm.

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3 Project 1.2 Impacts of upstream climate change induced developments for the Netherlands

Project leader: prof. Eelco van Beek

3.1 Problem definition, aim and central research questions

Climate change will not only have its impacts on the Netherlands but will affect our upstream countries Germany, Belgium, France, Luxembourg and Switzerland as well. It can be expected that these countries will take adaptive measures to cope with these changes. Of particular importance for the Netherlands are those measures that will further decrease the inflow to the main rivers or measures that will increase the extractions from the river. The ultimate result for the Netherlands will be that the cross-boundary inflow to the Netherlands will be reduced. In previous research on climate change impacts for the Netherlands (KNMI, RWS/WD, Deltares) only the ‘natural’ reduction of the inflow because of climate change has been taken into account. The possible impacts of upstream measures have been ignored. Under extreme conditions (dry years under G+ and W+) these impacts might be considerable and should be taken into account. This research project will try to quantify these impacts.

The ultimate aim of the research is to derive various scenario's of the effects of climate change and upstream developments on the cross-boundary inflow to the Netherlands. The underlying research is based on the following central research questions:

1. What are the expected impacts of climate change on drought in the upstream parts of the Rhine and Meuse river basins?
2. What are likely adaptive measures that upstream users and water managers can take to cope with these impacts?
3. What are the consequences of these measures in terms of cross-boundary inflow to the Netherlands?
4. What are the resulting boundary conditions for the various hotspots in the country?

3.2 Approach and methodology

The research will be carried out in close cooperation with theme 6, in particular for the first and last central research questions. Cooperation will be established with research organizations in the upstream countries at applied and academic level as well as the international commissions involved (IRC – International Rhine Commission; ICBR – International Commission for the Protection of the Rhine; IMC – International Meuse Commission). Close cooperation with the German policy-research project KLIWAS will be established. The Federal Insitute of Hydrology (dr. Thomas Maurer) is included as foreign partner in the project.

Approach and methodology to answer research question 1

- ∇ application of Regional climate model results forced by different Global Climate Models for different SRED emission scenario's, including bias correction.
- ∇ comparison with model results of national research institutes
- ∇ determination of spatial and temporal differentiated scenario's for rainfall and potential evaporation

Currently in the Netherlands the KNMI 2006 scenarios form the starting point for water resources management assessments. However, these scenario's will be replaced within due time. An important project which results will probably be used for an update of the KNMI 2006 scenarios is the ENSEMBLES project. The ENSEMBLES project provided a great number of climate scenarios for Europe derived from different AOGCM-RCM combinations using aforcing according to different SRES emission scenarios. The project is jointly carried out by a great number of meteorological offices and research organizations. The ENSEMBLE projections are the results of global climate model outputs, dynamically downscaled using high resolution regional climate models. Currently the RHINEBLICK project is using these results to arrive at water scenario's for the river Rhine basin that have commitment from the different Rhine countries. In 2010 for the River Meuse a comparable project (AMICE) will start. This project will (among other) provide discharge scenarios for the river Meuse, based on the same ENSEMBLE projects. So far the production of scenario's is in its early stages. The idea is that this project will make use of the work that has been done in the ENSEMBLE project and combine it with the results for the RHEINBLICK and AMICE projects. Also for our fresh water theme we consider it of utmost importance that we base our scenarios on internationally accepted boundary conditions. ENSEMBLE provides precipitation, evaporation and temperature data from the following AOGCM-RCM combinations:

Institute	Global Climate Model	Regional Climate Model	IPCC scenario
C4I	ECHAM5	RCA	*A2*
C4I	HadCM3	RCA	A1B
CNRM	ARPEGE	Aladin	A1B
DMI	ARPEGE	HIRHAM5	A1B
ETHZ	HadCM3	CLM	A1B
HC	HadCM3	HadRM3	A1B
HC	HadCM3	HadRM3	A1B
HC	HadCM3	HadRM3	A1B
KNMI	ECHAM5	RACMO	A1B
METNO	BCM	HIRHAM	A1B
MPI	ECHAM5	REMO	A1B
OURANOS	CGCM3	CRCM	A1B
SMHI	ECHAM5	RCA	A1B
UCLM	HadCM3	PROMES	A1B

The RHEINBLICK project will provide projections using the raw AOGCM results, the raw AOGCM-RCM combination results as well as the bias corrected results. These will be used to assess the range of possible future weather conditions, including an assessment of the magnitude of the uncertainty due to different sources. As the ENSEMBLES project only includes the A1b and A2 (only one run) emission scenarios the climate scenario's will be extended with other AOGCM results. At Deltares the results of all 4th assessment IPCC report AOGCM's for the River Rhine and Meuse are available. Also a simple bias correction scheme has been developed. The analysis will be extended with these results.

So far the scenario's for changed climate conditions have only be analysed on their effects of the regime of the River Rhine. In this project it is the idea to develop more tailor made climate scenarios for application in water supply studies. As such the results will also form a boundary condition for evaluating drought management plans already available in the upstream countries.

Approach and methodology to answer research question 2

- determination of impacts of cc scenario's for use functions, in particular agriculture
- literature review of adaptive measure considered in upstream countries
- inventory of drought management plans
- determination of impacts

In particular this part of the project will be carried out in close cooperation with institutes in our upstream countries. Depending on the availability of data and models that describe the relation between meteorology/hydrology and economic functions in those countries (comparable with NHI in the Netherlands) we will determine the spatial differentiated impacts of the climate change scenarios on these economic functions. This will be done in cooperation with the economists of project 1.1. It is expected that the main impacts will be on agriculture. If specific models are not available estimates of agricultural damage will be made by using general crop production functions.

The size of the impact in combination with the hydrological situation will determine if and adaptive measures are feasible. We do expect that some sort of inventory of such measures will be available in existing development and management plans in the various sub-basins. These will be collected and where needed extended to get a comprehensive picture of possible developments. In workshops with the water managers involved we will develop several scenarios for these upstream developments and determine, again in cooperation with project 1.1, the impacts these scenarios have on the economic sectors. Emphasis will be on those impacts in upstream countries that will influence the performance the same sectors in the Netherlands, in particular agriculture and shipping.

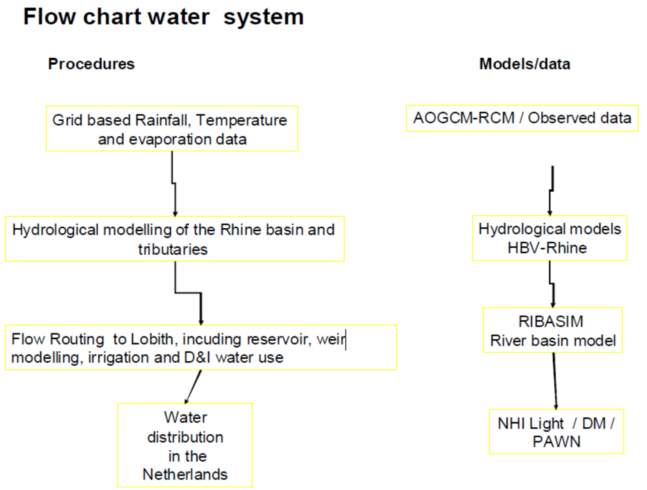
Approach and methodology to answer research question 3

- application of HBV to determine rainfall-runoff conditions
- application of water balance model at river basin level (RIBASIM)
- application of SOBEK to determine impacts on water levels (for shipping)

Discharge scenarios for the River Rhine using the raw ENSEMBLE AOGCM-RCM output data have been produced in the RHEINBLICK project. For the river Meuse, no runs have been produced yet, however the data and models to be used for the production of such discharge scenarios are available at the KNMI and Deltares. The idea in this project is to produce scenario's for both rivers and include an assessment of different sources of uncertainty to them. The sources of uncertainty that will be incorporated are: natural variability, uncertainty due to model errors of the AOGCM's, due to the RCM's, and due to the use of different hydrological models. The importance of the different uncertainty sources will change in time.

In this research project the discharge scenario's resulting based on the ENSEMBLE results will be translated into scenario's relevant for analysis of water supply to the Netherlands. To do so, we will start using the system that is currently in use in the Netherlands to provide discharge scenarios for the river Rhine (FEWS-GRADE RHINE). The core of this system is the HBV-Rhine hydrological model. Currently an experimental system to simulate the effects of climate change on the Rhine/Meuse basin, including the delta is developed in the KvK–KKF-coupling project. We anticipate that this system can be used for running these scenarios next year. This system will allow for using different hydrological models.

The FEWS-GRADE RHINE/MEUSE system has specifically been developed for flood assessment applications. Therefore, water abstractions, reservoirs and water diversions as (including scenarios for new developments as determined in the previous project component) are not well represented (or not at all). It is therefore that we propose to develop a water distribution modelling system based on the RIBASIM software. The runoff in this system will be simulated by the HBV-Rhine model (or others once the experimental system is ready). The drainage and distribution of the water along the river branches will be simulated by the RIBASIM application.



The ultimate result of this component will be various scenarios for water availability (time series of river discharges) at the border of the Netherlands.

Approach and methodology to answer research question 4

- What does this mean for external boundary conditions, e.g. Gouda?
- What will be the internal boundary conditions, rainfall and evaporation?

This last component will provide the boundary conditions for the case studies of WP-6. The time series at the border of the Netherlands will be translated in water availability at the various intakes of our integrating cases. This will be done by using the existing NHI modeling framework. When specific information on internal boundary conditions such as local rainfall and evaporation is needed for the case studies this project will support the case studies in retrieving the right data from WP-6.

3.3 Scientific deliverables and results

The ultimate result of this project will be combined climate change and upstream developments scenarios and the corresponding impacts for the Netherlands in terms of the cross boundary inflow of the Rhine and Meuse. So far jointly developed comprehensive scenarios have not been made yet. The methodology that we will use is state-ofthe- art. The inclusion of possible upstream developments that will influence the water availability for the Netherlands has certainly not been touched upon before.

Specific scientific deliverables are;

- Research reports containing the findings on the central research questions
- Scientific articles (peer reviewed) summarizing these findings

3.4 Integration of general research questions with hotspot-specific questions

The relation of this project with the hotspot-specific questions is mainly in providing the hotspots their fresh water boundary conditions for their intakes as a result of climate change and upstream developments. In combination with the research carried out in WP-2, WP-3 and WP-4 answers will be given to their questions on threats and opportunities. The integration will take place in WP-6 for the 3 selected case studies.

3.5 Societal deliverables and results

For the hotspots the most important societal deliverables and results are given above. The boundary conditions will determine the threats but also opportunities for the economic sectors. At the level of the Netherlands the resulting boundary conditions (the scenarios) are an important input for the Fresh Water project that is presently being carried out as part of the Delta programme.

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