


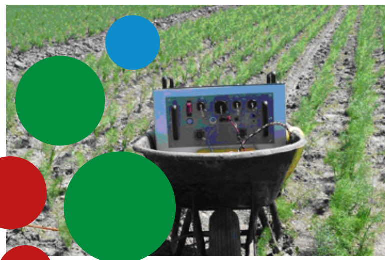

Kennis
voor
Klimaat

Balancing supply and demand of fresh water under increasing drought and salinisation in the Netherlands

Midterm report Knowledge for Climate Theme 2

Balancing supply and demand of fresh water under increasing drought and salinisation in the Netherlands

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1. Introduction

1.1. Climate change, drought and salinisation in the Netherlands

The latest climate impact assessments show that climate change will cause an increasing mismatch between demand and supply of fresh water in many densely populated deltas around the world. This mismatch is a result of droughts that will become more frequent resulting in lower summer river discharges and increasing salinisation. These processes are associated with changing atmospheric circulation, precipitation patterns and sea level rise, not only influencing the water supply but also the fresh water demand.
Recent studies for the Netherlands show that the current water supply strategy is not climate proof in the long-run (Klijn et al., 2012). Therefore, a future 'climate proof' fresh water supply is national priority on the Dutch water policy agenda.
Conventional strategies in the Netherlands rely on the intake of fresh surface water from the rivers Rhine and Meuse. This water is used to replenish regional surface water losses due to irrigation, evaporation and infiltration to the groundwater system. Large amounts of intake water are used to dilute surface waters and to mitigate the effects of saline groundwater seepage. These conventional strategies may not be robust, as river discharges become more erratic, salt water wedge from the sea intrudes further upstream of the rivers, water demand intensifies in drier growing seasons and saline groundwater seepage in low-lying areas with controlled water levels (and confronted with ongoing soil subsidence) increases. In addition, if current trends in the agricultural sector (towards more capital-intensive crops) continue, the demand for good quality water may increase further. This affects vital economic sectors, ranging from local to national level. The importance and urgency of this problem is underpinned by the Delta Program, the main policy framework in the Nerherlands accounting for adaptation in water management. The Delta Program has two main objectives:

1. climate proof water safety in the Netherlands
2. climate proof fresh water supply in the Netherlands.

In the call for proposals of Knowledge for Climate (KfC) the following main (hotspot) questions were identified:

A. How can fresh water supply be robustly designed in order to be flexible in anticipating a wide range of climate effects?
B. What opportunities are offered by reduction of water demand and/or water reuse?
C. What are opportunities and setbacks of water supply by allocation and buffering?
D. What opportunities are offered by water technology and spatial planning?
E. How can we adapt to periods of water scarcity and water quality changes?
F. How effective are these strategies on different scales?

These questions reveal a strong need for research on practical solutions and adaptation strategies.

1.2. Aim of the program

The aim of the program Climate Proof Fresh Water Supply (CPFWS), theme 2 within the Knowledge for Climate (KfC) program, is to develop knowledge about robust and flexible long-term solutions from a local to regional perspective that can contribute to successful strategies to bridge the growing mismatch between demand and supply of fresh water (quantity and salinity) in the changing Dutch Delta.

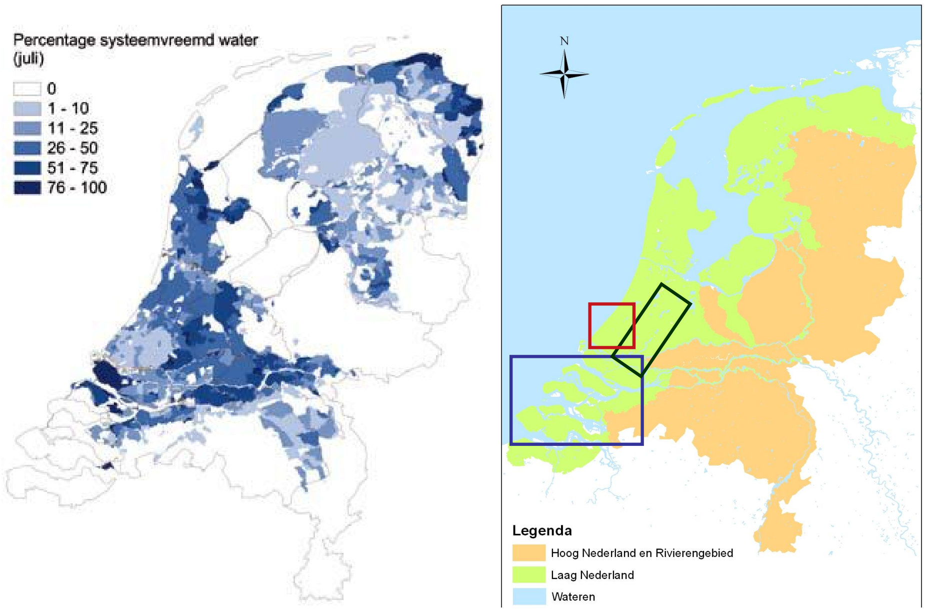

Figure 1.1 Average percentage of external water supply in July (left). Demarcation of 'Laag-Nederland' (right) with indication of hotspot areas in which the research is carried out: 'Zuidwestelijke Delta' (blue), 'Haaglanden'(red) and 'Groene Ruggengraat'(green).

The research scope is limited to 'Laag-Nederland' the lower Western parts (mostly below sea level) of the country. This area is strongly influenced by the availability of freshwater from surface water sources (see Figure 1.1) and has to deal with saline groundwater sources (see Figure 1.2). Therefore, in this area the main reason for the occurrence of fresh water shortage is a lack of 'good quality' or 'low chlorine' water sources. Within 'Laag-Nederland' the actual research is mainly carried out within three case studies: 'Zuid-westelijke Delta' (South-western delta, agriculture on islands, some of them have external fresh water supply some don't), 'Haaglanden' (area between The Hague, Delft and Rotterdam wit a large horticulture sector of major economic importance) and 'Groene Ruggengraat'(wetland and pasture area of high ecological importance close to main greenports).

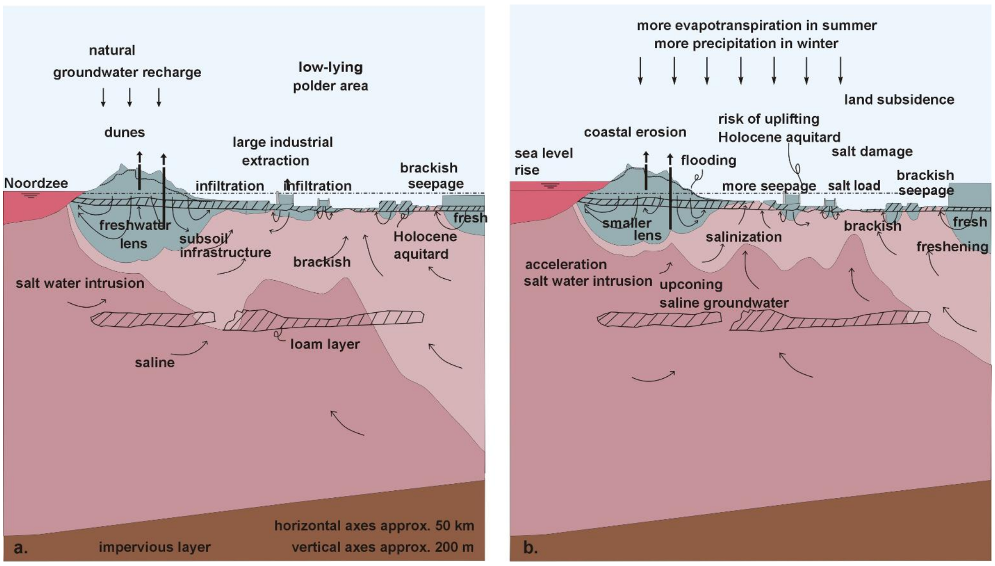

Figure 1.2 Schematized current (a) and future (b) physical processes in the Dutch coastal groundwater system (Oude-Essink et al., 2010).

Central research questions and workpackages

The main research questions were derived from the questions from the call for proposals of KfC, as described in section 1.1 and applied to the above mentioned scope of the program. The main research questions have led to the organisation of the program into six coherent work packages (WP's):

- What range of conditions should be taken into account to assess the severity of an inadequate fresh water supply (evaporation, precipitation, river discharges, sea level rise and related salt water intrusion, economic changes)? Two main questions get special attention: what are possible upstream contributions of changes in water use and what will autonomous-adaptation of the agricultural sector contribute? (WP1)
- How will local to regional solutions contribute to more self-sufficient and more robust and resilient fresh water supply in the Netherlands, divided into 3 categories:
  - *Water management* (WP2)*:* How will fresh-water availability within the coupled groundwater-surface water system change due to climate change and how can the self-sufficiency of water users be increased by iimproving and optimizing water management of individual farms, polders and regional water systems. Up to now, studies of the processes behind the dynamics and of the future behaviour of fresh groundwater storage and the salinisation from groundwater to surface water are limited. Even fewer studies exist of the effects of measures to counteract negative consequences. (Preliminary) results of field monitoring and modelling studies suggest that local and regional solutions – buffering and dynamic control of fresh water storage – could be feasible. It is, however, unknown which solution is most effective in which situation and to what extent and how these measures could be up-scaled to larger areas. This work package, addresses all these aspects.
  - *Land use* (WP3): Optimizing and using knowledge of salt tolerance of natural vegetation and crops. To what extent can tolerance levels of different land uses (in this study agriculture and nature) be stretched? What opportunities for the reduction of the fresh water demand are possible? There has been substantial research on salt- and drought tolerance levels of plant species. Some recent scenario studies have investigated potential impacts of climate change on plants. The main scientific progress that will be made in this program is the development of a new methodology that enables to take into account a realistic variation of dynamic boundary conditions. Besides, mechanisms within salt tolerant species (halophytes) will be further unravelled.
  - *Water technology* (WP4): What is the potential of water technology for providing solutions for regional self-sufficiency in fresh water supply? In the Netherlands, there is little experience with water technologies to
    - Store surface water in aquifers for later use by Aquifer Storage and Retrieval (ASR)
    - Desalinate brackish groundwater (e.g. by reverse osmosis or Memstil)
    - Dispose of the membrane concentrate by deep well injection.

    Yet, these techniques could become an option where fresh ground water is becoming scarce due to both ongoing salinisation and increasing demand of high quality water for agriculture, industry and drinking water. In addition, various polluted waters (like sewage effluent, drain water from glasshouses and rainwater) may become an alternative water source, when treated with modern techniques that out compete traditional expensive systems that require too much space or energy. However, implementation of these techniques is currently hampered by a lack of knowledge on (i) their performance under Dutch hydrogeochemical conditions and (ii) their servere environmental impacts (especially the brine issue). Research is therefore needed to fill up these knowledge gaps, and to adapt and improve the techniques mentioned, in order to substantially contribute to local or regional fresh water supply.

- What approach should be used to build robust and flexible adaptation strategies (WP5), given the uncertainties in the long-term prediction of future climate change effects, and of other relevant socio-economic developments? Compared to water safety issues little research has so far been carried out on decision making about drought and salinisation issues. Water safety and droughts are clearly different issues. Most focus in the Netherlands is on preventing an event (viz. the flood). Drought and salinisation issues on the other hand address a more continuous range of conditions and a more complex set of interests. In addition, a wide set of variables may change in the long-run (such as soil use patterns, developments in agriculture, etc.), requiring consideration of a broader set of uncertainties some of which may not easily be quantified (so-called deep uncertainties).
- How can knowledge about specific adaptation measures and available approaches for tackling uncertainty be integrated in building strategies for selected case studies (WP6). How can solutions be tested, synthesized and implemented in local to regional case studies. Many efforts are undertaken to embed adaptation strategies into regional development projects, the current corner stone of Dutch spatial planning. This gives the opportunity for tailor-made solutions for optimizing freshwater availability. However, this regional approach has some drawbacks, for example the transfer of burdens from one region to another. Therefore, this project addresses the question how a regional strategy relates to neighbouring regional and national approaches. This is also expressed in the three integrated cases (WP-6) provided by the program.

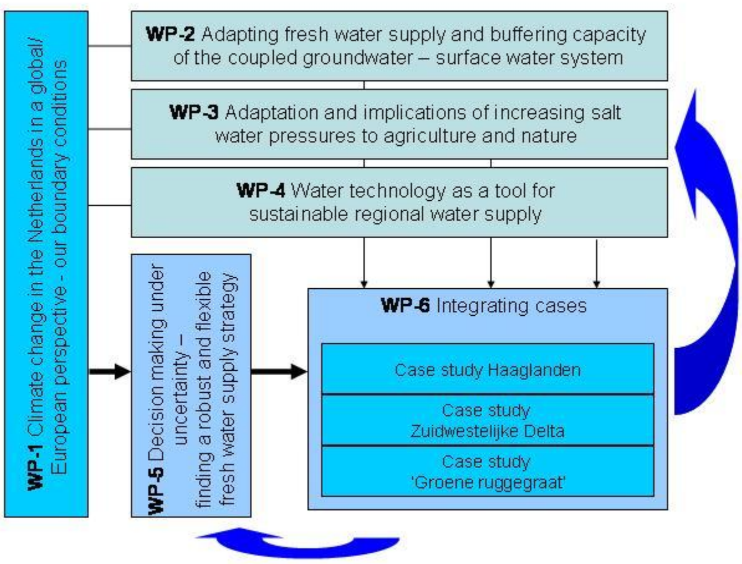

Figure 1.3 Outline of the program in 6 workpackages. Within the boundary conditions provided by WP1 adaptation measures along three different lines are developed in WP2 to WP4. These measures are tested and integrated into strategies in the 3 case studies (WP6) using concepts about how to deal with uncertainty from WP5.

Vision
The vision of the KfC theme 2 is that there is no shortage of fresh water but a mismatch between supply and demand in time and space. This mismatch can be bridged in present and future by creating a more robust system that not only relies on external water supply but on a broader mix of sources and buffers on a local to national level. The ambition of the consortium is to provide knowledge that can be used to assess available local to regional options compared to more national scale options within the Delta Program in 2014. For the stakeholders in the hotspots we aim at providing practical applicable knowledge by working together on pilot projects. In addition, we also see a difference between policy, practice and science in how the problem and potential solution are perceived. Therefore, we aim to add nuances to the national discussion by providing more in depth insight in:

- The main causes of change (a.o. climate, see for instance Figure 1.4)
- The system's reaction to these changes
- The main uncertainties in assessing drought risk
- The perception and reaction to drought risks.

The bottom-up approach of field studies, combined with modeling and conceptual approaches will enable us to upscale results.

Changes from the start of the program
The program and its initial ambition have remained relatively unchanged from the start of the program. The chosen bottom-up approach and local to regional focus has proven to work well in conjunction with the more national scale oriented Delta Program. Only one major change in research topics has been made. Instead of trying to investigate macro-economic changes due to changing water-availability in a national to European context, we have chosen to switch to a behavioural economic approach. So not the question how international markets respond to drought but how do individual farmers respond is investigated in work package 1. This approach fits better to the bottom-up approach of the program..

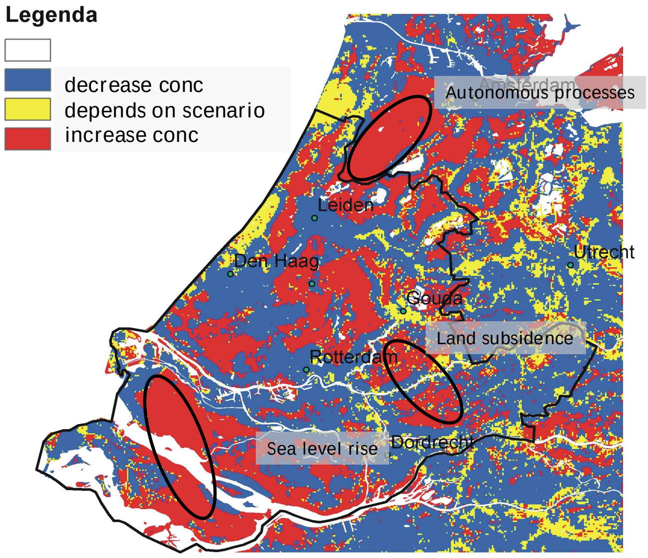

Figure 1.4 Qualitative trends in salinity of the groundwater and main causes under the full range of climate scenarios provided by KNMI (KNMI, 2006). Not every change is climate induced (Oude Essink et al., 2010).

1.3. Research approach

Our research approach consists of three different aims directly related to our central vision (see 1.2).

- Upscaling and downscaling. By conducting field-studies of local to regional processes, we are better able to understand the system, to improve the models and to upscale the results to a national level. On the other hand, we reduce the gap between science and practice by testing theoretical concepts in case.
- Co-creation. In order to bridge gaps between science, policy and practice and to be able to achieve more shared perspectives, the CPFWS program is deploying joint activities with other parties on different levels:
    i. Definition of specific research questions and products has been done together with the major stakeholders and co-financing parties: the involved waterboards, provinces, STOWA, Rijkswaterstaat and the Deltaprogram. These parties are represented within the steering committee of the program, meeting every 6 months to discuss the progress and in various advisory groups.
    ii. Research in case studies within the hotspots. All research projects have a connection to one or more case studies. This means that all researchers in the program have regular interaction with stakeholders, for instance during meetings in which adaptation options for the hotspots are discussed or in which field measurements are compared with modeling results.
    iii. Organizing joint activities and creating joint products: With STOWA (research program of the water boards) and in cooperation with the Delta Program joint workshops are being organized once a year. Some of our products contribute directly to specific research questions of the Deltaprogram (for instance the research on upstream water use). Results of the CPFWS results are directly incorporated in fact sheets for water managers (STOWA Deltafacts).
- Finding a valuable niche for the CPFWS program and at the same time making a good connection with other more scientific or policy oriented research programs. In other words, working on the coherence with related activities within and outside the KfC program.

  Relation with the Delta Program
  The main policy oriented research program in the Netherlands is the Delta Program. This program is executing applied research on fresh water supply at the national level. It addresses the following questions: what are the main challenges? What are possible strategies to cope with these challenges? What are their effects? This applied research is contributing to the policy making process which should lead to a national decision in 2014-2015 on how to organize the fresh water supply in the Netherlands for the long term. The CPFWS research is contributing to the Delta Program by giving more insight in the potential of local to regional strategies, and its benefits for the water management on a national scale. The Delta Program in return is providing the context and boundary conditions for the research of CPFWS in the hotspots.

  CPFWS within the KfC program
  Whereas the CPFWS research is focusing on the lower parts of the Netherlands dealing with salinisation, theme 3 (CARE) of KfC is focusing on higher parts (‘Hoog Nederland’)

also taking into account the drought issue and effects on nature and agriculture. |The CARE program, also follows an agent based modeling approach (as in CPFWS, work package 1). Theme 6 of KfC works on the improvement of climate scenarios and its hydrological consequences. These results will feed in changed ranges of boundary conditions for CPFWS. Theme 7 (Governance) of KfC studies water pricing as a possible strategy to cope with fresh water shortages. Within the hotspot, 'Zuidwestelijke Delta' this study is integrated in strategies developed by CPFWS. Within theme 8 of KfC (Tools for adaptation), a study is ongoing on the macroeconomics of water distribution from an European water market perspective. This study may provide new insights in economic context for the Netherlands. Deltares as a CPFWS partner is directly participating in this research, but no results were available for this report yet. The PhD research on system robustness is a joint project between theme 1 (Flood risks) and CPFWS. The concept of system robustness is applied to both drought risk (see Box 1.1) and flood risks.

Box 1.1 Drought risk

Drought risk can be defined as the combination of probability of (meteorological) drought and its consequences. The consequences are a function of the area's vulnerability and the local exposure to the drought, which is primarily determined by the geographical characteristics of the area and the water supply infrastructure (e.g. access to irrigation).

Alternatively, drought risk can be defined as the combination of hazard and vulnerability. We consider precipitation deficit as the drought hazard, a phenomenon that is external to the system. Drought hazard is described by a probability of occurrence can be mapped geographically, showing the areas that may be affected by this deficit. The vulnerability describes the relationship between the amount of precipitation deficit and the effect on functions and/or users (e.g., crop yield loss).

International dimension

International experts and institutes are also involved in the CPFWS research. Their input is either the involvement in the projects as actual research partner or the provision, advising or supervision in a project, a work package or the full program.

For example, the University of Kassel in Germany is participating in the research on upstream water use by applying their models to the Dutch climate scenarios. Another example: the group of Dr. Bouksila in Tunisia is sharing experimental facilities with CPFWS researchers in Wageningen and Amsterdam and co writing on joint papers (e.g. Bouksila et al., 2012).

For the full program, a Scientific Advisory Board is established who will meet twice during the course of the program to discuss the approach and progress of the projects. The first meeting is planned in October of this year.

CPFWS researchers are in addition visiting international conferences and workshops, following international literature and participating in other related, often international, research projects (for example the Rheinblick project, Figure 2.1) and networks. In this way, the national oriented CPFWS research is being checked against relevant international scientific developments. In May, a midterm integration report (in Dutch) has been finished (Jeuken et al., 2012). All researchers were asked to make an abstract of the five most relevant international references for their research. These references can be found in the reference section of this report.

How to read this report

This Mid-term report roughly consists of two parts. In the first part, chapter 2 and 3, a summary is given of the research and its results and mild conclusions being half way down the program. This is not done in a project-by-project summary but we have tried to give an integrated overview illustrated by some examples in textboxes. In the second part, chapter 4, a reflection is given on the progress of the work: are we on the right track, did we achieve what we aimed at: scientifically and societal?

2. Effects of drought and salinisation in a changing climate

2.1. Introduction

Droughts have multiple effects for the regional water system ín 'Laag Nederland:

- During low river flows, salt seawater is intruding the delta via the Nieuwe waterweg causing closure of fresh water inlets to the regional water system. In the current climate this happens sometimes in dry summers. Under climate change sea levels may rise and river discharges may be reduced further causing more frequent and longer closures of water inlets during dry summers. Recent results of the Delta program (Klijn et al., 2012) show that especially the water inlet near Gouda will have to close much more frequently in 2050 under a dry climate scenario (W+, KNMI06). Figure 2.1 shows that for river discharges there are large differences between the 4 KNMI scenarios but also between 2 different methods to calculate the climate effects (De Keizer.et al., 2012)
- Continuing sea level rise and soil subsidence will locally have additional adverse effects on saline seepage increasing the demand for external fresh water to maintain low chlorine concentrations in the system (Oude Essink et al., 2012)
- During droughts, evaporation of plants and surface water leads to an increase of the fresh water demand to maintain water levels and to fulfill irrigation needs. Rainwater lenses in parcels might get exhausted. These impacts will become more serious when due to climate change droughts occur more frequent. In addition, socio-economic developments through changing land use might lead to changes in the water demand.

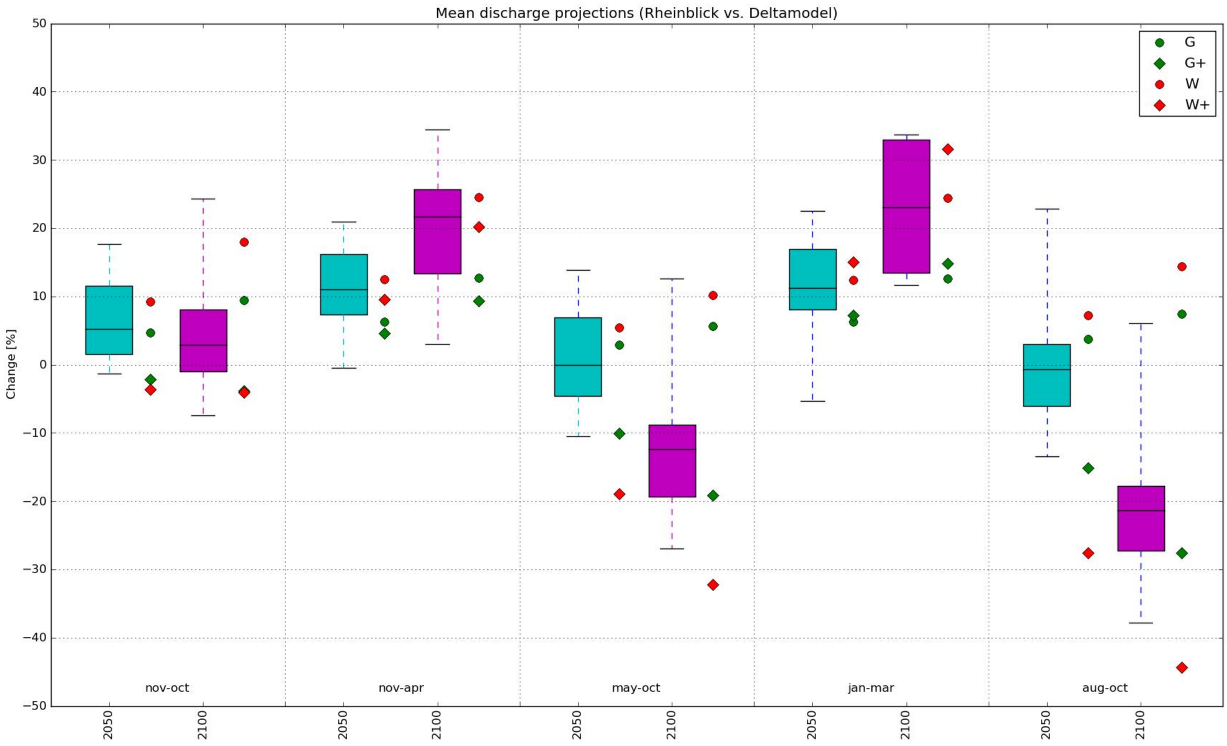

Figure 2.1 Comparison between model calculated average discharges of the River Rhine from Rheinblick2050 project (blue and purple Whisker plots showing the 5, 25, 50, 75 en 95 percentile) and the Delta scenarios (red and green dots and diamonds), for different periods in the year for 2050 and 2100. (www.chr-khr.org/projects/rheinblick2050)

The Delta Program is using the national hydrological model (NHI) to calculate the effects of changing climatic conditions and changes in land use (via the Delta scenarios, Bruggeman et al., 2011) on the fresh water availability for the regions in 'Laag Nederland'. A lot of work on national impacts has been done in previous studies (e.g. Van Beek et al, 2008, Oude Essink et al, 2010). The CPFWS program is (critically) taking these impacts as boundary conditions for developing and testing adaptation measures in the case studies. However, two specific studies are added by the CPFWS program, that are relevant for these impacts:

- The economic dimension of droughts
- The impacts of climate- and socio economic changes on the upstream water demand and consequences for low river flows.

Both studies are described below.

2.2. Economic drought effects

Introduction

The severity of a drought lies in its impacts. Economic loss serves as an indicator for estimating economic vulnerability to drought. Depending on the flexibility of production factors, the extent of economic losses due to droughts change over time. It is not always straightforward that an economy returns to a pre-drought level in the long term.

Two observations from international literature on economy-wide models can be drawn (Mechler, Hochrainer et al., 2010; Horridge, Madden et al., 2005; Wittwer and Griffith, 2010; Salami, Mideksa, 2010; Lennox and Diukanova, 2011). First, economic losses due to drought are substantial in the short-term; estimates of relative decreases in GDP vary between 2% and 11%. Part of these differences might be due to the characteristics of a county's economic structure and characteristics. A second conclusion is that droughts have a long-term impact on the economy. The long-term simulation studies how that the economy does not return to the pre-drought situation due to disinvestments and bankruptcy.

Droughts cause crop damage and result in a decrease in farm income. First estimates within the scope of the Delta program indicate that the economic loss to the Dutch agricultural sector may reach 700 million € in a 'dry year' with a precipitation deficiency of more than 220 mm in summer (frequency of 1/10 years). In an 'extreme dry year' with a precipitation deficiency of over 360 mm in summer (frequency of 1/100 years) the economic loss to the agricultural sector may reach 1800 million €. This is equal to 0.1% and 0.3% of GDP respectively. Due to climate change and socioeconomic developments these damages might increase fivefold in 2050, meaning that the agricultural sector will face a loss of 700 million € once every two years (Ministerie van Economische Zaken Landbouw en Innovatie, 2011).

The drought impact is not homogenous among farmers, indicating that some farm types are better capable of adapting to drought than others. Farmers adapt through changing cropping patterns, irrigation planning, irrigation technology choice, irrigation practices and the adoption of new innovative technology. According to agricultural economic literature farmers', adaptive capacity is determined by the natural and production characteristics, such as soil characteristics, irrigation technology use etc. These characteristics induce a degree of flexibility making it more easy or hard to adapt to drought events (Iglesias, Garrido et al., 2003).

Approach
Economic loss is an often-used indicator to measure the agricultural sector's vulnerability against droughts. The vulnerability of the agricultural sector depends on several aspects:

1. the hazard: drought duration and intensity
2. the sensitivity of the production process: e.g. type of crops and production technique
3. adaptive capacity: farmers' the ability to take adaptive measures

Due to restrictive assumptions (rationality), traditional economic models, that use a top-down approach, do not consider adaptive capacity as an important determinant of vulnerability (in literature this is sometimes called the 'dumb farmer approach'). Instead, farmers are proactive agents that adapt to changing circumstances. The drought vulnerability of the agricultural sector as a whole depends on the way individual farmers adapt. Using a bottom-up approach, where we investigate farmers' individual willingness to adapt using a survey and adaptation diffusion using Agent-Based Modelling, enables us to study the role of the adaptation process in the determination of the agricultural sector's drought vulnerability.

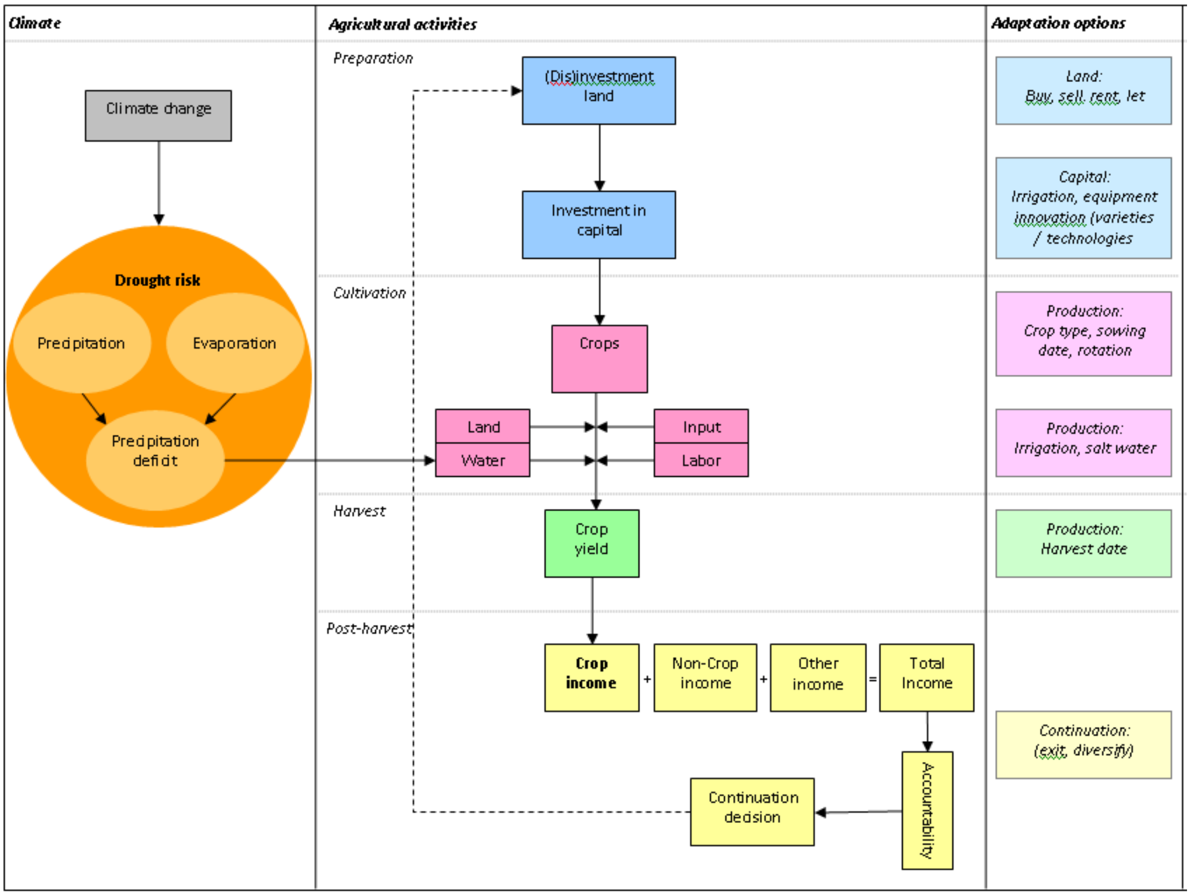

Figure 2.2 Conceptual model of Agricultural activities and adaptation options (van Duinen, 2011)

CPFWS focuses on individual (or autonomous) adaptation against droughts. Most projects within this theme focus on the technical feasibility of adaptation measures against water shortage and salt problems in the agricultural sector. The successfulness of these adaptation measures does not only depend on the technical feasibility, but also on the implementer's attitude towards these measures. A farmer's perception of drought (salt) risk, the effectiveness of adaptation options and costs are for example factors that determine a farmer's willingness to adapt. This project investigates these factors using a survey among farmers (n=300) in the 'Zuidwestelijke Delta', and therefore contributes to a more complete picture of the feasibility of several adaptation techniques.

Preliminary results:
A conceptual model describing the interactions between the agricultural activities on a farm, the pressures it is experiencing and the options to adapt (van Duinen et al., 2011). A module to calculate drought damage was added to the software for agent based modeling. We implemented a hypothetical case where farmers react to the physical environment (crop loss) and the social environment (crop loss of other farmers in their social network) to test the software (van Duinen et al., 2012). The questionnaire has been constructed and reviewed by several people including representatives of the agricultural organization (ZLTO).

Outlook
This fall the questionnaire will be distributed and executed. Model development and testing will be further continued. The outcomes of the questionnaire will provide data for the model. In the end we expect to gain insight in:

- the factors that determine farmers' willingness to adapt (survey)
- the dynamic adaptive behavior of farmers over time
- the diffusion of adaptation measures among the group of farmers

This bottom up research will not lead to estimation of the total economic loss to the agricultural sector in the Netherlands, to endogenous estimation of agricultural prices or estimation of crop price elasticities.

2.3. Impact of upstream climate and socio-economic changes on the low flow discharge of the river Rhine.

Introduction
The objective of this project is to combine projections on climate and socio-economic developments for the Rhine basin upstream of the Netherlands, to determine their combined impact on low-flow conditions. This way we can give answer to questions such as: Which sectors have higher water consumption rates? Which trends are foreseen for 2025 and 2050 in terms of sectoral water demand? What is the expected impact of climate or projected socio-economic developments on the water consumptions of sectors?
What is the overall impact on low flow in the Rhine at Lobith and should the Netherlands worry about what might happen upstream?

Approach
To investigate these questions CPFWS is following these steps:
1. Assess the current situation in terms of water demand for the sectors a. Domestic + small businesses, b. Industry, c. Energy, d. Agriculture
2. Develop future scenarios of water demand by selecting appropriate scenario's for climate and socio-economic development.
3. Translate scenarios to changes in water consumption patterns for the different sectors.
4. Apply a river basin model (Ribasim) and a water balance model (WaterGAp3) to estimate the effects of different scenarios on: sectoral water abstraction, sectoral water consumption, national water demand patterns and ultimately on discharges (low flows, droughts duration, drought intensity etc.). This work is carried out in cooperation with the Centre of Environmental System Research (CESR) of the University of Kassel. CESR results of the river basin simulation modeling for the Rhine will be compared with the output of Deltares RIBASIM model to identify similarities and discrepancies ofmption scenarios in the Rhine, coupled with expected climate change developments.

Preliminary results

Until know the current water demand of the different sectors in the upstream countries has been gathered by combining different sources of information about areas, yearly statistics, results from previous EU projects etc. Absolute amounts however remain uncertain. Table 2.3 shows the relative distribution between surface water use and groundwater use in the different areas oft the Rhine Basin (excluding the Netherlands).

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Percentage distribution of sectoral source of water in the Rhine basin												
			Agriculture		Industry		Energie		Domestic		Total	
		Unit	sw	gw	sw	gw	sw	gw	sw	gw	sw	gw
CHE	1	CHE	91	9	79	21	99	1	20	80	72	28
GER	2	Baden-Wurttemberg	30	70	95	5	99	1	24	76	62	38
	3	Bayern - Thuringen	25	75	94	6	99	1	3	97	55	45
	4	Hessen	10	90	95	5	99	1	0	100	51	49
	5	Nordrhein-Westfalen	9	91	80	20	99	1	16	84	51	49
	6	Rheinland-Pfalz	61	39	84	16	99	1	4	96	62	38
	7	Saarland	19	81	84	16	99	1	0	100	51	50
FRA	8	Meurthe-et-Moselle, Meuse, Vosges	42	58	65	35	100	0	22	78	57	43
	9	Moselle	3	97	31	69	100	0	15	85	37	63
	10	FRA-Bas-Rhin	1	99	21	79	-	-	0	100	7	93
	11	FRA-Haut-Rhin	12	88	63	37	100	0	6	94	45	55
LUX	12	LUX	50	50	5	95	99	1	11	89	41	59
BEL	13	Belgium	na	na	5	95	na	na	11	89	8	92
AUT-LIC	14	Austria- Lichteinstein	na	na	na	na	na	na	10	90	10	90
	average	all	29	71	62	38	99	1	10	90	50	50

Table 2.3 Use of groundwater (gw) versus surface water (sw) for different areas and sectors in terms of percentage.

Results in Table 2.2. shows for example that the upstream water use for irrigated agriculture in Germany takes about 75-80% of the water withdrawals from groundwater which has no direct effect on low flow conditions. The need for irrigation depends on climate variability and was further investigated looking at different climatological years with associated statistics for irrigation. Table 2.4 shows that during a very dry year a 3.6% increase in irrigated area brings about a 3-fold increase in irrigation water requirements. This effect is more relevant in regions with a stronger dependance on surface water for irrigation purposes, as for example parts of the Lorraine region in France

Year	Precipitation (mm/ year)	Precipitation change from normal year	Year type	Irrigated area (ha)	Change in irrigated area (%)	Max and Average IWR (m3/day)	Duration of irrigation period (months)
1976	638	-24,4	Very dry	131833	3,6	73.7 (Jun) – 21.4	6
2003	764	-9,5	Dry	129061	1,4	64.7 (Aug) – 15.7	6
1985	844	0,0	Average	127301	0,0	33.7 (Jul) – 6.8	7
2007	979	16,0	Wet	124331	-2,3	19.8 (Apr) – 5.7	7
2000	1122	32,9	Very wet	121230	-4,8	40.6 (Jun) – 9.6	6

Table 2.4 Effect of dry and wet years on total irrigated area and the duration of the irrigation period (IWR = irrigation water requirements) in the upstream Rhine basin.

These types of statistics will also be used to extrapolate the effects of climate change on irrigation water demand. First estimates of impacts of socio economic changes taken from the SCENES project (www.environment.fi/syke/scenes) show a potential large influence on low flows of more than 10% (depending on the chosen scenario) (Te Linde and Woelders, 2012). There are still large differences of a factor 6-8 between the estimates for the current water use in SCENES and previous studies of De Wit (2008) and De Rijk (2010). Therefore these results have to be used with care; no hard conclusions can be drawn yet.

Outlook

We will come up with new estimates of current water demand for the Rhine that enables us to improve previous estimates and provide us with a stronger basis for scenario and model analyses to give, with more confidence, answer to the questions asked. This project is expected to deliver its result by the end of 2012. In addition, estimates of upstream measures will be analyzed in an associated project.

3. Options for regional adaptation

3.1. Introduction

This chapter summarizes the main progress of the CPFWS program on different options for adaptation within the case study areas. The Delta Program is providing the main context. Within the Delta Program, strategies are developed along two axes or guiding principles:

- From adaptation by public investments to private investments
- From facilitating the water demand to accepting the available supply

The combination of these two axes results in four quadrants in which strategies can be placed. (see Figure 3.1)

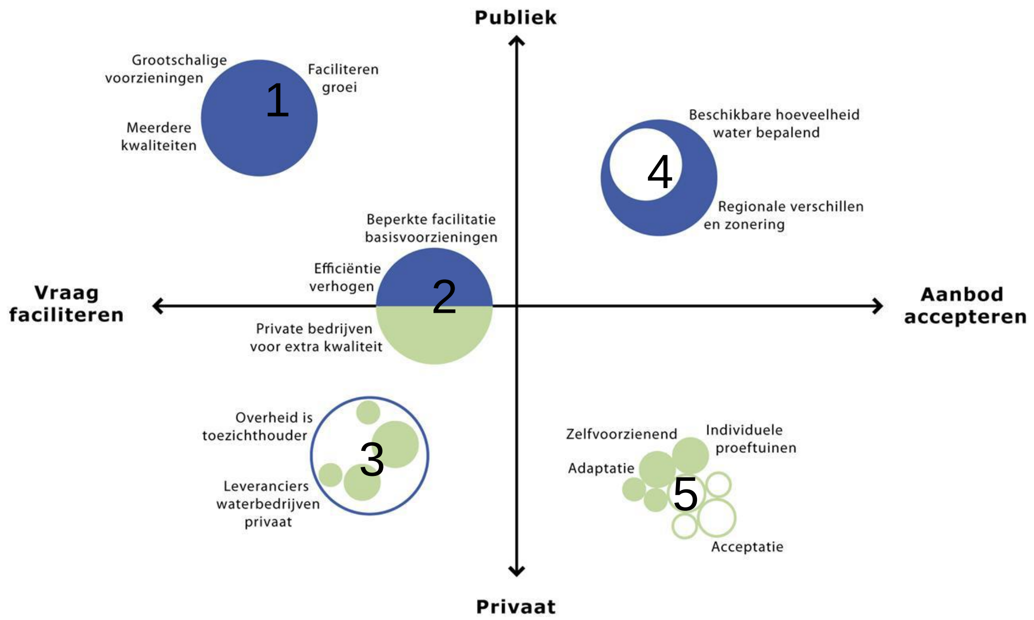


Figure 3.1 Five different strategies have been distinguished by theDelta Program ranging from facilitating water demand ('Vraag faciliteren') to accepting supply ('aanbod accepteren') and from public ('publiek') to private ('privaat'). (For more detail on individual strategies see Delta programma, 2012).

The CPFWS programme has classified the available options into different spatial scales (from parcel, via company, waterboard to national scale) and corresponding responsible authorities. (see Figure 3.2). Since CPFWS is focusing on local to regional solutions it is not surprising that most measures are relevant for the private domain and are based upon the acceptance that the public fresh water supply to the region is limited (strategy 5). This means that individual water users could try to increase their local source (for example by increasing the rainwater lenses in their land), to decrease the fresh water demand of their production process (for example by changing to more salt tolerant crops) or to simply accept incidental damage (and get a better insurance). On the larger scale, on the scale of cooperating farmers or polders/islands within the water boards, joint buffers of fresh water can be increased by either public or private financing or by spatial adaptation and optimized water distribution. On the other hand, the water demand could be decreased (strategy 2 and 3). Increasing the external supply to the region (strategy 1,2 and 4) is not studied in the CPFWS program but are treated as external scenarios.

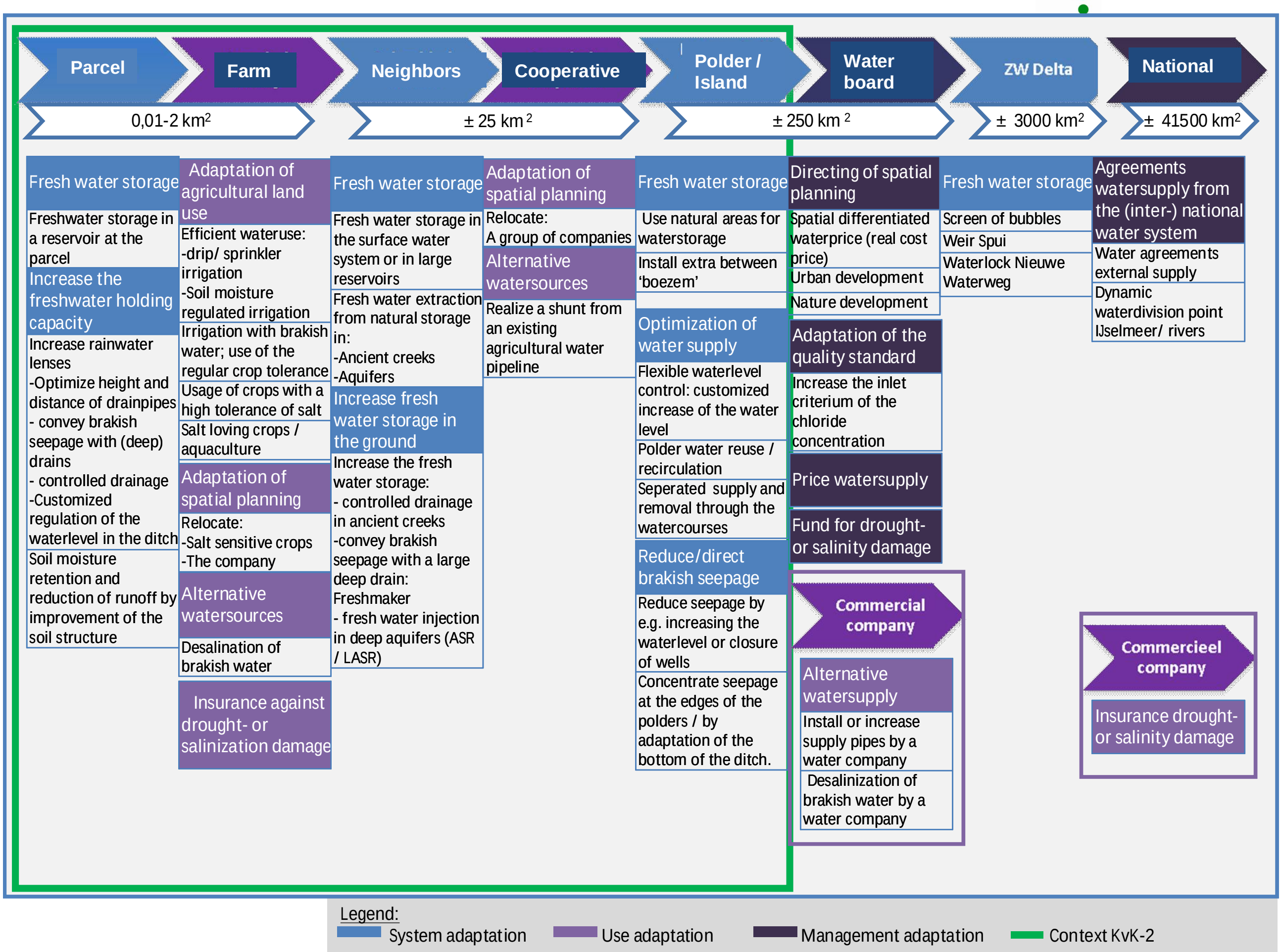


Figure 3.2 Classification of measures for fresh water supply on different scales. Indicated in blue the measures that adapt the system, in purple adaptation of water use and in black adaptation of water management. Within the green square the scales of focus of CPFWS. For all measures factsheets have been made (Tolk et al., 2012. see appendix A)

Up scaling lessons from field measurements

Central in the approach of CPFWS is that the research in work package 2 to 4 all starts with field experiments. These field experiments have all started in the first 2 years of the program. Understanding the bio-, chemical-, physical- system, in all its nuances is key to be able to subsequently study the effects of measures on this system. Therefore, 'controlled' experimental environments are created to study:

- The origin / routes of water and associated salinity in the ground water – surface water system of a polder (see Box 3.1) in project 2.1.
- The extent and salinity of fresh water lenses in a coastal extension and an ancient creek (see Figure 3.3) in project 2.2.
- The resistance of crops (less or more salt tolerant) under different saline conditions (irrigation) in project 3.1 and 3.2.
- The hydrological and geochemical processes in fen meadow areas in project 3.3.
- The interaction between the quality of a fresh water well and the surrounding groundwater (see Box 3.3) within an innovative ASR project in the case study Haaglanden (project 4.1).
- The drought risk perception among farmers with different backgrounds (obtained by questionnaire) in project 1.1 (see 2.2).

The processes and mechanisms that are better understood by the field experiments are in most cases translated into better formulations in existing computational models for the coupled groundwater-surface water system, for the interaction between root water uptake and the soil and groundwater system. This translation will be done in steps from more compex to simplified models. For example first the in the research of WP3, the root zone model (SWAP) model will be adapted and later on this will feed into the simplified version (MetaSWAP) that is used in the National Hydrological Instrument (NHI). Modeling in the end can be used to assess the regional and national impacts of adaptation measures. This type of model studies is typically done within the frame work of Delta Program where researchers of CPFWS are often involved (see for example Box 3.4). The experimental results of risk perception will be modeled in an agent based model, allowing us to investigate the reaction to certain changes and adaptation strategies. For the adaptation of nature to possible brackish conditions generalized conclusions and recommendations will be given that go beyond the specific location of research.

Figure 3.3 : Horticulture farm of Mr.. Louwerse (Walcheren): research- and pilot location for rain water lenses in ancient creeks.

With STOWA and with the Delta Program appointments have been made to up scale results into generalized conclusions for the low lying parts of the Netherlands. This is reflected in the integration report ('Integratie rapport', Jeuken et al. 2012) and our contribution to the Deltafacts of STOWA.
Another place for integration and up scaling of results are the contributions of CPFWS to adaptation strategies in the case studies and associated Hot Spots. For the region Haaglanden for example up scaling of the results of ASR

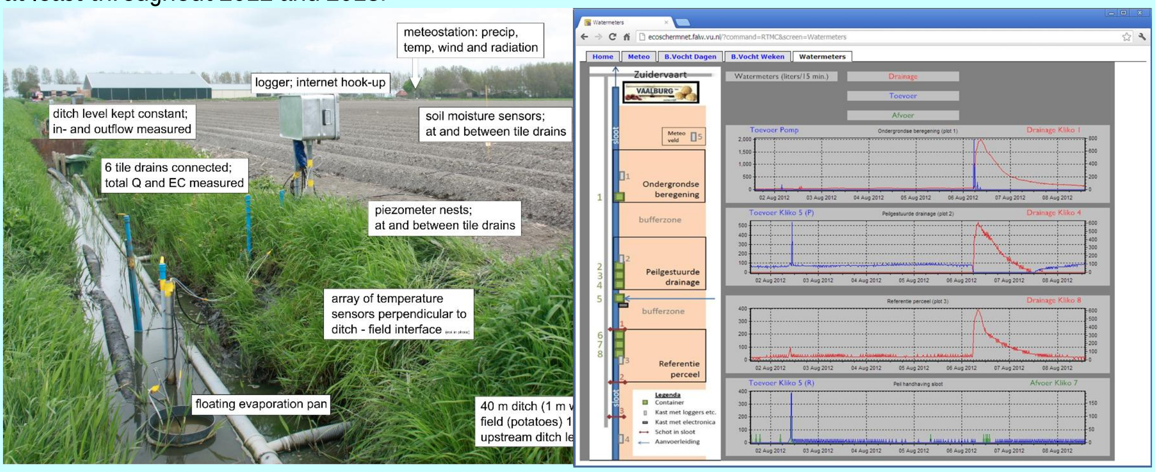
Box 3.1 Understanding the groundwater – surface water system by detailed measurements

Understanding the inner workings of the coupled groundwater – surface water system during dry summers is paramount to quantitatively evaluate adaptation strategies aimed at securing fresh water availability in a changing future. This understanding is lacking in settings with shallow water tables, dense drainage and a saline seepage component, as is common in the coastal region of the Netherlands. Especially the changes the system experiences during the state shift from draining to infiltrating during the summer period are still poorly understood.

To investigate the flow of water and solutes in this typical Dutch coastal setting, we instrumented a field site in the Schermer polder, about 20 km north of Amsterdam. The field site was set up jointly with the SKB research program “Alternative forms of sustainable soil and water management by farmers”. The field site encompasses a 40 m long ditch that drains a 110 m wide agricultural field. The ditch was hydrologically isolated by steel barriers, while the upstream ditch is led through the instrumented ditch via a long culvert. The water level in the ditch is kept at a constant water level, reflecting the normal water management in Dutch polders.

We installed flux and EC meters that measure both in- and outflow. Discharge from the tile drains in the field (every 5 m, at 0.8 m depth) is collected and measured, again with flux and EC meters. We measure soil- and groundwater movement using soil moisture sensors, piezometers with pressure gauges and groundwater temperature sensor arrays. In addition, we use geophysical methods (CVES, EM31) to assess the field-wide salinity distribution. We installed a meteorological station that measures precipitation, wind and radiation, while open water evaporation is measured using an in-ditch floating evaporation pan. Most sensors are connected to a logger with internet connection, providing real-time access to the gathered data.

The field site is operational since April 2012. The first months the field site had its occasional ‘hitches and glitches’, we are still working on perfecting the installations on the site. The data collected so far looks very promising, but have not yet been thoroughly analyzed. Measurements at the field site will continue at least throughout 2012 and 2013.



Measurement set-up field site project 2.1 and screenshot of real-time data.

Figure 3.4 Marsh Samphire irrigation with different concentrations Wadden seawater in in the summer of 2011 on the island of Texel (Foto: Diana Katschnig).

Box 3.2 Regional ASR suitability mapping in the Haaglanden region
The performance of ASR in the study was mapped using high-resolution geological and hydrochemical data, an ASR screening tool (Bakker, 2010) and a Geographical Information System (GIS). This way, we identified promising and unfavorable ASR sites (Figure 2). Clearly, successful small-scale ASR application is extremely site-specific in the coastal area.

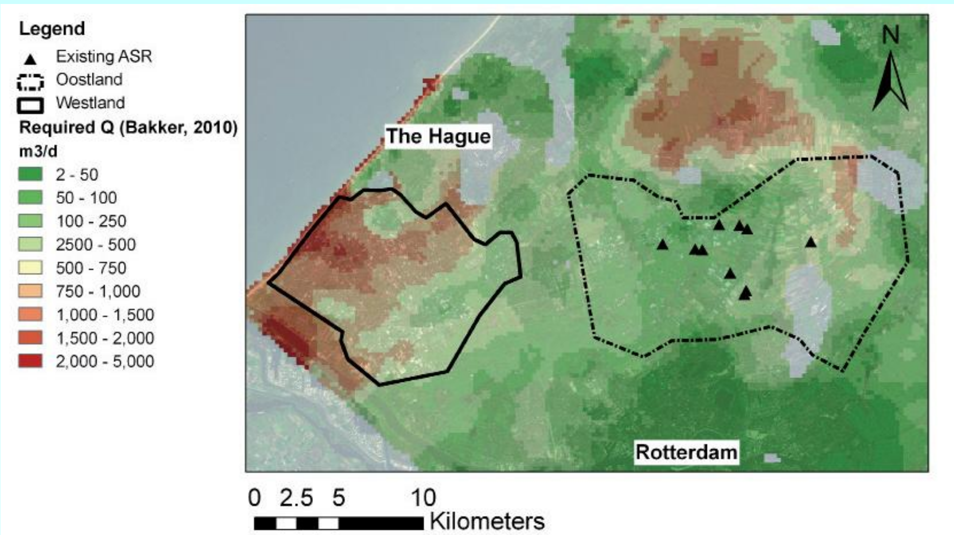


Figure 2: Required daily injection rate in winter to recover at least 60% in the following summer, indicating ASR suitability .

Frameworks for strategy development under uncertainty
Uncertainties in water management not only arise due to natural variability (for example in precipitation and evaporation), but also due to limited knowledge about system processes and differences in social values. For decision-making on long-term investments in water management, uncertainty about future developments in climate and socio-economy also becomes important. The CPFWS research has to deal with all these uncertainties. It is shown that the climate scenario that are used in the Netherlands and in the Rhine basin (see for example Figure 1.1) cover a wide range of possible trends from hardly any change to a serious increase of droughts, effects of upstream water use remain uncertain (see 2.3) and what

about the natural variability on a decadal time scale?. In addition, the reaction of farmers and markets is uncertain, as are autonomous international economical developments. These uncertainties can only partly be reduces by doing more research.
Therefore, we are searching for ways to reduce a system or strategy's sensitivity to uncertainty. The concept of sytem robustness is one of the proposed methods to deal with uncertainty. Adaptability or flexibility of the strategy itself, is another way to cope with uncertainty in decision-making. Both approaches are being applied in the case studies of CPFWS and ultimately will be part of our contribution to strategy building in the Hot Spots. To be able to discuss uncertainties on the same basis, the group of researchers involved in work package 5 have also develop a terminology document (Kwakkel et al., 2011).

System robustness
A robust system can remain functioning during external disturbances. This approach to robustness originates from the fields of biology, engineering, infrastructure and computer science, and is closely related to what is called *socio-ecological resilience* (Walker et al., 2004) in the ecosystems literature. What they both have in common is the focus on 'system performance' and the notion that disturbances cannot always be kept out of the system. If one system component happens to fail, this should not lead to failure of the entire system. A robust system is designed such that failure of one element will not lead to failure of the entire system. This means that the disturbance is first prevented from entering the system, and when it does enter, several mechanisms make sure that damage will be limited. Robust systems are particularly relevant when disturbances are uncertain and the consequences of failure are high, which is true for drought risks.
System robustness for disturbances can be quantified by means of a response curve, where the system's response is shown as a function of disturbance magnitude (Mens et al., 2011). To analyse system robustness, the disturbance, the system functions and the type of response to the disturbance thus needs to be defined. Applied to droughts this means for example:

Disturbance = precipitation deficit and/or too high chlorine concentrations in irrigation water
Functions = agriculture (for this case)
Response = difference between potential and actual crop yield

Ultimately, disturbance as described above will lead to damage. The level at which this starts to happen is called the resistance threshold. This threshold will be higher when alternative sources are still available. The sensitivity for the disturbance beyond this threshold is called proportionality. Maximum damage is reached when the entire crop yield is lost. However, before this threshold is reached, an area's economic damage may already be too large to recover from. This is called the recovery threshold, the level of which depends on farmers' financial reserves, additional sources of income, etc.
In a robust drought risk system, damage will be avoided for frequently occurring droughts and limited for less-frequently occurring droughts. Furthermore, robust systems are able to recover from a drought quickly. Damage can be avoided when alternative water resources are available at times of a precipitation deficit. Damage can be limited by influencing the spread of the water shortage through the system, for example by managing the water level in the canals. Furthermore, having different types of crops within an area, which are not all as sensitive to droughts at the same time will also limit the damage. The effect of measures on robustness of a well-defined system as the water board of Rijnland (see Box 3.4) will be further investigated in the coming period using a simple assessment model.

Adaptation pathways
To meet the changing circumstances future planning should allow for dynamic adaptation over time. In a recently submitted paper of Haasnoot et al. 2012, the method of adaptation

pathways (AP) (Haasnoot et al, 2012A) and of adaptive policy making (APM) (Walker et al.., 2001) were combined.

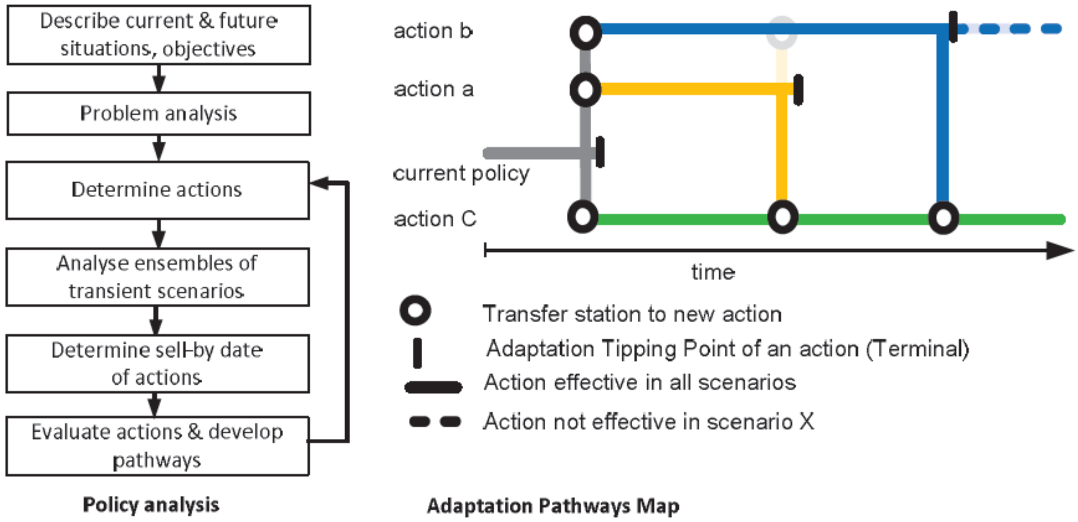


Figure 3.5 Stepwise policy analysis to construct adaptation pathways (left) and an example of an adaptation pathways map (right). After Haasnoot et al., 2012B, under review.

APM is a theoretical approach describing a planning process with different types of actions (e.g., 'mitigating actions' and 'hedging actions') and signposts to monitor to see if adaptation is needed. In contrast, AP provides an analytical approach for exploring and sequencing a set of possible actions ('adaptation pathways') based on alternative external developments (scenarios) over time. The combined method is called 'Dynamic Adaptive Policy Pathways' (DAPP).
Within the Delta program a methodology called 'Adaptief Deltamanagement', which is closely related to DAPP, has been proposed for strategy development Construction of adaptation pathways is also a key element in this method, in which the order of possible decisions, starting at present is made visible including the options to transfer to another strategy when necessary or opportune. In addition, possibilities to combine the realization of strategies with other investment agendas are listed (translated from Deltaprogramma (2011)).
Researchers of CPFWS were involved and have been reflecting on this methodology of the Delta Program. For the case study 'Zuidwestelijke Delta' a thorough analysis of uncertainties will be made using the exploratory modeling method to determine the key indicators determining the adaptation tipping points (Kwadijk et al., 2010) of different strategies (Kwakkel and Haasnoot, 2012). In a next step adaptation pathways will be constructed with the help of generic algorithms. In this way short and longer term adaptation options will be made visible including the most critical conditions that will trigger the main decisions.

3.2. Prelinary results and conclusions

Relevant climatic and hydrological developments for the fresh water supply in the Netherlands remain largely uncertain. Two out of four climate scenarios from KNMI point in the direction of substantial drier summers as a result of changing atmospheric circulation patterns. A recent study for the Rhine shows that this will lead to lower discharges but not necessarily to such low discharges as used in the Delta scenarios. The influence of upstream water usage remains uncertain. In fact sea level rise, subsidence and autonomous salinisation are the most prominent trends with localized effects on groundwater and salt water intrusion.
Strategies therefore should be considered within a large range of uncertainties, be flexible by itself and help to increase the robustness of the system.

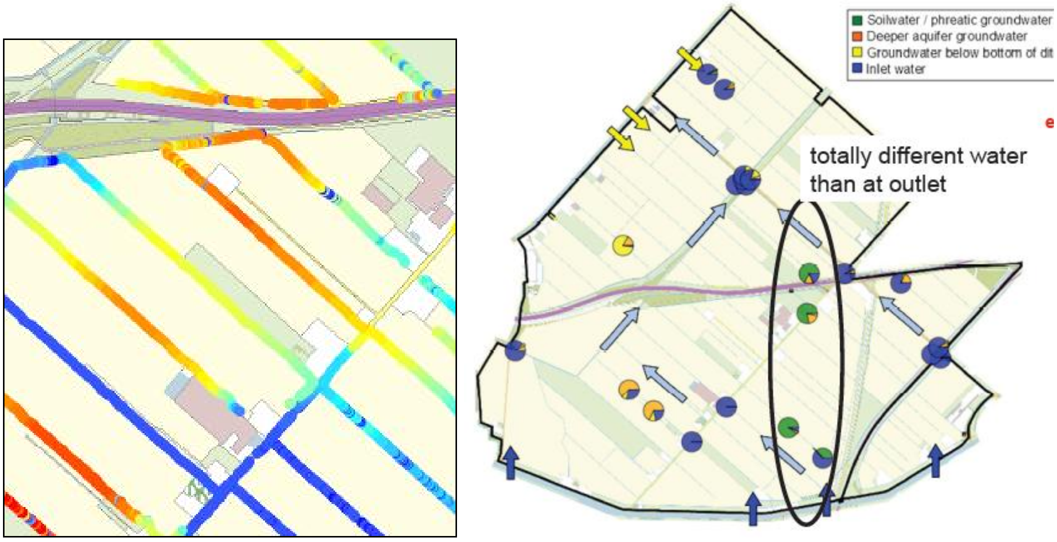


Figure 3.6 Measured conductivity in ditches in the Haarlemmermeer polder (red=high salinity, blue is low salinity) (left) and measured origin of measured water obtained via tracer analysis (right).

The CPFWS program is investigating solutions on a local to regional scale along three lines: based on improvement of 1) water management, 2) land use (agriculture and nature) and 3) using technology
In this way the program and its local to regional partner can work complementary to the national Delta program for fresh water supply. Half way the program the following careful conclusions can be drawn:

Salinisation of regional water ways can be counteracted by better regulating the water inlet to and distribution through the system in time and space, allowing higher salinity when and where crops are more resistant or by smartly choosing locations for irrigation water intake (see Figure 3.6).The loading of surface water in polders by upward salt seepage is indeed very scattered due to very localized boils. Boils have been estimated to contribute up to 60 % of total salt seepage, and a methodology to make these estimations has been developed (De Louw et al., 2010, 2011). Tentative data for the Haarlemmermeer polder indicate an even higher percentage of salt load caused by boil seepage (unpubl. data wp 2.1).

The dynamics of *rain water lenses* in coastal areas appear to be mainly determined by seasonal netrainfall fluctuations, and quite robust estimation methods to predict the thickness of these lenses, also under climate change, have been developed (Eeman et al., 2011, 2012; De Louw et al., 2011). For the shallow freshwater lenses, we constructed a first-order vulnerability estimate in the form of a map (Pauw and Oude Essink, 2011). A more accurate quantification of the development of shallow freshwater lenses in the future requires insight into the accuracy of models across model scales. This will be the main research topic in the coming period. The robustness of rain water lenses can be improved on the small to medium scale by adapting the drainage in parcels and restoration of ancient creeks in combination with active injection of fresh water. On a larger scale the reaction of fresh water lenses in coastal extensions remain subject to more research.

The currently used *salt tolerances* in the Netherlands seem out dated. Knowledge about mechanisms in the root zone and plant is incomplete and the climatological variability in the Netherlands is insufficiently taken into account. A new, stochastic, methodology has been developed to quantify the hazard of salinity due to changes in time of rainfall and soil water replenishment from groundwater, for Dutch and other situations, enabling a risk assessment accounting for temporal changes (Suweis et al., 2010, Shah et al., 2011). First research results show

that improvements are possible and lead to more realistic estimates of salinisation effects on crops.
Less rigorous and more realistic salt standards for crops could reduce the need for water for flushing and the amount of compensation for damages. This leads to a better basis to account for regional differences and will probably lead to a better acceptance among stakeholders.

Box 3.3 Optimizing the ASR well design
In a less suitable area for ASR (see Box 3.2), an optimized well configuration using Multiple Partially Penetrating Wells in a single borehole (MPPW) was tested in a field trial. Using this MPPW, the depth interval at which water was injected and recovered, could be controlled. By injecting freshwater at the base of the aquifer (winter 2012) and recovering it at the aquifer top (spring, summer), the potential freshwater recovery was tripled, compared to a conventional fully penetrating ASR well.Site-selection and local optimization using Multiple Partially Penetrating Wells significantly increase the success of ASR, making it an efficient technology to improve local fresh irrigation water availability. Continuation of the current ASR field trial should further explore the maximum increase in freshwater recovery.
Further on, water quality changes related to the injection and storage of fresh, oxic rainwater in a brackish, anoxic aquifer are studied, since water quality constraints for the recovered irrigation water are strict. An important drawback of such ASR systems in coastal areas is the contamination of the ASR well by ambient brackish/saline groundwater during the recovery stage due to buoyancy effects.

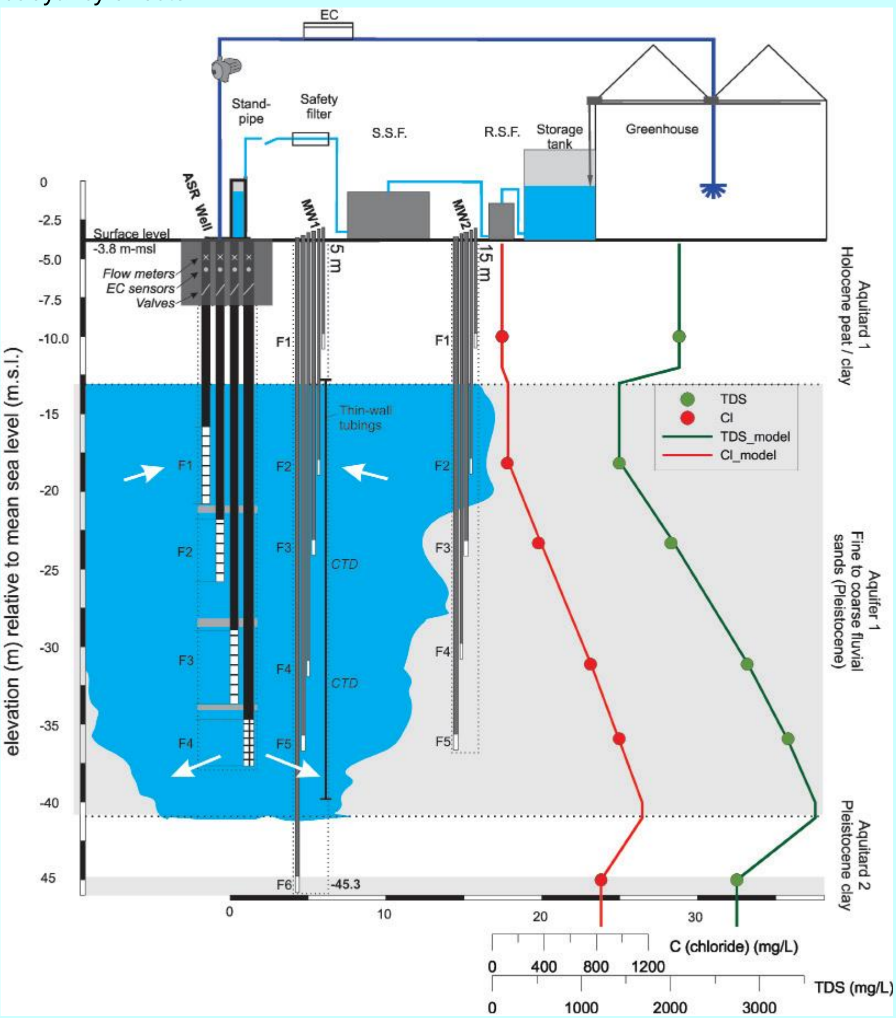


Figure 1: Set-up of the ASR field trial using the MPPW

Irrigation of *salt tolerant crops* with brackish and salt water in leads to a reduction of the fresh water need of these areas and offers the opportunity to redevelop areas that are judged too

saline for regular agriculture production. Knowledge about the physiological aspects of salt tolerance is gained by studying salt tolerant crops and used to improve existing modesl or to breed salt resistant crops with a good market potential. Previous research has already led to good examples as the salt potato.
The current way of dealing with water and salt stress in modeling (including SWAP, NHI), was challenged for (i) halophytes (Vermue et al., 2012, submitted) and (ii) salt intolerant crops (Kuhlmann et al., 2012), inspiring to develop alternative approaches. (Katschnig et al., 2012) and that of Flowers (2004), Flowers and Colmig (2008), Rozema and Flowers (2008), and a WP3-international halophyte and saline agriculture workshop (2012, Amsterdam; Rozema & Flowers&Muscolo: organizers and guest editors) give an enticing view of what may be possible with saline agriculture.

Impact research of *salinity on natural terrestrial systems in* Fen meadows has only recently started within the CPFWS program. Based on literature we conclude that there is little evidence for damages above mentioned tolerance levels of 200 to 300 mg/L Chlorine. The research within CPFWS can contribute to a stronger evidence basis. In addition, the study for wet ecosystems in the Rotte and Rotte lakes near Rotterdam (part of case study 'Groene ruggengraat') seems to indicate that the tolerance of most aquatic plant species is higher than assumed in the current water management (Veraart and van Gerven, 2012).

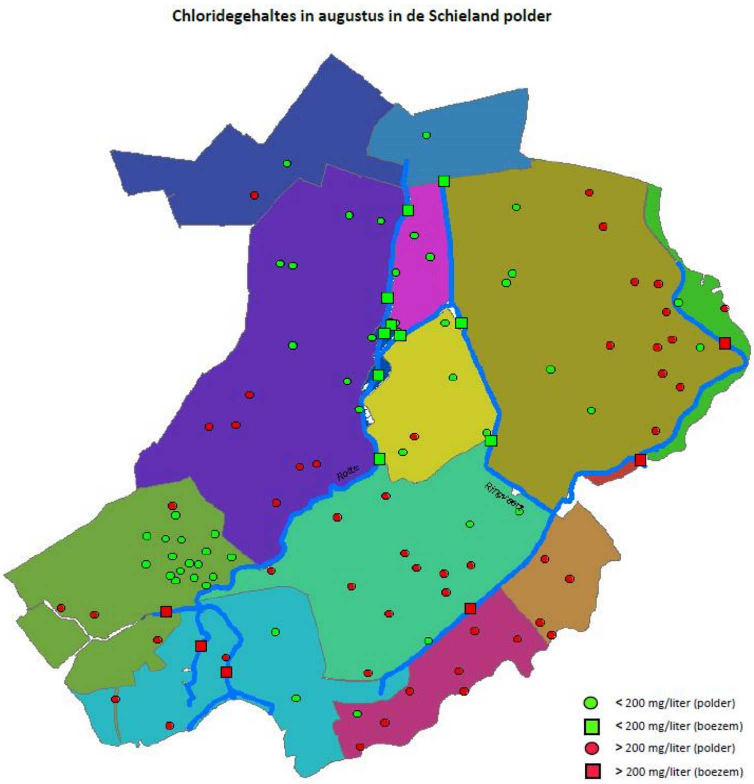
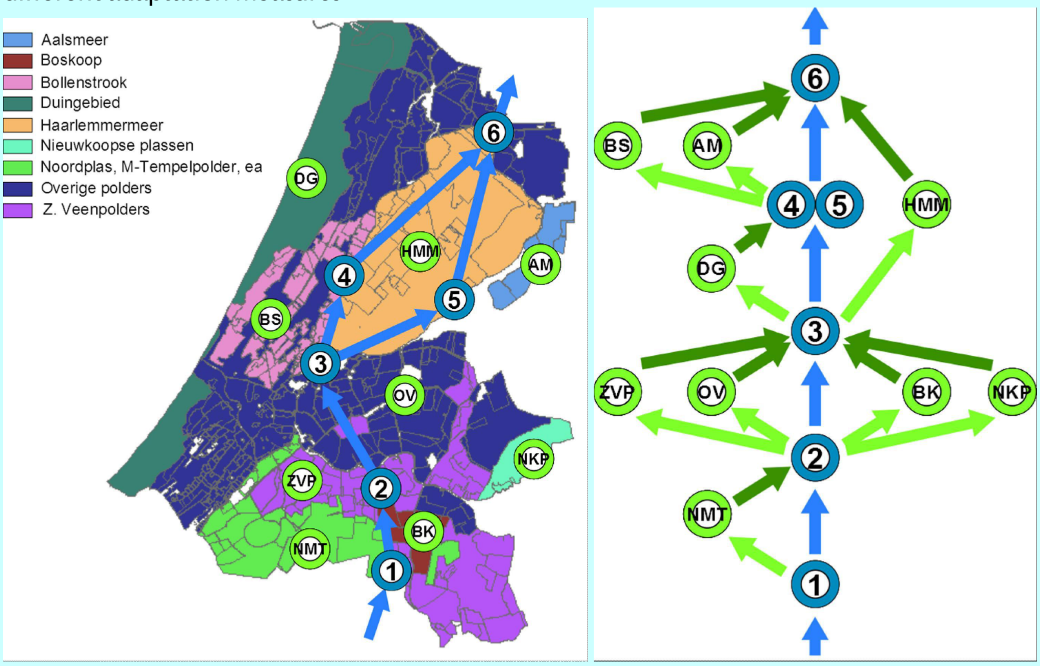


Figure 3.7 Measurements of Chlorine in the Rotte and Rotte lakes system in august 2003 (Veraart and van Gerven, 2012)

Based upon the above-mentioned intermediate insights the resistance threshold (in terms of robustness) of the regional system in 'Laag Nederland' could be higher than assumed until now. Moreover, by smarter distributing the available water in combination with spatial planning the sensitivity to higher chlorine (proportionality) of the whole system could be reduced.

The islands in the 'Zuidwestelijke Delta' have different future perspectives for fresh water supply. For the areas without external supply of fresh water, like 'Schouwenduivelland', there are opportunities to increase the buffering capacity of parcels and ancient creeks. The fruit farmers on ‘Zuid Beveland’ have limited access to fresh water supplied by a pipeline. Joint research of the agcricultural organization (ZLTO) and CPFWS has shown that optimization of water use on the scale of collective farms can reduce costs (Bal et al., 2012). Areas with unlimited access to fresh water, like ‘Goerree’ may gain efficiency by smarter water management taking into account better insights in actual salt tolerances. It showed that small scale measures which adapt the drainage structure to increase the water holding capacity of the soil are relatively cheap, and may be promising if their functionality is sufficiently demonstrated in pilot projects. Measures like drip irrigation are in the Water Optimization Plans (WOP’s) found to be very effective for fixed crops like the fruit production, while they may be expensive or labor-intensive for rotational crops.

Box 3.4 Simplified model for the water board of Rijnland to look for manouvre space for different adaptation measures.



In the model the region is subdivided in different hydrological units (polders, greenports) coupled to a simplified distribution network. For each node and unit balances of water and salt are calculated as a result of precipitation deficit, drainage, seepage, irrigation and flushing. The objective is to keep water levels at agreed levels and to limit crop damage (which is coupled via salt tolerance functions to the salinity of irrigation water) to a minimum. The model was developed by researchers of WP2 together with researchers outside CPFWS and has assembled knowledge that has been gained over the course of many years. It allows for the assessment of measures such as raising the salinity in the intake water, decoupling of water use categories, prevention of local seepage etc (Stuijt et al., 2012).

For the highly capitalized horticulture sector are various technological solutions available that could increase the availability of good quality fresh water for irrigation. The CPFWS research sofar has shown that the potential for sub soil storage (ASR) is larger than currently is being used. Not all areas are suitable,. Some ares can be used with some technical adoptions to the system. In suitable areas, ASR is a cost-effective alternative for desalinization. The dependence on external water supply will by further reduced. For the region ‘Haaglanden’, a quantitative model has been set up describing the monthly fresh water demand of all horticulture companies in the area. Demand and supply have not been matched yet. Therefore, it is difficult to estimate necessary dimensions of solutions under different future scenarios yet.

Local to regional measures for improving the fresh water supply, ask for a more substantial role of agricultural entrepreneurs. Better insight in the impacts of salinisation in combination with transparent choices in water management will give them a better grip on risks and direction for autonomous adaptation.

The above results indicate, with some caution, how the vulnerability of the fresh water supply in 'Laag-Nederland' can be reduced with restricted public means. Solutions fit within the Delta program quadrant with initiatives that are more private and less dependence on the main water system.
What the societal costs and benefits will be is not clear yet. The question still remains if optimization of current management, acceptance of higher salt standards and some small scale adaptation of land use will be enough for the far future. The dry climate scenarios for 2050 and beyond fro example imply long periods of closure of fresh water inlets near Gouda. Autonomous process of subsidence and historical salinisation of groundwater will continue.
Increasing the robustness of the regional system will at least serve to better cope with current day climatological variability and may postpone and keep options open for larger infrastructural measures or major transitions in land use.

3.3. Outlook

Up till now most research time has been spent on gathering (field) data, starting up test pilots, building models and composing qualitative adaptation strategies in the case studies. Quantitative output on effects of adaptation measures is still missing. The evaluation of strategies should take place on a national level. This requires further up scaling of CPFWS results to volumes and euros etc. For this, we will further cooperate with the Delta program.
We need not only look at costs and benefits of measures but also how they contribute to the robustness of the regional system, how they match the farmer's perception and how the influence the flexibility of strategies since we are dealing with an uncertain future with possible surprises. The gathered data and improved models will further be used to answer the scientific questions which are remaining.

4. Reflection

4.1. Scientific achievements

The CPFWS consortium believes it is on the right track in answering the main research questions. New experimental data have been gained which have provided us already with better insight in the complex interactions (quantity and salinity) within the coupled ground water– surface water system in polders, parcels, coastal extensions and in a pilot set up for ASR. First steps to catch the heterogeneity of these processes in models have been made. We see that the knowledge on salt tolerance of crops and plants in the Dutch situation is growing due to modelling and new experimental efforts. CPFWS researchers organized an international halophyte and saline agriculture workshop this year. A special scientific issue in 'Experimental and Environmental Botany' on this subject (Rozema & Flowers & Muscolo: editors, 2012) is under preparation. We have made good progress on translating theoretical concepts of robustness and flexibility to applications on well defined drought risk systems. As could be expected with new PhD research, most scientific peer reviewed paper will appear in the second half of the program. A lot of time until now has been spent on defining the research plan and conceptual approach, literature research, building or adopting models and gathering the necessary experimental data. However, since the work of CPFWS is well embedded in other ongoing research activities (not everything starts from scratch) some workpackage have been able to produce several peer reviewed papers (see 5.1). Researchers of CPFWS have further made distributions to several conferences (a.o. SWIM, IGS-SENSE, IEMS, Planet under Pressure, Deltas in times of climate change, AGU) as convener, with key notes, oral presentations and posters.

Outlook

Further efforts will be directed towards knowledge integration, finishing the modelling setup and applying the developed models and theoretical findings to better understand and quantify the problem and the estimate the effects of adaptation measures and strategies. We aim at writing a peer reviewed overview paper to summarize the intermediate thoughts and results within a year from now. At the end of the program the scientific end results are expected to appear as a KfC book.

Some more detailed expected scientific results:

- Experimental data on salt tolerance of common crops and halophytic crops will be acquired, to be implemented in SWAP and to assess the differences with the current salt tolerance functions for Dutch climate conditions
- Based on empirical data that will gathered using a survey, we will determine the factors that shape farmers' drought and salt risk perception and their adaptation motivation with respect to several adaptation options
- The salt risk assessment methodology will be translated in a meta-model, for communication towards stake-holders
- A shortlist is provided regarding shortcomings of current salt stress modelling and improvements needed for common limited tolerance, and halophytic crops
- Impact of short term surface water salinity on salt accumulation in peaty low wetlands is expressed in terms of measurable properties of the wetland 'soils'.
- Sensitivity of several red list species for soil salinity will be quantified.

4.2. Societal impact

The CPFWS consortium is actively participating in the societal discussion on Fresh water supply within the Delta Program and case study level in the Hotspots of KfC. Joint activities with the water boards and Rijkswaterstaat have been successful and drawn attention to water manager and researchers and to a lesser extent agricultural and nature organizations. Each year a major event was organized. In 2011 a one day workshop on self-sufficiency ('Self-suffiency at myth or …?')was organized together with STOWA and the KWN (Royal water network), discussing several innovative studies (from within and outside the program) on concepts promoting self-sufficiency on a local to regional scale. This year the 'Zoet-zout 2-daagse' was organized by KfC, STOWA and Rijkswaterstaat. During this 2-day event an overview was given on adaptation strategies on all scales 2012 in plenary presentations, strategic discussions were held in parallel workshops, field experiments were shown during excursions and in depth discussions on research were organized in poster sessions. There was a substantial contribution of the CPFWS research. During these kinds of meetings, we are able to share knowledge and work on shared perceptions.
In the 'Zuidwestelijke Delta' and on a national level concrete products are expected from CPFWS contribute to process of strategy development in the Delta Program. For the region Haaglanden the study on water demand, and options for water supply for the Horticulture sector is important input for regional planning. The outcome of the case-study on the Groene Ruggengraat will provide valuable input for the Hotspot strategy of the Rotterdam area and the provincial plans.
The CPFWS results have had considerable spin-off. There have been two follow up projects within the KfC third tranche, focusing on valorizing obtained scientific results. Within these follow up projects we are able to further test and implement promising concepts from the CPFWS results on sites in the region 'Haaglanden' and 'Zuidwestelijke delta'. The knowledge institutes of the CPFWS consortium all take part in the 'top sector proposal Leven met zout water', that encourages increasing the market potential of knowledge and innovative methods to improve the fresh water supply, mainly abroad. To further promote (internationally) small scale measures KfC is establishing a foundation 'Doe meer met regenwater' which can built upon CPFWS results for the Netherlands.

Outlook

We will keep on contributing to the national discussion on fresh water supply. A next occasion will be the science conference of the Delta program in 2013, which KfC will be hosting in Wageningen. Furthermore we aim to compare our approaches more with those abroad and increase international cooperation on the issue. We want make a start with this by organizing a practitioners session during the ECCA-conference coming year in Hamburg, Germany and inviting researchers and policy makers working on similar issues. In the Fall senior researchers of CPFWS will contribute to the SENSE summer-school on 'dealing with uncertainties' to share knowledhe with PhD students working on KfC and or other programs.

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Apendix A Example factsheet:

Fresh water conservation with controlled drainage

Figure a) Controlled drainage installed in fields in the Netherlands, where the drains are connected to a collector drain; b) and a vertical pipe which acts as the control unit for the water level.

To internationally promote small scale water buffers the 3R initiative (Retention, Recharge and Reuse) is founded. By this initiative some books with international, practical examples of water buffering are produced. The example below of controlled drainages comes the most recent book: A. Tuinhof, F. van Steenbergen, P. Vos and L. Tolk (2012), Profit from storage, the costs and benefits of water buffering. This case is based on the factsheet in Tolk et al., 2012.

Technology

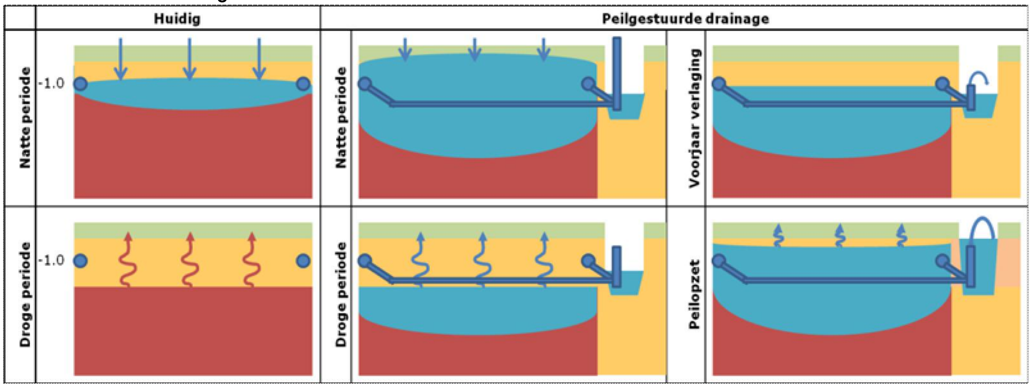
Drainage is often applied in agricultural areas. Its purpose is traditionally to carry of rain water and to lower the groundwater level in order to avoid wetness damage to the crops. However, the fast removal of the rain water decreases the capacity of the soil to store the water for dry periods. With controlled drainage the water level in the ground can be influenced and altered during the year. It provides the possibility to increase the groundwater level so that water can be stored in the ground, and to decrease the groundwater level to prevent wetness damage.

Controlled drainage exists of a relative simple technique, which can either be applied to existing drains, or can be introduced when new drains are installed. The core of this technique is that the drains, that normally discharge their water towards the ditches, are now connected to a tube. The trick is that the water level in this tube, and thus the groundwater level can be altered. To accomplish this, the end of the tube where the water flows out is connected to a vertical pipe. The head of the latter can be changed, by which the level at which the water flows out is changed. If the overflow from the vertical pipe is at a high level, much water can be stored in the soil. When the level is decreased, the water stored in the ground will flow out, until the groundwater table is in equilibrium with the head of the vertical pipe.

It is possible to collect the water that is released from the drains when the head of the outflow is lowered. A pilot with this starts at Texel in the Netherlands. In principle the quality is good even if the deeper groundwater is saline, since the upper layer of water that is extracted from the soil in this manner consist of fresh water that floats over saline water in the ground. The quality of the water however depends on the practice on the field from which it is drained, like the use of pesticides and fertilizer.

In saline groundwater environments the controlled drainage practice has another advantage. In this area the so-called fresh water lens becomes substantially larger if the winter groundwater level is increased. Normally fresh, rain fed water floats on top of saline water. In areas with saline seepage this provides a buffer against salinization of the rootzone. With traditional drainage the fresh water is discharged, this buffer is reduced. Moreover, a lower groundwater level increases the seepage flow, thus increasing salinization. These two negative effects of tradition drainage can be reduced by controlled drainage. If the groundwater level is increased in winter, the fresh water lens will grow thicker, and the buffer against salinization thus can be increased.

At the start of the growing season, or when heavy equipment has to enter the field, the groundwater level can fast be lowered to the desired depth. This prevents damage to the crops due to wetness. If enough water is available, the water level in the field may be increased when water shortage occurs in the dry period, by increasing the water level in the drains, which then function -depending on the soil conditions- as subsurface irrigation channels. By this dynamic control of the groundwater level through controlled drainage, more water can thus be stored in the ground, without the risk of wetness damage.



Figure, Controlling the water level in the soil and increasing the amount of fresh water stored in the soil with drainage in which the water level can be dynamically controlled. Blue indicates fresh and red salt water. The left panel shows the traditional drainage, and the middle and right panel the increased amount of fresh water with controlled drainage, in the wet (upper panel) and dry (lower panel) period.

Where is it applied?

Controlled drainage is applied in several pilots in the Netherlands. The effectiveness of controlled drainage depends on amongst other the soil conditions. In sandy soils the resistance of the soil is limited and controlled drainage is shown to be effective. In clay soils the effect may be less pronounced, and pilots in these kind of soils run at the moment.

Controlled drainage increases the amount of water that can be hold within a region, only if it is used as a substitute for traditional drainage. It is only applicable to area that are drained, or need to be drained, to avoid wetness damage.

It can be applied to reduce peak floods, especially when the growing season does not coincide with the wet season. In drained areas, where peak floods need to be reduced at the moment the groundwater level can be increased, controlled drainage may be used as a means to increase the buffer function of the soil.

In areas with saline seepage, like in low lying deltas all over the world, the fresh water lens may be increased with controlled drainage. Moreover, it helps to harvest the fresh water from the soil in an otherwise saline water environment. In extended coastal areas, where the shallow groundwater is saline, controlled drainage can reduce the risk of salinization of the crops.

Cost and benefits

The costs of the construction of a controlled drainage system are about 4000,- euro per hectare if also new drains are installed, at an distance optimized for controlled drainage. The costs can be lower if the system is applied at existing drains. Then the costs are about 600,- to 2400,- euro per hectare (table XX).The exploitation of a controlled drainage system is slightly less than that of traditional drainage, since it was found that the flushing of the pipes to clean them could be easier done when the drains are connected. If the system is used for infiltration, or if the water that comes from the drains should be saved, additional costs must be made to store the water in for example a basin. This will in this case be the most expensive part, and the cost for a basin exceed the cost of the actual controlled drainage system.

	Lifetime		Construction				Exploitation		Total	
	year		€/ha		€/ha/yr		€/ha/yr		€/ha/yr	
	min	max	min	max	min	max	min	max	min	max
Drainage tubes	10	20	0	1600	0	160				
Collector drain and vertical pipe	15	20	600	2400	30	160				
Total (average)									30	320

Tabel, costs for the construction of controlled drainage (Tolk, 2012).

The benefits of the system lay in the increased water holding capacity that decreases peak flow, the reduced irrigation request by the increased groundwater level, and the buffering against salinization. This thus reduces the external water request and may increase the crop yield. The quantification of the latter benefits is still under investigation. When due to climate change the salinization in coastal areas will become more severe, the benefits of controlled drainage will increase.

Financing mechanisms

At the moment most controlled drainage systems in the Netherlands are pilot systems, which are financed by research institutes. However, once the benefits are clear the investment will be the responsibility of the farmers. If the prudential considerations are advantageous, the Dutch farmers may decide to invest in controlled drainage to overcome drought or salinization. Where controlled drainage is necessary to control peak run-off, the water board may provide a subsidy to the farmers to install controlled drainage. In one Dutch Waterboard, the application of controlled drainage for water quantity control is already obligatory.

Implementation

Controlled drainage is directly after construction applicable and functional. After installation of the collector drain and the vertical pipe the system can be used to rise the water level in the wet period, and lower it in the growing season, or if heavy machines have to enter the land. If the system is also desired to infiltrate water in a salinzed environment, a basin, or another way to store water for infiltration should be constructed as well. This is more expensive and at the location of basin agricultural land is lost. Therefore, the construction of the basin will be the most difficult part in the implementation if the system is also used to collect water from. The actual controlled drainage technique is relatively easy to implement.

Successes and challenges

Waterboards in some parts of the Netherlands have adapted controlled drainage as a solution to diminish peakflow. Pilots have shown promising results increasing the amount of fresh water in the soil. Challenges are now to make the controlled drainage marketable. Therefore a clear benefit and commercial pilots are needed. The communication of the successes which are already shown should help to convince farmers that controlled drainage may be a relative cheap solution to combat salinization. Waterboards in other parts of the Netherlands may follow the Waterboard that already uses controlled drainage against flooding. A challenge here is the shift in of the responsibility from the waterboard to the farmer and to promote small scale, decentralized measures.

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Apendix B Cofinancing parties

Co-financing party	Contribution to:	Amount K€
Province 'Zuid-Holland'	Hotspot Roterdam region(HSRR) / case Groene Ruggengraat	190
Municipality Rotterdam	HSRR	44
Waterboard Schieland	HSRR	10
Rijkswaterstaat Zuid-Holland	WP-1	30
Waterboard 'Delfland'	Hotspot Haaglanden	48
Municipality 'Westland'	Hotspot Haaglanden	40,8
Municipality 'Pijnacker'	Hotspot Haaglanden	16
Province 'Zeeland'	Hotspot Zuidwestelijke Delta (HSZWD)	75
Waterboard 'Scheldestromen'	HSZWD	5
Waterboard 'Brabantse Delta'	HSZWD	5
Ministry of Infrastructure and Environment (I&M)	General program	180
I&M – matching projects	WP-1	140
Ministry of Economics, Agriculture an Innovation – matching projects	WP-3	132
STOWA	General program	280
Research foundations OASE	WP-3	60
Waterboard 'Rijnland'	WP-2	80
GZB	WP-3	15

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