Vulnerability of deltas and robuste and flexible adaptation strategies to climate change, climate variability and sea level rise

Applicants

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Discipline: Waterbeheer/ hydrologie
Kerndomein: 9.3

Abstract

The aim of this research is to answer how vulnerable deltas are to climate change and sea level rise and what robuste and flexible adaptation strategies can be developed to be able to maintain the desired socio-economic and environmental functioning of the delta. For this purpose a conceptual framework for to assess vulnerability and evaluate adaptation strategies for climate change and variability will be developed. We will use complex detailed hydrological models to make a thoroughly enough impact assessment and a rapid assessment models to analyse transient scenarios to evaluate effects of events and the possibility to change the adapation strategy.

Research Question

The central question of this research is "How vulnerable are deltas to climate change and sea level rise and which robuste and flexible adaptation strategies can we define?"

The three main reasons for why this is an intriguing question, include the following:

Firstly, extreme events in the last decades have raised questions about the robustness and flexibility of water management strategies in low-lying densely populated deltas. The floods in 1993 and 1995 in the Netherlands have increased the awareness of the vulnerability of living in a delta (Middelkoop et al. 2000,Vis et al. 2001,Vis et al. 2003). Climate change and sea level rise will increase the risk and damage from current en future harmful impacts, with deltas as among the areas most at risk. "Europe must adapt now", is the main message of the EU in the Green Paper on adapting to climage change (EEA 2005). If no adaptation measures are taken, we may be forced into sudden unplanned actions which are far more costly (Stern review, EU 2007). Furthermore, climate change itself is not the only thing contributing to this increasing vulnerability, future demographic, societal, economic and political developments will increase the vulnerability and the cost to societies of climate change and climate variability (Stehr and Von Storch 2005).

Secondly, even though a lot of progress has been made in understanding the earths climate, uncertainties remain on e.g. climate projections, impacts and the benefits of adaptation measures (Schiermeier 2004, EEA 2005, IPCC 2007a, EU 2007). Based on the extended and improved information for the new Synthesis Report of the IPCC Fourth Assessment Report (AR4 SYR) (available this year) the dutch meteorological instutite developed new estimations on the expected climate change and sea level rise in the Netherlands (KNMI, 2006). This resulted in commotion among dutch water managers as they had to update their impact studies to analyse if their designed management strategies were still appropriate. This problem is related to the classical approach of many of current climate impact studies: use scenarios as a starting point for impact assessment and define adaptation strategies based on the impacts (examples of these studies are EEA 2005, Droogers & Aerts 2005, Middelkoop et al. 2000, Haasnoot & Van der Molen 2005). An other disadvantage of the method is that the results of such studies depend strongly on the choosen scenario(s) and the assumptions made on scientific and socio-economic uncertainties related to these issues.

Finally, adaptation to climate change and sea level rise means dealing with uncertainties to define robuste and flexible adaptation strategies to reduce vulnerability and achieve good living conditions for human and nature no matter what the ultimate climate change appears to be (a robuste strategy) and select strategies which do not exclude other strategies in case the climate changes in a different way then expected (a flexible strategy).
Little is yet known on how effective various adaptation options are to reduce vulnerability and also on what other barriers or positive effects there are for these options (e.g. environmental, economic, social or behavioural) (EEA 2005, Klein et al. 2005, IPCC 2007b). Furthermore, robustness and flexibility to various weather conditions is actually in contrast which what occurred in water mangement during the last centuries. In most areas the water management is optimised for human activities. Dynamic conditions which are characteristic for deltas, are often not possible or acceptible any more. Climate change and variability force us to reconsider these strategies. It was already mentioned by the IPCC in the TAR: Water managers need research and management tools aimed at adapting to uncertainty and change, rather than improving climate scenarios (IPCC 2001) .

Research aims

The aim of this research is therefore to answer the following questions:

- How vulnerable are deltas to climate change, climate variability and sea level rise?
- Which robuste and flexible adaptation strategies can we define to maintain the desired human and ecosystems?
- What is the effectiveness of these strategies considering different future states and implementation paths?
- What can we advise water managers on dealing with uncertainties on climate change and sea level rise in a delta?

Approach

Dealing with uncertainties related to climate change, sea level rise and living in a delta involves exploring possible futures and effects of these futures and adaptation strategies. To explore this we will develop a Framework to assess vulnerability and define robuste and flexible adaptation strategies to climate change and variability. For the development of the Framework for climate adaptation we will execute the following tree steps:

1. Determine a outline of the framework and adopt cases to test it.
2. Assess vulnerability to climate change: analyse sensitivity, adaptive capacity and exposure.
3. Determine adaptation strategies and analyse their success.
4. Evaluate the strategies on robustness and flexibility.

The Framework will consist of an assessment of the vulnerability, development of adaptation strategies and an evaluation of the success of the strategies. The vulnerability of a system is defined as the extent to which a natural or social system is susceptible to sustaining damage from climate change (IPCC 1995). It depends on three key issues: 1) the sensitivity, the degree to which a system will respond to climate change (harmfull or beneficial); 2) adaptive capacity, the degree to which a system can adapt to impact or diminish potential damages and 3) the degree of exposure. In order to reduce the vulnerability of a system to climate change, adaptation strategies are needed. Adapation to climate change involves building adaptive capacity or implementation of measures to reduce adverse effects. The success of an adaptation strategy depends on the degree to which it results in achieving the objectives. This will depend on the future (unknown) state of the world through the objectives themselves determined by future human values and through the future climate change and variability (Middelkoop et al. 2001, Haddad 2005). Criteria used to evaluate the succes of an adaptation strategy are for example: efficiency (cost/benefit), effectiveness to reducing adverse impacts, equity and legitimacy (Smit et al. 1999, Middelkoop et al. 2004, Adger et al. 2005). Two key indicators of effectiveness are the robustness to uncertainty and flexibility or the ability to change in response to altered circumstances (Adger et al. 2005).

Part 1. Conceptual framework basis and selection cases

Duration:6 months

The first part of the PhD involves the development of a conceptual framework for the assessment of vulnerability to climate change and variability and the evaluation of the success of adaptation strategies considering the unknown future state of the world. There are some frameworks on adaptation to climate change existing of a concept and definitions of terms, but they lack an integrated impact assessment and a real evaluation of the adaptation (Tol et al. 1998, Leary 1999, Smit et al 1999, Brooks 2003). Furthermore, they did not take into account the aspect of time, for example, the change of adaptation strategy after an event, after more information on climate change or on technology becomes available or after new human values by a change of world view.

We will focus on water management strategies, but will include also socio-economic developments and possible future human values. Regarding the evaluation of the success of strategies we will focus on the robustness and flexibility as these are key indicators for effective strategies in an uncertain changing world. The evaluation of adaptation strategies will be based on criteria such as benefits, damages, feasibility, irreversibility and costs for different future climate and socio-economic scenarios on the short term and the long term. The criteria will be further defined during this part of the PhD. Storylines will be used to help perform the evaluation. There are three main reasons to use storylines to: history learns us that adaptation is triggered by climate events, impacts depend on the change of average conditions *and* climate variability and ensure consistency between climate, socio-economic and timing aspects.

An imaginary case will be used to develop the conceptual framework. Furthermore a dutch case and a foreign case will be selected to elaborate and to test the conceptual framework. The case will be selected based on the applicability and the availability of information and hydrological models. Possible cases are for example the lower Rhine or Meuse basin in the Netherlands and the Missisippi delta.

<u>Deliverable:</u> First paper on a conceptual Framework to assess vulnerabilty to climate change and variability and define robuste and flexible adapatation strategy with the focus on water management.

Part 2. Vulnerability assessment

Duration:12 months

Most impact assessment studies on climate change use scenarios as an entry point and follow the whole cause effect chain (figure 1). Subsequently, they use adaptation measures as input to analyse if adverse effects for different sectors and thereby the vulnerability can be reduced (e.g. Vermulst et al. 2000, Vis et al. 2002). Others use the effect chain to determine the vulnerability in terms of risks to climate events like drought and flood combined other indicators like poverty, equity, gdp, health, education and governance (Tomkins & Adger 2004, Brooks et al. 2005, Haddad 2005). The start of this cause effect chain, the physical boundary conditions, is however uncertain as scientists do not know exactly when and what the climate change or sea level rise will be (IPCC 2007). Furthermore, with each step in the effect chain, existing of atmospheric, hydrological and ecosytem processes the uncertainty increases because of the complexity, the feedback and interactions. Even more uncertainties are introduced by socio-economic developments influencing the water system characteristics (such as land use changes, use of other crops) and/or the water demand (such as population growth, use of other crops) (Middelkoop et al. 2004, EEA 2005).

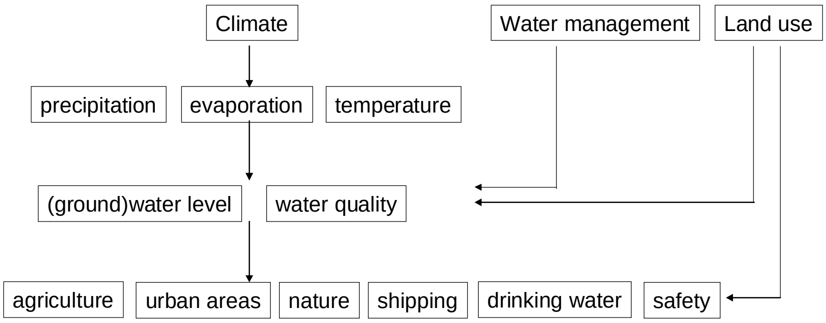

Figure 1. Example of Cause effect chain, from the drivers climate change and variability, water management and land use to effects on different sectors.

For the vulnerability assessment, determined by sensitivity, adaptive capacity and exposure, we will start at the end of this cause effect chain, namely with the limits of the sectors, to be able to better cope with the uncertainties. The sensitivity and adaptive capacity will be determined using a method used for habitat analysis (Guisan and Zimmerman 2000, Van der Lee et al. 2006, Haasnoot and Van de Wolfshaar in prep). In habitat studies response curves defined by expert judgement or measurements are used to determine the habitat suitability for species or a group of species resulting in spatial information indicating a range of optimal conditions (value of 1) to disadvantegeous conditions (value of 0). In low suitable areas there is a small chance that the species will be found there, although it may occur in a bad condition. As each sector has its own requirements on environmental conditions, we can do the same for other sectors. We will describe their optimal conditions and identify critial thresholds in terms of physical boundary conditions under which they can not function anymore. By considering the adaptive capacity by a change of the response curves, technical possibilities, knowledge and wellfare are taken into account. Finally, we will compare the optimal conditions (sensitivity and adaptive capacity) with the physical boundary limits of climate change and sea level rise (exposure) to identify mismatches (figure 2). If they occur, then these are the vulnerable ‘hotspots’ for which adaptation strategies should be defined.

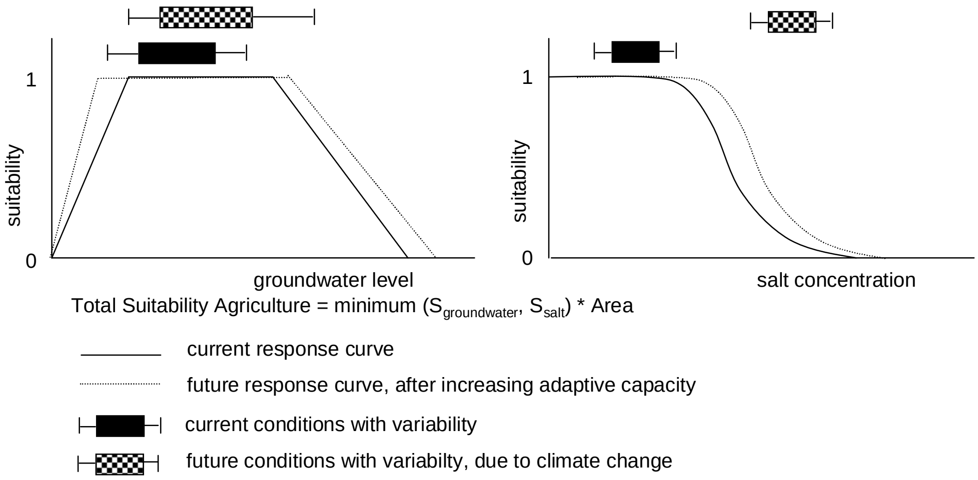

Figure 2. Example of response curves for agriculture. Too low groundwater levels will result in damage while too high groundwater levels or water above the ground level will also damage the plants. Too high salt concentration increases de suitability. The optimal conditions depends on the average conditions and the conditions after and event and differs per crop type.

Deliverable: Second paper on vulnerability of living in a delta under current and future climate conditions, including a method to assess vulnerability taking into account the uncertainties on climate change and variability.

Part 3. Determine adaptation strategies and analyse success

Duration: 18 months

Adaptation strategies will be defined for each case based on the vulnerability assessment and possible future states of the world. In addition, we will use storylines like the SRES (IPCC 1992) and local translations such as the WLO scenarios for the Netherlands (WLO 2006) to describe possible futures.

Analysing the robusteness and flexibility of strategies requires complex models to make a thoroughly enough assessment of the effects on the one hand, but on the other hand it requires rapid assessment models to analyse transient runs to evaluate effects of events and the possibility to change the adapation strategy if the new information becomes available (e.g. from events, research, change in human values). For the selected cases a sensitivity analysis will be done with existing complex hydrological models to relate climate change and variability and adaptation strategies on the one hand to effects on abiotic boundary conditions (river discharge, groundwater levels, water quality etc.) on the other hand. The results of the complex models will be used to parametrise the rapid assessment model (RAM), which will also assess effects on ecosystems and socio-economic aspects like nature, safety, damages, drinking water. As the name says a RAM has a small calculation time can be used to run time-series. This will be useful to analyse effects of events and the flexibility of a strategy to change to an other. The recovery or irreversibility of events and strategies will come forward during the analysis of time series. On the other hand, the simplicity of the reponse curves may result in underestimation or the invisibility of relevant effects. The rapid assessment model will be built upon the method used for habitat analysis as described before. The suitability or damage for sectors will change with climate change and water management as they influence the conditions directly. Also, the requirements defined for each function may change e.g. as part of adaptation strategies. The model results will be used to analyse the success of the adapation strategies for the criteria defined in part 1. The importance of the criteria and the objectives of the strategies may change through time in correspondence to the storylines.

Deliverables: Third paper on impact of climate change and sea level rise in the deltas and the success of adaptive strategies by considering several transient runs with climate events and their effects on the human and ecosystem functions (e.g. nature, safety, drinking water, yield losses for agriculture).

Part 4. Evaluation of adapation strategies and recommendation for water managers in deltas

Duration: 12 months

Part 3 involves the evaluation of the adaptation strategies on their robustness and flexibility. To do this we will use criteria like the functioning of the system at different moments, under different climate conditions and under different socio-economic circumstances. Based on the evaluation recommendations for water managers will be made. With this information the conceptual framework developed in part 1 of the PhD. will be adjusted if necessary and finalised.

Deliverables: Final dissertation.

Deliverables

- First paper on a conceptual Framework to assess vulnerabilty to climate change and variability and define robuste and flexible adapatation strategy with the focus on water management.
- Second paper on vulnerability of living in a delta under current and future climate conditions, including a method to assess vulnerability taking into account the uncertainties on climate change and variability.
- Third paper on impact of climate change and sea level rise in the deltas and the success of adaptive strategies by considering several transient runs with climate events and their effects on the human and ecosystem functions (e.g. nature, safety, drinking water, yield losses for agriculture).
- Rapid Assessment tool to analyse effects of events and the flexibility of a strategy to change to an other.
- Final dissertation.

Finances

	2008	2009	2010	2011	Totals
Marjolein Haasnoot (PhD)	50	53	55	58	216
Eelco van Beek (U-Twente, WL-ZWS)	20	10	10	10	50
Jaap Kwadijk (WL-ZWS)	10	5	5	5	25
Hans Middelkoop (UU)	10	5	5	5	25
materials	10	10	10	10	40
	100	83	85	88	356