

climate changes spatial planning

Adaptation

Financial arrangements for disaster losses under climate change

dr. L.M. Bouwer

dr. W.J.W. Botzen

prof.dr. J.C.J.M. van den Bergh

prof.dr. J.C.J.H. Aerts

KvR 061/12

Financial arrangements for disaster losses under climate change

Authors

dr. L.M. Bouwer [1, *]
dr. W.J.W. Botzen [1]
prof.dr. J.C.J.M. van den Bergh [2, 3]
prof.dr. J.C.J.H. Aerts [1]

* Project leader

1 Institute for Environmental Studies, Vrije Universiteit, Amsterdam, The Netherlands
2 Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, Spain
3 Faculty of Economics and Business Administration, Vrije Universiteit, Amsterdam, The Netherlands

Note: contributions to this project have been made by various additional individuals, who are listed in the publications list in Appendix 2

IVM Institute for Environmental Studies

icta

VU University Amsterdam

KvR report number KvR 061/12
ISBN ISBN/EAN 978-90-8815-056-2

This project (A9; Financial arrangements for disaster losses under climate change) was carried out in the framework of the Dutch National Research Programme Climate *changes* Spatial Planning. This research programme is co-financed by the Ministry of Infrastructure and the Environment.

Contents

Summary

Summary in Dutch

Dit project heeft de invloed van antropogene klimaatverandering op het optreden van schades als gevolg van extreme weersomstandigheden onderzocht, en financiële regelingen (inclusief verzekeringen) om met deze schades om te gaan bestudeerd. Het project bestond uit vier activiteiten: analyse van de huidige financiële regelingen; beoordeling van de risico's van extreme weersomstandigheden; potentieel van nieuwe regelingen, en betrekken van de stakeholders. Een overzicht is gemaakt van financiële regelingen voor schade door extreem weer in Nederland. Vooral veranderingen in intense regenval en overstromingen hebben grote risico's voor de nationale verzekeringssector. Financiële regelingen voor de overdracht van overstromingsrisico's in Europa zijn geanalyseerd, en sommige aspecten van particuliere verzekeringen kunnen het verminderen van overstromingsrisico's bevorderen. De wereldwijde trend van toenemende economische schades door extreme weersomstandigheden doet zich voor als gevolg van toenames in blootstelling, gerelateerd aan de groei van bevolking en rijkdom. Toekomstige klimaatverandering zal naar verwachting tevens leiden tot toenemende schades. In 2050 kan de schade in de agrarische sector door hagelbuien toenemen met 25% tot meer dan 200%. Een casestudy van een gebied langs de rivier de Maas laat zien dat verwachte schades als gevolg van overstromingen van rivieren zou kunnen toenemen met 96 tot 719%, als gevolg van een combinatie van klimaatverandering en sociaaleconomische ontwikkeling. Het verwachte aantal potentiële slachtoffers als gevolg van overstromingen in West Nederland kan verviervoudigen in 2040. De resultaten van het project geven aan dat er mogelijkheden zijn voor een (gedeeltelijk) particuliere verzekering tegen overstromingsschade. Afschaffing van het huidige publieke compensatiesysteem kan de totstandkoming van een dergelijke markt stimuleren. Deze studie stelt voor om overstromingsrisico's in Nederland te verzekeren via een publiekprivaat partnerschap in de vorm van een drielagen verzekeringsprogramma; waarbij kleine schades worden betaald door huishoudens; dekking van de rest van de schade door de verzekeringssector; en de dekking van zeer grote schades door de overheid. Veel huiseigenaren blijken ook bereid te zijn om investeringen te doen in het verminderen van risico's. Schattingen van de effectiviteit van deze mitigerende maatregelen op mogelijke schade door overstromingen langs de rivieren zijn in de orde van 1 miljard Euro of groter.

Summary

This project has studied the impact of anthropogenic climate change on the occurrence of losses from extreme weather, and financial arrangements (including insurance) to deal with these losses. The project consisted of four activities: analysis of current financial arrangements; assessment of extreme weather risks; potential of new arrangements; and stakeholder involvement. An overview has been made of financial arrangements for extreme weather risks in The Netherlands. Especially changes in extreme rainfall and flooding hold severe risks for the national insurance sector. Flood risk transfer mechanisms in Europe have been analysed, and some aspects of private insurance arrangements may hold benefits for reducing flood risks. A global trend of increasing economic losses from weather extremes is occurring because of increases in exposure, related to growth in population and wealth. Future climate change is expected to lead to increasing losses as well. By 2050 hailstorm damages to the agricultural sector could increase by between 25% and more than 200%. A case study along the river Meuse shows that expected losses from river flooding could

increase by between 96 and 719%, due to a combination of climate and socioeconomic change. The expected potential number of fatalities from flooding in the west of The Netherlands could quadruple by 2040. The project results indicate that opportunities may exist for a (partly-) private flood insurance system. Abolishment of the current public compensation system could stimulate the emergence of such a market. This study proposes to insure flood risk in The Netherlands with a public-private partnership in the form of a three-layered insurance programme, including small losses paid by households; reimbursement of the remainder of the damage by the insurance sector; and coverage of very large losses by the government. Many homeowners also appear to be willing to make investments in risk reduction. Estimates of the effectiveness of these mitigation measures on potential flood damage along the rivers are in the order of 1 billion Euros or larger.

1. Introduction

1.1 Context

Extreme weather events have caused considerable damages over recent decades in The Netherlands and Europe. With climate change, changes are expected in the frequency of extreme weather events. The approach for dealing with these changes, especially in the water sector, has traditionally been to improve protection and hazard prevention, complemented by measures to reduce the consequences of the weather hazards. Most adaptation strategies in the Dutch water sector focus either on implementing technical measures, such as building dikes, or enforcing spatial planning policies; such as buffering of rainwater.

While proposed adaptation measures in the water sector will likely contribute to reducing risks, increased attention is being paid to explore financial and insurance arrangements to alleviate negative impacts of climate change and extreme events. Yet little research has been conducted in developing such tools and evaluating their efficiency in terms of costs and benefits. Commercial insurance in The Netherlands is available for individual households to cover damages due to storms and local heavy rainfall, as well as a number of other risks. But weather-related losses in many other sectors in society, like crop losses in the agricultural sector are generally not covered. In these cases, the national government has often acted as an “insurer of last resort” by providing relief.

This research project examined to what extent climate change will lead to additional risks, and in what way current and new financial arrangements can serve as strategies to alleviate part of the financial consequences of changing extreme weather.

This research project was carried out by the Institute for Environmental Studies (IVM) in collaboration with FutureWater, during the period 2005-2010. Indispensible collaboration has been provided by a number of other research organisations, including HKV-lijn in water, TU Delft, KNMI, and Deltares, and various foreign institutes, as well as government organisations including the Water Board of Rivierenland, Ministry of Transport, Public Works and Water Management, and commercial market parties including Interpolis/Eureko, Verbond van Verzekeraars, Rabobank and Munich Re. We are sincerely thankful for their advice and input.

1.2 Objectives

The project "A9 Financial arrangements for disaster losses under climate change" was developed to study risks of climate change for damages from extreme weather, and develop financial arrangements (including insurance) to deal with these risks.

The project proposal defined a general approach, of developing sets of financial arrangements for flood related risk sharing for The Netherlands. The project was divided in two parallel tracks: the first track explores risks, damage and adaptation measures within the water sector, focusing on spatial dimensions. The second track developed risk arrangements within the insurance sector and national government and methods to evaluate them.

The objectives of the project were:

1. To provide an overview of current financial arrangements related to extreme weather events; in particular insurance and government relief for extreme precipitation in the Netherlands, the EU. And, to provide an overview how existing and future water management policies may be integrated with new financial arrangements.
2. To develop spatial risk and damage maps related to extreme weather events (precipitation and flooding) for a case study area, both for the current situation and under projected climate change. The case study results will be extrapolated to the national scale by determining risks at the spatial level of zip codes for the Netherlands as a whole.
3. To develop a set of new financial arrangements and evaluate their efficiency in terms of public and private services rendered as well as possibilities for spatial differentiation. The arrangements will be developed for the case study and the national scale.
4. To involve relevant actors in activities related to water management, risk and disaster management, relief, insurance and banking, spatial planning and damage control.

In the amendment to the proposal, the following items were added:

- Case studies would focus on
  - Rivers
  - Coast of North Holland.
- Overview of insurance arrangements in other countries.
- Attribution of causes of changes in losses over time.

Implementation of these additions has been achived through the following:

- Case studies have been focussed on droughts along the rivers in Waterboard Rivierenland; flood risk for dike ring 36 along the Meuse river; and flood casualties risk for dike ring 14 (west Netherlands).
- An overview of insurance arrangements for flood risks has been made and published.
- An extensive analysis has been made of published loss attribution studies, and has been published in the high profile journal Bulletin of the American Meteorological Society.

1.3 Approach

The approaches taken in the project consisted of the following parts:
Task 1: Inventory of current financial arrangements
Task 2: Assessment of current and future risks
Task 3: Economic analysis of financial arrangements
Task 4: Involving stakeholders

Task 1 was carried through a series of studies, involving a review of the academic literature, supplemented by reports from the private sector and government organisations.

Task 2 was carried out using various statistical and modelling approaches, and included analysis of loss data, provided by the insurance sector. It was chooses to focus on the following weather related hazards:

- River and coastal flood damages (related to rainfall and high seal-levels);
- Hail damages;
- Drought damages.

This choice is based on the fact that these hazards pose severe threats to economic activities in The Netherlands, and these are only partially covered (in the case of hail) by commercial insurance products. While damages from windstorms can also lead to large losses, for these losses commercial insurance is generally available and such products have a very high penetration rate in the country. Also, various other research projects have studied the effects of storm, and potential impacts of climate change, including for The Netherlands.

The extrapolation of the implications of climate change for weather-related damage risks has been implemented not within the current A9 project, but through a series of affiliated projects. This was decided in order to take advantage of the current project to study in detail the relations between damage and climate change, and avoiding unnecessary difficulties in upscaling findings that are representative mostly for the local level to national level, and to take advantage of other projects that did have the required information available for upscaling. These projects where results have been geographically extrapolated to the national scale include the following:

- Attention for safety (Aandacht voor Veiligheid, AVV) within the KVR programme; focussing on a) damages and b) loss of life. For the latter see the publication by Maaskant et al., 2009;
- ACER project (A7) within the KVR programme; where the developed approach on establishing flood damages has been applied to the entire Rhine Basin, including territories outside the Netherlands.

Task 3 was carried out using survey approaches, and econometric analysis of results. Also, various financial arrangements in different countries were described and analysed, and reported on. It was chosen to focus on a few types of arrangements, namely 1_ government transfer mechanisms, in particular the WTS law, that enables government to compensate individuals, and 2) on commercial insurances. The latter is motivated by the debate in The Netherlands on the introduction of a commercial insurance product for the flood damages due failure of primary flood defences. Other commercial and non-commercial products and their relation to risk reduction and climate adaptation have been studied in a separate paper co-published with Warner et al. (2007).

Task 4 was carried out through organisation of various targeted workshops and meetings, as well as through presentations at stakeholders (including the insurance sector) and at conferences, scientific and political; including World Water Forum and climate convention (UNFCCC) meetings. Chapter 5 reports more extensively on these activities.

1.4 This report

The next chapters (Chapters 2-5) describe the main outcomes and results of the four tasks described in Section 1.3. All analyses and results have been published extensively earlier in academic papers including one paper in Science, reports and two PhD theses.

Chapter 6 discusses the major conclusions from the project, and provides an outlook of related work and future research needs.

The appendices of this report provide an overview of the milestones and output, linked to the original project proposal (Appendix 1); the scientific output of the project (Appendix 2); as well as presentations and contributions to conferences and meetings (Appendix 3).

2. Current financial arrangements

2.1 Overview of risk transfer and insurance in The Netherlands

A thorough understanding of the effects of climate change on the insurance business is important for the sector in order to guarantee adequate pricing of insurance premiums and risk management. Current risk sharing arrangements for major weather risks in the Netherlands have been examined (see Table 2.1). A considerable proportion of the main climate risk categories is covered by private insurance companies. In particular, the effects of increased risks of extreme precipitation and flood damage to cars can be substantial. Further, insurers cover a large part of windstorm and hailstorm damage, which may be affected by climate change even though this is still uncertain. The major climate change related risk for the Netherlands is damage due to the collapse of dikes, due to either peak river discharges or storm surge levels. This is the largest threat in terms of potential damages, although probabilities are relatively low. This risk is currently carried by the government via the Calamities and Compensation Act (WTS). This arrangement does, however, not provide a right to compensation. Drought is another major risk for which no risk sharing arrangement is available. It should be noted that households and businesses would also face increasing climate losses apart from possible premium increases, due to deductibles and limitations on coverage.

Table 2.1.
Current risk sharing arrangements of the main weather risk in the Netherlands (from: Botzen et al. 2010 in Natural Hazards: Table 3).

Weather event	Climate change	Potential damage	Main damage category	Risk sharing agreement
River flood	Increase in risk	Large-very large	Motor vehicles	Private insurance
			Other property	Government (WTS)
Storm surge	Increase in risk	Very large	Property	None
Extreme precipitation	Increase in risk	Large	Property households	Private insurance
			Property business	Limited private insurance
			Crop losses	Public-private partnership
Windstorm	Uncertain	Large-very large	Motor vehicles	Private insurance
			Property households	Private insurance
			Property business	Private insurance
Extreme drought	Increase in risk	Medium-large	Crop losses	None
			Waterway transport	None
Hailstorm	Uncertain	Medium-large	Crop losses	Private insurance
			Motor vehicles	Private insurance
			Property households	Private insurance
			Property business	Private insurance

A broad range of insurance arrangements in The Netherlands that are affected by climate change can be identified. This requires adequate risk management strategies of insurance companies to handle increased risk. In particular the Dutch insurance sector is very vulnerable to the effects of climate change on extreme precipitation compared with other weather risks. Drought, and large scale flooding which has a smaller probability, have the ability to inflict much large damages but are not insured. Furthermore, insurers have considerable exposure to windstorms and hailstorms but the effects of climate change on the frequency and severity of these events are uncertain. Climate change also brings new business opportunities for the insurance sector, apart from increased exposure to risks under current arrangements. For example, extending crop insurance policies to cover drought damage in the form of a public–private partnership may be a viable arrangement to meet demand for compensation when severe drought periods become more frequent.

Key publications:

Bouwer, L.M., Botzen, W.J.W. & Aerts, J.C.J.H. (2007). Klimaatverandering en verzekeren van rampschade. *H2O, Tijdschrift voor Watervoorziening en Waterbeheer,* Nr. 22, 23-25.

Botzen, W.J.W., Van den Bergh, J.C.J.M. & Bouwer, L.M. (2010). Climate change and increased risk for the insurance sector: a global perspective and an assessment for the Netherlands. *Natural Hazards,* 52(3), 577-598.

2.2 Flood risk transfer mechanisms in Europe

Different financial arrangements for dealing with flood damages exist in Europe. These arrangements spread the impacts of flood losses over individuals and over time. In addition, these arrangements may under certain conditions enhance adaptability of European societies to changes in the frequency and intensity of weather hazards that may be caused by variations and changes in the climate. In this study a classification is made of insurance and financial compensation arrangements for flood damage. Private/commercial flood insurance with risk-based premiums may improve adaptability, since such premiums are better capable of transferring price signals of actual flood risks than compensation systems with contributions (premiums, taxes) that are unrelated to actual risks. Insurance can, therefore, provide better incentives for investments in risk reduction measures.

The actual insurance and compensation systems for flood damage were examined for 19 European countries. The availability of commercial flood insurance in Europe is widespread (Figure 2.1). However, actual market penetration is high (50% or more) in only 7 countries. We statistically tested whether the kind of financial arrangement and its characteristics, such as market penetration, are related to flood risks and socio-economic characteristics of a country, such as population size and level of GDP. This analysis indicates that the surface area and population size of a country are important factors that determine the type of flood insurance system adopted. There may be potential to increase the share of (commercial) flood insurance in some European countries, while flood risks may be too high for a pure private insurance market in other countries. This implies that a continued role for governments is warranted in financial arrangements of flood damage, in addition to public investments in loss prevention and damage mitigation. Further harmonisation of insurance regulation in Europe could foster further development of private insurance markets.

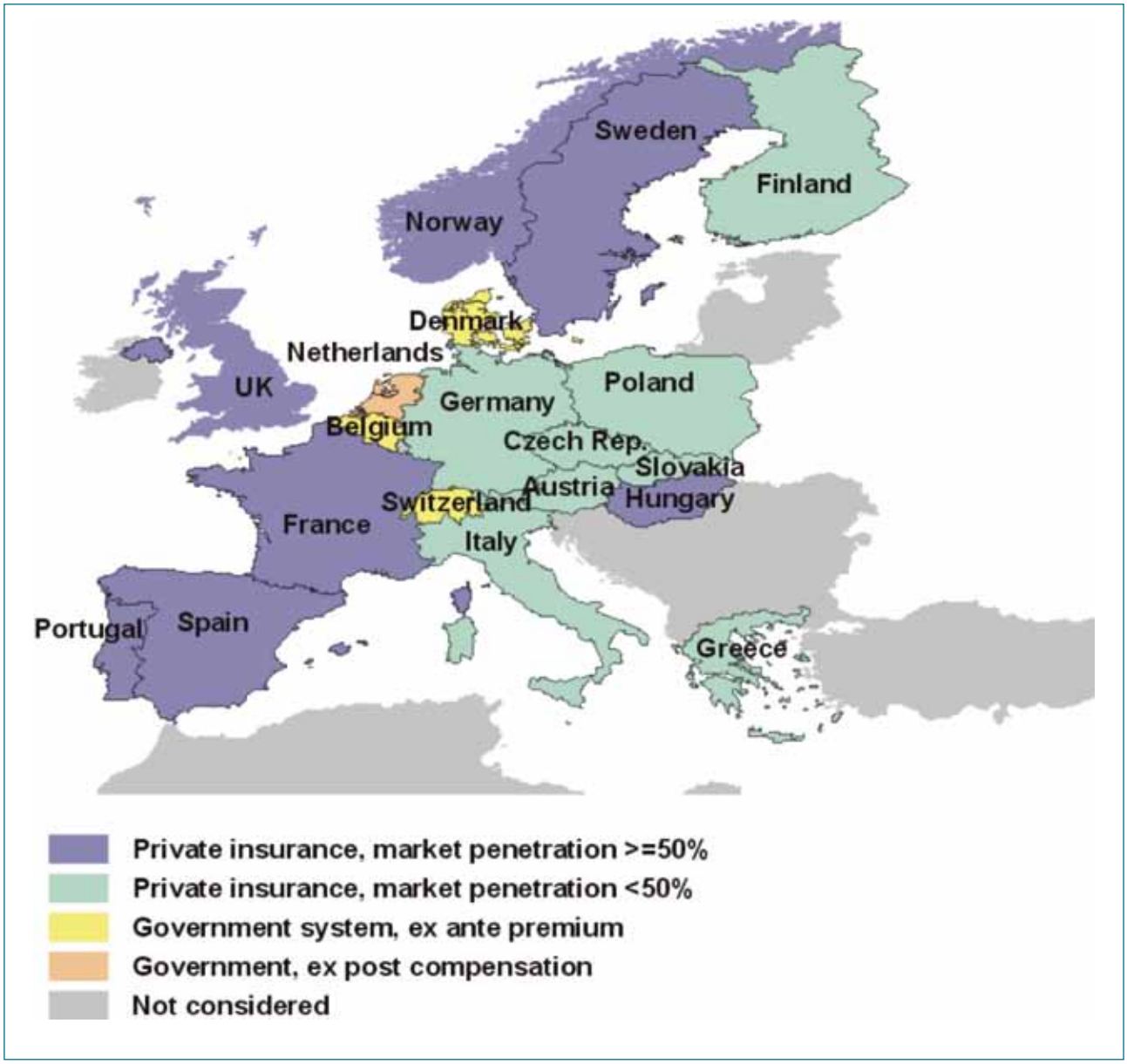

Figure 2.1.
Overview of national flood insurance and compensation systems in Europe (from: Bouwer et al. 2007, IVM report W-07/08: Figure 4.1).

Key publication:

Bouwer, L.M., Huitema, D. & Aerts, J.C.J.H. (2007). Adaptive flood management: the role of insurance and compensation in Europe. IVM-report (W-07/08), Institute for Environmental Studies, Amsterdam, 33 pp.

3. Assessment of current and future extreme weather risks

3.1 Global trends in risks from weather extremes

Global costs of weather-related disasters have increased, as is evident from various reports of the insurance industry, as well as government organisations. Interestingly, global losses from extreme weather have increased more rapidly than global average economic growth over the past 3 decade. As population and assets in areas at risk from natural hazards will very likely grow, and extreme weather is projected to increase because of climate change, losses will probably continue to increase as well.

An important question is to what extent losses from extreme weather are sensitive to changes because of anthropogenic warming of the atmosphere, and whether losses have already increased because of climate change. Some studies have attempted to determine in detail why economic losses from weather hazards may have increased. A total of 22 studies were analysed that have systematically analysed well-established records from natural hazard losses, cover economic losses, they cover at least 30 years of data, and they are peer reviewed. The general approach taken in these studies is to correct or normalise the original economic losses for inflation and changes in exposure and vulnerability that are related to growth in population and wealth. This correction shows losses as if all disasters occurred in the same year (i.e., with the same exposed assets). Table 3.1 indicates the number of studies that found a trend in the recorded losses. Economic losses may show variations related to decadal shifts in weather extremes that occur naturally or related to long-term trends in extremes. Because climate has a high variable natural component on decadal time scales, there will be variations in losses, even after adjusting for socioeconomic changes. Anthropogenic climate change that is due to the emissions of greenhouse gases causes changes in extremes over longer periods — for detection and attribution typically longer than 30 years.

Table 3.1.
Number of studies on trends in losses related to extreme weather (based on Bouwer in press: Table 1).

Studies	No change	Increase	Increase due to anthropogenic climate change?
Bushfire	1	0	0
Tropical storm and windstorms	6	2	?
River flood	3	2	?
Tornado, thunderstorm, hail	2	2	?
Various weather	3	0	0
Total	**15**	**6**	**?**

All studies show that increases in exposure and wealth are by far the most important drivers for growing disaster losses. Most studies show that disaster losses have remained constant after normalisation. Studies that did find increases after normalisation did not fully correct for wealth and population increases, or they identified other sources of exposure increases or vulnerability changes or changing environmental conditions. No study identified changes in extreme weather due to anthropogenic climate change as the main driver for any remaining trend. Therefore, it can be concluded that anthropogenic climate change so far has not had a significant impact on losses from natural disasters. Considerable uncertainties remain in some of these studies, because exposure and vulnerability that influence risk can only be roughly accounted for over time.

Key publications:

Bouwer, L.M., Crompton, R.P., Faust, E., Höppe, P. & Pielke Jr., R.A. (2007). Confronting disaster losses. *Science*, 318, 753.

Bouwer, L.M. (in press). Have disaster losses increased due to anthropogenic climate change? *Bulletin of the American Meteorological Society*, doi:10.1175/2010BAMS3092.1.

3.2 Risks of increasing damages to crop yields

For the insurance project, estimates were made by Future Water of the impact of the heat wave and drought of summer 2003 in the Watership Rivierenland in Central Netherlands (polder Quarles van Ufford). Due to increasing seepage from polders to the lower lying dry river beds during dry spells, like 2003, water shortage in the polders along the main rivers increases. The relative changes in drought are calculated as the difference between potential and actual evaporation (evaporation shortage). The yield is proportional to this evaporation shortage. In an extreme summer in 2050 yields are estimated to decline considerably (See Figure 3.1 below).

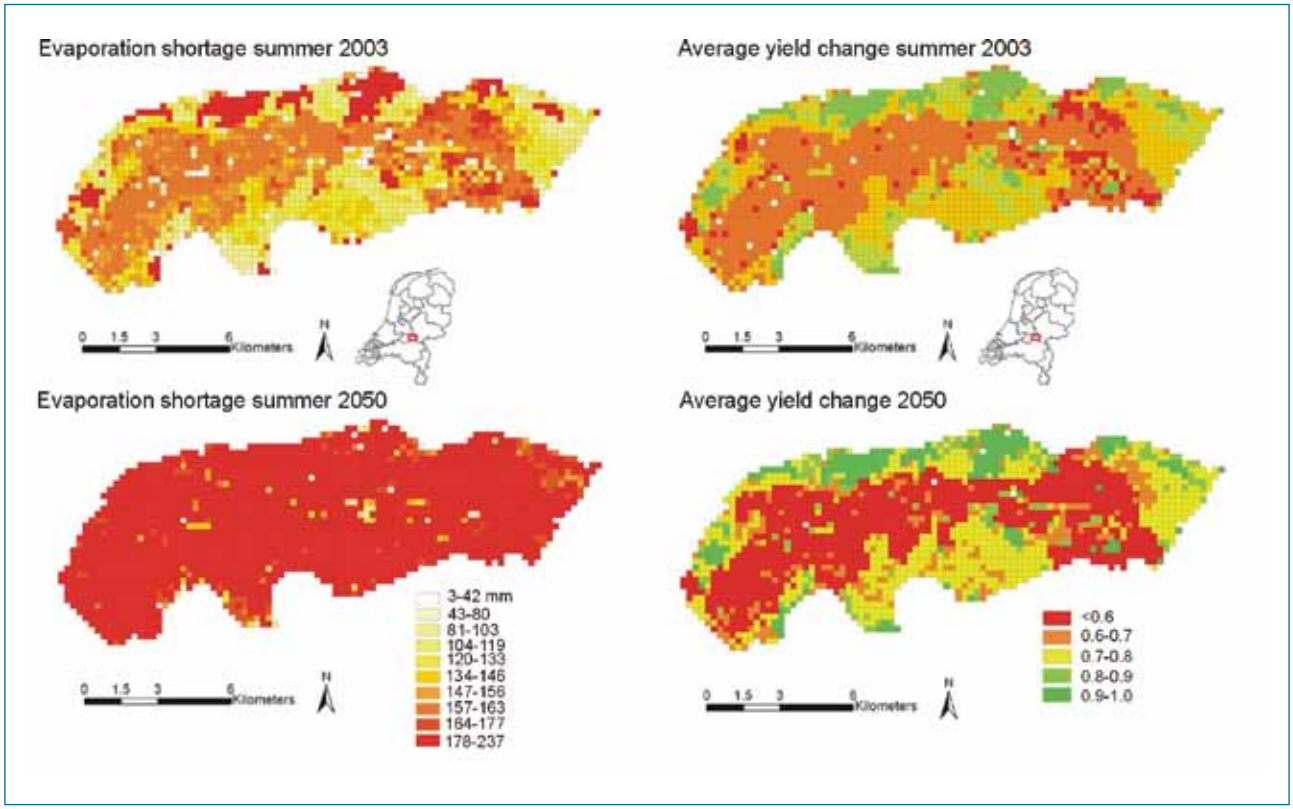

Figure 3.1.
Estimated evaporation shortage and yields in 2003, and 2050.

Key publication:

Van Heerwaarden, C., & Ketelaar, H. (2006). Invloed van klimaatverandering op kwel en wegzijging langs de grote rivieren. *H2O, Tijdschrijft voor Watervoorziening en Waterbeheer*, 5, 34-36.

3.3 Hail damage

There is much uncertainty about the effects of anthropogenic climate change on the frequency and severity of extreme weather events like hailstorms, and subsequent economic losses, while this is also relevant information for the design of climate policy. Few studies conducted indicate that a strong positive relation exists between hailstorm activity and hailstorm damage, as predicted by minimum temperatures using simple correlations. This relation suggests that hailstorm damage may increase in the future if global warming leads to further temperature increase. In our analysis estimates were made of a range of Tobit models of relations between normalized insured hailstorm damage to agriculture and several temperature and precipitation indicators for the Netherlands. Temporal dynamics were explicitly modelled.

A distinction was made between damage costs for greenhouse horticulture and outdoor farming, which appear to be differently affected by variability in weather. 'Out of sample' forecast tests showed that a combination of maximum temperatures and precipitation predicts hailstorm damage best. Extrapolations of the historical relations between hailstorm damage and weather indicators under climate change scenarios show a considerable increase in future hailstorm damage. Our estimates show that by 2050 annual hailstorm damage to outdoor farming could increase by between 25% and 50%, with considerably larger impacts on greenhouse horticulture in summer of more than 200%. The economic implications of more hailstorm damage for, and adaptation by, the agricultural and insurance sectors are discussed.

Table 3.1.
Estimated change in hailstorm damage to outdoor farming and to greenhouse horticulture under climate change (from: Botzen et al. 2010 in Resource and Energy Economics: Table 5).

Projection	Outdoor farming	Greenhouse horticulture
Yearly scenarios		
Moderate	+25%	+36%
Warm	+49%	+70%
Summer scenarios		
Moderate	+25%	+116%
Warm	+48%	+219%

Key publication:

Botzen, W.J.W., Bouwer, L.M. & Van den Bergh, J.C.J.M. (2010). Climate change and hailstorm damage: empirical evidence and implications for agriculture and insurance. *Resource and Energy Economics,* 32(3), 341-362.

3.4 Flood damage risks

Due to a combination of increasing exposure of people and assets, and expected changes in the global climate, the potential for flood losses are expected to increase. Only few studies have assessed in detail the potential range of losses in the future and the factors contributing to the projected increase. In this work we have estimated future potential damage from river flooding, and analyse the relative roles of land-use, asset value increase and climate change on these losses, for a case study area in dike-ring 36, in the south of The Netherlands along the river Meuse. Projections

of future socioeconomic change (land-use change and increase in the value of assets) are used in combination with flood scenarios, projections of flooding probabilities, and a simple damage model.

For this case study it is found that due to socioeconomic change, annual expected losses may increase by between 35 and 172% by the year 2040, compared to the baseline situation in the year 2000. If no additional measures are taken to reduce flood probabilities or consequences, climate change may lead to an increase in expected losses of between 46 and 201%. A combination of climate and socioeconomic change may increase expected losses by between 96 and 719% (Figure 2.2). Asset value increase has a large role, as it may lead to a doubling of losses.

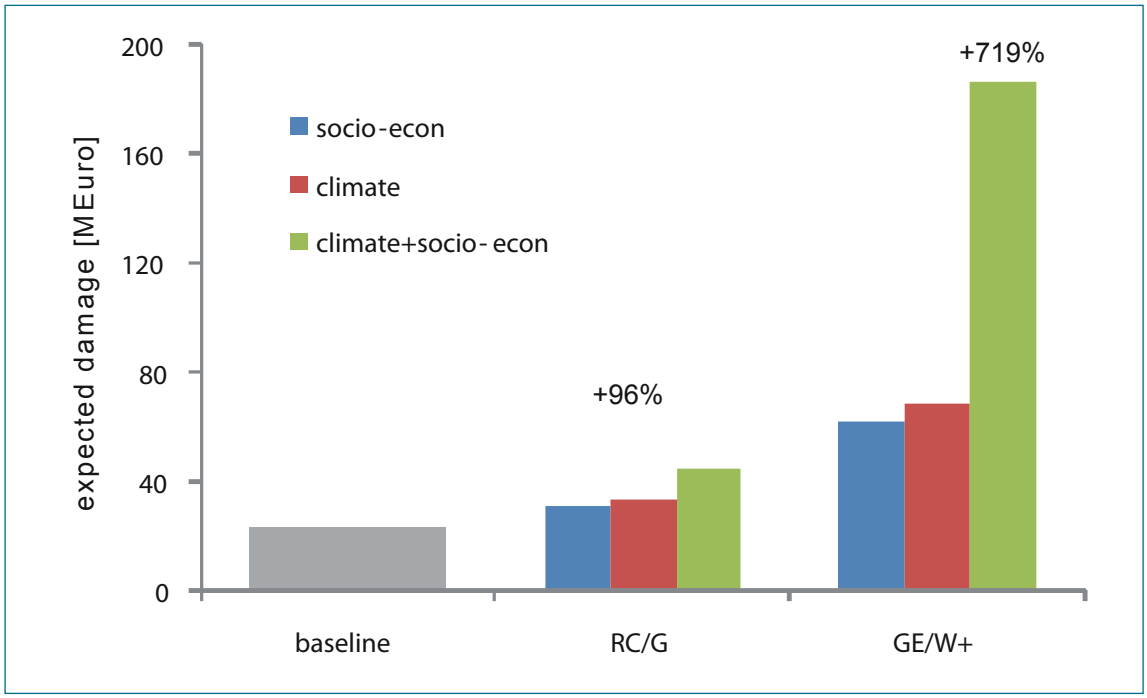

Figure 3.2.
Projected annual expected losses for 2040, compared to the baseline (2000), and their components, supposing no.

The use of single loss estimates may lead to underestimation of the impact of extremely high losses. Therefore loss-probability curves were also constructed for future risks, in order to assess the increase of the most extreme potential loss events. The approach thus allows a more detailed and comprehensive assessment than previous studies that could also be applied in other study areas to generate flood risk projections. Adaptation through flood prevention measures according to currently planned strategies would counterbalance the increase in expected annual losses due to climate change under all scenarios.

Key publications:

Bouwer, L.M., Bubeck, P. & Aerts, J.C.J.H. (2010). Changes in future flood risk due to climate and development in a Dutch polder area. *Global Environmental Change*, 20(3), 463-471.

Bouwer, L.M., Bubeck, P., Wagtendonk, A.J. & Aerts, J.C.J.H. (2009). Inundation scenarios for flood damage evaluation in polder areas. *Natural Hazards and Earth System Sciences*, 9(6), 1995-2007.

3.5 Flood casualty risks

Potential loss of life is considered an important indicator of flood risk. The future development of potential loss of life due to flooding was examined for the western part of The Netherlands, dike ring 14, which is at risk from flooding of river and coast. The analysis is based on projections and spatial distribution of population under a high economic growth scenario and a loss of life model. An estimate of potential loss of life due to a flood event can be given based on information regarding flood characteristics; an analysis of the exposed population, evacuation and shelter; and an estimate of the mortality amongst the exposed population. The mortality is estimated with a so-called mortality function, which relates mortality amongst the exposed population to flood characteristics. The mortality function that is used in this analysis relates the mortality to the flood depth.

The results show that the projected population growth in flood prone areas is higher than average in the Netherlands between the years 2000 and 2040. Due to this effect the potential number of fatalities is projected to increase by 68% on average for 10 different flood scenarios, not including impacts from climate change and sea level rise. Only sea level rise of 0.30 metre leads to an average 20% increase in the number of fatalities. The combined impact of sea level rise and population growth leads to an estimated doubling in the potential number of fatalities (Table 3.2).

Table 3.2.
Estimated changes in number of potential fatalities due to flooding in the year 2040, compared to the baseline in 2000 (from: Maaskant et al. 2009: Table 5).

	Lower bound	Upper bound	Average
Population growth	23%	124%	68%
Sea-level rise	0%	40%	20%
Population growth and sea-level rise	23%	207%	103%

Taking into account increasing probability of flooding due to sea level rise and extreme river discharges, the expected number of fatalities could quadruple by 2040. The results give a conservative and upper bound estimate of the increase of the risk level; that is when no preventive measures are undertaken. The research shows that for the analysis of flood risk it is important that the exact spatial distribution of population growth is considered, as it is essential for arriving at reliable estimates of future risks.

Key publication:

Maaskant, B., Jonkman, S.N., & Bouwer, L.M. (2009). Future risk of flooding: an analysis of changes in potential loss of life in South Holland (The Netherlands). *Environmental Science and Policy*, 12(2), 157-169.

4. New financial arrangements

4.1 Survey of willingness to pay for private flood insurance

Natural disasters may increase in frequency and severity in the future as a result of climate change, which is likely to have an impact on the demand for natural disaster insurance. Insights about individual risk beliefs and behavioural responses to changing risks are relevant for insurance managers, as it allows them, for example, to estimate the demand for new insurance products that cover weather-related damage. A study has been conducted that elicits individual risk beliefs and the demand for low-probability, high-impact flood insurance using the contingent valuation survey method among approximately 1000 homeowners in the Dutch river delta.

The results indicate that opportunities may exist for (partly-) private flood insurance, and that abolishing the current ex-post public compensation scheme of flood damage can stimulate the emergence of such a market. Individuals generally do not behave in accordance with the expected utility model since a significant proportion of homeowners neglect the low-probability flood risk. Moreover, the willingness-to-pay (WTP) for flood insurance is adjusted considerably less than proportionally if flood probabilities rise due to climate change. Individuals follow a process of Bayesian updating of flood probabilities, since perceptions of flood risk are an important determinant of the WTP, while objective risks derived from geographical characteristics influence the WTP to a lesser extent. Communication of baseline probabilities and changes in flood probabilities using risk ladders facilitate the comprehension of risk by respondents, and has a considerable effect on the level of the WTP and its sensitivity to probability changes. Moreover, a stated preference survey using choice modelling with mixed logit estimation methods examines the effects of climate change and the availability of government compensation on potential market shares of flood insurance.

Figure 4.1 hows the estimated demand curves for flood insurance that reflect potential market penetration. The results indicate opportunities for a private flood insurance market.

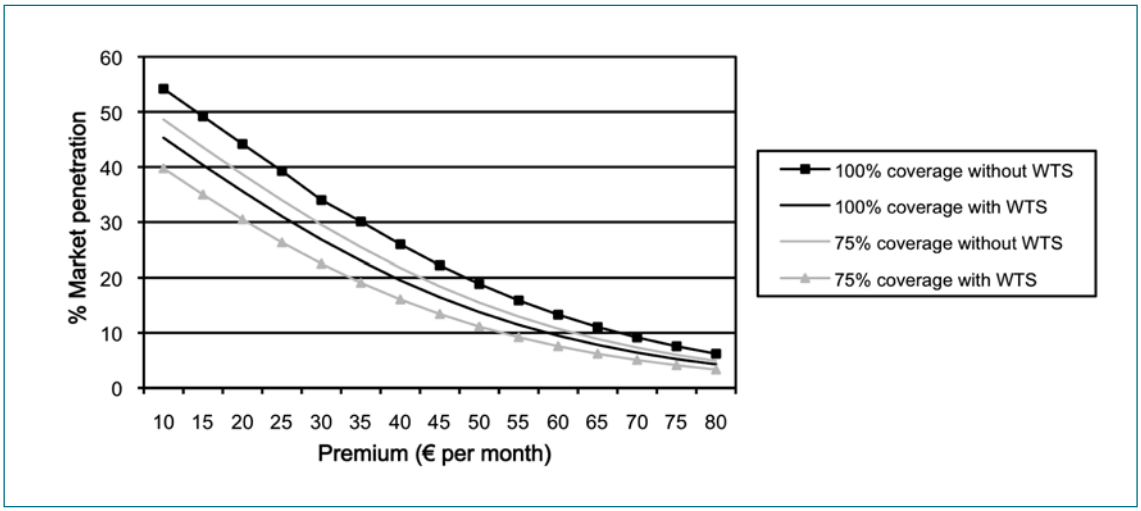

Figure 4.1.
Demand curves for insurance products under 75% or 100% coverage and with or without government compensation for damage (with/without WTS)
Note: WTS stands for availability of government relief via the "Calamities and Compensation Act".

Key publications:

Botzen, W.J.W. and van den Bergh, J.C.J.M. (submitted). Risk attitudes to low-probability climate change risks: WTP for flood insurance. *Journal of Economic Behavior and Organization*.

Botzen, W.J.W. and van den Bergh, J.C.J.M. (submitted). Monetary valuation of insurance against flood risk under climate change. *International Economic Review*.

4.2 Potential benefits of insurance for loss mitigation

Climate change is projected to increase flood risks in certain regions due to an increase in both precipitation and sea level rise. In addition, socio-economic scenarios project an increase in urbanization in flood prone areas, which results in a higher damage potential. The combined effect of climate and land use change on flood risks requires innovative adaptation policies to cope with rising risks. Increasingly, attention is paid to the role insurance can play in mitigating damage by providing incentives to policyholders to undertake damage reducing measures. The willingness of homeowners in the Netherlands to undertake measures that mitigate flood damage in exchange for benefits on hypothetical flood insurance policies is examined using surveys.

The results indicate that many homeowners are willing to make investments in mitigation (see Table 4.1). In particular, approximately two-thirds are willing to invest in water barriers in exchange for a premium reduction and about a fifth are willing to replace floor types that are vulnerable to flooding with water resistant floor types. Furthermore, about a quarter are willing to move central heating installations to floors safe against flooding in favor of a reduction in the insurance premium. Estimates of the effectiveness of these mitigation measures to limit potential flood damage in the river delta indicate that prevented damage could be substantial, namely in the order of 1 billion euro or larger (see Table 4.2). Reductions in (absolute) flood risk due to mitigation are especially large under climate change. A probit model indicates that existing arrangements for compensating flood damage, risk awareness and perceptions, and geographical characteristics are important determinants in the decision to undertake mitigation.

Table 4.1.
Responses to the mitigation questions.

Mitigation measure:	% for whom the measure Is relevant (A)	% of (A) who are willing to undertake the measure (B)	% of total sample willing to undertake the measure (A*B)
1) Buy sandbags that can be used as water barrier	100%	68%	68%
2) Replace current floor with a tile floor	72%	20%	14%
3) Move laundry and dryer machines to a higher floor	43%	8%	3%
4) Install central heating boiler on a higher floor	19%	24%	5%

Table 4.2.
Estimates of prevented damage by mitigation in dike ring area 36.

Mitigation measure:	Homeowners who undertake the measure	Total prevented flood damage (Mln €)
1) Buy sandbags that can be used as water barrier		
- Pessimistic effectiveness and low expected damage	60248	506,7
- Pessimistic effectiveness and high expected damage	60248	1427,9
- Optimistic effectiveness and low expected damage	60248	1048,3
- Optimistic effectiveness and high expected damage	60248	2855,8
2) Replace current floor with a tile floor		
- Low expected damage	12758	99,9
- High expected damage	12758	272,1
3) Move laundry and dryer machines to a higher floor	3048	2,1
4) Install central heating boiler on a higher floor	4040	31,7

Key publication:

Botzen, W.J.W., Aerts, J.C.J.H. and Van den Bergh, J.C.J.M. (2009). Willingness of homeowners to mitigate climate risk through insurance. *Ecological Economics*, 68 (8-9): 2265-2277.

4.3 Possible financial arrangements for flood risks

Climate change is projected to cause severe economic losses, which has the potential to affect the insurance sector and public compensation schemes considerably. This study discusses the role insurances can play in adapting to climate change impacts. The particular focus is on the Dutch insurance sector, in view of the Netherlands being extremely vulnerable to climate change impacts. The usefulness of private insurance as an adaptation instrument to increased flood risks is examined, which is currently unavailable in the Netherlands. It is questioned whether the currently dominant role of the Dutch government in providing damage relief is justified from an economic efficiency perspective. Characteristics of flood insurance arrangements in the Netherlands, the United Kingdom, Germany, and France are compared in order to identify possible future directions for arrangements in the Netherlands. It is argued that social welfare improves when insurance companies take responsibility for part of the risks associated with climate change.

This study propose to insure flood risk in The Netherlands with a public-private partnership in the form of a 'three-layered insurance program', as has been suggested for insuring natural catastrophe risk in the USA. Figure 4.2 gives a schematic representation of the proposed insurance arrangement. In this three-layered program, a first layer of small losses is paid by households. Deductibles in insurance contracts stipulate that households pay for part of the flood damage they suffer themselves. Examples are a deductible of a fixed amount, which means that policyholders need to pay any damage caused by the insured event below this amount themselves, or a deductible that specifies a fixed percentage of the total damage that needs to be paid by the policyholder. The insurer reimburses the remainder of the damage in both kinds of deductibles. Deductibles of a fixed amount could give few incentives to the policyholder to prevent losses above this amount, because these losses are in principal covered by the insurance company. This may be less of a problem with deductibles that are a fixed percentage of the total damage. In the second layer of the insurance program, private insurance companies cover larger losses using risk based premiums. Insurers may

partly hedge the portion of flood risk they cover by purchasing reinsurance coverage or diversify risks further on capital markets via catastrophe bonds, options or futures. The government covers a third layer of very large losses to prevent problems with insurability of highly correlated risks, and the limited financial capacity of the Dutch insurance sector. A certain maximum amount of damage defined as a 'cap' could be specified that will be paid by the insurance sector, while the government will compensate the remaining damage if actual flood damage exceeds this cap.

Layer 3	Government
	Capital markets
Layer 2	Reinsurance companies
	Primary insurance companies
Layer 1	Households and companies

Figure 4.2.
A three-layered insurance program.

Key publication:

Botzen, W.J.W., J.C.J.M. van den Bergh (2008). Insurance against climate change and flooding in the Netherlands: present, future, and comparison with other countries. *Risk Analysis*, 28, 413-426.

5. Dissemination and stakeholder involvement

5.1 Conferences and workshops

Dissemination of project results took place through publications (various journal articles have been published from this project; see Appendix 2), as well as presentations at scientific conferences, workshops and meetings with stakeholders (see Appendix 3).

The most important events by our research team for this project include the following events (international events indicated by *):

- Initial scoping meeting in Amsterdam (23 November 2005)
- Symposium on flood risk and climate change (18 May 2006)*
- Workshop on climate change and the finance sector (13 September 2006; hosted by Rabobank; and organised in cooperation with the programme bureau of KvR)
- Connecting Delta Cities Conference, New York, USA (June 2009)*
- Session on risk and insurance at COP15 in Copenhagen, Denmark (December 2009)*.
- Session on insurance and risk at the Rotterdam Delta Conference, Netherlands (September 2010)*
- Special sessions at IVM in Amsterdam on risk and insurance, including events with the following key scientists:
    - Dr. Robert Muir Wood (May 2006)*
    - Prof. Roger Pielke Jr. (May 2007)*
    - Prof. Howard Kunreuther (22 October 2009)*

Further, various presentations of the A9 project (by Jeroen Aerts, Wouter Botzen and Laurens Bouwer), most importantly at the following relevant international events:

- Munich Re workshop on disaster losses, Hohenkammer, Germany (25 May 2006)
- Floodrisk 2008 Conference, Oxford, UK (2 October 2008)
- Workskhop on climate change and insurance, Innsbruck, Austria (5 March 2009)
- International Choice Modelling Conference, Harrogate, UK (1 April 2009)
- Munich Re workshop on disasters and insurance, Germany (7 October 2009)
- Fourth World Congress of Environmental and Resource Economists, Montreal, Canada (July 2010)

5.2 Stakeholders

Various stakeholder organisations have been involved in the research, including government organisations, and private companies in The Netherlands and abroad. Frequent interactions took place with Munich Reinsurance Company in Germany, including a workshop on trends in disaster losses in 2006, and the publishing of a joint publication in Science in 2007.

Extensive collaboration has been established with Euroko Re (part of Eureko, the consortium owning Interpolis insurance company in The Netherlands). Data on hail damages have been used for analysis. Further, contacts have been established with the Dutch Association of Insurers (Verbond van Verzekeraars). A number of meetings were held with their on issues committee on climate change that published reports on general issues of climate change, and rainfall damages in 2010. Collaboration has now been set up for 2011, to continue to work with the Dutch Association of Insurers, and sharing of loss data and information for studies on extreme weather risks in The Netherlands.

Collaboration was established with the Waterboard Rivierenland for the case study on droughts. Further work has been performed in the project “Attention for Safety” (Aandacht voor Veiligheid) focussing on future flood risks; which was associated with the A9 project, and was commissioned by the Dutch Ministry of Transport, Public Works and Water Management.

6. Further research

From the A9 project, a number of new initiatives have started, building on earlier results. Research will on climate risks and insurance will continue within the following key projects:

- International comparative analysis of flood risk management measures and adaptation policies (part of Theme 1: Climate Proof Flood Risk Management within the Knowledge for Climate programme)
- Relationship between perceived flood risks, problem ownership and household and business adaptation choices (Hotspot Region Rotterdam projects 07 and 08 within the Knowledge for Climate programme)
- Individual behaviour under low-probability/high-impact climate change scenarios (Veni grant from NWO to dr. Wouter Botzen)

- Costs of Natural Hazards (FP7 coordination action funded by the European Commission)
- European responses to climate change: deep emissions reductions and mainstreaming of mitigation and adaptation (FP7 research project funded by the European Commission)

Appendix 1. Project milestones

	Milestones for scientific output
W1	Dissertation spatial differentiation of damage under climate change: Bouwer, L.M. (2010). Disasters and climate change: analyses and methods for projecting future losses from extreme weather. Doctoral Thesis. Faculty of Earth and Life Sciences, VU University Amsterdam, pp. 141, ISBN 978-90-8570-596-3.
W2	Dissertation cost-benefit of financial adaptation measures in the water sector: Botzen, W.J.W. (2010). The Economics of Insurance against Climate Change. Doctoral Thesis. Faculty of Economics and Business Administration, VU University Amsterdam, pp. 340, ISBN 978-90-8659-417-7.

	Milestones for economic output
E1	Overview of financial adaptation measures: Bouwer, L.M., Huitema, D. & Aerts, J.C.J.H. (2007). Adaptive flood management: the role of insurance and compensation in Europe. Report W-07/08, Institute for Environmental Studies, Amsterdam, 33 pp.

	Milestones societal output
M1	Stakeholder workshops: See Chapter 5
M2	International workshop: See Chapter 5

	Milestones for innovation, including knowledge transfer
I1	Scientific articles: See Appendix 2
I2	Participation in scientific conferences: See Appendix 3

Appendix 2. Project publications

Journal articles:

Aerts, J.C.J.H. and Botzen, W.J.W. (submitted). Climate change impacts on long-term flood risk and insurance: A comprehensive study for the Netherlands. *Global Environmental Change*.

Aerts, J.C.J.H., Botzen, W.J.W., Van der Veen, A., Krywkrow, J. and Werners, S. (2008) Dealing with Uncertainty in Flood Management Through Diversification. *Ecology and Society*, 13 (1). 41.

Botzen, W.J.W., Aerts, J.C.J.H. and van den Bergh, J.C.J.M. (submitted). Risk reduction or elimination? Risk attitudes and adaptation to sea level rise. *Climatic Change*.

Botzen, W.J.W. and van den Bergh, J.C.J.M. (submitted). Monetary valuation of insurance against flood risk under climate change. *International Economic Review.*

Botzen, W.J.W. (2011). Alistair Munro: Bounded rationality and public policy: A perspective from behavioural economics. Book Review. *Environmental and Resource Economics* DOI10.1007/s10640-010-9445-7.

Botzen, W.J.W. and van den Bergh, J.C.J.M. (submitted). Risk attitudes to low-probability climate change risks: WTP for flood insurance. *Journal of Economic Behavior and Organization*.

Botzen, W.J.W., Bouwer, L.M. and van den Bergh, J.C.J.M. (2010). Climate change and hailstorm damage: Empirical evidence and implications for agriculture and insurance. *Resource and Energy Economics*, 32 (3): 341-362.

Botzen, W.J.W., van den Bergh, J.C.J.M. and Bouwer, L.M. (2010). Climate change and increased risk for the insurance sector: A global perspective and an assessment for the Netherlands. *Natural Hazards,* 52 (3): 577-598.

Botzen, W.J.W. and Marey, P.S. (2010). Did the ECB respond to the stock market before the crisis? Empirical evidence and policy implications. *Journal of Policy Modeling*, 32 (3): 303-322.

Botzen, W.J.W., Aerts, J.C.J.H. and Van den Bergh, J.C.J.M. (2009). Dependence of flood risk perceptions on socio-economic and objective risk factors. *Water Resources Research*, 45: W10440.

Botzen, W.J.W. and Van den Bergh, J.C.J.M. (2009). Managing natural disaster risk in a changing climate. *Environmental Hazards*, 8 (3): 209-225.

Botzen, W.J.W., Aerts, J.C.J.H. and Van den Bergh, J.C.J.M. (2009). Willingness of homeowners to mitigate climate risk through insurance. *Ecological Economics*, 68 (8-9): 2265-2277.

Botzen, W.J.W. and Van den Bergh, J.C.J.M. (2009). Bounded rationality, climate risks and insurance: Is there a market for natural disasters? *Land Economics,* 85 (2): 266-279.

Botzen, W.J.W., J.C.J.M. van den Bergh (2008). Insurance against climate change and flooding in the Netherlands: present, future, and comparison with other countries. *Risk Analysis*, 28, 413-426.

Botzen, W.J.W., Gowdy, J.M. and van den Bergh, J.C.J.M. (2008). Cumulative CO_2 emissions: Shifting international responsibilities for climate debt. *Climate Policy*, 8: 569-576.

Botzen, W.J.W. & Bergh, J.C.J.M. van den (2008). Verzekerd van of tegen klimaatverandering? *Kwartaalschrift Economie*, 2, 225-234

Bouwer, L.M. (submitted). Projection of future disaster losses under climate change. *Risk Analysis.*

Bouwer, L.M. (submitted). Reply to comment on "Have disaster losses increased due to anthropogenic climate change?". *Bulletin of the American Meteorological Society.*

Bouwer, L.M. (in press). Have disaster losses increased due to anthropogenic climate change? *Bulletin of the American Meteorological Society*, doi:10.1175/2010BAMS3092.1.

Bouwer, L.M. and Botzen, W.J.W. (in press). Comment on "The economics of hurricanes and implications of global warming" by W.D. Nordhaus. *Climate Change Economics.*

Bouwer, L.M., Bubeck, P. & Aerts, J.C.J.H. (2010). Changes in future flood risk due to climate and development in a Dutch polder area. *Global Environmental Change*, 20(3), 463-471.

Bouwer, L.M., Bubeck, P., Wagtendonk, A.J. & Aerts, J.C.J.H. (2009). Inundation scenarios for flood damage evaluation in polder areas. *Natural Hazards and Earth System Sciences*, 9(6), 1995-2007.

Bouwer, L.M., Vermaat, J.E. & Aerts, J.C.J.H. (2008). Regional sensitivities of mean and peak river discharge to climate variability in Europe. *Journal of Geophysical Research*, 113, D19103.

Bouwer, L.M., Crompton, R.P., Faust, E., Höppe, P. & Pielke Jr., R.A. (2007). Confronting disaster losses. *Science*, 318, 753.

Bouwer, L.M., Botzen, W.J.W. & Aerts, J.C.J.H. (2007). Klimaatverandering en verzekeren van rampschade. *H2O, Tijdschrift voor Watervoorziening en Waterbeheer*, Nr. 22, 23-25.

Bouwer, L.M. & Aerts, J.C.J.H. (2006). How can we maximize the impact of adaptation measures to support sustainable development? *Natural Resources Forum*, 30(4), 328-329.

Bouwer, L.M., Vermaat, J.E. and Aerts, J.C.J.H. (2006). Winter atmospheric circulation and river discharge in northwest Europe. *Geophysical Research Letters*, 33(6), L06403.

Bouwer, L.M. & Aerts, J.C.J.H. (2006). Financing climate change adaptation. *Disasters*, 30(1), 49-63.

Bouwer, L.M. & Vellinga, P. (2005). Some rationales for risk sharing and financing adaptation. *Water Science and Technology*, 51(5), 89-95.

Bubeck, P., Botzen, W.J.W. and Aerts, J.C.J.H. (submitted). Do flood risk perceptions influence mitigation behaviour? *Risk Analysis.*

Hoff, H., Warner, K. & Bouwer, L.M. (2005). The role of financial services in climate adaptation in developing countries. *Vierteljahrshefte zur Wirtschaftsforschung*, 74(2), 196-207.

Droogers, P. & Den Besten, J. (2006). Droogte- en natschade onder wijzigende afvoernormen. *H2O, Tijdschrift voor watervoorziening en waterbeheer*, 4:31-34.

Droogers, P. & Van den Hurk, B. (2006). Waterbeheer en de nieuwe KNMI klimaatscenario's. *H2O, Tijdschrift voor watervoorziening en waterbeheer*, 12: 25-28.

Immerzeel, W.W. & Droogers, P. (2008) Calibration of a distributed hydrological model based on satellite evapotranspiration. *Journal of Hydrology,* 349(3-4), 411-424.

Immerzeel, W., Graafstaal, H.G., Brouwer, B. & Warmolts, B. (2006). Evaluatie wateraanvoer Noordoostpolder. *H2O, tijdschrijft voor watervoorziening en waterbeheer,* 21:36-38.

Maaskant, B., Jonkman, S.N., & Bouwer, L.M. (2009). Future risk of flooding: an analysis of changes in potential loss of life in South Holland (The Netherlands). *Environmental Science and Policy*, 12(2), 157-169.

Olsthoorn, X., Van der Werff, P., Bouwer, L.M. & Huitema, D. (2008). Neo-Atlantis: The Netherlands under a five-metre sea level rise. *Climatic Change*, 91(1-2), 103-122.

Pahl-Wostl, C., J. Sendzimir, P. Jeffrey, J.C.J.H. Aerts, G. Berkamp & K. Cross (2007). Managing change toward adaptive water management through social learning. *Ecology and Society*, 12(2), 30.

Pielke, R.A., Jr., Agrawala, S., Bouwer, L.M., Burton, I., Changnon, S., Glantz, M.H., Hooke, W.H., Klein, R.J.T., Kunkel, K., Mileti, D., Sarewitz, D., Tompkins, E.L., Stehr, N. & Von Storch, H. (2005). Clarifying the attribution of recent disaster losses: a response to Epstein and McCarthy. *Bulletin of the American Meteorological Society*, 86(10), 1481-1483.

Poussin, J., Botzen, W.J.W. and Aerts, J.C.J.H. (submitted). Stimulating flood damage mitigation through insurance: An assessment of the French CatNat system. *Ecological Economics*.

Seifert, I., Botzen, W.J.W., Aerts, J.C.J.H. and Krebich. H. (submitted). Household attitudes toward flood insurance in Germany and the Netherlands. *Ecological Economics*.

Sheremet, O., and Lucas, A. (2009) Global Loss Diversification in the Insurance Sector. *Insurance: Mathematics and Economics*, 44(3), 415-425.

Van Heerwaarden, C., & Ketelaar, H. (2006). Invloed van klimaatverandering op kwel en wegzijging langs de grote rivieren. *H2O, tijdschrijft voor watervoorziening en waterbeheer* 5: 34-36.

Ward, P.J., Beets, W., Bouwer, L.M., Aerts, J.C.J.H. & Renssen, H. (2010). Sensitivity of river discharge to ENSO. *Geophysical Research Letters*, 37(12), L12402.

Warner, K., Bouwer, L.M. & Ammann, W. (2007). Financial services and disaster risk finance: examples from the community level. *Environmental Hazards*, 7(1), 32-39.

Books:

Aerts, J. C. J. H., Major, D. C., Bowman, M. J., Dircke, P., Marfai, M. A., Abidin, H. Z., Ward, P. J., Botzen, W.J.W., Bannink, B. A., Nickson, A. and Reeder, T. (2009). *Connecting Delta Cities. Coastal Adaptation, Flood Risk Management and Adaptation to Climate Change*. Amsterdam, The Netherlands: VU University Press.

Reports:

Botzen, W.J.W. and Van den Bergh, J.C.J.M. (2009). Insurance against climate change. Climate Research Netherlands: Research Highlights, ISBN 978-90-8815-015-9, p. 41.

Bouwer, L.M. (2009). The cost of natural disasters under climate change. Climate Research Netherlands: Research Highlights, ISBN 978-90-8815-015-9, p. 38.

Bouwer, L.M., Huitema, D. & Aerts, J.C.J.H. (2007). Adaptive flood management: the role of insurance and compensation in Europe. Report W-07/08, Institute for Environmental Studies, Amsterdam, 33 pp.

Droogers, P. & Loeve, R. (2005). Natschade bij optimale afwatering. Waterschap Hunze en Aa's. FutureWater rapport, Wageningen, 41 pp.

Graafstal, H., & Droogers, P. (2006). Modeling climate change impact on forests: an overview. FutureWater Report 51, Wageningen.

Immerzeel, W.W., Van Heerwaarden, C.C., & Droogers, P. (2007). FutureViewR: gedetailleerd hydrologisch en oppervlaktewater model getest op Quarles van Ufford, FutureWater rapport.

Immerzeel, W., H.G. Graafstal en R. Loeve (2006). Evaluatie wateraanvoer in de Noordoostpolder. FutureWater Report 50, Wageningen.

Loeve, R., Droogers, P. & Veraart, J. (2006). Klimaatverandering en waterkwaliteit. Wetterskip Fryslan. FutureWater Report 58, Wageningen.

Van Drunen, M., Bouwer, L.M., Dellink, R., Gupta, J., Massey, E., & Pauw, P. (2009). *Financing adaptation in developing countries: assessing new mechanisms*. IVM-report (W-09/02), Institute for Environmental Studies, Amsterdam.

Warner, K., Ranger, N., Surminski, S., Arnold, M., Linnnerooth-Bayer, J., Michel-Kerjan, E., Kovacs, P., Herweijer. C., Bals, C., Bouwer, L.M., Burton, I., Cutter, S., Osman Elasha, B., Höppe, P., Loster, T., Mahul, O., Mearns, R., Sokona, Y. & Ward, B. (2009). *Adaptation to climate change: linking disaster risk reduction and insurance.* United Nations International Strategy for Disaster Reduction, Geneva.

Book chapters, conference proceedings, etc.:

Aerts, J.C.J.H., Smith, A.E.F. & Bouwer, L.M. (2008). Abrupt climate change: analogies in impacts and coping mechanisms. In: *What if... abrupt and extreme climate change?* Netherlands Organisation for Scientific Research (NWO), The Hague, 65-82.

Bouwer, L.M. & Vellinga, P. (2008). Klimaatverandering en overstromingen, met een focus op Nederland. In: Dietz, T., Den Hertog, F. & Van der Wusten, H. (eds.). *Van Natuurlandschap tot Risicomaatschappij: de Geografie van de Relatie tussen Mens en Milieu*. Amsterdam University Press, 186-190.

Bouwer, L.M. & Vellinga, P. (2007). On the flood risk in The Netherlands. Chapter 24 in: Be-gum, S., Stive, M.J.F. & Hall, J.W. (eds.). F*lood Risk Management in Europe: Innovation in Policy and Practice*. Springer, Berlin, 469-484.

Bouwer, L.M. (2007). Flood insurance systems in Europe and their relationship to physical, socio-economic and institutional environments. Amsterdam, The Netherlands, Conference on the Human Dimensions of Global Environmental Change.

Bouwer, L.M. (2006). The benefits of disaster risk reduction and their effects on loss trends. Hohenkammer, Germany, Climate Change and Disaster Losses Workshop: Understanding and Attributing Trends and Projections.

Pielke, R.A., Jr., Bouwer, L.M., Compton, R., Faust, E. & Höppe, P. (2008). Catastrophe losses in the context of demographics, climate, and policy. In: Managing the changing landscape of catastrophe risk, 10th Aon Re Australia hazards conference, 21-31

Appendix 3. Project presentations

Aerts, J.C.J.H., Botzen, W.J.W., & Bouwer, L.M. (06-03-2009). Adapting to climate change: long-term perspectives for flood insurance in The Netherlands. Innsbruck, Austria, adaptation to climate change: the role of insurance, international seminar.

Botzen, W.J.W., (07-2010). Monetary Valuation of Insurance against Flood Risk under Climate Change. Montreal, Canada, Fourth World Congress of Environmental and Resource Economists.

Botzen, W.J.W., Bouwer, L.M. & Van den Bergh, J.C.J.M. (02-07-2010). Climate change and hailstorm damage: empirical evidence and implications for agriculture and insurance. Montreal, Canada, Fourth World Congress of Environmental and Resource Economists.

Botzen, W.J.W. (1 April 2009). Monetary Valuation of Insurance against Climate Change Risk. Harrogate, UK, International Choice Modeling Conference.

Botzen, W.J.W. (14 April 2009). Monetary Valuation of Insurance against Climate Change Risk. Amsterdam, The Netherlands, Eureka Seminar, Faculty of Economics and Business Administration, Vrije Universiteit Amsterdam.

Botzen, W.J.W. (26 June 2009). Monetary Valuation of Insurance against Climate Change Risk. Amsterdam, The Netherlands, EAERE Conference.

Botzen, W.J.W. (11 September 2009). Monetary Valuation of Insurance against Climate Change Risk. School of Economics, University of New South Wales (invited), Australia.

Botzen, W.J.W. (5 November 2009). Monetary Valuation of Insurance against Climate Change Risk. Rotterdam, The Netherlands, ESE Conference Behavioural Economics, Erasmus University.

Botzen, W.J.W. (5 February 2009). Limiting Extreme Climate Change Risk through Insurance: Preventing of a Dutch Neo-Atlantis. Washington DC, USA, World Bank (invited).

Botzen, W.J.W. (July 2008). Monetary Valuation of Flood Insurance in the Netherlands. FUR Conference IESE Business School of Barcelona, Spain.

Botzen, W.J.W. (August 2008). Willingness of Homeowners to Mitigate Climate Risk using Insurance" GeoForschungszentrum Potsdam, Germany.

Botzen, W.J.W. (16-05-2007) Bounded Rationality, Climate Risks and Insurance: Is There a Market for Natural Disasters. Driebergen, The Netherlands, Synergy in Climate changes Spatial Planning Research.

Bouwer, L.M. & Aerts, J.C.J.H. (16-09-2010). The need for socioeconomic information in the projection of future flood risks. Hamburg, Germany, Storm Surges Congress 2010.

Bouwer, L.M. & Aerts, J.C.J.H. (29-09-2010). Assessing future extreme weather risk: current approaches and estimates. Rotterdam, The Netherlands, Conference Deltas in Times of Climate Change.

Bouwer, L.M. (10-12-2009). Projections of disaster losses under future climate change. Copenhagen, Denmark, UNFCCC COP15.

Bouwer, L.M., Aerts, J.C.J.H. Botzen, W.J.W., & Van den Bergh, J.C.J.M. (15-10-2009). Klimaatverandering, schade en verzekeringen. Amsterdam, The Netherlands, KVR Eindproductendag.

Bouwer, L.M. & Aerts, J.C.J.H. (07-10-2009). Projections of disaster losses. Munich, Germany, Workshop on Understanding the Role of Insurance and Disaster Risk Reduction in Adaptation.

Bouwer, L.M. (09-06-2009). Climate information and scenarios for impact assessment and adaptation policy. New York, USA, Connecting Delta Cities workshop.

Bouwer, L.M. & Pielke, Jr., R.A. (10-03-2009). Attribution and projection of damage from extreme weather events. Copenhagen, Denmark, IARU International Scientific Congress on Climate Change.
Bouwer, L.M. (16-01-2009). Klimaatverandering en verzekeren. The Hague, The Netherlands, Issue Commitee Climate, Netherlands Association of Insurers.

Bouwer, L.M. (02-10-2008). Inundation scenario development for damage evaluation in polder areas. Oxford, United Kingdom, Floodrisk 2008.

Bouwer, L.M. (18-11-2008). Projections of future flood losses. Amsterdam, The Netherlands, VU Faculty of Economics and Business Administration.

Bouwer, L.M. (18-11-2008). Klimaatverandering en zeespiegelstijging: risico's voor Nederland. Almere, The Netherlands, VU Podium.

Bouwer, L.M. (28-05-2008). Climate change and flood risks: historical analysis and projections. Santa Barbara, USA, Donald Bren School of Environmental Science and Management, University of California.

Bouwer, L.M. (10-04-2008). Climate change and flood risks: historical analysis and projections. Santa Barbara, USA, Department of Geography, University of California.

Bouwer, L.M. (29-11-2007). Meer schade door klimaatverandering? Velp, The Netherlands, Manifestatie Samen voor Natuur: de Bindende Kracht van het Klimaat.

Bouwer, L.M. (31-10-2007). IATAL: a proposal for an International Air Travel Adaptation Levy. Bonn, Germany, UNFCCC Workshop on Finance and Investment Flows to Address Climate Change: the Way Forward.

Bouwer, L.M. (25-09-2007). Climate change adaptation and water resources management. Delft, The Netherlands, UNESCO-IHE, Climate Change in Integrated Water Management.

Pielke, Jr., R., Bouwer, L.M., Crompton, R., Faust, E. & Höppe, P. (17-09-2007). Catastrophe losses in the context of demographics, climate, and policy. Surfers Paradise Marriott Resort, Queensland, Australia, Managing the changing landscape of catastrophe risk, 10th Aon Re Australia Biennial Hazards Conference.

Bouwer, L.M., Aerts, J.C.J.H., Droogers, P., Botzen, W.J.W. & Sheremet, M.A.O. (13-09-2007). Financial arrangements for disaster losses under climate change. The Hague, The Netherlands, International Conference Climate changes Spatial Planning.

Bouwer, L.M. and Aerts, J.C.J.H. (06-06-2007). Climate change and the safety of The Netherlands. Amsterdam, The Netherlands, Fourth Conference of the European Society for Environmental History.

Bouwer, L.M. (26-05-2007). Flood insurance systems in Europe and their relationship to physical, socio-economic and institutional environments. Amsterdam, The Netherlands, Conference on the Human Dimensions of Global Environmental Change.

Bouwer, L.M. (19-04-2007). Atmospheric circulation and peak river discharges in Europe. Vienna, Austria, European Geosciences Union General Assembly.

Bouwer, L.M. (01-02-2007). Klimaatverandering en veiligheid. Amsterdam, The Netherlands, Tuschinski, Gemeente Amsterdam.

Bouwer, L.M. (16-11-2006). Klimaatverandering en zeespiegelstijging: risico's voor de Nederlandse kust. Edam, The Netherlands, VU-Podium.

Bouwer, L.M. and Te Linde, A.H. (25-07-2006). The flood risk in The Netherlands. London, UK, Risk Management Solutions

Bouwer, L.M. (25-05-2006). The benefits of disaster risk reduction and their effects on loss trends. Hohenkammer, Germany, Climate Change and Disaster Losses Workshop: Understanding and Attributing Trends and Projections

Bouwer, L.M. (11-10-2005). Financiering van klimaatadaptatie. Utrecht, The Netherlands, Young Energy Specialists for Development Cooperation.

Bouwer, L.M. (16-06-2005). Oorzaken en gevolgen van klimaatverandering. Amsterdam, The Netherlands, Greenpeace Milieucafé.

Bouwer, L.M. & Warner, K. (21-06-2005). Financial services and community climate change adaptation. The Hague, The Netherlands, Red Cross International Workconference on Climate Change and Disaster Risk Reduction.

Bouwer, L.M. (11-02-2005). Financial arrangements for disaster losses under climate change. Zeist, The Netherlands, Climate Changes Spatial Planning Conference.

Sheremet, M.A.O. (07-12-2006). Risk management and insurance under climate change: organizing the private catastrophe insurance in a sustainable way. Amersfoort, The Netherlands, NWO-VAM seminar.

Warner, K., Bouwer, L.M. & Ammann, W. (15-09-2005). Financial services and community level disaster risk finance. Beijing, China, DPRI-IIASA Annual Conference on Integrated Disaster Risk Management.

Climate changes Spatial Planning

Climate change is one of the major environmental issues of this century. The Netherlands are expected to face climate change impacts on all land- and water related sectors. Therefore water management and spatial planning have to take climate change into account. The research programme 'Climate changes Spatial Planning', that ran from 2004 to 2011, aimed to create applied knowledge to support society to take the right decisions and measures to reduce the adverse impacts of climate change. It focused on enhancing joint learning between scientists and practitioners in the fields of spatial planning, nature, agriculture, and water- and flood risk management. Under the programme five themes were developed: climate scenarios; mitigation; adaptation; integration and communication. Of all scientific research projects synthesis reports were produced. This report is part of the Adaptation series.

Adaptation

Dutch climate research uses a 'climate proofing' approach for adaptation. Climate proofing does not mean reducing climate based risks to zero; that would be an unrealistic goal for any country. The idea is to use a combination of infrastructural, institutional, social and financial adaptation strategies to reduce risk and optimalise opportunities for large scale innovations. Climate changes Spatial Planning realised projects in a multidisciplinary network that jointly assessed impacts and developed adaptation strategies and measures. The following themes were central to the programme: water safety, extreme precipitation, nature and biodiversity, agriculture, urban areas, transport (inland and road transport) and the North Sea ecosystem. In special projects, the so called hotspots, location-specific measures were developed that focused on combining 'blue', 'green' and 'red' functions.

Programme Office Climate changes Spatial Planning

P.O. Box 1072
3430 BB Nieuwegein
The Netherlands
T +31 30 6069 780

c/o Alterra, Wageningen UR
P.O. Box 47
6700 AA Wageningen
The Netherlands
T +31 317 48 6540
info@klimaatvoorruimte.nl

www.climatechangesspatialplanning.nl