DELTAS IN TIMES OF CLIMATE CHANGE II

OPPORTUNITIES FOR PEOPLE, SCIENCE, CITIES AND BUSINESS

INTERNATIONAL CONFERENCE

ROTTERDAM, THE NETHERLANDS 24 – 26 SEPTEMBER 2014

ABSTRACTS

Scientific Programme
Deltas in Depth

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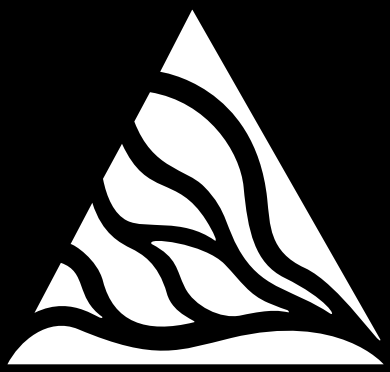


Deltas in Depth

Science has been fundamental to understanding climate change and the broad range of its direct and indirect impacts; we now understand better the vulnerability of cities and rural areas, how people's lives are being affected and how they are responding. Scientific research can contribute to innovations in technology, governance and ways of doing things so that communities, organisations and regions can better adapt to climate change.

Globally, researchers and practitioners are at work trying to solve the problems posed by climate change. Increasingly, this research and the learning and application of new knowledge is being done in partnership with practitioners and decision-makers. The co-production of knowledge leads to new questions being asked that are more relevant to societal stakeholders. It also means that new knowledge and tools are being applied more quickly and effectively. And this, in turn, should lead to new questions feeding research agendas.

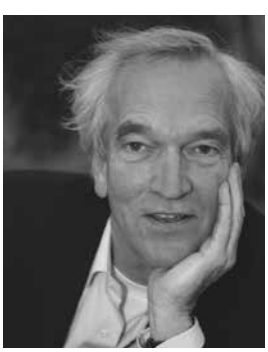
Over the last five years delta regions have become a focus for climate impacts, vulnerability and adaptation research and of greater policy attention. Deltas are hubs for economic activities, attracting many people with their highly productive ecological and agricultural systems and because they serve as the link between hinterlands and the oceans. Climate change affects the security and welfare of people in deltas and requires responses from societies. Indeed, with evidence of deepening vulnerability and accelerating climate change, we may expect cascading 'adaptation emergencies' in future. We need to learn quickly how to cope with these while ensuring sustainable development.

The first conference 'Deltas in Times of Climate Change' was held in Rotterdam in 2010. The focus was then on impacts and adaptation strategies. Four years further and with many more results from adaptation research, this second conference will zoom in on scientific research and practical experiences relating to the implementation of adaptation strategies, often achieved through new partnerships between science and practice. One of the goals of the conference is to exchange the results of this research and experience, and to make them available more widely.

At the conference 56 scientific sessions covering eleven themes will be held. The sessions will be of interest to scientists, policy makers and practitioners. In November 2013 we sent out a call for papers. This resulted in the submission of 400 abstracts. The conference's 44 convenors assessed the abstracts and proposed a programme, which the conference's Scientific Committee approved. In total almost 350 abstracts were selected for oral and poster presentations. In this book you will find the abstracts of the oral and poster presentations per theme. We look forward to meeting you at this conference and hope you have a useful and inspiring time in Rotterdam.

Frans Berkhout, Chairman Scientific Committee
Pier Vellinga, Chairman Steering Committee

Frans Berkhout



Pier Vellinga

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Deltas in Depth Theme 1:

Climate projections and extremes

DD 1.1-1

KNMI'14: NEW CLIMATE CHANGE SCENARIOS FOR THE NETHERLANDS

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Research questions
A previous set of climate change scenarios released in 2006 (KNMI'06) has been used in many assessments of the impact of regional climate change in the Netherlands and surrounding on various sectors in the Netherlands. It is used as reference in operational water management design, ecological surveys, energy consumption and more. The experience with KNMI'06 triggered new requirements, the UN climate panel IPCC has produced a new report, and scientific progress has changed the knowledge that is relevant for assessing regional climate change and variability. Therefore, a new generation of scenarios is released in May 2014 (KNMI'14).

Research methodology
We explore a large Global Climate Model ensemble (CMIP5) in terms of regional climate change. 4 scenarios are defined that span the range of global model output. Extensive use of in-house modelling global and regional climate modelling tools and (international) collaboration in research programs have allowed a further extension expressed the types of variables included, the spatial detail, the role of natural variability at various time scales, and the ability to generate synoptic "future weather"images that are consistent with the scenarios.

Results
Compared to our previous scenarios, the general picture still holds: winters get wetter, extreme precipitation increases both in summer and winter, cold extremes become milder while warm extremes intensify, wind patterns show small changes compared to natural variability, and sea level continues to rise. Major changes are the envelope of sea level rise projections (upper limit increased near the end of the 21st century), reduced severity of summer droughts (although extremely dry summer are still possible in the new scenarios), and addition of a set of projections for 2030.

Importance for stakeholders
Many stakeholders were consulted for the design of KNMI'14. For some sectors and applications the new scenarios may change the perspective on climate change as depicted by the scenarios. But the increased spatial and temporal detail, additional variables and new information on natural variability will sharpen this perspective relative to the previous generation.

DD 1.1-3

FUTURE CHANGES IN EXTREME TEMPERATURE EVENTS USING STATISTICAL DOWNSCALING MODEL IN THE JHELUM BASIN, PAKISTAN

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In the 21st century, climate change is considered to be one of the greatest environmental threats to the world, and changes in extreme events have more negative impact on human society and natural environment than mean changes in climate. This study presents projections of future changes in extreme temperature events under A2 and B2 scenarios using a statistical downscaling model (SDSM) over the Jhelum basin in Pakistan. Bias correction is also applied to the downscaled daily maximum and minimum temperatures before calculating 8 intensity and 4 frequency indices, in order to get as close as possible to realistic results. The validation (1991-2000) shows great reliability of SDSM in obtaining future changes for the periods of 2011-2040, 2041-2070, and 2071-2099, relative to 1961-1990. Increasing mean annual and seasonal changes, in intensity indices, range between 0.48-4.27°C (B2) and 0.76-4.93°C (A2) in the 2080s. In frequency indices, the increasing changes in hot days and nights lie between 37-118 (B2) and 150-165 days (A2), and decreasing changes between 291-375 (B2) and 354-442 days (A2) in cold and frost days in the 2080s.
All intensity and frequency extreme indices reveal more warming towards the end of this century in the Jhelum basin. The changes in the highest and lowest night time temperatures are simulated as higher than the highest and lowest day time temperatures. In contrast, the changes in high night time temperatures (hot nights) are lower than high day time temperature (hot days). Two frequency indicators (hot days and nights) and other two (cold days and nights) show increasing and decreasing trends, respectively, towards the end of this century. It is also clearly observed that the high emission scenario (A2) presents higher magnitudes of future changes than the low emission scenario (B2). This warming trend in extreme temperatures can reduce agricultural produce directly due to increase in day time temperature, changes in snow cover due to increasing changes in the lowest temperatures, and this trend can also cause early snowfall and rapid glacier melting.

DD 1.1-4

THE KNMI'14 CLIMATE CHANGE SCENARIOS: THE WIND CHAPTER

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The low-lying Netherlands are vulnerable to storm surges. Therefore, it is of paramount importance for the safety of the Netherlands to assess potential changes of the storm climate on the North Sea induced by climate change. To do so we analyze two types of climate model output. The first type is ouput from the CMIP5 models under rcp4.5 and rcp8.5 forcings. The second is from a set of runs with the regional climate model RACMO that form the basis of the wind part of the KNMI'14 climate change scenarios. The RACMO runs where resampled to obtain weather situations that are consistent with pre-specified circulation regime changes. The results from both analyses agree in their main findings: projected changes in the North Sea wind climate, especially wind strength, are small with respect to natural variability. None of the CMIP5 models exhibits significant changes over the North Sea under global warming, and the spread between models is large. The RACMO runs confirm these results. If potential changes in atmospheric

circulation patterns are taken into account, small changes in the wind direction distributions are visible. However, none of the scenarios exhibits an increase of the -for the Netherlands- most dangerous wind direction (North).

DD 1.2-0 UNDERSTANDING AND PROJECTING SEA LEVEL CHANGE

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The rate of global mean sea level rise (GMSLR) has increased during the last two centuries, from a rate of order tenths of mm yr-1 during the late Holocene, to about 1.7 mm yr-1 since 1901. Ocean thermal expansion and glacier melting were the dominant contributors to 20th century GMSLR, with relatively small contributions from the Greenland and Antarctic ice sheets. Process-based models suggest that the larger rate of rise since 1990 results from increasedradiative forcing (both natural and anthropogenic) and increased ice-sheet outflow, induced by warming of the immediately adjacent ocean. Confidence in projections of global mean sea level rise has increased since the AR4 because of improved physical process-based understanding of observed sea level change, especially in recent decades, and the inclusion of future rapid ice-sheet dynamical changes, for which a quantitative assessment could not be made on the basis of scientific knowledge available at the time of the AR4. By 2100, the rate of GMSLR for a scenario ofhigh emissions (RCP8.5) could approach the average rates that occurred during the last deglaciation, whereas for a strong mitigation emissions scenario (RCP2.6), it would remain at rates similar to those of the 21st century. In either case, GMSLR will continue for many subsequent centuries. Although there has been much recent progress, projections of ice-sheet change are still uncertain, especially beyond 2100. Future sea level change will not be globally uniform, but models still exhibit substantial disagreement in projections of ice mass loss and ocean dynamics, which are the main influences on the pattern. It is very likely there will be a significant increase in sea level extremes, primarily the result of increases in mean sea level. However there is low confidence in region-specific projections of storminess and associated storm surges.

DD 1.2-1 A GEOLOGICAL PERSPECTIVE ON POTENTIAL FUTURE SEA-LEVEL RISE

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During ice-age cycles, continental ice volume kept pace with slow, multi-millennial scale, changes in climate forcing. Today, rapid greenhouse gas (GHG) increases have outpaced ice-volume responses, likely committing us to more than 9 m of long-term sea-level rise (SLR). We portray a context of naturally precedented SLR from geological evidence, for comparison with historical observations and future projections. This context supports SLR of up to 0.9 (1.8) m by 2100 and 2.7 (5.0) m by 2200, relative to 2000, at 68% (95%) probability. Historical SLR observations and glaciological assessments track the upper 68% limit. Hence, modern change is rapid by past interglacial standards but within the range of 'normal' processes. The upper 95% limit offers a useful low probability/high risk value. Exceedance would require conditions without natural interglacial precedents, such as catastrophic ice-sheet collapse, or activation of major East Antarctic mass loss at sustained CO_2 levels above 1000 ppmv.

DD 1.2-2 THE KNMI'14 SCENARIOS FOR SEA-LEVEL RISE ALONG THE NORTH SEA

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Research question

Global mean sea level is expected to keep rising during the 21st century and beyond, due to ocean expansion, the melting of land ice and other processes related to global warming and climate change (IPCC-AR5). Because of the immediate societal relevance and the fact that the pattern of sea-level rise is spatially non uniform, it is highly important to examine the impact of the sea-level rise at regional scales. Here we present a set of temperature-dependent sea-level scenarios for the North Sea coast. These scenarios are part of a larger set of climate scenarios (KNMI'14) for a range of atmospheric climate variables, and are intended to provide consistent and plausible images of the future climate of the Netherlands.

Methodology

Many processes contribute to sea-level rise. Primary contributors to present-day sea level change are the expansion of the ocean due to warming and the reduction of the amount of water stored on land, mostly in the form of ice and snow. These processes are taken into account in the scenarios. Main data source is the output from 42 Atmosphere-Ocean general circulation models that contributed to CMIP5. Based on these data, different scenarios are construction by stratifying the results along global temperature change (dTglob). Two distinct time paths are chosen for dTglob, corresponding to a moderately warming scenario and a warm scenario. Results are represented as likely ranges.

Results

Results are compared to IPCC-AR5 and the previous KNMI'06 scenarios. The results are broadly consistent with KNMI'06, but differ in the details of the different contributions. For example, science has advanced to that stage that presently spatially non-uniform 'fingerprints' of all major land-ice contributions to sea-level rise can be generated, to examine the regional consequences of the melting of the Greenland and Antarctic Ice Sheet. This has led to lower projected contributions from the Greenland Ice Sheet, but larger contributions from Antarctica. The latter remains a component accompanied with large uncertainty, due to the uncertain response of the West Antarctic Ice Sheet to a warming world.

Societal relevance

The consequences of sea-level rise will pervade through almost the entire society of the Netherlands. It therefore needs little discussion to emphasize the importance of having available a set of state-of-the-art sea-level scenarios. Being based on the same data as IPCC-AR5, the KNMI'14 sea-level scenarios are expected to be useful for companies and governments preparing for the consequences of sea-level rise.

DD 1.2-3 PREPARING FOR SEA LEVEL RISE IN NEW YORK CITY

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Research question
Following Hurricane Sandy (October 2012), New York City launched a Special Initiative on Rebuilding and Resilience (SIRR), a plan with over 250 initiatives to protect against current and future climate hazards. In support of this work, the New York City Panel on Climate Change (NPCC) provided updated sea level rise projections using a cutting edge six -component methodology.

Methodology
The probabilistic approach combines Coupled Model Intercomparison Project 5 (CMIP5) ocean change outputs from global thermal expansion and local ocean mass density changes, ice mass loss (glaciers and ice sheets), with additional components including the gravitational/rotation/isostatic fingerprint of ice loss, changes in anthropogenic global land water storage, and local land subsidence in order to provide local sea level rise projections for decision-making. The projections simulate future sea level for three time slices, using two representative concentration pathways and 24 GCM models.

Research results
The results indicate that sea levels in the NYC region could exceed the global average, with the 10th and 90th percentiles respectively rising from between 20 and 76 cm in the 2050s to between 33 and 147 cm in the 2080s. In the absence of any change in storm characteristics, rising sea levels alone would dramatically increase the frequency and intensity of coastal flooding.

Societal importance for stakeholders
The range of potential outcomes helps planners to make decisions on different types of climate change adaptation, including infrastructure, taking into account adaptation lifetime and estimates of uncertainty. With the updated climate risk information, the City is preparing for the future, working to protect coastal populations and critical infrastructure.

DD 1.2-4 NATURAL HAZARDS AND MIGRATION IN THE COASTAL REGION OF BANGLADESH

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Recent population census of Bangladesh shows that in March 15, 2011 total population of Bangladesh is about 153 million with an average population growth rate of 1.34%. In contrary to this figure, some of the coastal districts of the South West region, namely Khulna, Bagerhat, Barisal and Jhalokathi show an average population growth rate of -0.25%, -0.47%, -0.13% and -0.17% respectively. In all of these districts, population growth rates were positive for the period from 1974-2001. The objective of this paper is to find the reason of this negative population growth for these specific coastal districts.

Preliminary field investigation shows that migration is the basic cause of this negative population growth. In order to find the reasons of this migration, patterns of natural hazards and socio-economic responses due to these are analyzed. It is found that the most noticeable natural hazard in this region during the period 2001-2011 (for which negative population growths were found) were two cyclones, namely Sidr (year 2007) and Aila (year 2009). Apart from cyclone and storm surge, this region also suffers from water and soil salinization, river erosion and drainage congestion. The cyclones like Sidr and Aila caused a long term environmental damage, for example - drainage congestion, soil and water salinization and disruption of overall hydro-morphological equilibrium (morphological shock). These natural hostilities make people of this region feel insecure and ultimately they decide to migrate. In most of the areas, the middle class people can't take relief like poor people and have no alternative but to migrate. The proximity and good communication of safer places (like Chittagong or even India) in terms of availability of job and free from frequent natural hazards make this migration inevitable.
If the incidents mentioned above are projected linearly considering the climate change effects, it is obvious that climate change will trigger frequent happenings of these kinds of natural hazards. People will feel insecure and intra-country and inter-country migration will happen as an irreversible consequence.

DD 1.3-1

CLIMATE CHANGE IMPACTS ON TROPICAL CYCLONES AND EXTREME SEA LEVELS - EXAMPLES FOR FIJI AND SAMOA

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More frequent and severe inundation events associated with climate-change related sea level rise is often cited as the biggest single threat to coastal communities. Assessing this threat requires a baseline understanding of local extreme sea levels and their drivers, including astronomical tides, low frequency (annual and interannual) sea level variability, and higher-frequency phenomena such as storm surges. Knowledge about which of these components dominate and how the latter two may change with a changing climate will be important for successful adaptation and mitigation strategies to rising sea levels. Efforts are currently underway to improve the understanding of how the short-term signal can influence extreme sea levels through high spatial resolution numerical modeling projects. Ultimately, these projects will lead to improved overall understanding and therefore prediction of sea-level variability and inundation events under projected climate change scenarios for Pacific and Indian Ocean island nations. In this study we combine stochastic cyclone modelling with hydrodynamic modelling to build a more complete picture of extreme sea level hazard along the coastlines of Fiji and Samoa. We then use this approach to investigate how future projected changes to ENSO, tropical cyclones and sea level rise may influence coastal stormtide risk around this coastline. It is anticipated that such studies can provide guidance on the relative importance on storm tide risk of factors such as ENSO variability, sea level rise and tropical cyclone intensity and frequency change, which may assist in the prioritisation of their consideration in impact studies given the large uncertainties around projected changes to these influences in coming decades. An example of how this information can be downscaled to include the effects of nearshore wave breaking in Apia, Samoa will also be given.

DD 1.3-2

DYNAMICS OF EXTRA-TROPICAL TRANSITION OF TROPICAL CYCLONES HITTING WESTERN EUROPE IN A WARMER CLIMATE

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Recent simulations with a high resolution version of the global climate model Ec-Earth has revealed the possibility of tropical cyclones hitting Western Europe in a warmer climate. Some of these tropical-cyclones undergo extra-tropical transistion and re-inforce to hurricane strength when they approach Western Europe (Haarsma et al. 2013). Here we discuss the mechanism responsible for this transistion and reintensification. In particular the role of latent heat release and baroclinic instability will be discussed. The connection of latent heat release with atmospheric rivers will be analysed. In addition the occurence of extreme weather, such as heavy precipitation and wind gusts, in these storms will be analyzed. They are a potential risk for the eco-systems and society. An additional risk for the agricultural sector is that these storms will occur during the harvest season in autumn.
Haarsma, R.J., W. Hazeleger, C. Severijns, H. de Vries, A. Sterl, R. Bintanja, G.J. van Oldenborgh and H.W. van den Brink, *More hurricanes to hit Western Europe due to global warming.* Geophys. Res. Lett., 2013, doi:10.1002/grl.50360.

DD 1.3-3

HIGH RESOLUTION MODELLING IMPROVES THE SIMULATION OF EXTREME WINDS IN THE COASTAL ZONE

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The land surface of the Netherlands is situated below sea level for 40% of its area, and adequate protection against high water is crucially important for safety and [economic] well-being. More specifically, water defences in the Netherlands must offer protection against water levels and wave conditions at normative conditions, known as Hydraulic Boundary Conditions (HBCs). To obtain reliable HBCs, accurate wind fields are required. Here we report on a program to improve on existing methodologies to calculate extreme wind fields by making use of the high resolution prediction model HARMONIE.
Specifically, we ask the question: Can HARMONIE improve on more traditional operative modes of calculating wind fields such as provided by reanalysis techniques?

Since 2012 HARMONIE has been used by KNMI for high resolution weather forecasting. It runs at a resolution of 2.5 km grid size. An explicit comparison is done between HARMONIE and the much lower resolution ERA-Interim dataset obtained from the European Centre for Medium-Range Weather Forecasting (ECMWF). We make an assessment not only of regions that benefit most from the increased resolution, but we also assess the added value of the high-resolution model for the prediction of storm surges along the coast.
Largest improvement from using the HR model is reached in coastal areas and for large inland water bodies like LakeIJssel. In these areas, wind and surface stress values of ERA-Interim become less accurate due to the coarse resolution. Smaller water bodies (FrisianLakes, rivers) are too small to be explicitly resolved by HARMONIE. Far from

the coast, the benefit of the HR model is smaller than in the coastal zone. However, especially for high wind speeds [> 10m/s], it is still noticeable.
On inland water bodies such as Lake Ijssel HARMONIE is able to represent the impact of atmospheric stability and of land-sea transitions on the wind patterns realistically. This illustrates that the benefit of the high resolution implies more than adding a refined land-sea mask.
Storm surge calculations with the WAQUA model are closer to the observed water levels when using HARMONIE than when using ERA-Interim as input for wind fields. The direct effect of resolution difference between HARMONIE and ERA-Interim explains only a small part of the difference in surge prediction. Apparently, the effect is indirect: the better land-sea representation of HARMONIE results in higher winds along the coast, even if the results are represented on the same coarse resolution as ERA-Interim.

DD 1.3-4

RESPONSE OF HOURLY PRECIPITATION EXTREMES TO CLIMATE PERTURBATIONS: RESULTS FROM A MESOSCALE MODEL

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Research question
Observations of extreme (sub-)hourly precipitation at mid-latitudes show a large dependency on the dew point temperature often close to 14% per degree, which is 2 times larger than expected based on the increase in moisture content of the atmosphere. In literature, it is argued that this behavior is linked to the response of convective precipitation to moisture increases.

Methodology
This hypothesis is investigated in the non-hydrostatic weather prediction model Harmonie by simulating a selection of 11 cases over the Netherlands characterized by intense convective showers . First, for each case a reference simulation representing present-day climate conditions is performed. Then, these experiments are repeated using perturbations of the atmospheric profiles of temperature and humidity: (i) using an idealized approach with a 2 degrees warmer (colder) atmosphere assuming constant relative humidity, and (ii) using changes in temperature and humidity derived from a long climate change simulation.

Research results
On average, an increase of extreme hourly precipitation of 11% per degree for the idealized perturbation, and 9% per degree for the climate change perturbation is found. For the most extreme events these dependencies appear to approach a rate of 11-14% per degree, in closer agreement with the observed relation.

Societal importance
Short duration precipitation extremes have a large impact on society, for instance on urban flood risks. Unfortunately, present-day climate models are not well suited in this respect as they use simplified prescriptions of atmospheric convection, and related precipitation extremes. Here, we provide supporting evidence from a mesoscale atmospheric model that precipitation intensity could well increase considerably faster than suggested by climate model simulations.

DD 1.3-5

RESOLUTION DEPENDENCE OF EUROPEAN PRECIPITATION IN A STATE-OF-THE-ART ATMOSPHERIC GENERAL CIRCULATION MODEL

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Long climate model simulations have necessarily been run at coarse spatial resolutions. Downscaling techniques are typically applied to general circulation models (GCMs) to obtain details at a finer resolution. Dynamical downscaling is done by embedding a high resolution regional climate model within a coarse resolution global model, allowing for a better representation of orographic and coastal effects, as well as more resolved model physics. Large scale synoptic systems are still largely dependent on the driving GCM.In this study, we use two sets of 5-year 6-member ensemble simulations of a state-of-the-art atmosphere only GCM (AGCM, EC-Earth) to investigate the effect of GCM spatial resolution on modeled precipitation over Europe. The objectives of the analysis are to determine whether climate models have sufficient spatial resolution to have an accurate representation of synoptic systems affecting precipitation. We investigate if there is a significant statistical difference in modeled precipitation between a medium resolution (~112km horizontal resolution) and a high resolution (~25km horizontal resolution) model of a state-of-the-art AGCM, if either of ensembles gives a better representation of precipitation in the current climate, and what processes are responsible for the differences in modeled precipitation.We find that the high resolution ensemble gives a more accurate representation of European winter precipitation than the medium-resolution ensemble, both in the mean-state and in the extremes. The medium resolution ensemble has more precipitation in most of the northern half of Europe and less precipitation in the southern half. Our results suggest that synoptic systems are better simulated in high resolution GCMs, providing for a more accurate horizontal moisture transport and moisture convergence. High resolution regional climate models may have a too small spatial domain to capture this effect. Our findings may be valid for other GCMs as well, showing the necessity to analyze other GCMs that may become available in the future with such high horizontal resolutions.

DD 1.4-1

CLIMATE MODELLING - THE NEEDS AND REALITIES OF CITIES

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While global and region climate models provide information on the future averages of meteorological parameters, they do not provide sufficient detail to adequately understand the probability of increased frequency, magnitude or duration of extreme events like heat waves, droughts or intense summer storms on local municipal infrastructure. Neither does the information detailing the expected constancy of precipitation in the years ahead, help municipalities to understand the reduction in snowfall (a benefit to snow clearing budgets) or the increased likelihood of severe summer storms (a very large dis-benefit to city budgets). Municipalities need to have this level of detail so that they have a solid basis for understanding the requirements and options on how to replace aging infrastructure.
This paper examines a global climate model - regional climate model - weather forecast model combination that created future hourly averaged data on a very fine grid (1x1 km) over the Greater Toronto Area for the period 2040-2049. Outputs are compared to a current simulated period (2000-2009) and an assessment made of projected

changes into the future. Comparisons with observed data allow a true picture of the model uncertainties to be calculated along with statements about the level of confidence one can expect.
The power of the approach is displayed by examining a recent severe storm in detail showing a significantly better comparison with measured data than other approaches. The future statistics show, among other things, an almost 3-fold increase in the amount of water in the 1 in100-year storm and significant variability in many weather parameters across the municipality.
Finally the paper presents a summary of expected impacts on issues that are important to municipalities and how this type of data can be used to inform future municipal infrastructure decisions on a riding-by-riding basis.

DD 1.4-2 SATELLITE RAINFALL RETRIEVAL OVER COASTAL ZONES

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Background
Accurate estimation of precipitation over deltaic regions is important for climate studies, flood prediction, sediment and nutrient transport, flood inundation mapping, and hazard control. Since observations from rain gauges and ground radars in these regions are lacking or are very sparse, satellites offer the only reliable source of information. Yet, while the accuracy of spaceborne microwave precipitation retrieval over oceans from microwave satellites, such as the TRMM (Tropical Rainfall Measuring Mission), has considerably improved over the past decades, accurate precipitation retrieval over coastal regions remains a challenge mainly due to the interference of land-ocean background radiations.

Research question
In view of the GPM (Global Precipitation Measuring Mission), a constellation of satellites launched in February 2014, there is a great potential to improve the accuracy and space-time resolution of precipitation retrievals over land and complex topography, including land-water interfaces. This will require the development of new methodologies.

Research results
A new precipitation retrieval algorithm has been developed that offers demonstrated advantages in improving rainfall retrieval over coastal zones and especially in estimating extreme storms at high spatial resolutions. The developed methodology relies on a sequence of detection-estimation steps: the detection step makes use of a simple k-nearest neighborhood classification rule, while the estimation step relies on the modern developments in manifold learning and regularized estimation paradigms. The algorithm makes use of two joint dictionaries, the spectral and rainfall dictionaries, containing elements or atoms of spectral responses of different rainfall profiles. We demonstrate the improved accuracy of the retrieved precipitation over the Ganges, Mekong, and Amazon deltas for several extreme storms as compared to the current NASA products (2A-12).

Societal importance for stakeholders
Having accurate estimates of precipitation over coastal regions will improve our ability to understand the socio-ecological response of these vulnerable systems to extremes, make more accurate climate projections, and improve flood forecasting and risk management practices. This work is part of a global project on ‘Catalyzing action towards

sustainability of deltaic systems (DELTAS)' funded by the Belmont Forum and contributing to the forthcoming 2015 'Sustainable Deltas Initiative' endorsed by ICSU. The work will complement other contributions from the DELTAS consortium that have been submitted for the Deltas in Depth sessions and the Deltas in Practice Workshops.

DD 1.4-3 ASSESSING THE RATE OF SUBSIDENCE IN THE BENGAL DELTA

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High rate of Relative Sea Level Rise (RSLR) is a common phenomenon in the deltas, due to compaction of deltaic deposits, tectonics and isostasy. During the last couple of years, several researches and studies have been carried out, for assessing the RSLR of the Bengal Delta. According to those researches the rate of RSLR in this delta varies from 10 to 25 mmy-1 where subsidence is the main contributor. The results coming out from those researches indicate a frightening future of the Bengal Delta, which may have pronounced implications on the local people, decision makers and developing partners to invest for any types of development or adaptive works against climate change. This article presents the findings of the research which has assessed the rate of subsidence of this delta through adapting different approaches. We tried to check the historical changes in landform or river courses during the last 250 years to assess the existence of any high rate of local or regional scale of subsidence. We analyzed the ground water level changes in the tidal plains due to extraction and assessed the contribution of it in subsidence. We also analyzed the tidal water level data for assessing decade scale rate of subsidence and the carbon dating data from secondary sources to assess the subsidence in millennium scale. We developed a methodology for assessing subsidence in century-scale using archeological monuments in the tidal plains.
Digital Elevation Model based on surveys in 1950s and tidal gauge data were used to relate the average level of tidal plains with the tidal variations, when tidal movement was free to enter into the tidal plains. Moreover, relation between the level of tidal plains, homestead platforms and plinths are established using the spot level surveys data. Archaeological monuments in the tidal plains, other than active delta area, were used for assessing the subsidence. Based on the analyses, it appears that the rate of subsidence in a particular location can fairly be estimated from the difference in levels between plinth of the monuments and recently constructed structures dividing the age of the archaeological monument.
We did not find any significant amount of ground water mining in the tidal plains, different analyses show that the rate of subsidence in different time-scale vary from 1 to 3 mmy-1, which is far below the recently published rate of subsidence in the Bangladesh tidal plains.

Deltas in Depth Theme 2:

Flood risk management

DD 2.1-1 SOCIAL DISRUPTION BY FLOODING, A EUROPEAN PERSPECTIVE

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Research question and importance for stakeholders

One of the aims of Dutch flood risk management policy is to avoid social disruption by flooding. The definition of social disruption, however, is yet unclear. When is a society disrupted, and what factors shape the extent of the disruption? These questions need to be answered when making this policy aim operational and thus being able to steer on avoiding social disruption. The impacts of major floods in Europe over the last 10 years have been studied aimed at learning about the causal factors that shape social disruption.

Methodology

A lot of research has been carried on physical and social factors that play a role in the extent of social disruption by disasters. In the Netherlands, these scientific results have been integrated into the Dutch National Risk Assessment, where the possible impacts of all kinds of threats and disasters that might strike the Netherlands are quantified as a combined effect of these physical and social factors. One of these disasters is a (major) flood; the estimated impact may be interpreted as a measure for the social disruption by flooding. The methodology of the Dutch National Risk Assessment has been applied to 6 major floods in Europe, where the input for the assessment was derived from the scientific literature, technical reports and articles in newspapers and other media.

Research results

Five impact levels are discriminated for the scores of the assessment methodology: modest, substantial, serious, very serious and catastrophic. The scores for five out of six European floods are ‘very serious’. To a large extent, this high score results from the size of the flooded area, and social factors such as loss of trust in authorities, no flood risk awareness and lack of options to act. Remarkably, the same score was estimated for a major river flood in the Netherlands (a major coastal flood is considered catastrophic). This Dutch river flood scenario is considered highly unlikely. On a European scale, however, major floods that are potentially socially disruptive are events that happen every now and then. Options to restrict social disruption include adequate risk and crisis communication: raising flood risk awareness, being clear on what may be expected from authorities during a flood, and timely communicating correct and clear flood warnings.

DD 2.1-2

HOW TO AVOID SOCIAL DISRUPTION. OPTIONS FOR THE DUTCH FLOOD RISK MANAGEMENT POLICY TO REDUCE THE SOCIETAL RISK

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In the 2014 outlines of the Dutch Delta Programme, three main objectives were announced as the basis of the future flood risk management policy: a tolerable individual risk for everyone behind the dyke (Note that the Netherlands has 52 dike ring areas which are protected against flooding from see, rivers and large lakes), protection of the most vital infrastructure and finally the avoiding of social disruption as a consequence of flooding. This last objective raises two questions: what is social disruption and how can the goal of avoiding social disruption be achieved by flood risk management in a most efficient way.
The concept of social disruption is defined in many different ways, yet the common denominator is that it contains both physical elements like economic damage, number of casualties and size of the flooded area as well as social psychological elements which concern the disruption of everyday life and feelings of fear and dissatisfaction. Though social disruption comprises many factors, the amount of casualties is a key, if not the most important one. Yet the contemporary policy, as well as the contemplated revised policy, does not steer directly on the potential number of casualties nor are goals formulated with respect to societal risk (in the case of flooding this concerns the societal risk for the Netherlands in its entirety). This paper discusses possible ways to set targets for the societal risk and analyses options to meet these targets. Large numbers of casualties are mainly caused by two factors: one is taken by surprise either because storm surges are much more severe than expected or levees breach way before the water level reaches the crest of the levee or the authorities and citizens make the wrong decisions with respect to evacuation.
It is shown that the use of levees with different criteria for the allowed probability of failure (with a relatively limited probability of failure for a limited part of the flood defense system compared to other levees in the same system) or the shift to a more adaptive evacuation planning strategy, where, depending on the time left before the flood arrives, a choice is made between leaving the endangered area or seeking a shelter locally is most promising to meet possible targets set to the societal risk. A spatial analysis shows that a large city like Utrecht offers many opportunities to shelter locally.

DD 2.1-3

IS CALCULATION OF CASUALTIES FROM FLOODING IN GERMANY DESIRABLE: METHODS AND CASE STUDIES

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Increased population pressure and climate change are expected to cause higher flood risks not only in coastal areas. Several methods were developed to estimate the flood related tangible and intangible losses in the past. Combined with the probability of flooding, the overall risk can be quantified. Germany experiences flood risk from different sources: storm surges, river floods and cloudbursts. Thus, different methods have been applied in Germany to

determine intangible losses. In the presentation we will focus on the differences between approaches from different countries in calculating intangible flood risks focusing on the number of casualties and the local individual risk to be victim of flooding and the transferability of such approaches to other study areas/ nations.
In particular, two different methods are being compared to find similarities and differences between methods for determining intangible losses (casualties): The insights from the joint research project "XtremRisk"(Extreme storm surges at open coasts and estuarine areas: Risk assessment and mitigation under climate change aspects) are compared to the methods from the Netherlands as developed in the research project "Waterveiligheid 21e eeuw, WV21"(Flood risk in the 21st century) project and applied in the Hueller Bach area (in the catchment of the Emscher, Germany). The aim of the latter project was complete the flood risk management strategy of the Emschergenossenschaft in which climate change aspects are also taken into account.
Both methods have been practically implemented in different studies in Germany leading to a set of case studies that vary in risk source and the vulnerability characteristics of the area. Both methods are based on spatial information on flood depth and the likelihood of flooding. Differences mainly occur due to the mortality equations.
The case studies will show that it is possible to quantify intangible flood risk and will allow the discussion if a) more information is desirable and b) what the results can be used for, as this information is often very sensitive and could lead to an immediate request for flood risk reduction measures. The implications of such research will be presented and critically discussed at the "Deltas in Climate Change"conference by researchers and stakeholders/clients.

DD 2.1-4

SOCIETAL FLOOD FATALITY RISK ASSESSMENTS: AN ADVANCED METHOD AND ITS APPLICATION TO THE RHINE-MEUSE DELTA

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In the Netherlands the possibility of societal disruption by floods plays an important role in the discussion on future flood risk management strategies. One of the indicators to assess societal disruption is societal flood fatality risk. Societal flood fatality risk is related to the probability of many fatalities during a single event. In deltas protected by flood defences, such as the Netherlands, impacts of extreme events depend on the location and number of failures in the flood defences. The number and location of breaches depend on the failure probabilities of the embankments and the flow of river water through the breaches into the flood-prone areas. These flows reduce the river water levels and discharges and thus the probabilities of failures downstream. This retention effect proves to be very relevant.
The assessment of flood risks in deltas protected by defences, accounting for the above described retention effect, requires an advanced method which enables (1) the joint analysis of both storm surges and river discharges (2) the incorporation of hydrodynamic interaction of loads and breaches at different locations to include the retention effect and (3) a complete and dynamic analysis of flood probabilities, breach growth, flood patterns, and flood consequences.
A new method has been developed which meets these requirements. The method results in FN curves which provide the probability of events with N or more fatalities. Results further include the potential loss of life (expected annual number of fatalities) and the contribution of the subareas to the total societal flood risk. The method also gives insight in which flood scenarios contribute most to societal disruption. To support the decisions on flood risk management strategies, the outcomes were compared with various views on potential tolerable risk levels from different countries and scientific fields.The paper discusses the method, its application to the Rhine-Meuse delta and the use of the outcomes in the discussion on future flood risk management strategies.

DD 2.1-5

FLOOD HAZARD MAPPING: ON THE PURPOSEFUL COMBINATION OF INDIVIDUAL FLOOD CHARACTERISTICS IN BEHALF OF HAZARD ZONING

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Increasing vulnerability to flooding ranks among the most important factors that explain why the damage of flood disasters is steadily increasing worldwide. This implies that sound spatial planning and related building codes may be considered as measures to reduce flood risk, or at least to prevent that society's vulnerability increases further. The planning of such consequence-reducing measures requires access to accurate and comprehensive maps of flood hazard.

To date, society and economy in the Netherlands are organized in such a way that no restrictions apply on settlement or development in flood-prone areas, with the exception of active river floodplain. Inspired by the UK's PPS25, the Netherlands' Delta Programme on Urban Development and Re-development investigated whether a framework for spatial planning could be drafted in view of future flood hazard developments. The first key question was: how to distinguish a small number of hazard zones as basis for a practical policy framework, given the wealth of data on individual relevant flood characteristics that have recently been mapped to comply with the EU Floods Directive?

We investigated various methods, building on earlier investigations on this issue, and tried many ways of combining the geographical data that have been collected from many different national and regional sources to comply with the requirements of the European 'floods directive'. We established that for fatalities the most distinctive exposure characteristics are time of arrival of the first water and flooding depth. For damage, flooding depth is decisive. And for both, obviously, the probability of flooding is a key factor determining flood hazard too, which cannot be neglected. But it appeared very difficult to establish this probability in a reliable way for embanked areas (the majority of our country), whereas it is also a very difficult concept to communicate to lay-people or even policy makers.

We propose a method to unify all relevant hazard characteristics into two comprehensive maps: one for flood damage hazard (FDH) and one for flood fatality hazard (FFH). Our method allows adding up all flood types (pluvial, regional runoff, and breaching of primary or secondary embankments) and all probabilities (from frequent to very unlikely) by building on quantitative models. Next, we combine the two into one hazard zone map for policy purposes, aimed to call attention to flood hazard as factor to take into account when considering a spatial development and to further guide investigations. This step involved substantial expert judgement.

DD 2.2-1

7 ALFA LESSONS IN RURAL EUROPE: COMBINING FLOOD MANAGEMENT, FARMING AND FORESTRY

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Research question

Creating new capacity for water storage or discharge of peak floods within river catchments helps to decrease the risk of flooding. In the ALFA project, six partners have undertaken measures to create new capacity for water storage and discharge in the U.K., France, Germany, Belgium and the Netherlands. The measures implemented by the six partners occur in predominantly rural areas distributed over the whole catchment: upper, middle and lower part. In this paper we want to present and compare these measures with two basic questions in mind: what type of measure is most adequate in which part of the river basin? And how do you combine areas used for water storage or discharge with other functions and stakeholder interests?

Results

Work in the catchment of the Eden River (UK) is a good example of how to influence the upstream part of the river. With the help of hydraulic modelling, we have identified the areas that are key to influence the timing of the peak flows. There, land management is being adapted for example to improve infiltration. In the middle part of the river we use retention areas for peak-shaving. The Hördt polder (Ger) is being prepared as such an area. Finally, in the lower part of the catchment we want to discharge the peak flow as quickly and safely as possible by removing obstructions or bottlenecks. The Room for the River programme in The Netherlands has been set up to improve river discharge and more than thirty measures have been identified to increase discharge capacity.

Societal importance for stakeholders

These measurements affect the local communities, their economic activities (farming, agriculture and forestry) and other interests such as ecology. As a result, a close cooperation between flood authorities and the businesses/SME's based in these areas has developed, giving rise to interesting examples of water friendly farming practices in the UK and in the Netherlands (e.g. Deventer and the Overdiepse polder) and to experiments with water friendly forestry in the Hördt.

ALFA stands for Adaptive Land use for Flood Management and is a project subsidized by the EU through the INTERREG IV NWE fund. Rijkswaterstaat Room for the River is lead partner for ALFA.

DD 2.2-2 CREATING SPACE FOR CHANGE: MANAGED REALIGNMENT AND FLOOD RISK REDUCTION IN LOW-LYING COASTAL AREAS

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The ultimate consequence of climate change to society is that we cannot continue living the way we do. The environment around us is changing and adaptation is a necessity rather than an option. The economic, environmental and social sustainability of coastal communities will progressively depend on how efficiently and effectively we can adapt to change and manage increasing flooding and erosion hazards. In many coastal locations, upgrading of hard engineering defences is now constrained by high economic costs, undesired environmental impacts and unacceptable consequences associated with potential failure of existing defences. Managed realignment approaches are increasingly promoted in government strategies worldwide as an alternative able to provide sustainable flood risk management with additional environmental benefits. Managed realignment is a relatively new approach and existing evidence of performance is so far debatable. Can managed realignment provide sustainable flood risk management for low-lying coastal areas? What are the limitations and can these be addressed in a reasonable time frame?
In Europe management realignment is often understood as the creation of intertidal areas by artificially restoring tidal flow into embanked land. Elsewhere managed realignment is synonymous of managed retreat, i.e. relocation of structures and people from high risk areas. Here managed realignment is considered a general term describing a range of methods aiming to create space for coasts to evolve more dynamically, restoring their natural adaptive capacity. The methods of managed realignment include: removal, breach or realignment of coastal defences; controlled tidal restoration; and managed retreat. Therefore, managed realignment experiences are more widespread than first anticipated but preferred methods of implementation vary geographically. Focusing on long-term sustainability of flood risk reduction, different methods of managed realignment will be contrasted using examples implemented in low-lying coasts, including deltas, in Europe and elsewhere.
Most projects are designed taking into consideration flood protection criteria. However, there is little evidence that effects on flood risk are quantified after implementation. Certain characteristics related to the method of implementation and the suitability of sites pose clear challenges for the sustainability of flood risk management at the local level. The most climate-proof alternative to reduce people and property at risk from flooding resides in a multi-layer approach combining managed retreat and other managed realignment methods. Evidence shows that uptake of managed realignment is constrained due to issues related to land availability, public acceptance and stakeholder engagement. Reasons underlying these constraints and ways forward to address them will be discussed.

DD 2.2-3 A COMPENSATION MECHANISM FOR FLOOD PROTECTION SERVICES ON FARMLAND

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A key element in the management of riverine flood risks are reservoirs for the transient storage of flood waters. Such reservoirs would usually be built on farmland and, in case of a serious flood event, used to lower the flood peak. Farmers' willingness to have their lands included in a reservoir critically depends on the compensation they

receive in case the reservoir is flooded. Our paper proposes a new compensation scheme that consists of an annual unconditional payment and a compensation payment in case of flooding.
The aim of the paper is to examine the risk allocation properties of the scheme and to determine the optimal share of the fixed annual fee in the total expected compensation. Next to the specification of the payment scheme a contract offered by the river authorities to farmers must also specify clear rules on the use of the reservoir, such as minimum water levels above which the flood gates may be opened.
We employ contract theory[1] to examine optimal contract design stipulating rational responses by farmers, i.e. farmers will sign the contract and participate in the scheme when it is advantageous to do so. We show how the optimal payment scheme depends on farmers' degree of risk aversion.
We find that the conditional payment in case of flooding will usually not cover the full damage to all types of crops. Hence, cultivating more expensive crops becomes more risky. However, the two-tier payment (annual fee + conditional flood payment) can generate sufficient revenue for farmers to cover all (expected) damages in the long term. Under this system farmers have an incentive to make adjustments to their activities, lowering the damage profile of land use, and the annual fee helps to cover the costs of land use change. The flood payment is assumed to be uniform, each hectare of land being eligible for the same level of payment.
We calibrate our micro-economic model with data from a case study of the Tisza river, Hungary,[2] and suggest a contract design for this case. We also address the issue of contract adjustments over time as the rainfall distribution (in particular the distribution of extreme events) shifts due to climate change.

[1] Bolton&Dewatripont (2005) Contract Theory. MIT Press.
[2] Ungvári&Kis et al. (2013) Floods and Water Logging in the Tisza River Basin (Hungary). Deliverable no.: D 4.2, EU-EPI Water, Grant Agreement no. 265213

DD 2.2-5 SOFT FLOOD RISK MANAGEMENT: IMPACT IN DELTA'S AROUND THE WORLD

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Research question
This article compares the current flood risk management practices in four populous deltas across the world: Rhine/Meuse/Scheldt delta (The Netherlands), Pearl River Delta (China), Red River Delta (Vietnam), and Ganges (Bangladesh) from a sustainability perspective. We make an inventory of the diverse national 'soft' flood management practices and discuss their potential for Sustainable Flood Risk Management (SFRM).

Research results
These areas share several socio-economic and water management characteristics and vulnerable to coastal and urban flash flood risks. They are densely populated, with coastal megacities arising esp. in East and South Asia, and have great economic value because of international transport facilities and trading. They are mostly located on low-lying plains and experience increasing flood risk from (i) intense precipitation, (ii) cyclonic storm surges, (iii) global

sea level rise and (iv) rapid urbanization in the flood-prone areas. Current risk mitigation strategies for risk mitigation are focussing primarily on 'hard' engineering measures, which still the common practice but normally costly and not resilient under climatic changes.

Societal importance
'Softer' approaches such as flood warning systems, evacuation, land use planning and flood insurance are being investigated and applied in different ways across the world. For example, in The Netherlands, professional networks buzz with discussions about so-called 'multi-layer flood management' in which 'hard' defebces play a role but are not the sole solution. In view of increased costs of 'hard' flood defences, these 'softer' approaches are expected to contribute to achieving sustainable flood risk management (SFRM).

DD 2.3-1 COSTING NATURAL HAZARDS

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Reported costs of natural hazards are at historically high levels, and show an increasing trend. However, these cost assessments do not reflect the complete set of costs of natural hazards. Manny assessments account only for direct costs and even these alone are assumed to be at least 50% higher than is internationally reported. A better understanding of the total costs, comprising damage and risk mitigation costs, is urgently needed to accomplish efficient risk management of natural hazards. A cost-benefit analysis that excludes certain cost categories leads to sub-optimal decisions. Here we show our vision for integrated cost assessment in risk management which is represented by the new cost assessment cycle. The cost assessment cycle involves the continuous monitoring of costs associated with natural hazards risk management, thus enabling the early detection of inefficient risk mitigation strategies. A close link between the cost assessment cycle and the risk management cycle guarantees integrated cost assessment and supports improved decision making for more efficient risk management. Making better, more efficient decisions for natural hazard risk management will gain even more importance in view of global environmental change.

Ref:
Kreibich H, van den Bergh JCJM, Bouwer LM, Bubeck P, Ciavola P, Green C, Hallegatte S, Logar I, Meyer V, Schwarze R, Thieken AH (2014) Costing natural hazards. Nature Climate Change, 4.

DD 2.3-2

ROBUST FLOOD RISK MANAGEMENT AGAINST ACCEPTABLE COST: HOW THE CHOICE OF CRITERIA AFFECTS THE RANKING OF STRATEGIES

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Flood risk management strategies consist of sets of measures along the entire river catchments and the flood-prone area, and may for example combine embankments, retention areas, spatial planning, and disaster management plans. To obtain a preferred strategy, assessment criteria are needed. In many policy studies, the key economic criterion is the ratio between the benefits and cost of a strategy. Other studies try to find the optimal investment strategy by minimizing the sum of cost and (residual) flood risk. We see three challenges with using these economic criteria: 1) they can yield a different ranking of strategies, which makes it difficult to choose, 2) they do not distinguish between low-probability/high-consequence risk and high-probability/low-consequence risk, and 3) they require assumptions on return periods of extreme river discharges, while these are both uncertain and changing into the future due to climate change.

To overcome these problems, robustness analysis can be used. Such an analysis will give insight into the relationship between flood magnitude and flood consequences. This shows how sensitive the system is to varying discharges. A more proportional relationship is believed to represent robust systems that are able to deal with a variety of extreme discharges, including the ones exceeding the protection level. Proportionality is calculated as the maximum change in flood consequences for a given change in flood magnitude. The smaller this value, the more proportional the relationship and the more robust the system. By adding proportionality to the set of economic criteria, the ranking of strategies may become easier.

This presentation shows a flood risk assessment of a variety of strategies for the Meuse River valley in the Netherlands, based on the aforementioned criteria. Strategies include making room for the river, strengthening embankments, and various combinations of these. The results show that the three criteria indeed lead to a different ranking of strategies. The proportionality criterion helps to select a robust strategy that also scores well on the two economic criteria. River systems that are robust for varying discharges are also better prepared for climate change.

DD 2.3-3

ECONOMICAL OPTIMAL WATER SAFETY IN A MULTI-LEVEL SYSTEM: A NEW METHOD APPLIED TO THE IJSSELMEER REGION

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The goal of our research is to develop a new methodology to assess the economical optimal level of flood risk management, given that multiple dikes determine together the safety level of the hinterland. This methodology is applied to the IJsselmeer region. In this region, the Afsluitdijk separates the North Sea from an enclosed lake IJsselmeer. The Houtribdijk separates lake IJsselmeer from lake Markermeer. These two barrier dams (type B flood barriers) alleviate the hydraulic load on the dikes that do protect the hinterland directly (type A flood barriers). Our methodology is also capable of assessing different methods for controlling water levels: discharging (the current approach) or pumping.

Our approach explicitly models the dependencies between the type A and type B flood barriers. Given these dependencies, our methodology is able to determine the optimal safety levels of the type A and type B flood barriers simultaneously. The optimization problem is stated in the form of an Integer Programming model and solved to proven optimality by using an easy to use solution procedure.
Economical optimal safety levels for all type A en type B flood barriers are presented. The optimal safety level of the Houtribdijk is much lower than the current legal standard. For a minority of the type A barriers, a higher safety level seems economically appropriate.
Due to the flexibility of the methodology (called Diqe-Opt), we are also able to perform 'what-if'-analyses in close co-operation which local stakeholders. By using the Diqe-Opt model, we could assess in a cost-benefit analysis that the water levels in the region are better managed by pumping stations. Moreover, the model was able to assess the safety effects of several measures that aim to enlarge the fresh water supply. This resulted in the identification of a fresh water measure that enlarges the water supply in de region by 200% at moderate costs of 25 million euro.
The Ministry of Infrastructure and Environment asked for the new methodology. Legal standards for flood protection are being actualized by the Delta Programme of the Dutch government. The decisions to install pumping stations in the Afsluitdijk and to enlarge the water supply in the region by about 200%, were underpinned and initiated by our analysis. Last but not least, our methodology is easy to implement in other areas of the world where a multi-level system determines overall water safety.

DD 2.3-4 ROBUST MANAGEMENT OF FLOOD RISK UNDER DEEP UNCERTAINTY: AN APPLICATION TO DHAKA CITY

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The socio-economic changes as well as climatic changes have been the main drivers of uncertainty in environmental risk assessment and in particular flood. The level of future uncertainty that researchers face when dealing with problems in a future perspective with focus on climate change is known as Deep Uncertainty, since nobody has already experienced and undergone those changes before and our knowledge is limited to the extent that we have no notion of probabilities, and therefore consolidated risk management approaches have limited potential.
This paper aims at incorporating a set of data mining and sampling tools to assess uncertainty of model outputs for flood risk assessment of Dhaka city under future climatic and socio-economic changes and providing a decision support system for robust decision making. Under deep uncertainty, analysts cannot employ statistics that are derived from observed historical data and therefore, we turn to non-statistical measures such as scenario analysis. We construct several plausible scenarios with each scenario being a full description of what may happen in future and based on a meaningful synthesis of parameters' values with control of their correlations for maintaining internal consistencies.
In this study, flood risk assessment is carried out within a recently developed conceptual framework, KR-FWK (i.e. KULTURisk Framework from the name of the European project within which it originated) for integrated (physical and economical) risk assessment and evaluation of risk prevention benefits on multiple receptors. With reference to the widely adopted conceptual model, risk is considered as the result of combination of hazard, vulnerability and exposure. We consider vulnerability as a result of the interactions between physical (territorial) characteristics and the susceptibility and capacities of the socio-economic system to adapt and cope with hazard considered. After constructing an uncertainty matrix to identify the main sources of uncertainty for flood risk of Dhaka City, we identify several hazard and vulnerability maps based on future climatic and socio-economic scenarios. The vulnerability of

each flood management alternative under different set of scenarios is determined and finally the robustness of each plausible solution considered is defined based on the above assessment.
Compared to traditional assessments, the robust management approach of flood risk used in this study generates more information about the flooding events. Consequently, the results are useful in evaluating policy alternatives and minimizing property loss in the study area.

DD 2.4-1

FLOOD INSURANCE IN ENGLAND- ASSESSMENT OF THE CURRENT AND PROPOSED INSURANCE SCHEMES IN CONTEXT OF RISING FLOOD RISK

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Flooding is the largest natural disaster risk in the UK and it is expected to rise even further as we experience a changing climate and continue putting more people and property in harm's way. Managing this growing flood risk requires a broad portfolio of measures to reduce the probability of flooding, keep impact and damages to a minimum and provide financial support for the residual risk. Agreeing on how we pay for this now and in the future is a challenge, with competing drivers such as fairness, economic efficiency, political feasibility and public acceptance all playing their part. One example for this is the recent debate regarding the future of flood insurance. The UK has a unique approach to flood insurance through an agreement termed the Statement of Principles whereby insurance is provided by the private industry, while government commits to flood risk management. However, frequent flooding and concerns about affordability have prompted a review of the current system. After more than two years of negotiations details of a new scheme (Flood Re) have now been published.
While rising flood losses and increasing costs of insurance are the two main reasons for reforming the existing insurance arrangements, one important aspect has been widely neglected in the debate: how the existing arrangement and new flood insurance proposal reflect on the need to manage rising flood risks.
We investigate this in the context of the assumption that insurance can support and trigger risk reduction behaviour if correctly designed and implemented. We ask if and how the existing and the proposed scheme contain incentives for risk reduction or whether they will increase moral hazard. By applying our analytical framework we find an absence of formal incentive mechanisms in the existing, and in the newly proposed Flood Re scheme. We highlight some of the barriers for applying insurance to risk reduction and point to some possible modifications in the Flood Re proposal that could deliver a greater link between risk transfer and risk reduction. Our investigation offers insights into the challenges of designing and implementing flood insurance schemes - a task that is currently being considered in a range of countries, including several developing countries, who hope to apply flood insurance as a tool to increase their climate resilience.

DD 2.4-2 JAKARTA CLIMATE ADAPTATION TOOLS

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Jakarta is one of the most susceptible cities in Asia to flooding. Since 2000, floods with damages exceeding USD 1 billion have occurred at least three times. The problem is expected to worsen in the future due to changes in the physical environment (e.g. land subsidence, climate change, deforestation) and socioeconomic changes (e.g. population growth, increase in assets in flood-prone areas). Hence, a large number of initiatives have been set up to contribute to improving the city's flood risk management. One of those is the project *Jakarta Climate Adaptation Tools* (JCAT). JCAT aims to contribute to the development of tools to assess, compare, and optimise options for climate adaptation and flood risk management. In this contribution, we synthesise the project's main scientific and societal results.

JCAT has developed tools for assessing flood risk, river discharge, erosion, and sediment delivery in Jakarta. The tools have been utilised to assess the impacts of future scenarios of changes in physical and socioeconomic conditions, and to assess costs and benefits of several adaptation options. The results show that river discharge has increased slightly over the late 20th century, due to upstream land use changes. Sediment delivery has increased by more than 60% between the beginning and end of the 20th century, due to both land use and climate change. The value of assets potentially exposed to extreme coastal floods is already high. In the absence of adaptation, this will increase 4-fold by 2100 due to subsidence alone (without factoring in the impacts of population growth and increased wealth). Surveys have been carried out to estimate the actual flood damages in the Pesanggrahan river area during the 2013 flood: ca. USD 0.5 million and USD 07 million for the residential and business sectors respectively. A river flood risk model has also been developed: under current conditions, the expected annual damage exceeds USD 300 million per year. Projections of changes in flood risk in the future are currently ongoing.

The tools are now being used to assess the potential reduction in risk, discharge, and sediment yield that could be achieved through several adaptation options or measures. Such analyses are being carried out for stakeholders, such as DKI Jakarta. JCAT also contributed to the discussion on the assessment of flood damage and loss at the 5th Asian Ministerial Conference on Disaster Risk Reduction, and to an assessment of flood risk in Eastern Asia by Munich Re.

DD 2.4-3 MITIGATING FLOOD RISK UNDER CONDITIONS OF STRONG GROWTH AND WEAK PLANNING: CONSTRAINTS AND SOLUTIONS IN CAN THO CITY

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Research question
Which institutional constraints for successfully managing future flood risk can be observed in the Mekong Delta's Can Tho City, under conditions of strong urban sprawl coupled with a weak planning framework? How can these constraints be overcome?

Methodology
Besides the consideration of published conceptual and empirical literature, the analysis draws in particular on 14 months of empirical research in Can Tho City, Vietnam. Data on planning and flood risk management practices were obtained in over 70 expert interviews and numerous focus group discussions with decision makers from within the state bureaucracy but also international cooperation agencies and civil society organizations. Knowledge on current flood coping measures and future adaptive capacities was gathered in semi-structured interviews with households and small enterprises, followed by a standardized survey (n=588). Future flood exposure is assessed through a combination of urban sprawl scenarios (generated from past growth patterns, development master plans and expert appraisal) and future flood hazard maps considering, inter alia, expected climate change impacts (using modeling results generated by colleagues from the GeoForschungsZentrum in Potsdam).

Research results
The findings disclose a cascade of institutional barriers hampering the effective implementation of flood risk mitigation measures in the rapidly growing city of Can Tho. These barriers are tightly linked to legal reforms in the field of urban planning and risk management as well as to the transforming political economy of land use certification. The findings suggest that even if existing barriers in terms of lacking hazard awareness and technical know-how to project scenarios for future population growth and hazard trends could be overcome, there remain significant mismatches in terms of risk evaluation, considered time-scales and development visions between the now powerful real estate industry, the liberalized planning agencies and the supposedly corrective state regulators. The situation is further convoluted by the fact that the principle of checks and balances between those three groups of actors has been undermined through weak legal institutions and cronyism following the reform and privatization process.

Societal importance for stakeholders
In response to these challenges, concrete institutional and technical recommendations for overcoming the current deadlock in moving towards effective flood risk mitigation under conditions of strong growth and weak planning are developed. These are relevant also for other deltas in transition countries facing similar challenges.

DD 2.4-4 EVALUATING THE EFFECTIVENESS OF FLOOD DAMAGE MITIGATION MEASURES BY THE APPLICATION OF PROPENSITY SCORE MATCHING

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Research question
What are the private flood damage mitigation measures that are the most effective at reducing flood damage to households?

Methodology
We answer this question by being the first study in the field of flood risk to apply propensity score matching. Propensity Score Matching is an econometric evaluation technique that refines the previous estimates of various household flood damage mitigation measure effectiveness by simultaneously controlling for many sources of bias. Furthermore, the overall methodology was refined to be suitable for flood risk management. This study uses extensive survey data collected in response to the 2002, 2005, and 2006 floods along the German Elbe and Danube catchment areas.

Results
The results of this study indicate that when compared to previous studies the effectiveness of mitigation measures, the measures that households can employ to protect themselves, are less effective than previously indicated. Previous studies may have overestimated the effectiveness of several measures by between 1,700-14,500 euros. However, despite the lower effectiveness estimates the measures investigated are still effective as they are estimated to have prevented 6,700 euros to household contents damage or 14,000 euros of building damage (dependent on the measure).

Societal relevance
The wider societal relevance for stakeholders are three fold. The first is that we provide a more accurate estimate of the effectiveness of various household damage mitigation measures. These refined estimates allow for more accurate cost-benefit analysis and allows for risk mangers to more accurately project expected damage from a flood. The second is that a ranking of the various mitigation measures can be made; scarce educational/incentivizing resources can be allocated to the most effective measures. The final relevant aspect for stakeholders is that we have developed an evaluation methodology that can be used to evaluate various flood risk management projects. The application of a rigorous evaluation methodology based on empirical data is a very useful complement to more risk-model based evaluation studies.

DD 2.4-5 THE POTENTIAL OF WIDE GREEN DIKES ALONG THE DOLLARD

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The necessity to reinforce the dikes along the Dutch Wadden Sea coast, and the ambition to mutually strengthen the important landscape and nature values of the Wadden region, initiated a search for innovative dike concepts. Triggered by the wide green dikes along the adjacent German Dollard coast, water board *Hunze en Aa's* is eager to explore the suitability of this eco-engineering concept along the Dutch Dollard coast. A wide green dike has a grass covered shallow sloped seaward face (with a slope of around 1:7) and merges into the adjacent salt marshes. Normally, incoming waves are dampened by the foreland. Only during storm conditions waves will reach the dike. The shallow seaward slope reduces wave attack, and therefore a cover of grass (on a thick clay cover) is sufficient to protect the dike against erosion during extreme conditions, and no stones or asphalt revetment is required. In this paper we analyse the spatial impact of such a Wide Green Dike along the Dollard under different climate change scenarios and compare the costs (based on standard prices per unit) and benefits with a traditional reinforcement. Our assessment revealed that the advantages of Wide green dikes along the Dollard are primarily formed by their lower initial investment costs (based on standard prices per unit), the easiness to repair them, their adaptability, and their spatial quality compared to a Traditional dike reinforcement. Both concepts are designed to withstand an extreme storm surge with a probability of 1/4000 years. The more shallow slope of the Wide green dike will break waves more effectively than the slope of the Traditional dike, which will result in less wave run up, and subsequently in a lower required crest height. Moreover, the Wide Green dike fits better in the Wadden Sea landscape.
The results demonstrate the potential of a Wide green dike not only for the Dollard region, but also for similar dike stretches with salt marsh area adjacent to the dikes and an ambition to mutually strengthen safety and landscape and nature values. The Wide Green Dike forms a flexible and adaptable measure to improve the flood protection. However, the extraction of clay forms a major concern. In view of sustainability and cost-efficiency, extracting clay from a nearby location is preferred.

DD 2.5-1 SPATIAL AND TEMPORAL PATTERNS OF RAINFALL AND INUNDATION IN THE AMAZON, GANGES, AND MEKONG DELTAS

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Research question

Hydrologic changes in river delta systems occur over a broad range of time scales, from hours (tides), to decades (urban development), to millennia (river bank avulsion). Regular delta flooding supports sediment dispersal processes and is important for the healthy functioning of many natural ecosystems. At the same time, flooding in populated areas can be catastrophic to communities and infrastructure. This research investigates spatial and temporal surface inundation response to local rainfall patterns and major precipitation events over the Amazon, Ganges-Brahmaputra,

and Mekong deltas. Inferred inundation sensitivity maps are compared with land-cover and land-use patterns within and across the three deltas.

Research results

Rainfall is estimated using an improved detection algorithm based on TRMM (Tropical Rainfall Measuring Mission) data. Surface inundation is obtained from a new microwave-radar based global time-series, SSWAMPS (Satellite Surface Water Microwave Product Series). This inundation data record is augmented by high-resolution SAR where and when available. These complementary high spatial and temporal resolution data records improve our ability to relate precipitation events to changes in surface hydrology and flood state. Surface water sensitivity to local rainfall is shown to be closely related to land-cover and land-use patterns. Rainfall-inundation relationships tend to be weaker in agricultural areas supplied with river and groundwater for irrigation, as well as indeveloped urban areas with flood protection and drainage systems. In addition to differences in rainfall-inundation response strength, we also find variation in timescales of water retention, suggesting spatial differences in resilience to major rainfall events. Observed land-cover relationships can be used to improve spatially-explicit inundation risk estimates and in evaluating future land-cover and land-use change scenarios.

Societal importance for stakeholders

An improved understanding of how delta surface hydrology responds to precipitation is important both in the short-term for accurate flood prediction, as well as on longer-term planning horizons. This will enable local and regional managers to best protect both human communities and natural ecosystems in the face of long-term changes to the climate and hydrological systems.

Broader impacts

This work is part of a global project on 'Catalyzing action towards sustainability of deltaic systems (DELTAS)' funded by the Belmont Forum and the forthcoming 2015 'Sustainable Deltas Initiative' endorsed by ICSU. The work will complement other contributions from the DELTAS consortium that have been submitted for the Deltas in Depth sessions and the Deltas in Practice Workshops.

DD 2.5-2

HOW TO OBTAIN INFORMATION ON THE EFFECTIVENESS OF POTENTIAL FLOOD RISK MANAGEMENT MEASURES IN ONLY A FEW MINUTES?

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Flood risk management in the Netherlands mainly focuses on flood protection through (re-)construction of levees and dikes, or by the lowering of water levels by giving more room to rivers. However, more recently a 'multi-layer' flood risk approach was adopted in national policy, that not only looks at preventive measures, but also at adaptive measures that reduce the adverse consequences of floods, by reducing the exposure or the vulnerability. Examples of such measures are the construction of secondary dikes that divide large polders into smaller compartments, wet proofing or dry proofing of buildings and building on mounds.

One of the problems that impede the implementation of measures that aim at a reduction of flood consequences, is that spatial planners and project developers have little knowledge on which measures might be effective in a particular area.

To overcome this problem, we developed a series of geographical maps indicating the effectiveness of different measures, given expected water depths, flow velocities, flood duration and flood frequency. The maps can be used on a national or catchment level as well as a regional level. For each measure type, the maps indicate whether the measure is suitable given the expected water depth, flow velocity and flood duration, and whether it is economically efficient (will investments be earned back?). In addition, a simple assessment guideline was developed to help the user with the ranking of the measures.
This way, the maps help spatial planners, investors and other people involved in flood risk management and/or spatial planning, with rapidly selecting a number of potential measures that could be taken to reduce the flood risk in a certain area, and that are economically efficient.

DD 2.5-3

HAZARD TO LOSS: MODELING OF INLAND FLOODING AND ASSOCIATED ECONOMIC LOSSES IN THE DELAWARE RIVER BASIN

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Research question
Inland flooding, whether from tropical cyclones (TCs) or other related extreme rainfall events, causes significant economic losses (as well as fatalities) in the United States. Yet, little is known about the relationship between extreme inland floods and economic losses. Difficulties on establishing this link partially arise from the fact that current flood hazard estimation methods are based on flood data collected in a limited number of locations; therefore they fail on spatially characterizing flood extent and magnitude. We aim to fill this knowledge gap through an integrated physical and economic science hazard to loss assessment that allows us to produce a detailed characterization of homeowners' flood claims at a given inland-location and flood level magnitudes that led to those claims.

Methodology
In this study, we apply a spatially distributed and parsimonious hydrological model to simulate floods across the entire river network. We use a normalized index called flood ratio (FR) to characterize flood magnitudes across a large range of scales. To demonstrate our methodology, we simulate four actual extreme flood events that caused serious damages on the Delaware River Basin. We then perform a complete hazard to loss flood risk assessment by empirically linking and modeling the FR to registered insurance claims held by the federally-run National Flood Insurance Program controlling for other relevant exposure and vulnerability characteristics.

Research results
We demonstrate that our simulated FR accurately captures the location and the spatial extend of floods/claims, and can be used to estimate expected flood losses. These results highlight the technological capabilities that can lead to a better integrated risk assessment of extreme inland floods.

Societal importance
This capacity will be of tremendous value to a number of public and private sector stakeholders dealing with flood disaster preparedness and loss indemnification. For example, our inland flood risk assessment results could provide guidance to federal, state and local authorities in order to better sensitize inland residents who think that storms affect

only coastal areas. Notably, it is this type of inland risk assessment that is a priority for the National Weather Service (NWS) as evidenced by their a U.S. Department of Commerce September 2012 service assessment of Hurricane Irene where improvement on how the NWS "communicates the risk of inland flooding and educate[s] the public, media, and emergency managers on that risk"was the number one overarching recommendation.

DD 2.5-4 THE BRISBANE RIVER CATCHMENT FLOOD STUDY

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Research question
The State of Queensland, Australia, initiated a comprehensive hydrologic assessment as part of the Brisbane River Catchment Flood Study (BRCFS) in response to the devastating floods in January 2011 and subsequent recommendations of the Queensland Floods Commission of Inquiry. The goal of the study is to produce a set of competing methods for estimating design floods in the Brisbane River catchment.

Methodology
One of the proposed methods is based on Monte Carlo Simulations (MCS). In this approach, a large number of synthetic events is simulated with a hydrological model. Flood Level exceedance probabilities at key locations are subsequently derived from the model simulation results. The method has the advantage over more "traditional"approaches in flood risk analysis in that it explicitly considers all relevant physical processes that contribute to flood events. A practical disadvantage is that it is generally more complex to implement.
The main challenge in the MCS approach is to generate realistic and representative synthetic flood events. This means the synthetic events should correctly account for probabilities, mutual correlations and physical interactions of all relevant flood generating factors in the Brisbane River catchment. This is accomplished by the use of a variety of statistical distribution functions, correlation models, a hydrological simulation model and a reservoir simulation model.

Research results
The main output consists of proposed frequency distributions of water levels, discharges and flow volumes at key locations in the catchment. Additionally, a large set of simulated synthetic flood events is provided. Results show that the relevant statistical characteristics of the synthetic events are in accordance with corresponding characteristics of observed events. This demonstrates the validity of the approach and provides confidence in the reliability of the derived frequency distributions. A further added value of the method is that it serves as a validation of "traditional methods". A final advantage is that this method can be used to show impacts of climate variability and of anthropogenic impacts in the catchment on flood frequencies.

Societal importance for stakeholders
A hydrological assessment of flood frequencies is an essential ingredient of flood risk analysis and, subsequently, floodplain management plans. It provides information for locations where flooding impacts are greatest and, hence, where implementation of mitigation measures can be expected to be most cost-effective and/or can be expected to result in an optimal risk reduction to floodplain inhabitants.

DD 2.5-5 FLOOD DAMAGE FREQUENCY ESTIMATION FOR FLOOD RISK ANALYSIS

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Flood risk is defined as the probability of suffering damage or loss. As observations of damage are sparse, the probability of damage can hardly be derived directly. Therefore, the traditional approach to flood risk analysis utilizes the return period of flood peak discharge at a gauging station situated nearby as a proxy for the probability of consequences. The probability of flood hazard is derived from the statistical analysis of the annual maximum discharge at a given gauge. On that note, the T-years flood discharges derived from these statistics are used to estimate inundation extent and depths, to analyze vulnerability and finally to determine risk assuming a similar probability for peak discharges, inundation depths and consequences.
Objections concerning the validity of this procedure arise firstly from marked spatial heterogeneity of flood event characteristics and secondly from the non-linear transformation of discharges to water levels and further to flood damage. In this study, we scrutinize the appropriateness of the traditional proxy approach by comparing the outcomes in terms of risk to an approach based on a direct statistical analysis and frequency estimation of flood damage. Further, we investigate the dependency of flood risk on spatial aggregation levels (ranging from location based to regional units) underlying the statistical analysis of flood damage.
We conduct our risk analysis with a specific focus on damage to residential buildings using the regional flood model (RFM) (Falter et al. submitted 2013) within the Mulde River basin (A_E = 6.000 km^2) in Germany. This framework enables a continuous simulation of the entire flood risk chain including hydrological, 1d-hydrodynamic and 2d-inudation processes as well as flood damage estimations. In our study RFM is driven by synthetic meteorological input data produced by a multi-location weather generator (Hundecha et al., 2009). This set up provides a record of ca. 2.000 flood events affecting the study area with spatially detailed information on inundation depths and damage to residential buildings. For this sample flood damage frequency analyses are carried out at the hydrodynamic simulation unit (100x100 meters), at municipality level and at the regional level to determine flood risk for residential buildings.

DD 2.6-1

DEVELOPING LONG-TERM VIEWS ON WATER-RELATED ISSUES IN MYANMAR, THE NETHERLANDS AND VIETNAM

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A remarkable political decision was made in 2007 to ask renewed advice (after the advice of the Delta Committee installed following the 1953 flooding) on the robustness of the Dutch coast against anticipated climate change. The so-named 2nd Delta Committee was installed chaired by former minister Veerman. In their very first meeting the committee concluded that a more comprehensive and more integrated view on all water issues in relation to climate and environmental change was needed. A year later the Delta Committee Report (2008) was submitted to the Government and nearly immediately accepted by the Government.
Inspired by this very forward political action, the Prime Minister of Vietnam asked former minister Veerman and his committee to assist in the drafting of a similar comprehensive and integrated advice on all water-related issues in the Mekong Delta Region. Although there exist many very similar issues such as sensitivity to flooding and droughts, increasing salinity intrusion, water allocation issues, the intensity of these sensitivities is rather different. For instance while the flooding probability in the upper Mekong Delta Region is 1/1 year, it is 3 to 4 orders of magnitude flood safer in the NL. Another large difference is in the degree of economic development, which required a good analysis of possible development scenarios. Four economic development scenarios were defined in a joint Vietnam-NL effort and the most probable scenarios were used as a base for structural and non-structural measures, dealing with themes like flood defense, draught reduction, salinity intrusion prevention, agricultural and aqua cultural policies, water allocation and governance. This took place in 2012 and 2013 and the plan was submitted to the Vietnam Government in December 2013.
Recently, the Government of Myanmar has asked the assistance of former minister Veerman and his committee in drafting an Integrated Water Resouces Management Plan for Myanmar. This effort is presently being executed in close collaboration with Myanmar experts. It has become clear that the three countries share similar water-related problems, but that also differences exist. For instance, Myanmar has national control of its whole water system with the Irrawaddy catchment area located totally in the country, which implies a much more favorable governance situation. Also, the groundwater extraction issue that is prevalent in Vietnam is not an issue in Myanmar.
The similarities and the differences will be discussed and a focus will be on transferable concepts between the three countries related to climate change.

DD 2.6-3 RECONCILING DIFFERENT FLOOD RISK CONCEPTS IN BEHALF OF ADAPTIVE FLOOD RISK MANAGEMENT PLANNING

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Deltas are so vulnerable to sea level rise and climate change that they cannot afford to wait what mitigation may bring. The Netherlands therefore puts huge efforts in adaptation research and planning for the future, for example through a national research programme Knowledge for Climate and a Delta Programme for the 21st century. In both programmes flood risk has been defined as one of the key issues to address.
The Delta Programme involves a policy analysis which encompasses a future outlook, establishing whether a policy transition is required, an assessment of alternative flood risk management strategies, and their planning in anticipation without running the risk of regret of doing too little too late or too much too early. This endeavour, addressed as adaptive delta management, calls for new approaches. For flood risk management it may entail reconsideration of the underlying principles and of the application of portfolios of technical measures versus spatial planning and other policy instruments to achieve' multiple flood security'.
To support this policy analysis and strategic planning procedure, our KfC-Theme 1 research consortium 1) developed a conceptualisation of flood risk which reconciles the different approaches of flood defence management practice and spatial planning in order to bridge the gap between these previously detached fields, 2) investigated the effectiveness and attractiveness of a wide variety of possible measures related to the key elements of this conceptualisation, and 3) looked abroad in order to be better able to reflect critically on a possible Dutch bias which could have resulted from many centuries of experience of successful adaptation to flood risk, but which may be no longer sustainable into the future.
In our presentation we explain the multiple conceptualisation of flood risk, and we show how this may influence the framing of the adaptation challenge, how it influences which investigations are being given priority, and how it influences the outcome of the policy analysis in terms of preferred flood risk management strategy. We also show how neighbouring countries achieve at other solutions by their different framing of the future flood risk challenge, and draw lessons for the Netherlands' flood risk management practice.

DD 2.6-4 FROM POLICY CONCEPTS TO DELIVERY OF INTEGRATED FLOOD RISK MANAGEMENT

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Worldwide many nations are adopting new policy concepts related to integrated flood risk management (IFRM). Resilience, multi layered safety, adaptive delta management, mainstreaming adaptation, to name a few. Policy makers and scientists explore and improve these. However, the implementation of these policies receives much less of their attention. The 'implementation-gap' compromises the planning process, budgeting, and the delivery,

operation and maintenance of measures. The lessons from implementation processes should have feedback loops towards the development of new IFRM policy programmes. This is not self-evident, yet particularly relevant for adaptive approaches. The research questions addressed in this paper are what lessons from implementation can be transferred and applied in IFRM policy making and how can this be done effectively. The lessons relate to the system analysis, planning process and governance needed for IFRM.
This paper presents a detailed analysis of the implementation process of the 2.3 billion Euro Dutch flood safety programme Room for the River (RftR). The 2 years of research into RftR comprised 55 interviews, a survey of 155 respondents and elaborate document analysis. Subsequently, the research analysed the transfer, uptake and application of lessons learnt to the successor Delta Programme. The researchers have been actively involved (*action research*) in 2 policy pilot projects in the context of the Delta Programme. The Delta Programme investigates how the Netherlands can adapt to the effects of climate change. The first case study is Dordrecht where the new multi-layer-safety (MLS) approach has been applied. MLS comprises three flood safety layers to reduce flood risk: flood protection, spatial planning, and emergency response. The second case study is climate adaptation mainstreaming in the urban regeneration of Wielwijk in Dordrecht. The results highlight 5 generic lessons to deliver IFRM: Start with a clear integrated vision on flood risk management, consider multiple and diverse interests, fit-for-purpose governance arrangements, structured planning process with funnelled design freedom, adaptive management and learning. Points of improvement are: operation and maintenance, innovation and private involvement, administrative pressure. Knowledge transfer between programmes can be improved by explicit management of monitoring and dissemination of lessons learnt. Various governance arrangements have been identified for this.
The frequency and consequences of flood events are changing and so are our responses through emerging IFRM and adaptation policies. For these new policy responses to be effective, their implementation processes must be considered in an early stage. This research substantiates recommendations to do just that.

DD 2.6-5 IMPROVING FLOOD RISK GOVERNANCE: EXPLORING THE OPPORTUNITIES AND BARRIERS IN SIX EUROPEAN COUNTRIES

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Research question
The implementation of a multi-layer approach to Flood Risk Management requires innovative Flood Risk Governance Arrangements (FRGAs). These should address several societal domains, including water management, spatial planning and disaster management. However, insights into the question how national flood policies and regulations systems enable or constrain certain FRGAs are still limited and fragmented. This paper therefore aims to contribute to insights in the possibilities of innovative FRGAs by addressing the following question: “what are relevant similarities and differences between national flood policies and regulations systems of The Netherlands, Belgium, Sweden, Poland, France and The Netherlands for understanding the possibilities to establish FRGAs that enable the implementation of a multi-layered approach to Flood Risk Management?”

Methodology
In the framework of the EU FP7 project STAR-FLOOD, policy analysts and legal scholars in the aforementioned six countries have made a study at the country level based on desk research and a limited number of qualitative semi-structured interviews with key actors. The authors of this abstract have translated the findings in a preliminary overview of relevant similarities and differences between the countries.

Research results
The findings have shown large differences between the countries in terms of the competent authorities for implementing FRM strategies, the financing arrangements that are in place, the degree and ways in which integration between water management and spatial planning is taking place, the extent to and ways in which stakeholder involvement takes place, the substantive and procedural norms and goals that are in place and the way in which discourses on flood management have evolved in each country. Besides that, the countries also vary in terms of their actual flood experience as well as their track record in implementing certain FRM strategies. Notwithstanding the differences, some similarities between The Netherlands, France, the UK and Belgium have been identified, making them different from both Poland and Sweden.

Societal importance for stakeholders
The findings reconfirm that one-size-fits-all solutions for improving flood risk governance do not exist. Nevertheless, this exploration of similarities and differences does provide an overview of the scope for action of various actors. The findings will enable policymakers and practitioners to critically reflect on their own flood risk governance practices and provide them with ideas for improving them.

DD 2.6-6 MISI-ZIIBI: LIVING WITH THE GREAT RIVERS, CLIMATE ADAPTATION STRATEGIES IN THE MIDWEST RIVER BASINS

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Climate Change is NOT just coastal. The 2011 Mississippi/Missouri floods throughout the Midwest, USA followed by the 2012 drought and the 2013 floods, demonstrate that increased climate variability across cannot be ignored over the long-term. Extreme weather has a direct, and often negative, impact on the river's functioning and adjacent land-uses, and thus also the Mid-West's ecology, economies and communities. Increased climate variability may mean more frequent extreme weather throughout the Mid-West. More floods and droughts demand that stakeholders along the Mississippi and Missouri River system adapt at-risk communities, ecologies and economies to this uncertain future. The **research question** is one of design: to create and promote sustainable, healthy river systems that enrich local communities, drive local economies, and provide key ecological services up and down the river system. **MISI-ZIIBI** was the first in a series of multi-disciplinary workshops that investigated spatial design strategies through the studying of innovative, integrated approaches for climate adaptation and sustainability along the Mississippi and Missouri rivers in the Midwest. Initially focusing on the St. Louis region, the first workshop outcomes and **research results** were a broad-based set of proto-typological, multi-scaled planning scenarios worthy of more detailed study and intended to be transferable to other Midwest regions. The March, 2013 workshop approach brought together multiple disciplines of Dutch and American participants in an interactive design-based setting. The participants

sought input from local stakeholders and communities to ground the work in the specific realities and existing initiatives already at hand. The workshop intends to foster a new dialogue about both policy and design along the Mississippi and Missouri Rivers in the Midwest in relation to climate change and weather extremes, as well as the changing functioning of the river economically and ecologically and what this means for the adjacent communities. The workshop products were a series of scenario-based and scalable design strategies that investigated possible prototypes for integrated and sustainable models for land-use planning, flood-risk-protection, community and economic resilience, drought tolerance, ecological benefits and sustainable design developments along Midwest metropolitan river regions. **MISI-ZIIBI** asked groups to work at the St. Louis regional scale, in addition to various fluvial zones that included agricultural, suburban and urban typologies. The intent was these areas of study reflected overall conditions transferable to other Midwest city-regions. <b>The graphic-based outputs of MISI-ZIIBI will aid the community, stakeholders and government officials as they develop ways to respond to the MISI-ZIIBI's climate challenges.

Deltas in Depth Theme 3:

Fresh water management

DD 3.1-1

MODELLING IMPACTS OF CLIMATE CHANGE AND SOCIETAL CHANGE ON FLOWS AND NUTRIENTS IN THE GBM DELTA OF BANGLADESH

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Research question

How will future climate change impact flows and nutrient fluxes into the Ganges Brahmaputra Meghna (GBM) Delta and how will these be modified by future socio-economic changes in the upstream catchments.

Research results

A semi-distributed flow and water quality model (INCA- Integrated Catchments Model) has been set up for the whole of the GBM River systems. These massive rivers transport large fluxes of water and nutrients into the Bay of Bengal via the GBM Delta system in Bangladesh. Future climate change will impact these fluxes with changing rainfall, temperature, evapotranspiration and soil moisture deficits being altered in the catchment systems. At the same time other environmental and socio economic adaptation will alter fluxes due to range of factors. These include increased population levels, changing land use, new agricultural developments and new standards for effluent discharges and associated water quality. In addition, a number of proposed dams and water transfer have potential to significantly impact upon flows entering the Delta.

In this study the INCA model has been used to assess potential impacts of climate change using the UK Met Office GCM model linked to a regionally coupled model of South East Asia, covering India, Tibet and Bangladesh. Results indicate a slight shift in the monsoon season with increased wet season flows and increased temperatures which alter nutrient fluxes. Socio-economic changes such as additional urban, industrial and agricultural water demands, along with changes in water infrastructure such as dams, have the potential to impact on water availability within the Bangladesh GBM Delta region. However, water quality could be improved as the general clean-up of effluent discharges are introduced as part of the National Ganga River Master Plan.

Societal importance to stakeholders

The GBM Delta supports one of the most densely populated regions of people living in poverty, who rely on ecosystem services provided by the Delta for survival. These ecosystem services are dependent upon fluxes of water and nutrients. Freshwater for urban, agriculture, and aquaculture requirements are essential to livelihoods. Nutrient loads stimulate estuarine ecosystems, supporting fishing stocks, which contribute significantly the economy of Bangladesh. Thus the societal importance of upstream alterations together with the local impacts of climate change in Bangladesh are very significant to many stakeholders in Bangladesh at the local, regional and national levels.

DD 3.1-2

SALINITY INTRUSION AND WATER AVAILABILITY UNDER CHANGING CLIMATE IN THE COASTAL GANGES DELTA IN BANGLADESH

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The coastal area of the Ganges Delta in Bangladesh is characterized by a network of tidal rivers, seasonal variation of freshwater water flow as well as salinity variation both in time and space and rich coastal ecosystem. The present temporal and spatial variation of salinity is likely to deteriorate further as a consequence of sea level rise in the changing climate. The salinity levels in this area exhibit a distinct seasonal variation. Average salinity concentrations in the coastal zone are higher in the dry season than in the monsoon due to lack of freshwater flow from the upstream. A research was carried out to assess the effects of climate change and trans-boundary flow as external drivers of change on salinity intrusion and water availability in the Ganges coastal zone of Bangladesh.

The results show that sea level is very likely to cause considerable changes in river salinity in the coastal area of Ganges Delta in 2050. These changes are likely to impact severely on some areas such as decrease the potable water (0-1ppt) and irrigation water area (0-2ppt). Simulation results show that about 14% potable water area decreases with increase of sea level rise and decrease of upstream freshwater flow. The area currently suitable for irrigation is decreased by 9% in A1B scenario. This decrease in the availability of freshwater is very likely affect the freshwater fish habitat and drinking water supply in the coastal urban cities. The fisherman and agriculture farmers are going to be affected more. Constructing a barrage over Ganges river for storing and diverting water flow during lean periods is expected to improve water availability in the South West Gangetic Delta in Bangladesh. The salinity zoning maps prepared on the basis of the research further indicate that the temporal and spatial changes of salinity level and water availability in the changing climate scenario are instrumental for devising adaptation measures. The study further revealed that introduction of salt tolerant variety of rice which can grow in saline water is an prospective and alternative option.

Keywords
Salinity intrusion, coastal area of Bangladesh, water flow, simulation, sea level rise, fish habitat, irrigation, agriculture, aquaculture and salinity.

DD 3.1-3

CENTRALIZED AND DE-CENTRALIZED WASTEWATER REUSE IN MAPUTO, MOZAMBIQUE

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Maputo, like other Deltas cities in developing countries suffers from i) freshwater shortage, ii) improper sanitation, iii) limited access to safe drinking water and iv) reuse of untreated wastewater (e.g. for irrigation). Furthermore, despite the good work done in the country regarding water supply and sanitation since the independency from the colonial power in 1975, more than 50 % of the Mozambican population still lacks access to an improved water source (WHO, 2013). With the country also lagging behind on the access to basic sanitation (UNECA, 2013). Therefore, a project

has been started by TU Delft, UNESCO-IHE, the Mozambican University Eduardo Mondlane and other Dutch and Mozambican parties, to study the potential for centralized and de-centralized wastewater reuse systems in the city of Maputo. The project focusses on both social and technical aspects and its main objective is developing integrated social and technological knowledge, technologies and tools that enable the local water sector to include water reuse in overall planning and design of the urban water system. The practical work started in April 2014 in Maputo and in this work the first results of the technical feasibility of water reuse in the city of Maputo are presented. The centralized system is mainly located at the existing wastewater treatment plant. The operation of the plant was characterized and based on this, potential improvements for operation and re-use were proposed. For the de-centralized re-use, pilots area(s) in the peri-urban areas of the city were selected. This selection was made based on the following criteria: i) availability of wastewater, ii) existence of a sewer network, iii) physical and chemical characteristics of the wastewater, iv) presence of potential customers. For both the centralized and de-centralized systems, an economic analysis will be presented, this will include a discussion on the optimal abstraction and treatment methods and locations, and the best distribution method for the treated water . The added value of this work is twofold. First, it will allow alleviating the pressure on the already strained water sources (mostly rivers) that provide drinking water to the city. Second, the systems will produce “water-fit-for-use”, which means being projected to treat wastewater to meet the needs of a specific use, for example irrigation. In this way, the health risk untreated wastewater reuse is diminished. References UNECA. (2013). Assessing progress in Africa towards the Millenium Development Goals. WHO. (2013). Progress on sanitation and drinking water.

DD 3.1-4 ASSESSMENT OF EVAPORATIVE WATER LOSS FROM DUTCH CITIES

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Societal importance

Reliable estimates of evaporative water loss are needed in support of assessment of the urban water budget and division of sweet water resources among various needs, including water supply to citizens, evaporative cooling of cities and survival of urban vegetation. In the Western part of the Netherlands, water extraction by evaporation may accelerate degradation of the wooden foundations of many buildings. Maintaining liveability in cities under climate change by adaptation measures relying on evaporative cooling while at the same time saving water and preventing adverse effects of water extraction is extremely challenging. Assessment of urban evaporation at various scales may help to achieve this goal.

Research questions

Relatively little quantitative information is available on the role of urban evaporation in the urban water budget, because it is extremely difficult to reliably estimate this quantity in practice at the required timescale (about one day). Data from specialized observations are sparse. Therefore, our research questions are: 1) How much of the

precipitation received at the city scale is lost as evaporation? 2) Can urban evaporation be reliably estimated by utilizing routinely available meteorological observations?

Methods
Evaporative water loss from Arnhem and Rotterdam in the Netherlands is assessed using data obtained from three measurement techniques: scintillometry, eddy covariance, and sapflow observations. The short timescale of these measurements allow assessments from daily to seasonal and annual periods, while also allowing evaluation of biophysical principles underlying various estimation methods.

Results
We found the evaporation to be between 20% and 60% of the precipitation in the summers of 2012 and 2013. In particular in Arnhem, the response of evaporation to precipitation events appeared to be strong. This is presumably caused by the specific characteristics of the built environment in Arnhem, which may have a strong impact on the interception reservoir. The impact of trees on urban water consumption is estimated to be small at the city scale. However it may be quite strong locally, as suggested by a measured water uptake of up to 170 litres per tree and per day. We show that estimation of urban evaporation from routine weather data is a particularly challenging task owing to the complexity and heterogeneity of urban environments. However, we demonstrate how our observations can be used to evaluate and improve methods based on such data, ultimately leading to reasonable urban evaporation estimates in the absence of specialized observations.

DD 3.1-5 POPULATION VULNERABILITY TO SEASONAL FRESHWATER FLUXES AND DIARRHEAL DISEASES IN BENGAL DELTA

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Research question
Freshwater management, both quantity and quality, has become increasingly complex due to increased urbanization and changing climate patterns in populated delta regions. Frequent occurrence of droughts and floods and accompanying institutional and policy failures in freshwater management and services directly impact access to water and sanitation at local scales, and public health burden over large geographic areas. The highly populated floodplains of the Bengal Delta region in South Asia have a long history of endemic and epidemic water-related diarrheal diseases. Previous studies have not addressed the dynamics of population vulnerability due to the influence of spatio-temporal changes in regional freshwater fluxes. Here, we analyze spatial and temporal variability of cholera incidence across six surveillance sites in the delta region and their association with regional hydroclimatic and environmental drivers. More specifically, we employ salinity and flood inundation modeling across vulnerable coastal and inland districts of Bangladesh to test earlier proposed hypotheses on the role of large-scale hydroclimatic and environmental drivers for the estimation of population vulnerability across the delta.

Research Results
The results of our analyses show that large areas of the highly populated floodplains in this region are at high risk of endemic and epidemic cholera in both dry (spring) and wet (fall) seasons due to large spatial coverage of salinity intrusion and flood inundation, respectively. Population centers along the floodplain corridors of the lower Ganges-

Brahmaputra-Meghna river system remain vulnerable to seasonal and interannual variability of cholera transmission mechanisms with respect to underlying hydroclimatic drivers during spring and fall. Our results show strong influence of seasonal and interannual variability in estuarine salinity on spring outbreaks and the impact of inland delta flooding on fall outbreaks.

Societal Importance for Stakeholders

A large segment of the population on Bengal Delta floodplains remains vulnerable to the biannual cholera transmission mechanisms due to seasonal changes in the freshwater environment over large geographic regions. A striking similarity across different geographic locations over a ten-year period of time suggests that large-scale seasonal hydroclimatic processes over a large extent of the Bengal Delta region modulate cholera incidence making it possible to predict the timing and magnitude of diarrheal outbreaks. Such low-cost and high-end modeling approaches can serve as the basis for freshwater management approaches where crowd-sourced disease occurrence and local environmental data can be merged with such a system for disease early warning systems and training of adaptation personnel across rural regions.

DD 3.2-1 WATER QUALITY OF FAYOUM SURFACE WATER, FAYOUM PROVINCE, EGYPT

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Egypt is classified as water scarce and the climate change increases the stress on the waters resources throughout Egypt due to the limited supplies and growing population and increased competition on water from the upper Nile basin countries. Climate change induced sea level rise also poses a large risk for Egypt since the Nile delta is highly populated with agriculturally important. Coastal communities in Egypt will face inundation of low lands and salt water intrusion and contamination of ground water resources, exacerbating soil salinity and affecting food security. This will oblige a significant proportion of population to abandon their land and homes. Consequently, an increasing in land reclamation is needed which increases the stresses on water demand in Egypt.

So, water resources management is an obligatory task in Egypt. One of the water resources management tools is the water quality assessment. Poor water quality has a direct impact on water quantity in a number of ways. Polluted water that cannot be used for drinking, bathing, industry or agriculture effectively reduces the amount of useable water within a given area. From this point of view, we selected one of Egyptian regions called Fayoum Province to study and assess its surface water quality. Total 43 water samples from irrigation canals, drains and Lake Qarun were collected from Fayoum Province to evaluate their quality for drinking and irrigations purposes. Heavy metals content, dissolved oxygen, electrical conductivity and microbiological analyses were studied. The results showed that the surface water in Fayoum Province suffers from high microbiological contaminations. Most waters cannot be directly used for drinking or agricultural purposes. The high levels of fecal coliform and F.streptococcu indicates a direct human impact on the water quality. The levels of metals content of all waters were relatively low except some elements such as Al. All drainage waters and some irrigation waters have high salinities and cannot be used for irrigation of agricultural fields except after mixing with fresh water. All drainage waters and agricultural returns are conveyed to Lake Qarun (alkaline saline lake). The lake has relatively low heavy metals content as compared to

other waters due to adsorption of heavy metals by the lake bottom sediments. We recommended the necessary of application of environmental protection laws that deal with water quality and pollution control in addition to public awareness rising.

DD 3.2-2 WATER - AIR BUBBLE SCREENS REDUCE SALT INTRUSION THROUGH SHIP LOCKS

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Research question

The increasing population and ship/cargo traffic in delta areas as well as the growing demand for more and longer storage of fresh water at lower river discharge invited the following research question toward minimal salt transport through ship locks.

A Dutch tradition is the application of air-bubble screens for reducing salt intrusion through ship locks (Abraham & Van den Burgh, 1962). We define the ratio between the hindered and unhindered salt intrusion (i.e. lock-exchange flow) as Salt-Leak Ratio (SLR). The original air-bubble screens were initiated by releasing compressed air through perforated pipes across the lock floor yielding an SLR of about 50%.

We investigated a new design of bubble screens in ship locks by using an innovation in air-flux regulation (Flowthrough Inc.) in an optimal spatial arrangement of air diffusors. Our final novel addition is a fresh-water screen located on the sea side adjacent and parallel to the bubble screen. The upward vertical flow and thus momentum of the water screen protects the tow of the bubble screen against through flow; the water screen mixes fresh-water rather than sea water into the bubble screen. The research question thus reads is the SLR of this unique water-air bubble screen well below the SLR of traditional bubble screen?

Methodology

Rijkswaterstaat offered Deltares the usage of an operational ship lock (145m length, 14m width, 5m depth), called the Stevinsluis (Den Oever, North-Holland, Netherlands). In this lock our novel water-air bubble screen was added to the original bubble screen, based on perforated tubes. With and without these screens we observed the salt transport by monitoring the reduction in salt mass inside the lock before and after closure of the lock door to the fresh-water side. To that purpose 5 vertical row with 5 conductivity-temperature-depth (CTD) meters were installed along the lock wall and two buoys each with 5 CTD's monitored the salt stratification near but outside the lock doors.

Research results

Based on observations in the well-instrumented and operational ship lock we present evidence that this combined water-air bubble screen yields the lowest SLR of 0-15% ever recorded compared to the 25% SLR of the optimized bubble screen being half of the 50% SLR of the traditional bubble screen.

Societal importance for stakeholders

The elevated salt intrusion by increased sea water - fresh water cargo transport can be mitigated by the application of water-air bubble screen in ship locks.

DD 3.2-3 AIR BUBBLES AGAINST SALT INTRUSION, PROMISES AND MISCONCEPTIONS

Yann Friocourt, Rob Uittenbogaard, Otto Weiler
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Research question

The current freshwater supply in the coastal areas of the Netherlands is quite sensitive to intrusion of salt water from the sea. This situation is a direct consequence of the geography and economics of the Netherlands, a low-lying deltaic area crisscrossed with an extremely dense network of waterways intensively used for shipping. Salt water enters freshwater reservoirs via open waterways or via the numerous shipping locks the country boasts. As a result of this quasi-unique situation, Dutch engineers have developed measures to limit salt intrusion, among which air injection has been standing for the best part of 50 years. Now that air injection seems to experience a revival, we believe it is time to demystify how it works and how it should be considered.

Methodology

Deltares and its predecessors have held a central role in research over air injection as a measure against salt intrusion for decades. This research has be carried out through a large number of laboratory experiments in scale models or experimental tanks, but also in real shipping locks temporarily turned into full-scale testing facilities. With the advent of computational fluid dynamics, numerical simulations have also offered interesting insights in the precise working of air injection to limit salt intrusion.

Research results

Several usages for air injections can be differentiated: as a barrier against salt and fresh water in shipping locks, as a mixer in estuaries, or as a water transporter in a waterway. Thanks to technical improvements and to possible combinations with water barriers, the concept of pneumatic barriers in shipping locks has been greatly improved compared to its basic original design, making it more efficient, more effective, and less prone to ageing. Air bubbles prove very effective vertical transporters of water so that the effectiveness of the system ranks higher than many other possible measures against salt intrusion. However, certain aspects such as the energy requirements should be kept in mind when considering implementing air injection in practice.

Societal importance for stakeholders

This particular case exemplifies how technical and scientific advances may greatly improve the effectiveness of measures designed decades ago. It is also a specific example of a measure whose mechanisms may not be fully understood by the general public, so that a societal debate may become skewed because of misconceptions. The role of a scientific institute in reestablishing scientific facts then becomes crucial.

DD 3.2-4 UPSCALING DETAILED PROCESS STUDY TO REGIONAL EFFECTIVENESS ON WATER SUPPLY: BUBBLE PLUMES IN THE ROTTERDAM WATERWAY

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Research question
Between 2011 and 2014, Deltares has been investigating whether bubble plumes could effectively be used to limit salt intrusion in the Rhine-Meuse estuary during times of low river discharge, and thereby improve the regional water supply. This concept was initially derived from air curtains used in some Dutch navigation locks. The research was carried out along two axes, funded respectively by Rijkswaterstaat together with the Dutch Ministry of Infrastructure and the Environment and Port of Rotterdam, and within the Dutch Delta Programme by sub-program Freshwater supply.

Methodology
First, the working mechanisms of bubble plumes were investigated with a combination of laboratory experiments and numerical simulations. A bubble plume was towed repeatedly along the bottom of a 30-meter long tank filled with fresh and salt water in order to reproduce a salt stratification. The mixing created by the bubble plume was accurately measured, and the structure of the plume was extensively filmed and photographed. The observed behavior was then further extended in numerical models in order to mimic that of several plumes and quantify their effects. Then a one dimensional model in combination with the Netherlands Hydrological Instrument (NHI) was used to compute the effectiveness of two bubble plume variants on the regional water demand and supply.

Research results
The laboratory experiments evidence that bubble plumes consistently result in vertical mixing, which in turns reduces the baroclinic transport and the salt intrusion. The long-term simulations indicate that the small variant of bubble plumes would slightly improve the salt intrusion situation. A larger variant would offer a substantial improvement in the northern part of the estuary. However, the improvement on the southern part would be limited, because salt intrusion there mostly results from surge conditions during which bubble plumes are less effective. In general however, the effectiveness for the regional fresh water supply is smaller than that of other, more structural measures.

Societal importance for stakeholders
Within de Delta programme different measures are investigated for safeguarding the fresh water supply. The bubble plume is an important measure which can contribute the fresh water supply in Delta areas. This study shows the importance of upscaling the detailed study of the bubble plumes to and systematic long-term policy-analyses for the fresh water supply to provide insight in the effectiveness at a regional scale. These results can help in de decision making for politics.

DD 3.2-5

ASSESSMENT OF WATER QUALITY CHANGES IN RAS JBEL AND GUENNICHE AQUIFERS OF TUNISIA DUE TO ARTIFICIAL RECHARGE

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In the aquifer of Metline-Ras Jbel-Raf Raf and the aquifer of Guenniche (North Eastern Tunisia), groundwater plays an important role for social and economical development. Water in both aquifers is the sole drinking and irrigation source for local residents. However, with the rapid increase in population, the extraction of groundwater is reaching its maximum capacity. This intensive exploitation has considerably lowered the water table in and around the water catchments. Groundwater salinization and degradation is usually observed through sampling of pumping wells. One supply augmentation practice, that is already being applied in north-eastern Tunisia, is artificial groundwater recharge using freshwater from SECADENORD. The purpose was to artificially replenish the overexploited aquifers, and thereby partially restore the water table levels while maintaining production capacity. The impact of artificial recharge on the quality and the quantity of both aquifers water then becomes a more pressing concern. Field measurements of piezometric levels and physicochemical parameters, along with hydrochemistry analysis of groundwater were carried out in both Ras Jbel and Guenniche aquifers during four campaigns before and after artificial recharge. Results of field and laboratory analyses showed variations of chemical compositions across the study areas. A drop in piezometric level is be remedied by artificial recharge of groundwater. Artificial recharge decreases also the high degrees of salinities in both aquifers.

DD 3.3-1

SALINE SEEPAGE IN DELTAIC AREAS: FROM PROBLEM TO SOLUTION

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Problem definition and research question

In many coastal areas, groundwater is brackish to saline which may pose problems for the sustainable exploitation of fresh groundwater. In low-lying coastal areas, saline groundwater may reach the surface by upward groundwater flow. This process is referred to as ‘saline seepage’ and was the main subject of my finished PhD-research in the Dutch delta. Saline seepage leads to the salinization of surface waters, shallow groundwater and soil water in the root zone. Climate change and sea level rise are expected to increase saline seepage and reduce the availability of both fresh surface water and groundwater. Predicting effects of future changes, defining effective water management strategies for a climate proof sustainable freshwater supply and successful implementation of any measure is only meaningful when the salinization processes are fully understood. The main objective of my research was to address the knowledge gap that exists of the understanding and quantification of the dynamic processes involving saline seepage leading to the salinization of surface water, shallow groundwater and soil moisture.

Methodology
The spatial varying and dynamic saline seepage processes were analysed and quantified based on field campaigns supported by numerical and analytical methods. The field campaigns involved field techniques applied at scales varying from local point scale to measurements at polder catchment and island scale using helicopter-borne electromagnetic measurements. Time varying field data was collected with an hourly to monthly frequency at agricultural fields and polder catchment outlets to monitor the dynamic salinization processes.

Research results
Two processes were identified as most important contributors to the salinization of the Dutch delta, (I) the preferential saline seepage through boils leading to surface water salinization, and (II) the interaction between thin rainwater lenses and saline seepage leading to the salinization of shallow groundwater and the root zone. Based on the results, the vulnerability of the Dutch delta regarding these processes to climate change was assessed. The most important results of the research will be presented in view of solutions for a climate proof sustainable freshwater supply.

Societal importance for stakeholders
The research was carried out in collaboration with farmers who were limited in their freshwater supply by saline seepage. By analysing and quantifying the salinization processes we were able to define promising solutions to increase the freshwater availability from which a few already have been tested in the field. These solutions will be presented.

DD 3.3-2 GROUNDWATER IMPACT ON ENVIRONMENTAL FLOW NEEDS OF STREAMS IN SANDY CATCHMENTS

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During recent years, water boards and water users in the Netherlands experienced water scarcity in streams and rivers. Although often underexposed, an important cause for this water scarcity is the deteriorated groundwater conditions resulting in reduced base flow. The deterioration of the groundwater conditions and base flow is probably caused largely by anthropogenic alterations of the water system, such as drainage, alteration of stream morphology, deep groundwater abstractions and shallow groundwater abstraction for spray irrigation. These catchment wide alterations threaten the magnitude and natural variability in stream discharge (environmental flow needs, EFN) of streams and hamper current restoration efforts on stream morphology. Additionally, groundwater recharge will probably decrease due to climate change causing even more base flow reduction in the future.
In our study we estimated the magnitude of the impact of anthropogenic alterations and future climate change on groundwater conditions and base flow in sandy catchments in The Netherlands. Additionally, we investigated if base flow in these catchments is sufficient under current and future conditions. For these purposes we introduced a methodology to assess the impacts of groundwater-related alterations and climate change effects on base flow and EFN using spatially distributed geohydrological models and scenario analyses.
Application of this methodology for two sandy catchments in the Netherlands, including the use of detailed distributed groundwater-surface water models, showed that base flow in main streams meets EFN requirements. However, cooperation with water managers pointed out that the minimum EFN threshold for base flow, the Dutch implementation of the WFD, is seriously questioned. Water managers found that under current circumstances, base flow in the main streams of the studied areas is too low for the assigned ecological and agricultural functions. In

addition, climate change potentially causes 33-70% additional base flow reduction in 2050, according to our model results.
Scenario analyses showed that anthropogenic alterations have had a significant impact: drainage caused 25-40% base flow reduction, deep groundwater abstraction caused 5-17% base flow reduction, and shallow groundwater abstraction for spray irrigation caused 10-28% base flow reduction. The overall conclusion of our study was that to effectively restore base flow conditions, both improvement of stream morphology as well as reduction of anthropogenic groundwater-related impacts on the catchment scale are required.

DD 3.3-3 VULNERABILITY OF GROUNDWATER TO SALINIZATION AND THE CASE OF THE BENGAL DELTA

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The effects of rising sea level and storm surges threaten freshwater resources and aquatic ecosystems along many world coastlines. Understanding the primary factors that affect aquifer vulnerability and determine the magnitude of system response is critical to developing effective management plans in coastal zones.

Research questions
What factors most affect vulnerability of fresh coastal groundwater resources to salinization?
What are the relative rates of different salinization processes (lateral and vertical)?
How is salinization affected by geologic heterogeneity present in complex delta aquifer systems?

Methodology
Salinization processes were assessed with variable-density groundwater flow and solute transport models. The rate and magnitude of salinization of fresh groundwater due to lateral seawater intrusion were assessed over a range of hydrogeologic settings, and the most vulnerable settings were mapped globally. In an application to the Bengal Delta along the central coast of Bangladesh, the effects of aquifer heterogeneity on the rate and extent of vertical (storm surge) and lateral (sea-level rise) salinization processes were investigated.

Research results
A primary factor affecting fresh groundwater vulnerability to lateral salinization is the ability of the water table to rise in response to a rise in sea level. Topography-limited systems, in which water-table movement is negligible, are vulnerable to salinization over a range of combinations of permeability and recharge. In contrast, recharge-limited systems, in which the unsaturated zone permits water-table rise, experience minimal salinization. These typologies were mapped over world coastlines as a first indicator of vulnerability. Some of the most highly vulnerable areas are world deltas. An example is the Bengal Delta, where sea-level rise combined with low elevation, dense population, and extensive groundwater use threaten to salinized water resources. Simulation results show that geological heterogeneity strongly affects salinity patterns and salinization rates. The lateral intrusion process is much slower than vertical salinization caused by inundation and storm surges, and groundwater pumping accelerates both mechanisms. The analyses show that large-scale factors may serve as a first indicator, but vulnerability of a coastline to salinization depends strongly on system characteristics.

Societal Importance for Stakeholders
The results of this work have implications for coastal managers who may use the developed indicators to initially focus efforts on vulnerability assessment and mitigation planning. The effects of local system characteristics and pumping on rates and patterns of salinization emphasize the need for site-scale impact assessments and management of pumping to minimize effects of salinization.

DD 3.3-4 GUIDING PRINCIPLES FOR FRESH WATER LENS DEVELOPMENT, EXPLOITATION AND MAINTENANCE IN ARTIFICIAL ISLANDS

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Research question
A fresh water lens may develop under newly constructed artificial islands in the ocean. The thus developed fresh water lens can be incorporated in the water supply system of the envisaged development on the island. The conditions for fresh water lens development can be optimized in artificial islands, since these islands are designed from scratch and the technical possibilities of dredging material and dredging equipment are large. However, there is currently little guidance on methods for optimizing artificial islands for fresh water lens development. We address this gap looking at the factors affecting 1) the development, 2) the exploitation and 3) the maintenance of fresh water lenses.

Research methods and results
In this research the geotechnical properties and hydrological characteristics of three land reclamation projects are used to study the potential fresh water lens development in land reclamations. The three land reclamations are The World in Dubai, Maasvlakte II in the Netherlands and Pluit City in Jakarta. Based on numerical analysis, we will present general design principles regarding the shape and characteristics of artificial islands and the capacity and continuity of recharge. An especially interesting aspect is how the fresh water lens can be exploited and maintained. Options for a permanent measurement system will be presented.
We conclude that optimization of artificial islands for fresh water lens development, exploitation and maintenance is technically feasible. The business case determines whether the optimizations of these islands will actually be applied in specific cases.

Societal importance
Water demand on newly constructed islands includes water for domestic purposes, drinking water, irrigation and industrial purposes like firefighting and dust prevention. Safeguarding the fresh water supply is one of the major challenges; since the island is constructed in the ocean there is usually no fresh water available to meet the water demand of the future land use. Fresh water is usually supplied by pipeline from the main land, or by desalination of seawater, and some small-scale rainwater harvesting and reuse. It is interesting to create a fresh water lens in the island to decrease the dependency on supply from the mainland and/or to decrease the costs related to desalination.

DD 3.3-5 SOPHISTICATED WELL CONFIGURATIONS TO ENABLE AQUIFER STORAGE AND RECOVERY (ASR) IN COASTAL AQUIFERS

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Research question

Freshwater resources in coastal areas are limited, resulting in problems like seasonal water shortage, overexploitation of freshwater aquifers, and seawater intrusion. We believe aquifer storage and recovery (ASR) of temporal freshwater surpluses is a (cost-)effective strategy to balance yearly water demand and supply. As ASR can be inefficient in coastal aquifers due to density-driven flow, the central question in this research was if sophisticated well configurations could achieve acceptable ASR performance.

Results

An ASR-Coastal system equipped with multiple partially penetrating wells (MPPWs) was successfully installed in a Dutch coastal greenhouse horticulture area in 2012 and enabled injection at the aquifer's base and recovery at its top. The system rendered recovery efficiencies of 40 - 60%, whereas <20 to <35% was recoverable by conventional ASR wells. This recovery increase was more than sufficient to guarantee local freshwater supply, even during long periods of drought. The MPPWs cannot fully overcome the loss by density-driven flow: a significant part the injected freshwater becomes unsuitable every year by mixing during injection at the salinized base of the aquifer. The interesting effect of this alternative, unique ASR scheme on chemical water quality development during aquifer passage (cation exchange, mobilisation/sorption of (trace) metals) is topic of further study.
Secondly, a parallel, superimposed horizontal directional drilled well (HDDW) pair was proposed to enable both shallow injection and recovery of freshwater in a freshwater lens, as well as interception of underlying saltwater. A natural fresh groundwater lens can thereby be enlarged during injection ('Freshmaker' concept), storing large volumes in the process. During subsequent storage and recovery, the enlarged freshwater lens is protected by the interception of deeper saltwater. The first Freshmaker prototype was successfully installed and tested in 2013. SEAWAT modelling preceding its operation indicates that the targeted (minimum) freshwater volume of 4,200 m^3 could only be recovered using the Freshmaker HDDW pair.

Importance for stakeholders

This research has led to the development and field validation of innovative and sophisticated, but yet cost-effective aquifer storage and recovery (ASR) solutions for freshwater management. With freshwater availability and demand increasingly being unbalanced and the on-going salinization in coastal areas, these sophisticated and effective ASR set-ups are expected to have major benefits to the (future) freshwater management.

DD 3.4-1 SIMULATING DROUGHT VULNERABILITY OF THE AGRICULTURAL SECTOR IN THE SOUTHWEST NETHERLANDS: AN AGENT-BASED APPROACH

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Research question

Even though the Netherlands has as maritime climate, summertime droughts occur causing a decline in fresh water availability and increasing salinziation. Insufficient fresh water or water with too high salt concentrations causes damage to crop production and crop quality, eventually resulting in a loss of farm income. Adaptive capacity, the ability of farmers to take adaptive actions, is a prerequisite for adaptation and an important determinant of the vulnerability and performance of the agricultural sector at an aggregate level. Understanding farmers' adaptive behaviour and its relation with the sector's vulnerability is a challenging task as farmer communities are complex systems in which individual adaptive behaviour and interaction between agents shape outcomes at the sector level through changes in the probability and severity of drought damage and the rate at which drought adaptation technology diffuses through an area. In turn, there is a feedback from macro outcomes into individual decision-making; individual farmers observe these outcomes at the macro level and adapt to them.

Results

This paper presents an agent-based model to explore how the adaptive behaviour of farmers at the micro level affects the vulnerability of the agricultural sector to climate-induced uncertainty regarding water availability. Agents' decision rules and social networks are calibrated based on the results of a survey among farmers in the southwest Netherlands. The model explores the emergence of diffusion patterns of adaptation strategies and the overall vulnerability of the agricultural sector in the case-study area under various drought scenarios. The macro outcomes of interest include the changes in (1) the vulnerability of the agricultural sector, for example the annual loss of harvest, % of farmers that go bankrupt and on near-zero profit margin, and (2) the diffusion of adaptation strategies (% of adopters). Furthermore we will present the sensitivity of the simulation results to several model assumptions.

Societal importance for stakeholders

Several sub-programs of the Deltaprogram develop strategies for a sustainable freshwater supply. Decreasing the vulnerability of society against droughts probably requires a range of measures and policy arrangements regarding the supply and demand of freshwater. However, it also requires insight in the capacity of society to cope with droughts. Understanding farmers' drought adaptation behaviour is essential to design efficient public drought risk management strategies. Insights in the factors motivating or hindering farmers to adapt enables policy-makers to develop tailor-made solutions and to tune public adaptation efforts to private adaptive actions.

DD 3.4-2 DEALING WITH THE UNPREDICTABLE: ANTICIPATION OF SALINITY STRESS TO CROPS UNDER ERRATIC WEATHER CONDITIONS

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Many regions worldwide experience periodic drought with insufficient water for crop transpiration, semi-arid and delta regions additionally deal with salinity of water resources.

Research question

To effectively deal with these stresses, farmers need instruments to assess the risks of yield reduction. However, the impact of both stress factors depends on weather, which can be predicted for periods exceeding one week only with increasing uncertainty. Our research questions is how to predict salt effects under unpredictable weather.

Research results

We investigated salt stress tolerance of common crops using literature and new experiments and developed a conceptual framework of drought and salt stress effects on crops under erratic weather conditions for evaluating the impact on yield and salt accumulation in soils. From simulations, guidelines for a priori sustainability assessment, uncertainty factors, and a basis for management were derived.

It appears, that the new salt tolerance parameterization leads to different effects on crop yields than old data. However, under Dutch conditions, salt exposure is commonly a temporary rather than a permanent problem, highly correlated with drought, and tolerance to salt may be cultivar dependent. Such factors may mitigate the sensitivity of crops for soil salinity, although direct exposure of above ground parts to salt, e.g. due to sprinkling, may render salt effects more severe.

For salt exposure via the root zone, periodically saline conditions sort a limited effect unless these periods persist too long or crops are very salt sensitive. As rotations schemes are adjusted to local conditions, it is possible to estimate how much yields are affected by salinity. These estimations have uncertainty bands, that depend on the variation of drought (hence saline) periods through the years and can be estimated only statistically. Since root zone salt exposure can be functionally related with yields, soil salinity frequency functions incorporate the hazard of crop failure risks. Where the quality of salt tolerance functions seem sufficiently well known, models inadequately represent both recovery of crops from salinity and ecotoxicological mechanisms.

Societal importance for stakeholders

Combined with farmers' experience, a risk assessment to support farm management is feasible. However, for pure prediction and for regional or national assessments using models as NHI, model improvement is necessary for agricultural risk assessment and suggestions are given for this. To predict salt salinity in soils with NHI, though, we developed several simple relationships that are accurate.

DD 3.4-3 EFFECTS OF LOW SALINITY LEVELS ON THE GROWTH OF PLANT SPECIES FROM DUTCH FENS

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Lowland ecosystems could be exposed to seasonally increased surface water salinity levels as a result of both climate change and increased upwelling of brackish groundwater. For policy makers and water managers it is useful to know the effects of salinity on these systems, to evaluate water management options in times of fresh water scarcity. We focused on plant species in Dutch terrestrializing fens. The plants at the edges of the floating root mats are in close contact with surface water and determine the structure and persistence of these ecosystems. Furthermore, they host a wide diversity of plant species, including red list species. Little is known about the salt tolerance of these species. To predict the impact of such exposure, ecologists can estimate sensitivity based on spatial distribution data or by the study of plant traits. However, these methods may not reflect the effects of temporary exposure to low levels of salinity.
Our research question is: How do low salinity levels affect plant species from terrestrializing fens?
We selected five species that exclusively occur in freshwater environments and exposed them to five low salinity levels and one control concentration in a greenhouse experiment. None of the selected species showed any particular traits regarding salinity tolerance. Results showed an overall biomass decrease starting from 200 mg/L Cl-. However, sensitivity (defined as relative growth rate RGR decrease compared to control group) differed significantly between species, with one species (*Comarum palustre*) showing no significant sensitivity up to a salinity level of 3000 mg/L Cl-. The other species showed mortality and significant reduction RGR, changes in root-shoot ratio and strong increases in wilted tissue.
Sensitivity differs significantly between plant species, and may not reflect long term spatial distribution patterns or salinity related traits. Regardless, threshold salinity levels derived from spatial distribution data may be useful as a conservative estimate for management purposes, on the condition that the data is of sufficient quality (e.g. high enough resolution). Policy makers and water managers should take into account that plants from the terrestrializing edges of floating fens can be affected by low salinity levels (200 mg/L Cl-) within a timespan of weeks. It yet needs to be assessed how much the root zone of floating fens may be exposed to short periods of increased salinity levels of adjacent surface waters.

DD 3.4-4 WATER AVAILABILITY: CLIMATE CHANGE ADAPTATION IN THE AGRICULTURAL SECTOR IN THE CZECH REPUBLIC

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As agricultural practices are climate-dependent and yields vary over years depending on shorter term weather patterns, the agricultural sector is particularly exposed to climatic change (Moriondo et al., 2010). Changes in temperatures and rainfall patterns directly affect crop yield and subsequent food production and indirectly affect changes in water availability (Nelson et al., 2009). In the Czech Republic, there is a significant tendency to more intensive dry episodes in the region, driven by temperature increase and precipitation decrease. These drought episodes have a substantial impact on national and regional agricultural production, with yields being consistently lower than in normal years.

Case study areas, Ústí region and South Moravian region are one of the driest areas in the Czech Republic. In Ústí region, we focus on hop growing sector, which covers more than 73 % of the total hop planting area in the Czech Republic. A particular specialty of South Moravian region is winegrowing, with more than 90 % of the total area of vineyards in the Czech Republic, which makes it vulnerable towards expected climate change impacts. The aim of the research is to investigate perceptions of local stakeholders towards climate change (in particular water availability, drought) as well as preferences towards suitable adaptation measures and strategies in particular agricultural sector. In order to investigate these questions, survey among farmers has been performed within the FP7 BASE (Bottom-up Climate Adaptation Strategies towards a Sustainable Europe) project.

Our preliminary results show that climate change impacts are perceived as important factor affecting agricultural production. However, climate change adaptation is currently not sufficiently mainstreamed into agricultural policies in the Czech Republic. Analysing perceptions of local stakeholders towards climate change impacts has the potential for policy implications, and can support the decision-making processes concerning regional agricultural adaptation policies.

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DD 3.4-5 SUMMER PATHWAYS OF WATER AND SOLUTES IN AN AGRICULTURAL FIELD

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Research question

Research on the flow of water and solutes in summer periods in humid climates is sparse, owing to an historical focus on runoff events and the relatively minor contribution of summer periods to the annual water balance. However, even in humid climates water is scarce during summer periods, resulting in decreasing crop yields or necessitating costly water allocation schemes. Climate change is expected to aggravate future water shortages. In the Netherlands, exfiltrating brackish groundwater, adversely affecting surface water quality, is an important secondary problem in case of fresh water scarcity. Our study therefore aims to better understand the flow of water and solutes specifically in summer periods, by investigating the water and salt balance of an agricultural field in the Netherlands.

Methods and results

We instrumented an agricultural ditch to enable direct measurements of water fluxes and salinity to both agricultural drains and the ditch separately. Measurements focused on the summer period and were taken during two measurement periods: May 2012 - November 2012, and April 2013 - October 2013. We subsequently modeled the flow of water, solutes and temperature within a rigorous uncertainty framework.
Our combined measurements-modeling approach allowed for a high-frequency separation of hydrological flow routes on this agricultural field. We observed and modeled a quick response of drain flow and a more damped ditch response. Drain salinities decreased during discharge events, the salinity of ditch exfiltration showed a more complicated response. Water loss was mainly attributable to infiltration, but without a significant groundwater response.

Societal relevance

Understanding the summer water balance is important for water managers and users, as fresh water scarcity results in a degradation of water quality and decreasing crop yields. This understanding is especially important in deep polder areas in the Netherlands, where brackish groundwater seepage (upward flowing regional groundwater) results in a significant salt load to surface water, and may damage crops if salts reach the root zone in dry summers. Improved insight in the fate of allocated fresh water resources allows for more (cost-)efficient water allocation schemes, making better use of scarce resources.

DD 3.5-1 UNDER WHAT CONDITIONS WILL LOCAL TO REGIONAL SOLUTIONS FOR FRESH WATER MANAGEMENT BECOME ATTRACTIVE?

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Coastal areas and delta's worldwide are threatened by changes in climate, subsidence and salinization with consequences for local livelihoods, food production and ecology. This often poses serious challenges for fresh water demand and supply in these areas. Different strategies for adaptation exist both on a large scale (including large reservoirs and extensive water supply systems) as on a more local to regional scale (increasing water use efficiency, increasing local water availability, adapting land use, etc.). This paper will focus on these local to regional adaptation strategies to cope with increasing (at the same time uncertain) salinity and droughts. It explores a series of research questions: What range of external 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)? What approach should be used to build robust and flexible adaptation strategies, given the uncertainties in the long-term prediction of future climate change effects, and of other relevant socio-economic developments? Which concrete options for adaptation are available on the local to regional scale in smarter water management, land use (crops) or in applying innovative water technology? How are risks and options perceived by local stakeholders and how can improved understanding by stakeholders contribute to better adaptation?
The paper will try to summarize end results of the Netherlands' Knowledge for Climate research program on Fresh water supply. It will present the new results on the above mentioned research questions in relation to the existing body of literature, results that are for a large part based on experimental evidence drawn for field and modelling experiments applied in case studies, mostly in The Netherlands. It explores how the local insights and knowledge gained from casestudies may have much wider applicability may be up-scaled and be of benefit to local to regional fresh water supply in other areas where people and economies might be threatened by shortages.

DD 3.5-2 IMPLEMENTING OPTIMAL FRESH WATER SERVICE LEVELS IN TIMES OF CLIMATE CHANGE

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Research question
How to develop and implement a governance agreement and investment portfolio among stakeholders on fresh water service levels to allocate regionally scarce fresh water resources. Allocation of fresh water is important to ensure maximum well-being and wealth in periods of drought (that will appear more frequently as result of climate change).

Methodology
A cost effectiveness and cost benefit framework is developed that on the one hand distinguishes different scales and levels, and on the other hand selects efficient measures to combat drought (e.g. save water, reuse water, distribute water efficiently). We compare the present versus future social costs and benefits for distinguished economic sectors and ecosystem services.

The analysis starts at the user level and selects the adaptation measures that can be taken at that level, given a certain quantity of fresh water. Adaptation measures at the next higher spatial level are evaluated whether they can be implemented more effectively (and efficiently) than the measures at user level. This approach is repeated at the next level to develop a set of cost efficient measures that can be implemented at different levels. Special attention is required for water users that are not able to implement adaptation measures themselves, e.g. ecosystem services The next step is to analyse whether the goals of private stakeholders differ from social optimal climate adaptation policies. Insight in these incentives helps to predict users' behaviour, and to develop incentives and governance structures appropriate to make them behave in such a way as to maximize the social benefits of scare fresh water resources.

Research results
Instead of government investments in large scale measure to provide drought prone areas with sufficient water, an incentives based approach will stimulate water users to implement measures themselves more efficiently. In the long run this approach will stimulate the adoption of new water saving technologies. Public water services are served best by infrastructural measures.

Societal importance for stakeholders
To facilitate the socially optimal provision of fresh water, the available fresh water has to be linked with public and private decision-making. The government has to warrant a proper amount of water for the water users that cannot invest in measures or substitute water for other resources (e.g. nature and poor people).

DD 3.5-3

ADAPTATION TURNING POINTS: IMPLICATION OF CLIMATE CHANGE FOR WATER SUPPLY IN THE PEARL RIVER DELTA, CHINA

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Concerned decision makers increasingly pose questions as to whether current management practices are able to cope with climate change and increased climate variability or whether alternative strategies are needed. Climate research has typically focussed on assessing the extent of climate impacts. Yet, at least equally important is the question for how much longer current policies and management are expected to suffice and when adjustments will be required.
In this paper, a methodological approach for identifying the policy implications of climate change is first presented and then applied to water management in the Pearl River Delta, China. This approach focuses on the identification of situations where policy objectives and societal preferences are compromised by climate change. We call this situation an 'adaptation turning point'. The assessment of adaptation turning points translates uncertainty about the extent of climate impacts into a time range over which it is likely that specific impacts occur and which can be used to take adaptive action. This paper will discuss the theoretical basis (how to define, identify and quantify adaptation turning points) and case evidence of adaptation turning points in the Pearl River Basin, China. The paper hopes to contribute to the ongoing debate on adaptation to climate change in Pearl River Delta by focusing on the specific situation where, due to climate change, the long-term sustainability of water supply in is risk. We aim to identify the

moment in time at which safe water supply may be compromised by climate change and the time window available for adaptation. The paper combines results from literature review and stakeholder consultation about objectives and critical situation in water supply with projections of a hydrological model and a water use model under different scenarios, including the recent IPCC RCP4.5 and RCP8.5 scenarios. For constructing adaptation pathways the paper discusses proposed management options and recent innovations to reduce salt intrusion and secure water supply. Experience so far is that expressing uncertainty in time (when will a critical point be reached) is easier to understand for stakeholders than the more typical presentation of the amount of change in a certain projection year. In addition, the assessment allowed for a meaningful dialogue between stakeholders and scientists about the amount of change that is acceptable, when conditions could be reached that are unacceptable, how likely these conditions are and what adaptation pathways to consider.

DD 3.5-4 POND ECOSYSTEMS: AN EFFECTIVE RESOURCE BASE FOR COMMUNITY BASED ADAPTATION TO CLIMATE CHANGE

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Climate induced hazards are expected to adversely affect the small isolated pond ecosystems (freshwater sources) in Bangladesh. Many of the poor households depend on these ponds for drinking water and other domestic needs, especially in the coast of the country. Variations in temperature, erratic behavior of rainfall, cyclonic events and salinity intrusion deteriorate pond water quality in the South-West coastal district of Satkhira,. A study consisting of both quantitative and qualitative tools were used to explore how climate change affects these ponds and associated livelihoods. The reseacrh also explores how the existing resources can be utilized as the capital of the local communities to adap with climate change. The survey covered 309 households in three study villages. The paper mainly argues in favor of the fact that the pond ecosystems can be a potential resource base for community based adaptation in the coastal regions of Bangladesh. More than 50% households expressed that temperature, rainfall variations and salinity intrusion directly and indirectly affect pond water. About 61 % households believe that the deterioration of the pond water quality is the main cause for increased incidences of diarrhea. Cyclone Aila in 2009 inundated most of the study ponds with saline water. This in turn affected small scale pond based irrigation and cultivation of fisheries for at least three consecutive years.

DD 3.5-5 RISK BASED DETERMINATION OF SERVICE LEVELS FOR FRESH WATER SUPPLY IN THE NETHERLANDS

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The Netherlands are situated at the downstream end of the rivers Rhine and Meuse. During periods with precipitation deficits, society is highly dependent on these rivers for its supply of fresh water, e.g. for water level management, drinking water supply and irrigation.
In order to assess the sensitivity of fresh water supply for climate change, Rijkswaterstaat currently develops a risk

based method, called 'Multi-layer water management', for the determination of service levels. The approach accounts for the priorities of the law-based 'Verdringingsreeks' (i.e. Water consumption hierarchy). This abstract addresses the the determination of return periods of demand and supply leading to water shortages in the Netherlands. The application of the methodology is illustrated with an example from the Meuse catchment area.
The availability of fresh water depends on the local situation at the intake location. Unavailability can be caused by e.g. low discharge or high salt concentration. Therefore, all intake locations in the national water system were divided in four different groups accounting for local characteristics. In order to assess the impact of climate change on water shortages, climate scenarios developed by KNMI were compared with a baseline. The comparison includes the scenarios G 2050, G 2100, W+ 2050 and W+ 2100 (numbers indicate target years).
Due to the correlation of water demand and river discharge, assessment of water shortages requires that the joint distribution is considered. Data of demand and discharge were derived from runs with a nationwide hydrological model, the Netherlands Hydrological Instrument (NHI). Its basis is a state-of-the-art coupling of groundwater (MODFLOW), unsaturated zone (metaSWAP) and surface water (MOZART-DM) models. The total area is divided in 244 districts for water supply. River discharges and water demands are calculated on a 10-day basis covering a period of 30 years.
The joint probability of water demand and discharge deficit was described with a transformed bivariate normal distribution. For computational convenience, discharge deficit was used instead of actual discharge. Transformation was based on the optimal power according to the Box-Cox method. The parameters of the transformed distribution were calculated using Maximum likelihood estimation. To avoid the impact of small values on estimated parameters, both water demand and discharge deficit were censored at a threshold near zero. Calculation of return periods of water shortages was based on a failure region and estimated using Monte Carlo simulation.

Deltas in Depth Theme 4:

Coastal systems and wetlands

DD 4.1-1 SUSTAINABLE MANAGEMENT OF DELTAS IN A CLIMATE CHALLENGED, ENERGY SCARCE WORLD

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Research question

The next several decades will be a time when climate change impacts will become increasingly severe and energy of all sorts will become much more expensive and scarce. These forces will affect the sustainability of deltaic management. The central question of this presentation is how can deltas be managed in the face of increasingly severe climate impacts when energy scarcity will limit options for management. Several issues related to climate change and energy scarcity will be addressed. For climate, these include temperature increase, accelerated sea-level rise, increased frequency of strong storms, and change in freshwater input to deltas. Energy scarcity is related not only to the availability of energy but also the net yield of different energy sources.

Research results

It is anticipated that global temperature will increase from 2 to 6 C in this century. This will likely result in a sea level increase of 1-2 m and an increase in the frequency in tropical storms on the order of 10-20%. Climate change will lead to both increases and decreases in freshwater availability to deltas and human activity will likely reduce freshwater availability, especially in dry areas. Availability of conventional fossil fuel resources will progressively decrease during this century and it is unlikely that unconventional sources (e.g., shale oil and gas) will be able to substitute for conventional sources to any great extent. As energy scarcity grows, the net energy yield of different energy sources will decrease. The Energy Return on Investment (EROI) of most fossil fuels is decreasing. For example, the EROI of conventional oil was about 100:1 in the middle of the 20th century but it has now decreased to between 20:1 and 10:1. This is very important because most delta management is very expensive and energy intensive.

Societal Importance for stakeholders

Deltas are extremely important both economically and ecologically. The value of ecosystem goods and services of deltas world wide is very high; hundreds of billions to trillions of dollars. Highly energy intensive management approaches will become less and less viable during this century because of the increasing cost of energy. Ecotechnology, and more specifically ecological engineering and self-design, are appropriate bases for sustainable delta management. This offers a cost effective alternative to energy intensive approaches. Highly engineered, energy intensive approaches such as exist in The Netherlands and the Mississippi delta will likely not be sustainable.

DD 4.1-2 SHATT AL-ARAB RIVER (SOUTHERN IRAQ) PRESENT AND FUTURE

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The Shatt Al-Arab River, part of the Euphrates-Tigris river system, forms the main source of fresh water for southern Iraq and plays an important role in maintaining the ecological balance of marine habitats in the north-western Arabian Gulf.

Upstream large-scale development of water regulators and dam structures, together with the drainage and re-flooding of the Mesopotamian Marshlands, a highly variable climate and droughts have instigated severe water shortages and river salinization caused by the intrusion of salt water wedges from the Gulf. This endangers agricultural activity along the river, causing substantial damage to what was once recognized as some of the largest date palm plantations in the world. Agriculture, the fishing industry and marine ecosystems have also suffered degradation in the delta area. What then, are the current and future challenges facing the Shatt Al-Arab River and what are the environmental and social implications?

Historic data of water quantity and quality were compared to data from the study of different sections of the river to examine the changes over the past few decades. A numerical model was used to simulate different scenarios to predict current and future changes.

The results show significant changes in the hydrological and physico-chemical characteristics of the upper reaches of the river. The amount of water discharged to the river via the Tigris-Euphrates river system has reduced over the years from 250m^3/sec ten years ago to quantities averaging no more than 50m^3/sec in recent years. The (TDS) has increased from 1.5 mg /L to 2.5 mg / L in 2013. The lower reaches of the river near the city of Al-Faw are dominated by saline waters due to diminishing volumes of fresh water from upstream. The findings from this study suggest a change to semi enclosed estuary characteristics.

Changes in water quality far exceed the guidelines for irrigation. This limits agricultural activities to highly salt-tolerant produce, deeming the river especially at the lower section unsuitable for human consumption. These changes have impacted on the ecosystem and the socio-economic status of the residents. Many have relocated to neighbouring cities, abandoning their agricultural and fishing livelihoods.

Simulation studies of the sediment deposition and transportation in the Delta of Shatt Al-Arab and measurement of TSS show significant shrinking of the delta towards the inner parts of the banks of the river rather than extending outwards due to overwhelming sea energy moving against the reduced discharge from the river.

DD 4.1-3 IMPACTS OF CHANGING CLIMATE PROJECTIONS ON RESTORATION OF THE MISSISSIPPI RIVER DELTA

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Research question
Can society adapt quickly enough to revised projections of climate change, sea level rise, wetlands loss and the end of cheap energy to save the Mississippi River Delta, one of the most vulnerable coastal landscapes on earth?

Methodology
A panel of leading scientists, engineers and socio-economic experts convened by the Environmental Defense Fund, National Audubon Society and National Wildlife has provided new understanding of the most significant obstacles facing restoration of the Mississippi River delta. The Scientific and Engineering Special Team (SEST) recently published its findings in a new book titled *Perspectives on the Restoration of the Mississippi Delta*, the first in the Springer series 'Estuaries of the World.' Release of the recent IPCC update on climate change (WGII, AR5) provides an opportunity to recalibrate restoration scenarios at the regional scale, including that now in progress for the Mississippi River delta. Bayesian and Monte Carlo statistical techniques were used to reassess the utility of adaptation options currently competing for funding.

Research results
New IPCC projections are still being absorbed by policy makers who must prioritize funding for actions to restore the Mississippi River. These range from long-distance pumping of offshore and river sediments to rebuild vanished wetlands to reconnecting the Mississippi River and entraining river sediments to disappearing delta wetlands and estuaries. The findings of the SEST report on the drivers for delta deterioration provide a starting point for statistically forecasting the comparative effectiveness of such measures over the revised range of climate change scenarios.

Societal importance for stakeholders
As is true for most large restoration programs, allocation of scarce restoration funds to different projects is a wickedly complex problem for political leadership. Decision-makers face an array of stakeholders, with very different perceptions of what must be done, including fishers, residents afraid of hurricane surge, and deeply entrenched economic interests like ports and the oil and gas industry. Proposed restoration projects will necessarily involve controversial trade-offs in the short-term, without which long-term sustainability is unachievable. Sound forecasts based on robust statistical methods can play an important role in ensuring that long-term consequences are adequately considered.

DD 4.1-4

ENVIRONMENT AND WATER RESOURCES VULNERABILITY IN THE LOWER ESTUARY OF THE SENEGAL RIVER FROM 2003 TO 2013

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The Senegal River estuary and its coastal interface the 'Langue de Barbarie,' sandy spit formed by the coastal dynamics, are highly vulnerable ecosystems where live disadvantaged and low economic communities. The effects of the Sahelian drought of 1970 resulted in a fragile hydrological, climatic and ecological balance. To overcome the reduction of freshwater inflows in the valley and delta, large dams have been established on the Senegal River; Diama downstream and Manatali upstream. However, in the lower estuary and the natural region of Gandiolais, the management of these dams causes serious environmental problems such as freshwater scarcity and especially recurrent flooding of the city of St. Louis.
The opening of a breach on the Langue de Barbarie in October 2003 was justified by the impending floods in St. Louis. After rapid drainage of waters and thus preservation of the city of St. Louis, this breach became the new mouth of the Senegal River. With an initial aperture of 04 m, the gap reaches a width of 5543 m ten years after, according to the monitoring carried out from LANDSAT satellite imagery. More than the rapid and dramatic expansion, it is the environmental and socio-economic impacts that are of concern today, putting this eco-socio-system at a critical stage of its evolution. The accumulation of vulnerability factors such as hypersalinization water and agricultural lands, rapid morphological changes of the 'Langue de Barbarie' spit sand caused by severe erosion at the coast, constitutes now a major challenge for local communities. Despite adaptation efforts of communities through the development of activities such as salt extraction or transfer of market gardening activities to less-favored areas, the situation is highly alarming, given the impoverishment of local communities. The evolution scenarios defined on the basis of knowledge are afraiding opening new loopholes as in 2012, which would correspond to a real disaster for the region.

DD 4.1-5

THE IMPORTANCE OF SCALE IN DEFINING VULNERABILITY OF THE GANGES-BRAHMAPUTRA RIVER DELTA TO ENVIRONMENTAL CHANGE

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Among the world's deltas, the Ganges-Brahmaputra river delta (GBD) is often cited as being highly vulnerable to future sea-level rise and environmental change, owing to its vast low-lying landscape and large human population. Here we present recent research from the GBD that highlights different, if not divergent, perspectives on the current status of this system and its potential response to future environmental change. The contrasting views emerge at different temporal and spatial scales, raising the question of how scientists, stakeholders, and decision makers might most effectively develop a shared understanding of large, at-risk delta systems.
Taking a broad perspective, the GBD reflects the robust processes (e.g., seasonal monsoon, tides) that have constructed and maintained it. Stream morphology and elevation data from the Shuttle Radar Topography Mission

(SRTM) reveal the system is interconnected by a labyrinth of fluvial and tidal channels that effectively convey sediment to most areas of the landscape through overbank flooding and tidal transport. The long-term stratigraphic record of the GBD also reflects a system in dynamic equilibrium, with major landforms persisting through changes in sea level, sediment loading, river avulsion, and delta lobe switching - together providing an encouraging outlook in the face of ongoing global environmental changes.
Nevertheless, evidence of an inherently robust natural GBD contrasts with areas that have been strongly impacted by human modification. For example, in recent decades 15,000 km^2 of coastal islands have been embanked ('poldered') for flood protection and agricultural development, resulting in sediment starvation and a loss of elevation (>1m) relative to natural tidal landscapes. This elevation loss yields a rate of relative sea-level rise equivalent to 20 mm/yr, more than 4× that observed in the GBD's natural mangrove forest. Furthermore, the reorganization of tidal channels in response to poldering has led to local bank erosion and undercutting or weakening of embankments, exemplified by the occurrence of multiple failures during Cyclone Aila (2009). These findings demonstrate that recent and ongoing anthropogenic modifications of the land surface and their impact could be comparable to, if not larger than, increasing rates of sea-level rise--cause for concern within many localized regions of the GBD. Looking ahead, human alterations of the physical environment cannot be avoided, but we can more reliably restrict negative consequences with a more realistic and precise understanding of human-landscape interactions. Effective risk analysis and the management of complex coastal systems require that scale of interest be well defined.

DD 4.2-1

COASTAL EUTROPHICATION DYNAMICS AND CONTROLS IN A CULTURALLY AND CLIMATICALLY STRESSED WORLD

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Estuarine and coastal watersheds support nearly 75% of the world's human population and they are experiencing unprecedented urban, agricultural and industrial expansion. The freshwater-marine continua draining these watersheds are impacted increasingly by nutrient inputs and resultant eutrophication, including symptomatic harmful algal blooms, hypoxia, finfish and shellfish kills and loss of higher plant and animal habitat. In addressing nutrient input reductions to control and reverse eutrophication, phosphorus (P) has received priority traditionally in upstream freshwater regions, while controlling nitrogen (N) inputs has been the focus of management strategies in estuarine and coastal waters. However, freshwater, brackish and full-salinity components of this continuum are connected structurally and functionally. Intensification of human activities has caused imbalances in N and P loading, altering nutrient limitation characteristics and complicating successful eutrophication control along the continuum by reducing only one nutrient. Numerous examples worldwide increasingly indicate the need for dual N and P input constraints as the only effective nutrient management option for long-term control of eutrophication. Climatic changes, specifically increased variability in freshwater discharge associated with more severe storms and intense droughts, interact closely with nutrient inputs to modulate the magnitude and relative proportions of N and P loading. The effects of these interactions on phytoplankton production and composition were examined in two neighboring North Carolina (USA) lagoonal estuaries, the New River and Neuse River Estuaries; which are experiencing concurrent eutrophication and climatically-driven hydrologic variability. Efforts aimed at stemming estuarine and coastal eutrophication in these and other similarly-impacted estuarine systems should focus on establishing N and P input thresholds that include effects of hydrologic variability, so that eutrophication, harmful algal blooms and habitat degradation can be controlled over a range of current and predicted climate change scenarios.

DD 4.2-2 CYCLONE INDUCED SALINITY INTRUSION CAUSES LOSS AND DAMAGE IN RICE FIELDS IN THE COAST OF BANGLADESH

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Saline intrusion related to climate stressors will become one of the most important issues in future. Salinity intrusion in soil and sources of freshwater caused by climate induced hazards especially cyclone and storm surges is adversely affecting the rice production in Satkhira, one of the most vulnerable coastal districts in terms of exposure to cyclonic events and sea level rise. A set quantitative (household survey) and qualitative tools (Focus Group Discussions, In-depth Interviews and Community Consultations) were applied to assess how the loss and damages were caused by salinity intrusion induced by cyclone Aila in the study district. The survey covered 360 households in four study villages. This paper explores the household level impact of salinity intrusion on rice production, how people adapt, and how different categories of households (e.g. size, land ownership, income) experience loss and damages. Salinity intrusion instigated by cyclone Aila devastated the rice production for three consecutive years (2009-2011). About 86 percent study households expressed that the rice production (aman) has decreased because of salinity intrusion in soil. The economy of the most of these households (99 percent) were found to be adversely affected by salinity induced factors including decrease of rice production, increase expenditure for additional irrigation, reparation of seed beds etc. It was also found that 61 percent of the farming households took adaptation measures to some extent. Of which, 39 percent practiced saline tolerant varieties to adapt with changing condition. However, the adaptation measures helped only for 13 percent households to improve the situation while 69 percent indicated that negative impacts still exist. This study also provides evidences that the loss of extreme poor households (52 percent) was about 74 percent of its last annual income due to cyclone induced salinity intrusion in rice fields in 2009. The lessons learned here would help us get an indication of what might happen elsewhere.

DD 4.2-3 PROJECTING FISH PRODUCTION IN BANGLADESH UNDER CLIMATE CHANGE

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The fisheries industry provides a crucial source of income and food to Bangladesh, and is second only to agriculture in the overall economy of the country. Fisheries accounts for 4.4% of Bangladesh GDP, 22.8% of agriculture sector and 2.5% of total export earnings. It also contributes 60% of the animal protein intake in Bangladesh, and even higher in populations near the coast. Inland capture fisheries contribute 1 Mt of fish catch, and marine capture fisheries an additional 0.6 Mt (2013 data). There is also a significant contribution of aquaculture products (ca 1.7 Mt) from ponds, haors, baors and shrimp farms. The main captured species (in both inland and marine catches) is Hilsa shad (*Tenualosa ilisha*), which accounts for ca 10.6% of the inland and marine catches. Hilsa is an anandromous fish widely distributed in the Indian Ocean. As part of the ESPA Delta project we are developing tools to predict the long

term productive capacity of Bangladesh marine fisheries, with particular interest in Hilsa shad. These tools are based on climate-driven ecosystem modelling projections of water properties, primary and secondary production in the Bay of Bengal, which are used to develop size-based and species-based predictions of fish productivity changes in the period up to 2040. Here, we present the fish projections for Hilsa Shad and total fish potential production of the Bay of Bengal, by size classes. These projections are contrasted with public data and survey data collected for that aim in ESPA-DELTA. Finally, these projections are contextualized in terms of the meaning for societies that are highly dependent on natural resources.

DD 4.2-4 PEATLAND MANAGEMENT IN A CHANGING WORLD

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Peat soils cover a large part of the western and northern Netherlands. Drainage for agriculture has caused increased soil aeration which has stimulated peat decomposition and, hence, soil subsidence. Current subsidence rates amount to 1-2 cm/yr, while most of these areas are already located several meters below sea level. So, these areas are vulnerable to flooding and management is complex and costly. Peat decomposition leads to high CO_2 emission rates; CO_2 is an important greenhouse gas.
Extreme summer droughts are expected to occur more often in the future in NW Europe due to climate change. During these droughts deep peat layers that had not previously been exposed to air will be oxygenated. River water is supplied to Dutch peat areas in summer to prevent drying out of the peat soils. However, the supply of this water is stopped in dry periods as soon as it has become brackish due to saltwater intrusion and evaporation to avoid possible adverse effects on peat decomposition and agricultural production.

Research question
What are the effects of summer drought and salinization on peat decomposition?

Methodology
We measured decomposition rates of peat samples from four sites contrasting in peat type (with the remains of a eutrophic vs. oligotrophic vegetation) and land use (agriculture vs. nature protection). We adapted salt and oxygen concentrations depending on the research question.

Results
As expected, aerobic decomposition rates were higher than anaerobic decomposition rates. Surprisingly, the decomposition rates remained high in anaerobic conditions after a brief period of oxygenation. We found that even one week of oxygenation released a latch on decomposition. In a thirteen-week period, one week of oxygenation increased decomposition rates with 80-350%, depending on peat type. Furthermore, we found that the aerobic decomposition rates were approximately reduced by 50% after salinization, whereas the anaerobic decomposition rates remained unchanged.

Societal importance
Dry episodes enhance the decomposition of deep pristine peat layers substantially, both short- and long-term. On the other hand, supplying brackish water would reduce decomposition rates. Therefore, we suggest that providing brackish water during dry periods would be a promising measure to reduce subsidence rates.

The research outcomes were used in stakeholder workshops. There, the stakeholders compiled spatial visualizations of the effect of climate change and peatland management on subsidence rates and the consequences for targets for agriculture, nature and recreation on an interactive mapping device. Doing so, we facilitated decision-making about the future management of Dutch peatlands.

DD 4.2-5 ENHANCED OLIVINE DISSOLUTION: CREATING A COASTAL CO_2 SINK?

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Research question
At present, enhanced olivine dissolution as a geo-engineering approach to counteract Ocean Acidification (OA) and capture CO_2 is only conceptual, and has not been studied beyond the large-scale modelling and sterile laboratory stage. A critical unknown is the kinetics of olivine dissolution under natural conditions in marine coastal environments. Various processes like wave-induced grain abrasion, dissolution by microbially-produced CO_2 (metabolic dissolution) and ingestion and transport processes mediated by bottom-dwelling macrofauna (bioturbation) may affect the dissolution rate of olivine in coastal settings.

Research results
To examine the dissolution of olivine in coastal settings, we performed olivine dissolution experiments in simplified mesocosm models, where olivine was subjected to different representative treatments. One experiment consisted of olivine grains subjected to constant shaking in solution media of increasing geochemical and biological complexity (artificial seawater, artificial seawater with and without Ca^{2+} and/or Mg^{2+}, natural seawater). In another experiment, olivine was placed in experimental aquaria with and without marine worms processing the olivine sediment. In both cases, significant increases in seawater alkalinity, dissolved inorganic carbon and pH were observed, while the reaction products silicate and nickel also showed elevated values.

Societal importance for stakeholders
As atmospheric CO_2 levels are rising, the surface ocean carbonate system changes via air-sea equilibration processes. This process is known as Ocean Acidification, described by the reaction:
CO2 (aq) + H2O ↔ H2CO3 ↔ HCO3- + H+ ↔ CO32- + H+

Ocean Acidification (OA) affects the global ocean on several levels
On the organism level, calcifying organisms like shellfish and hard corals, but also calcifying algae, are highly dependent on seawater chemistry: pH, alkalinity and carbonate saturation states in particular. Mentioned organisms are often at the base of marine foodwebs and/or provide physical structures (e.g. oyster reefs, coral reefs), which are paramount to the biodiversity and functioning of marine ecosystems. At the global level, the oceans take up circa 25 % of the yearly emitted CO_2. OA is therefore decreasing the ocean's CO_2 uptake and buffer capacity and diminishing its "geo-engineering potential".
To promote CO_2 uptake in coastal seas, one geo-engineering approach that has been proposed is to stimulate the rate of olivine dissolution, by distributing it on beaches, along coasts and in lagoons, integrated in existing sediment management programmes (e.g. dredging activities, beach nourishments, artificial islands). We discuss the potential of enhanced olivine dissolution for counteracting Ocean Acidification on a local scale, and creating coastal CO_2 sinks.

DD 4.3-1 THE STATE OF DELTAS IN TIMES OF CLIMATE CHANGE: CHALLENGES AND OPPORTUNITIES IN DATA COLLECTION AND INTEGRATED DELTA MODELING

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Deltas worldwide are hotspots of economic activity while also providing valuable ecosystem services. A solid knowledge base and predictive modeling framework for protecting these vulnerable coastal systems is imperative, and the DELTAS Belmont Forum initiative coordinates and enhances an innovative international work towards the development of a science-based framework for delta sustainability.

The biogeophysical and socioecomomic dynamics of delta systems are complex and intertwined, requiring a suitably versatile modeling framework that is scalable and may be applied from local to national levels to evaluate the unique functioning, critical stressors, and vulnerability of the world's deltas. A versatile framework needs to ingest both social, economic, and physical and ecosystem data into an open-access repository to allow planners to model and deliver optimized, viable solutions for their region. Additionally, it is a grand challenge to model delta systems in a truly coupled manner; numerical process models need to be creatively manipulated to allow for better science understanding of the human influence on delta processes. Another important basic challenge lies in the common definition of 'a delta region' and thus the specification of suitable boundary conditions for any modeling exercise. Any delta is inherently linked to its river drainage basin and its marine domain, but in what manner must numerical models and datasets treat the linked upstream-local delta-ocean system system, that is, as a continuum of linked processes or pre-specified treated as boundary conditions operating on a unique local delta which sits at the interface of land and ocean-borne forcings?

Recent advances in data management systems and delta-wide data collection efforts have made new intra- and inter-delta systems-based research possible. Inter-delta comparison studies rely on geographically broad, ideally global, datasets for consistent analysis of delta dynamics. SRTM topography, GRUMP and GPW population provide a global description of deltas and their populations in the coastal zone. Advancements in remote sensing of river discharge, surface inundation, subsidence and the coastal ocean provides new insight into delta hydrology and coastal zone risk. This is opening new research into the commonalities between delta systems, and how they respond to geophysical and anthropogenic change. Collaborative data analysis is being supported by new data management technologies, such as iRODS.

Similarly, paradigms in numerical process modeling have been shifting. The Community System Dynamics Modeling System - CSDMS- allows for easy user interaction through graphical user interfaces, model interoperability between different programming languages, protocols and low-level model coupling of models. New numerical models are now designed with standard interfaces to be 'couplable' and to operate with flexibility though simple web-based clients. Simple component models may serve a role in policy making and long-term planning, whereas detailed physics-based engineering models need to provide predictions at the local scale.

Increasingly, collaborative research efforts are multi-national in scope, and improved data management strategies and technologies are critical to success. Here we will outline how new data-sharing technologies and modeling frameworks are being used in the Belmont-DELTAS international research effort.

DD 4.3-2 BELMONT FORUM DELTAS PROJECT (BF-DELTAS) - TO SUSTAIN THE RESILIENCE OF DELTAS

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Background

The Belmont Forum-funded DELTAS project (BF-DELTAS: *Catalyzing Action Towards Sustainability of Deltaic Systems with an Integrated Modeling Framework for Risk Assessment*) is a partnership of institutions from the USA (University of Minnesota, lead institution; University of Colorado-Boulder; Vanderbilt University; Indiana University; City College of New York; and Conservation International); Japan (Geological Survey of Japan; and The National Institute of Advanced Industrial Science and Technology); France (Aix-Marseille University); United Kingdom (World Conservation Monitoring Center; University of Southampton); India (Anna University); Netherlands (Deltares); Bangladesh (University of Dhaka; Bangladesh University of Engineering and Technology); Vietman (Vietnam Academy of Science and Technology; World Wide Fund for Nature - Greater Mekong); Norway (Norwegian Institute for Air Research), Germany (German Aerospace Center; United Nations University); Brazil (University of Vale do Paraíba); Canada (Natural Resources Canada; University of Waterloo); and China (Nanjing University). The project is focused on increasing our understanding of the physical, ecological, and socio-economic aspects of deltaic systems which will, in turn, guide decision making to ensure sustainability and well-being of deltas in the face anthropogenic and climate stressors.

Objectives

The goal of BF-DELTAS is to develop a science-based integrative modeling framework that can be used to assess delta vulnerability and guide sustainable management and policy decisions at the regional and local scales. The specific elements of the project are: (1) Delta-SRES, to develop a theoretical framework for assessing delta vulnerability and the possibility for transitions to undesired biophysical or socio-economic states under various scenarios of change; (2) Delta-RADS, to develop an open-access, science-based, integrative modeling framework called the Delta Risk Assessment and Decision Support (RADS) Tool that will support quantitative mapping and definition of functional relationships of the bio-physical environment of deltas as well as their social and economic dynamics; (3) Delta-DAT, to consolidate data on bio-physical, social, and economic parameters into an international repository of integrated data sets and make these readily available; (4) Delta-GDVI, to develop Global Delta Vulnerability Indices that capture the current and projected physical-social-economic status of deltas around the world ('delta vulnerability profiles'); and (5) Delta-ACT, to work with regional teams and stakeholders *to put the products of Delta-SRES, Delta-RADS and Delta-DAT into action*, by demonstrating the implementation of the developed framework in three major deltas (Ganges-Brahmaputra-Meghna, Mekong, and Amazon deltas) before extending it to other deltas around the globe.

Possible role of BF-DELTAS in the SD2015 initiative

The DELTAS project will supply the actionable research, decision-support tools, databases, as well as the expertise and knowledge of the project's researchers, that can help achieve the SD2015 objective of increased awareness and attention to the value and vulnerability of deltas worldwide. The multidisciplinary and international research team of the DELTAS project will can help promote the regional cooperation at the scientific, policy, and stakeholder level that is necessary to achieve delta sustainability. A requirement of the DELTAS project is the dissemination of its outputs to diverse groups of researchers, managers and decision-makers at international meetings. When DELTAS collaborators attend these meetings, they will also have an ideal opportunity to engage

a broad audience in discussions on SD2015 (such as at the sessions of Deltas in Time of Climate Change II). Also, the DELTAS project includes training of, and collaboration with students and early career researchers, which will also be an important component of SD2015.

DD 4.3-3 DELTA ALLIANCE - FOR THE RESILIENCE OF DELTAS WORLDWIDE

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Background

Delta Alliance is an international knowledge-driven network organization with the mission of improving the resilience of the world's deltas. With increasing pressure from population growth, industrialization and a changing climate, it is more important than ever that these valuable and vulnerable locations increase their resilience to changing conditions. Delta Alliance brings stakeholders involved in delta management together in order to benefit from each other's experience and expertise and as such contribute to an increased resilience of their delta region, building on scientific research and practical experiences.

Delta Alliance has ten network wings where activities are focused: California Bay (USA), Ciliwung and Mahakam (Indonesia), Mekong (Vietnam), Rhine-Meuse (the Netherlands), Nile (Egypt), Pantanal (Brazil), Ganges-Brahmaputra (Bangladesh), Mississippi (USA), Yangtze (China) and Parana (Argentina). Some other 10 deltas have shown keen interest to join the Delta Alliance network, notably from Ghana, Taiwan, Senegal, Kenya, Ghana, Benin, Rumania, Myanmar, Italy, Spain.

One of the most important research activities of the Delta Alliance in the past years was a comparative assessment of the vulnerability and resilience of 10 deltas, addressing various aspects of delta development and management of the following deltas: Nile, Incomati, Ganges- Brahmaputra-Meghna, Yangtze, Ciliwung, Mekong, Rhine-Meuse, Danube, San Francisco Bay and Delta, and Mississippi River. An innovative framework for delta assessment has been applied, sufficiently generic to make this integrated approach applicable to deltas worldwide. The knowledge and research gaps identified give ample opportunities for valuable knowledge exchange and collaborative (research) projects between deltas. Currently this assessment is being complemented with another five deltas: Ayeyarwady (Myanmar), Parana (Argentina), Tana (Kenia), Zambezi (Mozambique) and Ouémé (Benin).

Objectives

Research and investment in addressing the unique challenges of river delta regions are happening in many projects and programs around the world. Delta Alliance provides a framework to support the symbiosis of these countless activities ongoing in delta regions, reducing unnecessary overlap and identifying gaps in efforts. Delta Alliance is a vehicle for increased cooperation between parties in river deltas worldwide, with the ultimate aim of improving the resilience of the world's deltas through more integrated and effective efforts, building on scientific research and knowledge exchange.

The members of Delta Alliance together develop and share knowledge to:

- envision resilient deltas
- measure, monitor and report resilience in deltas, and

- provide inspiration and support for improved resilience in deltas

In pursuing these goals, members strive to:

- share knowledge, expertise and best practices between deltas worldwide
- co-create and integrate knowledge across deltas, sectors and disciplines
- connect expertise and parties from throughout the watershed
- incorporate local knowledge in research and other knowledge-building activities
- provide knowledge and insight to support any use, including education, policy development, investments and disaster response.

Possible role of Delta Alliance in the SD2015 initiative: The Delta Alliance has many linkages with other networks and initiatives such as the Global Water Partnership strategy 2014-2018, the Belmont Forum Deltas project, the GEF Transboundary Waters Assessment Programme, the Alliance for Global Water Adaptation, and the SIWI/UNEP initiated From Source to Sea partnership. This will further contribute to the network and knowledge sharing activities envisaged in the SD2105 initiative.

DD 4.3-4 LAND-OCEAN INTERACTIONS IN THE COASTAL ZONE (LOICZ) - A FOCUS ON THE RESILIENCE OF DELTAS WORLDWIDE

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Background

LOICZ is a core project of the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP). LOICZ aims to provide science that contributes towards understanding the Earth system in order to inform, educate and contribute to the sustainability of the world's coastal zone with a focus on deltas. Deltas are intensively used by humanity worldwide and are increasingly threatened or/and modified by global environmental change as direct human impacts and climate change. They provide biogeochemical functions, coastal protection, and a wide variety of ecosystems goods and services to society. Deltas are maintained by a hierarchical series of energetic inputs and processes. The more energetic and longer term forcings provide large-scale sediment input and control changes in geomorphology while shorter term events are more important for modulating ecological processes. Deltas worldwide are experiencing intense changes in land use, industrial pollution, urbanization, erosion and subsidence, increased storm surges and sea level rise. In recent times, many deltas are eroding at alarming rates as victims of human actions due to the construction of dams and levees, ports and harbors, reduced water and sediment supply, groundwater and hydrocarbon extraction, and land reclamations.

Objectives

LOICZ is working to support sustainability and adaptation to global change in the coastal zone, with river mouth systems, deltas and estuaries as one of the four major hotspots. LOICZ aims to improve the understanding of the physical and human scale of these deltaic systems. Members of the LOICZ Scientific Steering Committee have developed a network of collaborators throughout the world to undertake the following aspects of research that are socially relevant:

- develop estuarine/ deltaic eco-hydrology models that combines oceanography and ecology to predict the fate of nutrients in deltas as well as the health of the delta ecosystem
- promote transdisciplinary approaches to sustainability that integrate biophysical considerations with social and economic factors
- assess deltaic systems in the context of the external biophysical inputs of energy and materials required to sustain them
- develop interdisciplinary indicators of coastal sustainability using co-design and co-production

In trying to achieve the above objectives, LOICZ scientists are promoting an ecosystem-based management of deltas that underlines the need for a broad scale approach to flux and risk assessments in context of global and system based drivers.

Possible role of LOICZ in the SD2015 initiative

LOICZ scientists are already involved in many global partnerships and linkages - key linkages include:
- Belmont Forum research on global deltas,
- the GEF Transboundary Waters Assessment Programme (GEF-TWAP)
- IW Learn (Global Water Assessment)
- Future Earth Program of ICSU

The LOICZ network is continuously expanding through the diverse Scientific Steering Committee and its Regional Nodes, located across the globe, which will enable capacity building and knowledge sharing as envisioned in the SD2015 initiative.

DD 4.4-1 DEVELOPMENT OF DELTAIC AND ESTUARINE WETLANDS UNDER DECADAL AND LONG-TERM CLIMATE VARIATIONS

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Coastal wetland areas around the world are subject to increasing pressure by global climate change and accelerated sea-level rise (SLR). The morphological development of coastal wetlands largely depends on the local tidal range and sediment availability as well as the occurrence of storm events. In estuaries, tidal range and sediment availability can significantly vary from the inner to the outer estuary and exhibit decadal and long-term variations. The riverine sediment discharge and the occurrence of strong and extreme storm events modulate both variables to a large extent.

In the present study, we investigate how decadal and long-term variations in river discharge and storm activity affect the morphological development of the marshes in the Río de la Plata (RdlP). River discharge of the major rivers flowing into the RdlP is influenced by intense human modifications and changes in climatic variables (primarily precipitation) in the river catchment. The El Niño Southern Oscillation thereby appears to have a major impact on the discharge regimes and introduces a large decadal variability on sediment availability for the marshes around the RdlP. Our hypothesis is that such variations are particularly important for the development of the marshes in the inner estuary that are located in the Paraná delta, which is subject to annual progradation rates between 40 and 70 m/yr. In contrast, marsh development in the outer estuary is assumed to be primarily controlled by variations in storm activity.

Using radioisotope analysis, we assess the long-term vertical accretion rates and explore how decadal variability of river discharge and storm activity affects the adaptive capacity of coastal marshes to long-term accelerated SLR. Data from 15 coring sites around the estuary and along the Atlantic coast are used to investigate the relative importance of variations in river discharge and storm activity on vertical accretion rates. Preliminary results indicate a large spatial variability in the marsh morphology along the estuary. Storm-induced waves appear to play a significant role in the development of the outer marshes on the Uruguayan side, while the availability of fine-grained sediments seems to be more important for the marshes in the inner estuary and along the Argentinean coast. In addition to the assessment of spatial variations of the governing hydrological and hydrodynamic drivers for estuarine marsh development, this study also contributes to a better understanding of decadal variability in environmental drivers that impact the long-term ability of estuarine marshes to persist under future climate conditions.

DD 4.4-2 THE ROLE OF NATURAL ACCRETION MECHANISMS IN DELTAIC SUSTAINABILITY. THE CASE OF THE EBRE DELTA

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Deltaic systems illustrate the complexity of coasts subject to marine and fluvial factors, resulting in highly dynamic domains that are suffering a deficit in sediment supply (regulation of the catchment basin, impounded coastal transport...). For the Ebre Delta (Spanish Mediterranean coast) the sediment flux arriving to the delta has been reduced by more than 90%, resulting in a deltaic system that is eroding horizontally and subsiding vertically at rates that produce significant land loss and episodic flooding. The present situation will get aggravated at decadal time-scale due to the expected acceleration in sea level rise because of climatic change, with relative sea level rise rates (regional component plus subsidence) well above the values for other non-deltaic coasts and an impact likely enhanced by changes in storm patterns. The result would be further coastal re-shaping and, therefore, enhanced vulnerability and a growing deficit in system sustainability.
Our main **research question** is how to promote natural accretive processes that may compensate the above described deficits, so that the overall deltaic body becomes more resilient in the face of climatic change and increased development pressures.
Our **research results** will allow quantifying how marine/riverine flooding can contribute sediment volumes that may offset in part the deficit presented above. We shall analyse the efficiency of vertical accretion due to marine and riverine flooding and vegetation trapping. It will be done for a highly erosive transect located at the apex of the Ebre Delta, that will serve to present an actual illustration, based on measurements and some flux calculations, of how natural mechanisms can contribute to the sustainability of this type of deltaic systems. The paper will present the balance between short-term "inconveniences"(local flooding) and mid-term benefits (higher sedimentary volumes). These benefits will become more apparent at longer time scales and under future extreme climate scenarios, a clear message to **stakeholders** who look for reduced vulnerability at the short time scale and forget about the deficits at larger scales. In the conclusions we shall discuss the social and economic benefits of a naturally-based enhanced resilience.

DD 4.4-4 SEDIMENTATION IN THE GANGES-BRAHMAPUTRA DELTA: NATURAL MANGROVE FOREST AND EMBANKED POLDERS

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Research question

The monsoon-driven Ganges-Brahmaputra river system transports ~1 billion ton of sediment from the Himalayas to the delta. Downstream spatial distribution of sediment flux into the deltaic distributary channel network and deposition rates onto the floodplain and delta plain are remarkably unconstrained, yet of critical importance to the understanding of the overall delta sediment budget and to assess the consequences of embanking the natural coastal system.

Methodology

We numerically model daily incoming sediment flux with a distributed hydrological basin model, WBM-SED. The model uses re-analysis climatology to calculate the water balance and routes water and sediment throughout the Ganges and Brahmaputra drainage basins. The estimated flux provides the upstream boundary condition to the delta and coastal zone. We use a simple approach to sediment routing over the delta distributaries and into tidal channels; we use channel network characteristics to distinguish between three orders of channels and route suspended load according to their planview dimensions. In the tidal delta, we reverse our simple routing scheme with sediment flux coming from the shallow marine sediment plumes. We then use process models to calculate cross-channel sediment flux deposited on delta islands during river flooding and tidal flooding.

Findings

Monsoonal flooding and a high tidal range are highly efficient mechanisms to re-deposit sediment onto the delta plain, especially in areas of high channel connectivity. This finding is corroborated by our field data on sedimentation rates in the coastal zone, which highlighted that over a single monsoonal season as much as 1 cm/yr of sediment is deposited widespread in the tidally-controlled areas of the natural mangrove forests of the Western delta. In contrast, embanked nearby ‘polders’ do not receive sediment anymore and channels maybe silting up as a consequence. Preliminary field data in the fluvial-dominated reach shows higher sedimentation rates locally (~5 cm/yr), but exhibits a more spatially varied sedimentation pattern. These results are comparable to rapid near-channel sedimentation as indicated by the numerical modeling.

Societal importance

In 2013, the Bangladesh Government and the Worldbank launched a Coastal Embankment Improvement Project aimed at improving the safety and agricultural productivity of existing polders. Our simplified concept helps highlight unknowns in the deltaplain storage term in the coastal zone of the Ganges-Brahmaputra delta, built an observational database, and ultimately is thought to inform embankment design and polder management.

DD 4.4-5 WATER AND SEDIMENT TRANSPORT PROCESSES IN THE ESTUARINE SYSTEMS OF THE GANGES-BRAHMAPUTRA-MEGHNA DELTA

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The Ganges-Brahmaputra-Meghna (GBM) delta is one of the largest tide dominated deltas in the world. It is also one of the most fragile, hosting important and diverse ecosystem resources including the Sundarban Mangrove forest. The functioning of these ecosystem resources largely depends on the availability of water and sediment transported through the complex estuarine networks of the region. In this paper we therefore use the Delft 3D and the HEC RAS unsteady flow models to examine the transport processes of water and sediment in the GBM delta system.
The upstream sources of water and sediments for the GBM estuaries are mainly derived from the Brahmaputra and the Ganges rivers, which together deliver around 2 trillion m^3 of runoff annually. It is found that the dominant contributor of flow for the Eastern Estuarine System (EES, 70% - 88%) is the Lower Meghna, for the Central Estuarine System (CES, 8% - 30%) it is the Brahmaputra, while for the Western Estuarine System (WES, 0.2% - 4%) the Ganges dominates. Analyzing the flow distribution along with the estuarine systems of the GBM delta, it is found that the Meghna estuary is the main conduit for water and sediment transport. This system is found to be largely ebb dominated. The tidal excursion at the entrance of the Lower Meghna estuary during the ebb is more than the length of the estuary itself, which drains the incoming sediments to the Bay of Bengal through the mouth of the Lower Meghna. A clockwise circulation found in the Bay of Bengal near the mouth of the estuaries particularly during the monsoon drives sediments and freshwater in the central and western directions. The computed flow volume, tidal prism and tidal excursion in the CES and WES show that the contribution of upstream freshwater flow in the ecologically sensitive Sundarban area is relatively low, whereas, the water (mostly freshwater during monsoon) and sediments in the central and western (including the Sundarban) parts are coming mostly from the Meghna estuary as a result of the clockwise circulation mentioned earlier.
Any future change of water and sediment transport processes due to either climatic or man-made activities will alter the equilibrium of the ecological system in this region and might affect the lives and livelihood of the large numbers of people living in the delta.

DD 4.5-1

ECOMORPHOLOGICAL EFFECTS OF HUMAN INTERFERENCES IN ESTUARIES AND THEIR CONSEQUENCES FOR MANAGEMENT

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Despite the growing recognition that estuaries and shallow coasts provide essential ecosystem services to the planet, they are under increasing pressure from human activities, being amplified by global change issues like sea level rise. In the Netherlands, the Delta works and other human interferences caused drastic changes in the estuarine and coastal ecosystems of the Rhine-Meuse-Schelde delta. The Oosterschelde and Westerschelde, two adjacent tidal water systems, evolved differently over the past century due to these human interventions. The Oosterschelde was partly closed off from the North Sea by a storm surge barrier and compartmentalization dams reduced the surface area of this tidal ecosystem. In the Westerschelde large intertidal areas has been reclaimed and the main channel has been deepened for navigation purposes. These changes evoked changes and feedback mechanisms between hydrodynamics and sediment dynamics, tidal flat morphology, and ecological processes.
Tidal flat and salt marsh habitats clearly responded differently in the two systems: intertidal habitats eroded/flattened in the Oosterschelde and accreted/steepened in the Westerschelde. Also subtidal habitats changed, with increased hydrodynamics in the Westerschelde and more calm conditions in the Oosterschelde. We used Species Distribution Models to demonstrate that this had far going consequences for the animal and plant species inhabiting these habitats, with redistributions and changes in species community as a consequence. Because of the feedbacks between biotic components present (e.g. stabilizers such as oyster reefs, mussel beds, and salt marshes and de-stabilizers such as lugworms Arenicola marina) and hydrodynamics, sediment dynamics and morphology, changes in the occurrence of these biotic components also affects the ecomorphological functioning of these estuarine habitats. As intertidal and shallow subtidal habitats like mudflats and salt marshes sustain coastal food webs and provide essential ecosystem services such as coastal protection, the need for conservation of these habitats (both quantity and quality) is increasingly recognized. The problems that arise nowadays in the Westerschelde and Oosterschelde, together with future climate change challenges like increasing sea level rise, call for new management strategies. Examples are given of pilot experiments to mitigate the loss/change of tidal flats (e.g. nourishments, oyster reefs as stabilizing structures). We discuss these strategies in the light of a sustainable management of these ecosystems.

DD 4.5-2 THE ROLE OF BIOGENIC REEFS FOR COASTAL ADAPTATION AND CONSERVATION

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Ecosystem engineers, such as oyster reefs and salt marsh plants, are increasingly recognized as ecosystem-based coastal protection and conservation structures in soft sediment environments. The use of ecosystem engineers is based on the natural capacity of the organisms to temper wave action and prevent shoreline erosion, combined with the potential to maintain their own habitat. This adaptive capacity secures the long-term sustainability of ecosystem-based coastal protection, especially in light of accelerating sea level rise.
Within the innovation program Building with Nature three-dimensional habitat structures (oyster reefs) were constructed on eroding tidal flats in the Oosterschelde estuary (The Netherlands) for mitigating erosion and for the conservation of ecological services. Oyster reefs form dense three-dimensional structures which can alter water flow and reduce wave action. They also provide other ecosystem services as they are keystone species in coastal environments because of their ability to create habitat on which complex food webs are based.
We studied natural and constructed Crassostrea gigas reefs to investigate their impact on tidal flat morphology and their ability to maintain their own structure. Height measurements revealed that both natural as constructed reefs can protect the tidal flat under their footprint, as well as an area beyond the boundary of the reef itself. The latter is determined by the dimensions of the reef, as well as local hydrodynamic conditions. Reefs are essential to the oyster population, as they provide substrate for new generations. Maintenance of the reef structure depends on the rate at which oysters recruit and die. Recruitment varies from year to year changing the rate of recruitment, in other words, the addition of shell material to the reef structure. Long-lived oysters disproportionally add shell material to the reef structure, buffering for this variation. We observed that recruitment differs over the tidal flat, with high recruitment at long inundation periods compared to short inundation periods. This could limit constructed oyster reefs to become a long-term sustainable reef.
An interesting, but largely overlooked ecosystem service provided by oyster reefs is their potential buffering capacity in perspective of ocean acidification. Oyster reefs constitute significant biogenic carbonate masses in estuaries. These biogenic carbonate masses can act as a buffer against acidification, and can become critical for the colonization and survival of species with carbonate shells.
We evaluate the potentials and limitations of this ecosystem-based coastal defence concept and lessons learnt are used to optimize their use in an ecosystem-based coastal defence.

DD 4.5-3 RESTORING ERODING COASTS BY STIMULATING SEDIMENT TRAPPING

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Worldwide, many densely populated and intensively used coastal margins suffer from erosion. In this abstract we focus on fine sediment coasts, originally characterized by salt marshes, mangroves or other wetland ecosystems. Erosion may occur because of sediment starvation (e.g. Mississippi delta), over-exploitation, deep ground water winning and/or mismanagement (north-Java), or a combination of these (Indus River). Erosion is likely to worsen in response to climate-change-induced sea level rise and increasing storminess. Stopping and reversing erosion requires the availability of sufficient fine sediments. Fortunately, in many cases fine sediments are still abundant (as in the larger Mississippi delta and the foreshore of north Java).
We established a simple net and gross budget of the fine sediment dynamics in the Dutch Wadden Sea and along the coast of Suriname. Both coasts accrete, and in both cases, the net sedimentation volumes involved are much smaller than the net and gross longshore fine sediment transport. Moreover, the net sedimentation volumes are orders of magnitude smaller than the gross sedimentation volumes, indicating very small trapping rates. In other words, if the trapping rate could be increases only slightly, net sedimentation on the coast would increase rapidly.
Coastal degradation is the small net result of large sedimentation and erosion volumes, the processes being induced by tides and waves, respectively. Sediment starvation leads to a reduction in gross sedimentation volumes, whereas for example the construction of fish ponds and removal of mangrove forests along the coast lead to reducing gross sedimentation and increasing gross erosion volumes.
Continuing on these arguments implies that eroding coasts in sediment-rich systems can be restored by increasing the trapping of fine sediments on the coast. This philosophy is being tested with pilots in north Java (Demak coast) through the construction of permeable groins to create calm water conditions and thereby, increase sediment settling and reduce sediment resuspension. Experiences with similar structures in Vietnam show that sediment trapping is significantly increased. These first results illustrate that it may be possible to tip the net sediment balance on a coastline with very simple and cost-effective measures that increase the trapped sediment marginally. Finding such simple solutions is key to maintaining prosperous coastal deltas in the face of climate change.

DD 4.5-4 OYSTER REEFS FOR COASTAL DEFENSE AND FOOD PRODUCTION: EXPERIENCE FROM BANGLADESH

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Protection of land resources from tides, waves, storm surges and other occasional inundation events is critical in many low-lying coastal areas particularly in the delta regions. While conventional structural engineering means such as dykes, groins, breakwaters etc. are in place for hundreds of years and are often delivering the intended results,

yet potential threats from accelerating sea-level rise and increasing cost of maintenance of these structures have created room for rethinking the coastal protection paradigm with new concepts. The concept of building with nature or eco-engineering, which is a unique approach of using ecosystems and their live organisms capable of self-maintaining and delivering certain coastal protection services, with additional important ecosystem functions and/or food for human populations, alone or in synergy with conventional structures, is getting momentum. At present, however, implementation at large of this ecosystem-based strategy is still limited, and requires further research and experimentation.
Thus, a prototype oyster reef is being tested in an erosion prone coastal area of Bangladesh to determine the potential role of this model in coastal defense and at the same time to produce oysters in a Bangladesh context. Initially, in 2012, the settlement of wild oyster spats on four different substrates, such as i) stone, ii) live oyster, iii) windowpane shell, and iv) oyster shell, were investigated. The results indicated that windowpane shell was the best substrate for spat settlement followed by live oyster, oyster shell and stone. Subsequently in April 2013, a 50 meters long and 2 meters wide reef structure made of concrete was placed on the mudflat of Kutubdia Island, located along the South-eastern coast, in order to provide wide substrate area for the spat to settle on as well to intervene fine sediment dynamics. Data on spat recruitment, survival and growth, water quality, shore profiles, sedimentological parameters are being monitored at regular interval. Early results suggest positive effects on the shore sediment budget by the reef structure. Moreover, the number of spat increased from 0.4 spats/m^2 in April 2013 to a maximum of 32.6 spats/m^2 in February 2014, and their average growth rate was 0.04 mm/day. These facts suggest potential sustainability of the oyster reef over time. Other ecosystem benefits of the reef, such as habitat for shrimp and crab is promising.
We discuss the potentials and limitations of this ecosystem-based coastal defence combined with aquatic food production in a Bangladesh context, including societal acceptance and socio-economic aspects.

DD 4.5-5 INTEGRATION OF ECOLOGY AND ENGINEERING IN COST-EFFECTIVE NATURE-BASED FLOOD DEFENCES

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Across the world, there is a growing realization that ecology and engineering need not be conflicting forces but can be complementary parts of coastal defense solutions. The use of natural landscapes for flood hazard reduction is achieved through ecosystem services, such as wave attenuation, sediment accretion, bed stabilization and services delivered to the ecosystem or to society.
In the Netherlands, several large scale nature based flood defense projects promote the transition from traditional engineering works to nature based flood defense approaches. They comprise complete soft sea defense solutions to hybrid designs using wetlands as integrated part of flood defense construction. Cost benefit analyses of these projects show positive results when compared with construction and maintenance of traditional engineering works. The ecosystem services that are utilized are generic and will be applicable to deltas worldwide.
This presentation will summarize the state of the art on our knowledge of nature based flood defense capacities and discuss its practical application in the Netherlands in the light of design concepts, construction and long term maintenance. The robustness against changing physical forcing will be discussed and the presentation will explore the practical applicability in other deltas in times of climate change.

DD 4.6-1 COUPLED NATURAL-HUMAN DYNAMICS IN THE MISSISSIPPI DELTA

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Introduction

Coastal communities around the world are especially vulnerable to climate change effects. Global warming and sea-level rise pose a serious threat to low-lying deltaic regions, raising serious concerns of how the society can plan and maintain sustainability in these deltaic regions. This paper presents initial results of a study of the sustainability of the lower Mississippi River deltaic region in Louisiana, USA, using a coupled natural-human (CNH) system dynamics approach.

Research question

The lower Mississippi River deltaic region is one of the most vulnerable coasts in the continental USA. The disappearing land is a critical problem especially along the coastline in the southern part of region. During the last decade a gradual population and economic growth in the northern part of the study area has been observed in contrast with a decline in the southern part surrounding New Orleans. A pressing question is: will southern coastal Louisiana reach the tipping point where it may become too costly to sustain? If so, could the same type of economic and ecosystem functions be gradually migrated to its northern neighbor?

Methodology

We will examine the sustainability of the lower Mississippi deltaic region using a coupled natural-human system approach. We will first develop models to assess the resilience of a deltaic system. We will then develop a system-level model to capture the linkages among the major components and to quantify the linkages through empirical validation. The land loss problem is illustrated using this system modeling approach.

Research results

An initial land-cover simulation with 15 variables show that land loss will continue in the southern part of the delta, with a projected loss of 76.8 km^2 by 2016. The study results provide a baseline condition of how and where LULC changes in relation to the 15 variables in a vulnerable coastal region.

Societal importance for stakeholders

Finding the factors contributing to the sustainability of a deltaic region will inform the policy makers and the public on how to increase resilience of the region and provide scenarios to better plan for the future. The study results from this region will shed lights on policy making in other deltaic regions around the world that are faced with similar threats and challenges from climate change.

DD 4.6-2 TOWARDS HOMOGENIZATION OF MEDITERRANEAN LAGOONS UNDER CLIMATE CHANGE

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In this study we investigate the hydrological response of ten Mediterranean lagoons to climate change by means of numerical models. The lagoons are the lagoons of Venice, Marano-Grado, Varano and Lesina in the Adriatic Sea, the Taranto basin in the Ionian Sea, the Cabras lagoon in Sardinia, and the lagoons of Ganzirri and Faro in Sicily, the Mar Menor in Spain and the Nador lagoon in Morocco. These lagoons give a representative picture of the lagoons situated around the Mediterranean basin. The lagoons range from a leaky type of lagoons to a choked type. The number of inlets ranges from just one in the Nador lagoon to 6 in the case of the Marano-Grado lagoons. Tidal range is from nano-tidal to micro-tidal. The depth ranges from an average depth of 1 m to up to 40 meters.
We assess the impact of climate change on lagoons in terms of changes in the following physical properties: water temperature, salinity, sea-lagoon water exchange and water renewal times (WRT). The last parameter deals with the lagoon exchange capabilities with the open sea and its internal mixing capacity. It is therefore an important parameter also for other processes, such as hydro-ecological dynamics and pollution dispersion.
Our results suggest that Mediterranean lagoons amplify the salinity and temperature changes expected for the open sea. Moreover, numerical simulations indicate that there will be a general loss of intra- and inter-lagoon variability of their physical properties. Therefore, as a result of climate change, one expectation will be the homogenization of the Mediterranean transitional water systems. The predicted changes in the physical properties will certain alter the whole lagoon biogeochemistry, with cascade effects on the biological and social systems. This study shows how numerical modeling can be a useful tool to study the hydrodynamic changes forecasted to happen in transitional water bodies like lagoons.

DD 4.6-3 MANAGEMENT OPTIONS TO ADAPT TO HIGH-END SCENARIOS OF SEA-LEVEL RISE: IMPLICATIONS FOR DELTAIC COASTAL WETLANDS

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We hypothesize that with a proper management fluvial-dominated deltas could survive high rates of SLR (> 1 cm yr^{-1}) that characterized the post-glacial period and will likely characterize the next centuries due to global warming. There are three main mechanisms for deltas to cope with SLR that are self-enforcing as the rates increase, tending to enhance the efficiency of the deltaic sedimentary trap: a) an increase in the frequency of delta lobe switching with accelerated SLR leading to the formation of new lobes in shallow areas; b) an increase in the frequency and magnitude of flood events in the delta plain as a consequence of an increased overflowing through the river natural levees, leading to enhanced sediment deposition; c) an increase in the frequency and magnitude of overwash events

in the delta fringe allowing sandy beaches to quickly adapt to SLR.
The current view is that coastal protection is the best strategy for future SLR up to 2 to 5 m, and beyond 5 m the retreat would be the best (or the only) strategy. However, for the case of deltas a more functional adaptation strategy based on system restoration can be envisioned provided that natural processes and ecosystem functions can be managed to increase system's resilience. The central element of this alternative strategy is the idea of "rising grounds", instead of "rising dikes", but a combination of both can also be foreseen and may be needed in many cases. This means that "rising dikes"will be only feasible if "rising grounds"is also implemented; if not, retreat will be the only long-term alternative. We propose that "rising grounds"is the best adaptation strategy in most deltas for high-end scenarios of SLR, though in some cases the option of retreating may be necessary in combination with structural and functional measures.

DD 4.6-4 SPATIAL VARIATION IN SOIL SALINITY IN RELATION TO HYDRO-CLIMATIC FACTORS IN SOUTHWEST COASTAL BANGLADESH

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A total of 1.65 million ha of land (70%) out of 2.34 million ha is affected by soil salinity within the Khulna and Barisal divisions of costal Bangladesh. Livelihoods in Bangladesh are largely dependent on agricultural practices but agricultural productivity in this region is lower than the national average and this is one of the major reasons for high incidence of poverty. Soil salinity limits cultivation of *rabi* (dry season) crops and delays planting of *kharif* (wet season) crops until rainfall reduces soil salinity. Simultaneously, river salinity and groundwater salinity pose major constraints on irrigation water quality.
There are numerous interacting factors that influence soil salinity, including rainfall, evaporation, depth to groundwater table, groundwater salinity, saline (tidal) river water inundation, storm surge inundation, and saltwater shrimp farming. The relative effects of these factors are spatially variable and complex. This paper describes how the spatial variation of soil salinity in southwest Bangladesh relates with hydro-climatic factors. The study describes analysis of published data and trend analysis of salinity and groundwater levels and correlation - multiple regression analysis. Improved understanding of the underlying mechanists that cause soil salinity will allow projection of future soil salinity under different hydro-climatic and anthropogenic scenarios, including changes in rainfall, sea level rise, reduced fresh water flow, increased irrigation withdrawals.
Fresh water diversions from the river Ganges in the western part of the study area has increased river water salinity and this combined with seasonal variations in rainfall and evaporation play a major role in salinity build-up. A strong correlation is found between increasing river salinity and increasing soil salinity in this area. In the eastern part of the study area, freshwater flow from the Brahmaputra River has displaced the salinity front seawards and river salinity is not the major contributor to soil salinity. In this region, groundwater is close to the surface during the dry season, and soil salinity variation correlates well with groundwater depth (and salinity), rainfall and evaporation.
Projections of future sea level rise may impact soil salinity in the eastern part through increasing groundwater levels, and in the western part through increasing river salinity.

DD 4.6-5 NEW CARBON MARKET PROCEDURES RECOGNIZING THE VALUE OF DELTA WETLANDS

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Research question

'Coastal blue carbon' refers to the contributions of coastal and delta wetlands to the global carbon cycle. These wetlands sequester carbon dioxide from the atmosphere and store it as biomass and soil carbon. Through carbon markets, blue carbon represents a means to valuate these ecosystems supporting the funding of their long-term sustainable management. Carbon markets require science-based greenhouse gas accounting for restoration and conservation, addressing e.g. the fluxes of methane and nitrous oxide and the fate of allochthonous and autochthonous carbon in wetland soils, the effects of hydrological connectivity with adjacent areas, and of sea level rise. Scientific methods too burdensome for practical implementation in coastal management may be replaced with conservative default values and simplifications or proxies, as presented in this paper.

Methodology

Eligible blue carbon projects must set project boundaries, determine baselines and quantify emission reductions. We explored how current scientific knowledge can be integrated into these concepts, focusing on their usability and affordability in coastal wetland management. Datasets of methane and nitrous oxide fluxes under various conditions were analyzed for thresholds and default factors that simplify GHG accounting. From literature on transportation and fate of soil organic carbon in coastal wetlands systems we derived an approach accounting for allochthonous carbon in a project's claim to net carbon sequestration. We formulated ways for projects to assess the effects of sea level rise.

Research results

The full results of our work are captured in GHG accounting methodologies submitted to the Verified Carbon Standard (www.v-c-s.org). In this paper we summarize the VCS requirements for wetlands restoration and conservation and how a blue carbon project can meet these. We emphasize practical simplifications identifying default factors and proxies and point to still existing challenges.

Societal importance for stakeholders

Restoration and conservation of coastal ecosystems brings benefits that support the livelihood of local communities, improve fisheries, and reduce risk of flooding,. However, available funds for these activities are overwhelmed by demand.
The methodology outlines procedures to estimate net GHG emission reductions and removals that underlie the generation of carbon credits, which are one way of giving blue carbon access to markets.

DD 4.7-1 ON THE FLOOD PROTECTION VALUE OF ESTUARINE AND DELTAIC WETLANDS: LOCAL EXAMPLE AND GLOBAL POTENTIAL

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Research question

Low-lying densely populated deltas and estuaries are world widely exposed to flood risks caused by storm surges. Global change is increasing these flood risks through accelerating sea level rise and increasing storm intensity. Furthermore, local-scale human impacts on deltas and estuaries are in many cases even more increasing the vulnerability to floods. Particularly, we address here the degradation and reclamation of tidal wetlands (i.e. temperate zone salt marshes and tropical mangroves) as a major reason for increasing vulnerability to flooding of estuarine and deltaic urbanized areas. We identify key factors that determine the extent of flood mitigation by tidal wetland conservation and restoration, and explore the potentials and limitations for global application of this approach of ecosystem-based flood mitigation.

Research results

First, we use the Scheldt estuary (Belgium and SW Netherlands) as an example where historic wetland reclamation has contributed to increasing flood risks, and where nowadays tidal marsh restoration is put into practice on a large scale as part of the flood defense system. Based on field data and hydrodynamic modelling, we show that the presence of large marshes results in a landward decrease of tidal and storm surge levels, because marshes increase the water storage capacity and increase the friction to landward propagating floods. The data and model simulations demonstrate that the reduction of tidal and storm surge flood levels throughout the estuary depends on the tidal marsh properties, including the surface area, elevation, vegetation and position of marshes along the estuary, and on properties of the storm surge, including peak water level and duration.
Secondly, a global analysis is presented of the potential application of tidal wetlands in flood mitigation in estuaries and deltas worldwide. Many of the largest urban populations that are at risk from coastal flooding are located in large deltas and estuaries, especially in Southeast Asia, North America and Europe. We show that many of these vulnerable deltaic areas are potentially well suited to include wetland conservation and restoration as an essential part of adaptation and mitigation strategies against storm surge flood risks.

Societal importance for stakeholders

The presented scientific insights should motivate governmental authorities and industry towards the larger-scale implementation of wetland conservation and restoration programs as an essential part of flood defense systems in deltas and estuaries worldwide. Societal benefits and potential obstructions to the large-scale implementation are discussed based on recently implemented case examples.

DD 4.7-2 BIO-GEOMORPHIC SHIFTS AND STABLE STATES IN INTERTIDAL FLATS AND MARSHES

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Research question
The intertidal zone of deltas, estuaries and coastal embayments consists of either vegetated high-elevation marshes (or mangroves in the tropics) or non-vegetated low-elevation flats. Large-scale shifts between bare flats and vegetated marshes have been reported worldwide. It is of significant importance to understand and predict such transitions, because tidal flats and marshes provide different ecosystem services to coastal societies. Previous modeling studies suggest that the ecological theory of catastrophic shifts between alternative stable ecosystem states potentially explains the transition between bare flats and vegetated marshes. However, up to now only few empirical evidence exists. In our study, the hypothesis is empirically tested that vegetated marshes and bare tidal flats can be considered as stable landscape states with rapid shifts between them.

Research results
We studied historical records (1930s - 2000s) of intertidal elevation surveys and aerial pictures from the Westerschelde estuary (SW Netherlands). Our results demonstrated the existence of: (1) bimodality in the intertidal elevation distribution, i.e., the presence of two peaks in the elevation frequency distribution corresponding to a completely bare state and a densely vegetated state; (2) the relatively rapid transition in elevation when intertidal flats evolve from bare to vegetated states, with sedimentation rates that are 2 to 8 times faster than during the stable states; (3) a threshold elevation above which the shift from bare to vegetated state has a high chance to occur. Our observations demonstrate that low-elevation bare flats and high-lying vegetated marshes behave as stable ecosystem states and demonstrate the abrupt non-linear nature of shifts between the bare and vegetated states.

Societal importance
Intertidal flats and marshes provide important ecosystem services to society including storm flood and erosion protection, food production, water quality regulation and carbon sequestration. The presented insights on the stability and abrupt shifts between bare flats and vegetated marshes have implications for the sustainable management of intertidal flats and marshes, i.e. it demonstrates that these ecosystems are relatively stable but once critical thresholds are exceeded, they may rapidly transform towards another stable state and it may be very difficult to restore the system to the original state.

DD 4.8-1 MODELING COASTAL DUNE DEVELOPMENT UNDER CLIMATE CHANGE

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In the Netherlands, a large part of the coastline consists of sandy beaches and coastal dunes. The beach-dune systems provides valuable ecosystem services, such as flood protection, nature development and drinking water

extraction. In the light of recent climate scenarios and sea-level rise projections, important changes may occur in the processes governing the growth and erosion of coastal dunes. Within the framework of the Knowledge for Climate project theme 1: Climate Proof Flood Risk Management, this study investigates the effects of changing environmental conditions on the development of coastal dunes and the implications for coastal safety.
To simulate effects of climate change on coastal dunes, a computer model was developed that incorporates climate-dependent processes relevant for dune building and erosion. The model builds on the sand transport algorithm of Baas (2002) and Nield and Baas (2008). This spatially explicit model simulates coastal dunes on a timescale of decades. The dominant processes and controls to be included were determined on the basis of measurements. After including these processes, the model was calibrated and validated with yearly elevation data of the Dutch coastline. Projections of wind climate, sea level and storm frequency were taken from recent climate scenarios and were translated to model input.
The preliminary results of the model show that the most important processes are captured and that validation results compare well with measurements. Simulations of future developments show how sea level determines the extent to which dunes are able to expand horizontally. With a steady rise in sea level, the dunefoot retreats, reducing the width of the dunes. Similarly, an increase in storminess leads to increasing erosion and landward retreat. Further simulations and done to explore effects of climate change on dune development.
This study highlights the importance of the balance between dune growth and erosion. This balance is positive only for a certain range of environmental conditions. However, nourishments can be applied to change the balance. For each climate scenario, critical nourishment levels were determined such that the functionality of the various ecosystem services can be maintained. Furthermore, the model can provide coastal and nature managers with details on the expected morphological developments of a beach-dune system.

DD 4.8-2 MANAGED REALIGNMENT: A SUSTAINABLE APPROACH TO RESTORE COASTAL HABITATS AND MANAGE FLOOD RISK?

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Climate change and environmental and financial concerns have led to a shift from the ‘hold-the-line’ approach of coastal protection towards more flexible soft engineering options. Managed realignment is increasingly seen as an alternative to hard engineering able to provide sustainable flood risk management with added environmental benefits. In Europe and elsewhere existing national and regional plans promote the implementation of managed realignment as a climate change adaptation required for the sustainability of coastal habitats and their capacity to deliver ecosystem services. In England and Wales, for example, Shoreline Management Plans foresee 10% of the coastline length to be realigned by 2030 and 15% by 2050. Effective adaptation strategies require the understanding of two different processes: how the natural environment will respond to changes and the factors influencing societal uptake. Managed realignment invariably involves changes in land use/land cover and it is timely now to assess what is known about: (a) public perception and (b) the potential impacts on the delivery of ecosystem services.
Managed realignment is a relatively new soft engineering approach aiming to maximise environmental and socio-economic benefits by creating space for coastal habitats to evolve more naturally. It is key to the concept of managed realignment the natural adaptive capacity of coastal habitats (i.e. the ability to dynamically adjust to changing environmental conditions) and the ecosystem services they provide (i.e. the benefits society gain from the presence of functional ecosystems). The great attraction to managed realignment is the opportunity to promote multiple functions, such as creation of coastal habitat, increased biodiversity, protection against storms, recreation, carbon sequestration

etc. Evidence of performance based on monitoring of existing managed realignment projects is still limited and so far indicate variable results, in some aspects dependent on site-specific characteristics, including method of managed realignment implementation.
Based on comprehensive literature review, this study will summarise the current understanding of managed realignment achievements and limitations regarding the delivery of ecosystem services. Outcomes from the literature review will be discussed in relation to perception of stakeholders (obtained from a social survey in the UK) to identify in what aspects practical knowledge contrasts with stakeholders perceptions. Studies from many countries indicate that negative public perceptions and poor stakeholder engagement are main obstacles to the wider implementation of managed realignment. Therefore, understanding the differences between stakeholders and practitioners can help improve current practice and guide educational campaigns and engagement efforts aiming to increase public acceptance.

DD 4.8-3 CONSERVATION AND DEVELOPMENT OF WADDEN SEA SALT MARSHES AS A LONG-TERM ADAPTION STRATEGY

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Concern about the effects of climate change triggered extensive research efforts to understand and predict the impacts of climate change and to search for sustainable and flexible strategies to adapt to the foreseen effects. This also applies to the Wadden region. At present, the northern part of the Netherlands is protected against flooding from the Wadden Sea by some 227 km of dikes. Along several dike stretches extensive salt-marsh areas are present. This leads to an increased interest for their potential role in a long-term adaptation strategy for the Wadden region.
This paper elaborates on the potential of salt-marsh preservation and development for coastal defence in relation to their biodiversity value in the Wadden area. The following research questions are investigated in two case studies: 1) what are the effects salt marsh conservation measures on the extent as well as on composition of salt-marsh habitats, and 2) what is the impact of these measures on the flood protection value of salt marshes.
Analyses of a series of aerial photographs showed that erosion protection at the Wadden barrier islands of Terschelling and Ameland resulted in a strong reduction in marsh edge retreat and, within decades, in the restoration of new marsh area with typical salt-marsh vegetation covers.
Modelling work (with SWAN) revealed that the wave-damping capacity of such a restored salt marsh is related to both elevation and width, and additional to plant characteristics. A salt marsh covered with a dense and rigid vegetation of relatively high and thin plants is several times more effective in wave height reduction (under moderate water depths) than an unvegetated salt marsh. These results imply that a vegetated salt marsh in front of the dike leads to reduced wave attack on the dike.
Although there are still many questions concerning dimensions, management, and performance, a vegetated salt marsh is an interesting option to adapt existing flood protection works to the effects of climate change. Furthermore, under favourable conditions, species composition in the newly formed marshlands will be comparable with that in natural pioneer salt-marsh zones. However, the modelling work indicates that spatial distribution of the different plants can have a considerable impact on wave damping. Therefore attention should be paid to vegetation management and maintenance issues.

Deltas in Depth Theme 5:

Urban adaptation to climate change

DD 5.1-1

TOWARDS REFLEXIVE ADAPTATION AND RESILIENT COASTAL COMMUNITIES

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The central question explored in this presentation is: What is required to build the adaptive capacity, resilience and sustainability of coastal communities in the Anthropocene? Insights are drawn from case studies in a forthcoming book, *Climate Change and the Coast: Building Resilient Communities*. A number of common themes are identified as important characteristics of an effective response to climate change that proactively builds adaptive capacity and resilience and fosters sustainable coastal development. On the evidence of these case studies, it is concluded that adaptation at the coast would benefit from being responsive, deliberative, transformative, holistic, integrative, inclusive, equitable and empowering. These characteristics are developed into a conceptual framework that is termed 'reflexive adaptation' that will help communities better understand and address distinctive features of the challenge presented by climate change. A set of priority actions, also drawn from the case studies, is outlined to help guide coastal communities translate this concept of reflexive adaptation into practical reality. A final encouraging conclusion that can be drawn from the case studies is that the process of social learning required to adapt to a changing climate is well underway. The challenge is to convert adaptation barriers into enablers of change. This is a monumental task, but, as the case studies show, momentum is growing to chart new adaptation pathways.

DD 5.1-2

CLIMATE PROOF CITIES - HOW DUTCH CITIES CAN PREPARE THEMSELVES FOR CLIMATE CHANGE IMPACTS

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Research question
Four years of urban adaptation research in the Netherlands has resulted in a host of policy relevant conclusions. The main question of the large scale research programme 'Climate Proof Cities' was: how can Dutch cities prepare for the impacts of climate change, with sub questions on the functioning of the urban climate system in the Netherlands, the impacts of climate change on and the vulnerability of cities, adaptation options in urban and building design, and the introduction of climate change adaptation in urban planning processes.

Methodology
A large part of the research (measuring/interviewing, modelling, designing) was executed in case studies together with the big cities in the Netherlands. Special attention was given to the integration of the research results and the communication to stakeholders.

Results

All cities in the Netherlands, big and small, appear to be vulnerable for the impacts of climate change. Analysis of satellite images reveals that a surface temperature urban heat island (UHI) exist also in smaller towns. Additional model outcomes reveal that the conductive heat flux is a major factor in the development of the night time ambient temperature UHI, as detected through fixed and mobile measurements. Vulnerability for extreme rainfall events is largely determined by thresholds that can be exceeded in all built up areas.

The pattern of vulnerability within cities has a high spatial variation, depending on the location of vulnerable groups or objects, the qualities of buildings, and the structure of the neighbourhoods. For the last, the degree of paving, the amount of green spaces and the building density are determining factors.

Increasing the resilience of cities can be done by employing localized adaptation options, often requiring cooperation between private and public stakeholders. A few of the urban adaptation options, such as green roofs or building isolation appear to be less effective in the Dutch circumstances than generally suggested. Most adaptation options can be included in urban renovation or restructuring projects, providing additional positive effects on the urban living conditions. In short: increasing the resilience of cities consists of an accumulation of many relatively small and not too costly measures. To ensure their implementation, mainstreaming of adaptation in other urban policy areas will be necessary.

Societal importance

These conclusions support the development of national policies under the Deltaprogramme, provide underpinning of urban adaptation strategies, and cost-efficient selection and implementation of adaptation options.

DD 5.1-3 THE UCCRN ASSESSMENT REPORT ON CLIMATE CHANGE AND CITIES: GUIDELINES FOR DEVELOPING CLIMATE CHANGE STRATEGIES

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The lack of scientific knowledge often constrains cities and urban policy makers when they develop and implement local climate change action plans and strategies. The Urban Climate Change Research Network (UCCRN) is a global network of urban researchers and experts in the field of climate change that provides scientifically sound decision support to cities to tackle climate change and its impacts. The aim of this paper is to present some results from the initial work of the UCCRN Second Assessment Report on Climate Change and Cities (ARC3-2). Drawing lessons from selected examples, the paper illustrates the need and importance of building a robust climate knowledge base in cities to support them in developing short term climate change actions and long term strategies to address both climate adaptation and mitigation while at the same time looking at synergies with sustainability agenda. The paper applies a multi-scalar perspective to analyze and discuss the main challenges that cities face when developing climate change actions and strategies as they have been identified in selected case studies. These challenges

are classified and analyzed according to different multilevel scales such as spatial, temporal, jurisdictional and managerial. Specific attention is drawn to the immediate short-term costs and (co-) benefits that certain actions generate while at the same time addressing long-term climate adaptation objectives. Currently applied methods of project and program procurement are not conducive to the inclusion of co-benefits, particularly non-monetized ones. For instance, it is very difficult to make the investment case for more green infrastructure, since the existing procurement framework for the water sector mandates that municipalities must choose the cheapest option. The paper discusses the experiences of different cities while developing climate change action plans to address both short-term and long-term climate risks and multiple benefits. Based on these experiences we have drafted a set of guidelines to support cities in developing climate change strategies with a clear focus on the science - urban policy making interface. The paper significantly contributes to the understanding of the interface between urban policymakers and researchers. Furthermore, it emphasizes the importance of building a multi-stakeholder knowledge base and support to cities for developing short-term climate change actions and long-term strategies with multiple benefits for the cities' inhabitants.

DD 5.2-1

NEW CHALLENGES FOR ADAPTIVE URBAN GOVERNANCE IN HIGHLY DYNAMIC ENVIRONMENTS: REVISITING TOOLS AND STRATEGIES

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The paper explores new challenges for adaptive urban and spatial governance in highly dynamic environments. It examines whether or not we have to rethink existing planning systems and tools in the context of climate change, natural hazards and societal transformation, focusing particularly on coastal and delta environments in emerging economies in Asia. Key pressures for urban governance and planning in these settings are explored. Against this background requirements for a more adaptive and strategic planning approach are discussed by examining the discourses about climate change adaptation - including adaptive urban governance - and strategic planning. Compared to earlier papers on urban governance in the context of climate change, this paper aims particularly to provide an entry point for the discussion of the adjustment and modification of specific planning systems and tools. Two case studies are used for a concrete exploration of the gaps and challenges of adaptive urban governance on the ground, considering particularly formal regulative planning tools. The findings from the case study analysis show opportunities but also constraints of existing planning tools to strengthen adaptive urban governance. At the same time, a number of gaps have been found between currently debated planning tools for adaptation and the requirements emerging from adaptive and strategic planning theory. Recommendations to further strengthen adaptive urban governance and strategic planning are derived.

DD 5.2-2 PRELIMINARY STUDY FOR AN ENVIRONMENTAL IMPACT ASSESSMENT OF FLOATING CITIES

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Research question
An integrated floating city concept proposes to expand existing delta cities using space on the water for floating urban construction and food production, while including measures against eutrophication. In this study, the environmental impact of several aspects of floating developments will be assessed, in preparation for a detailed environmental impact assessment of the project (EU Directive 2011/92/EU). The research includes a comparison of the environmental impact of floating and land based developments.

Methodology
The cause, extent and reversibility of environmental impacts of floating cities are assessed, knowledge gaps are indicated and design and monitoring recommendations are developed. The impact of land and water based urban development are then compared. Impacts are grouped in two categories: the first one includes impacts resulting from the use of space and surface, the second consists of impacts that are caused by protection measures, which are necessary to ensure the safety of urban settlements from environmental hazards.

Research results
The floating city concept can have positive impact on the environment, if negative impact is mitigated. Floating platforms can change the current flow, serve as habitat for macrobenthos, cause local climate change and obstruct sunlight, leading to the formation of an anaerobic zone under the platforms. Moreover, the novel habitat around floating platforms can facilitate the invasion of alien species and act as an ecological trap for others. Chemicals, light, noise and thermal pollution cause additional impact.
The comparison of urban development on land and water allowed identifying the benefits and risks of both urbanization methods. The impact of the use of both methods should be assessed and compared for each specific location, to find the environmentally beneficial method for the future expansion of coastal cities. This study can be used as a guideline for that purpose.

Societal importance for stakeholders
Currently, over half of the world's population resides in cities. The total urban area is expected to triple between 2000 and 2030 and is expanding especially fast in biodiversity rich coastal zones (Convention on Biological Diversity, 2012). Challenges for the future development of coastal and delta cities are not only to find strategies to face problems as sea level rise, eutrophication and land scarcity, but also to reduce the pressure on ecosystems. It is therefore important to assess new options for the future expansion of cities, allowing to find the best possible solution for each specific location.

DD 5.2-3 REEVALUATION OF HIGH STANDARD LEVEES ALONG THE ARAKAWA RIVER AS UPLAND EVACUATION AREAS IN THE LOWLANDS OF TOKYO

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The purpose of this study is to examine the land use of super levees along the lower reaches of the Arakawa River in Tokyo, and consider the need for reevaluation of super levees as upland evacuation areas in the event of a large scale flood in a low-lying area. A super levee is a high standard river embankment with a broad width. The ownership of the land on the super levee special development zone remains unchanged after the project. This special zone can be used for urban land use. Because a super levee project is often promoted in conjunction with an urban development project along the river, the creation zone will exist discontinuously for an extended period of time.
The population in low-lying areas in Japan's three major metropolitan areas of Tokyo, Osaka, and Nagoya, is said to be more than four million in total. These areas have been exposed to flood risks and the risks have been increasing due to climate change. Several tens of thousands of people cannot be assumed to be able to evacuate even if all tall buildings are assumed to be evacuation places. Therefore, especially in low-lying areas, it is necessary to create spaces that inhabitants can evacuate safely to in the event of a large-scale flood. In this view, each super levee can also be utilized as a large-scale upland evacuation area.
In the lower reaches of the Arakawa River, super levee projects have been complete or are in progress at 15 sites. The scale and land use of these super levees varies. Analyzing the possible evacuation spaces on the super levee, and evacuation routes to them in the event of a large-scale flood, we selected nine super levees along the Arakawa River. Seeing the ratio for possible evacuation spaces on the total upland area, super levees including high rise apartments tend to be higher than 100%. If possible evacuation spaces include public parks, the ratio tends to be about 70% to 90%. On the other hand, the ratio of detached house residential area type tends to be lower.
From the above examinations, we conclude that if further detailed analysis of possible evacuation spaces on the super levee and evacuation routes will be undertaken, super levees are able to function as upland evacuation areas in the event of a large scale flood in a low-lying area.

DD 5.2-4 THE ADAPTATION SUPPORT TOOL FOR CLIMATE RESILIENT URBAN DESIGN & PLANNING

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Research question
The added value of urban green and blue (water) is yet not fully utilized in current city climate adaptation practices. Urban planners, designers, and decision-makers, lack knowledge and confidence in urban green and blue adaptation measures, despite their recorded performance. Moreover, urban green and urban blue are often separately dealt with. How can barriers for integrated implementation be overcome, and how to enable urban communities to benefit from urban green and blue adaptation practices?

Methodology
The EU Blue Green Dream project combines the strengths of 15 academic and business partners in the UK, Netherlands, France and Germany to bridge the gap between scientific insights and practical approaches regarding blue/green's climate adaptation (www.bgd.org.uk). We collected performance data on control of flooding, drought and heat stress for a range of blue/ green measures at scales ranging from green roofs to urban lakes. Their applicability under specific local conditions was specified. This information is disclosed in a support tool for the planning process. The tool was developed in close cooperation with the end users and tested in several cases.

Research results
The Adaptation Support Tool (AST) offers urban planners, designers, developers and local actors assistance in the selection and packaging of urban blue/green measures in their city adaptation plans. More than 40 green adaptation measures are included in the AST, next to 'grey' solutions. The AST results are presented on a touch table, enabling parties to explore design options in a collaborative process. First, the AST ranks the adaptation measures on implementation suitability, based on local conditions of the project area. Next, the tool supports formulation of attractive packages of adaptation measures. The tool produces performance indicators on flood protection, groundwater recharge, droughts resilience, heat stress reduction, water quality impacts, costs and benefits of this package. These indicators are shown on a dashboard on the touch table. The co-creative design effort results in two or three alternatives that require further elaboration, taking dynamic effects into account. This includes runoff, hydraulic and groundwater modelling of extreme weather conditions. Costs and benefits of alternatives are made comparable so that final decisions can be made on the adaptation plan.

Societal importance for stakeholders
Integrated approach to reducing risks of flooding, drought and heat stress;
Quickly explore the benefits of urban green and blue adaptation measures for your project;
Co-creating climate resilient spatial plans using a touch table environment.

DD 5.2-5 THE CLIMATE ADAPTATION APP - PROVIDING FEASIBLE CLIMATE ADAPTATION MEASURES

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Research aim
Numerous books and methods have been developed on climate change adaptation. Very few are able to provide insight in feasible measures for a specific project and local conditions. The objective of this project was to develop a tool which is able to do this and inspire to create a more climate robust and resilient urban environment. Therefore, we developed an app with a technically sound basis, which is able to identify and possibly rank feasible climate adaptation measures within a minute.

Research results
The design of functionality of the app was made based on previous research projects, like the Living with Water project Water Robust Building. The ambitions and expectations were defined together with stakeholders. A technically sound selection and ranking framework has been developed that includes criteria on climate change adaptation targets, soil type, land use, landscape conditions and user preferences. Next, the database containing 120 measures has been developed as input for the app and all measures were ranked on the criteria listed above. The framework was used as basis for the app and has been implemented in JQuery Mobile and Javascript. The app offers all functionality described above and additional descriptions of the measures, images and photos on the 120 measures. The app has been successfully tested in workshops with the municipalities of Delft and Rotterdam the province of Utrecht. In addition the app has been tested in Copenhagen and feedback has been used from Ho Chi Minh City and New Orleans. Although the app can be used in cities around the world, climate information on three pilot cities is included: Rotterdam, Ho Chi Minh City and New Orleans.
Planned future development focuses on retrieving local conditions from globally available datasets and further tailoring the app for cities on detailed local conditions.

Societal importance for stakeholders
The climate adaptation app gives urban designers, engineers and other stakeholders in urban development projects insight in feasible measures for a project with a specific climate adaptation goal. The app generates a selection and ranking of feasible climate adaptation measures based on a few choices on project type and local conditions, making it possible to apply the app in workshops and training settings. If for instance, an urban development in a flood plain is to be prepared for river flooding, the app will rank feasible measures based on the local conditions and the user's input.

DD 5.2-6 PLANNING TOOLS AND DESIGN STRATEGIES FOR INTEGRATED STORMWATER MANAGEMENT

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Research question
Several cities worldwide are developing adaptation concepts to address changing precipitation patterns. However, only few cities simultaneously recognize the transformation process of their drainage system as an opportunity to enhance the existing urban fabric. The objective is to analyze what kind of planning tools and large-scale design strategies these cities are using to achieve an integrated stormwater management in public space. Furthermore, the conditions under which these design strategies can be applied to other cities will be described.
The following three case studies were chosen for the analysis: Rotterdam, New York and Singapore. The analysis is based on the assessment of corresponding plans and publications as well as on interviews with various actors.

Research results
New York amends its sewer system which is in need of renovation by introducing a green network in public space. It infiltrates, retains, evaporates, and purifies runoff. The area-wide Green Infrastructure Plan highlights implementation possibilities and serves as a cost-benefit-analysis for decision-making.

In Singapore, tropical rain has hitherto been discharged into open concrete channels as soon as possible. In recent years, however, this method has been rethought and replaced by a blue-green network. For this purpose, open space master plans have been created to improve the water bodies.
Rotterdam aims to temporarily store as much runoff as possible to provide flood protection in the case of an extreme precipitation event. Due to the high groundwater table and the dense urban fabric, a temporary blue network is created by flooding sealed areas such as urban squares in a controlled manner. Waterplan 2 provides the necessary requirements for doing so.
Common to all cities is the interdisciplinary analysis of the hydrological, urban and landscape planning situation at the city-wide level to identify priority areas. An overall concept with corresponding objectives and guidelines defines the design strategies that come into effect at all planning levels.

Societal importance for stakeholders
The implementation of integrated adaptation concepts contributes to sustainable urban development. By implementing large-scale design strategies, space for water is created in different ways and the quality of life within the cities improved. These approaches can be applied to other cities and are particularly suited to municipalities already showing drainage problems and/or heightened susceptibility to the impacts of climate change. In cases where public space is characterized by quality deficits or a lack of open space is observable, an integrated approach should be adopted.

DD 5.2-6a URBAN CLIMATE CHANGE RESEARCH NETWORK: NEW APPROACHES TO CLIMATE CHANGE, WATER, AND CITIES

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Cities are emerging as the 'first responders' to climate change in both adaptation and mitigation. Their efforts are playing a role in catalyzing national and international responses as well. The Urban Climate Change Research Network (UCCRN), a consortium of over 450 scholars and practitioners in developing and developed country cities around the world, was established in 2007 to enhance science-based decision-making on climate and other sustainability related issues in urban areas around the world. The UCCRN's first major publication is the First UCCRN Assessment Report on Climate Change and Cities (ARC3), which represents a four-year effort by ~110 authors from 50+ cities around the world, and is the first ever global, interdisciplinary, science-based assessment to address climate risks, adaptation, mitigation, and policy mechanisms relevant to cities. The UCCRN has initiated the process of developing the Second UCCRN Report on Climate Change and Cities (ARC3-2), to facilitate ongoing and active learning and to continue providing practical, evidence-based guidance for city decision-makers. Presented here are new approaches for responding to climate change in cities, emerging through the work of the UCCRN and the ARC3-2 report, with a particular focus on urban water and wastewater systems. Formal and informal water supply services are highly vulnerable to drought, extreme precipitation, and sea level rise, and a range of adaptation measure will be required to insure the safe functioning of water supplies, especially in coastal regions.

DD 5.3-2 MAINSTREAMING SOCIAL PARTICIPATION INTO ASSESSING RESILIENCE TO CLIMATIC HAZARDS FOR LAND USE MANAGEMENT IN TAIWAN

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Research question

As urban and metropolitan development become increasingly stressed with climate change, the ability to face these stresses, adapt to the unfolding changes and to build more resilient communities becomes critical for developing countries. However, challenges remain for metropolitan agencies in the identification and development of components and metrics for measuring resilience. Particularly, uncertainties in climate change phenomenon and diversification of localized contexts compel urban planners to incorporate stakeholders' participation, indigenous knowledge and local attributes into resilience assessment. This article aims to propose a novel methodology for assessing resilience, which can encourage social participation and communicate planner to shape metropolitan land use management policies to reduce climatic hazard risks.

Methods and data

We construct an integrated index to characterize metropolitan resilience for Taichung metropolis in Taiwan at the local level, and combine a fuzzy multicriteria decision analysis with a participatory geographic information system (PGIS) to assess and map integrated resilience to climatic hazards. Using focus group meetings and the data collected from participations of experts, officers and community members, we employ a multivariate analysis to explain why low resilient areas occur in specific locations, and why some areas are particularly less resilient. Moreover, we accomplish a cluster analysis to group the areas into types of resilience, as well as to show the spatial distribution patterns of various core areas in which various planning measures are needed to be adopted and which characteristics to improve or promote for increasing resilience.

Results and societal importance for stakeholders

Through a PGIS-based approach, results of the estimated integrated resilience show that spatial distribution patterns of resilience are highly heterogeneous over the case study areas. The multivariate and cluster analysis indicate that the key factors contributing to low resilience include inferior biophysical, socioeconomic, infrastructural conditions and lower adaptive capacity. Our findings also show that conflicts and tradeoffs may exist between some resilience factors, especially socioeconomic vulnerability and adaptive capacity. This implies that land use planners should trade land use regulation, coping, infrastructural improvement, social learning and adaptive capacity for other socioeconomic vulnerable characteristics which ultimately lead to higher resilience. Our analyses provide stakeholders and policy-makers with a better governance structure to design and synthesize appropriate patchworks of planning measures for different resilience clusters of areas to reduce climatic hazard risks.

DD 5.3-3 MAKING URBANIZED DELTAS ADAPTIVE - A METHOD

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Introduction
Climate Change has been mentioned as the most important challenge for the future of urbanized delta regions. However, we like to emphasize that only not climate change as such, but also the uncertainty concerning climate change is an important challenge. A second challenge is the uncertainty concerning future land-use in delta-regions, which is dependent from economic and demographic trends and influences. In order to be able to deal with these uncertainties, delta regions should be able to adapt to changing circumstances in the future, without destroying the natural system, which is necessary for deltas to maintain itself as a sustainable system.

Research question
The central question is: how to increase the capacity of urbanized delta regions to adapt to uncertain changes of in the future.

Method
The paper describes the development of a method, based upon theories of complex adaptive systems and aiming to improve the adaptive capacity of urbanized delta regions, to synchronise the various sectors in the areas, and to organise collective action. The method has been developed in the Southwest delta of the Netherlands, but is relevant and applicable for other delta regions as well. The method is composed by four elements: (1) a historical analysis, to define path-dependencies; (2) a future scenario-analysis, (3) a stakeholder-analysis, to define current claims and issues in the region, and (4) a 'Delta Envisioning System', which delivers the possibility for involved stakeholders to link current short term issues with possible long term developments.

Research results
The result is a spatial framework for the delta region, which delivers the possibility to link short term and long term challenges and ambitions concerning spatial developments. This spatial framework can be considered as a new, revised version of the framework of the 'Room for the River' program.
Societal impacts for stakeholders
The method and the final result enables the various policymakers and stakeholders to synchronize their ambitions and actions. Especially policymakers and stakeholders focusing on projects with a relative short term and small scale character (local communities, real estate developers) and those with a long term focus (flood defense and water management authorities, environmental NGO's) are challenged to define common goals and a common implementation strategy.
The method has resulted in first steps of implementation in several areas in the Southwest delta of the Netherlands.

DD 5.3-4 THE ROLE OF CITIZENS IN URBAN RESILIENCE TO CLIMATE CHANGE - A REVIEW

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Research question
More incidents of heavy rains and storm surges, as a consequence of climate change, do increasingly challenge the existing water systems, leaving a pressing need for holistic and resilient solutions. However, urban wastewater management has so far mainly been handled by wastewater utilities with traditional solutions based on underground sewerage systems. However, the urgency of climate change demands new solutions to relieve the pressure on the existing system. Involving citizens is a necessity for developing innovative solutions benefitting to the function of the system, and supporting resilient and liveable cities. The key question is how citizens can gain more active roles in water management in order to strengthen resilience to climate change in cities and the paper explores different approaches and perceptions to citizens' participation in resilience in existing research.

Methodology and research results
Focusing on the western world, literature searches carried out in Web of Science and Scopus identify scientific articles dealing with the concepts of 'citizens' and 'resilience' in relation to flooding issues. A total of 99 articles match these criteria and are reviewed with the purpose to investigate the current literature's analyses of the roles of citizen in creating urban resilience to climate change. Based on the literature review of citizen roles in urban resilience a new research agenda within resilience, climate change adaptation and participation is presented.

Societal importance for stakeholders
In practice, local authorities and wastewater utilities handle urban climate change adaptation. There is a need for supplementary and alternative solution to the underground sewage system and wastewater treatment, however, handling water issues on ground demand involvement from citizens and private stakeholders. This article contributes a state-of-the-art of urban resilience to flooding and citizen involvement.

DD 5.3-5 IMPROVING THE ALLOCATION OF FLOOD RISK INTERVENTIONS FROM AN URBAN AND LANDSCAPE DESIGN PERSPECTIVE

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Societal importance for stakeholders
Delta regions throughout the world are subject to increasing flood risks. Strategies are therefore being developed to protect inhabitants and economic value in these deltas. In order to develop sustainable urban deltas, there is a need for interdisciplinary approaches in which urban designers and civil engineers can collaborate.
Methods for an integrated approach to flood risk and spatial design exist. These methods typically assume involvement of landscape architects and urban designers in studies at a relatively late stage; their role is limited to the task of optimally embedding flood risk interventions at given locations.

A method is developed that combines the perspectives of flood risk protection and spatial quality in earlier stages of the formation of flood risk intervention strategies, thusallowing designers to be involved in those earlier stages.

Research question
The research presented investigates a research by design methodology that addresses the perspectives of flood risk protection and spatial quality in an early research stage, when choices with respect to different scales and types of interventions in a delta are addressed.
The study demonstrates the potential of the different spatial scales and flood risklayers at which flood riskinterventions can be implemented, to change the locations of flood riskinterventions.This allows the allocation of interventions to locations that are most suitable from a spatial perspective.
The method was developed for a specific case study area in the Dutch delta, Rijnmond-Drechtsteden, and includes: An inventory of differentflood riskprotection strategies; an inventory of spatial characteristics and spatial assignments of a region; a qualitative assessment framework; and researchby design on how the choice of scale and layer of a flood riskintervention can shift the local flood riskassignment.

Research results
It is demonstrated that the method can be successfully utilised to shift theflood riskintervention to a location that is most suitable from a spatial point of view. This allows the spatial assignment to receive a more prominent role in the development of flood riskstrategies. The method, with some site-specific adjustments, is likely to be relevant for other urbanized delta areas.

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DD 5.4-1

THE POTENTIAL OF FLOATING URBAN DEVELOPMENT AND FOOD PRODUCTION FOR COASTAL DELTA CITIES

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Research question
The research question that is addressed in this study is: what is the overall potential of floating urban development and floating food production to deal with global land scarcity, and what is the potential in three delta cities?

Methodology
An extensive literature survey was executed to evaluate relevant global trends in agriculture, land use, demographics and food and energy consumption, in order to estimate land shortage in 2050. The following land use typologies and processes were taken into account: 1) Urban area; 2) Food production area; 3) Biomass production area; 4) Climate change impacts; 5) Land degradation. Several aspects related to floating urban and agricultural space were

analyzed and compared with current urban and agricultural models. Two scenarios for 2050 were developed in order to estimate the future benefits and implications of floating development, by analyzing the required space, efficiency in terms of water, nutrients and CO_2.

Research results

The results include an evaluation of the space use efficiency of floating city expansions and food production. The conclusion of the article is that floating developments can be a promising solution to global land scarcity, especially if a symbiosis is created between cities on land and floating developments on water. This symbiosis is achieved using waste nutrients and CO_2 for the production of food and biofuel in floating cities, with the application of floating algae systems. This approach closes nutrient and waste cycles and can provide ecological services to coastal cities.

Societal importance for stakeholders

Delta cities face rapid urbanization, rising food demand, land degradation and increasing biofuel demand which will put pressure on the available land. At the same time, these cities are threatened by extreme events and the effects of climate change. Therefore, there is a need to study innovative solutions that provide a perspective to deal with these challenges. this study evaluates if floating urban expansion and floating food production can contribute to a solution for global land shortage and more specifically, the potential of floating developments in three delta cities: Rotterdam, Jakarta and Manila are evaluated. For the city of Rotterdam, also a pilot project for implementation is presented.

DD 5.4-2 THE ROLE OF PUBLIC-PRIVATE PARTNERSHIPS TO ADDRESS CLIMATE RISKS:CASE OF THE LONDON CLIMATE CHANGE PARTNERSHIP

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As climate risks continue to mount it is increasingly clear that managing these cross-cutting risks cannot be addressed successfully at any single institutional or spatial scale or by any one category of actor. As such, private sector, government and other sectors of society need to cooperate and develop well-functioning partnership approaches for supporting climate risk reduction and adaptation. However, partnerships are often underpinned by complex multi-scale governance arrangements that need to be better understood and existing partnerships have often proven ineffective in managing risk from natural hazards. This paper presents findings from a case study of the novel London Climate Change Partnership (LCCP) as a lens for understanding the effectiveness of public-private partnerships to address climate risks, specifically flood risk in the delta city of London. This case study forms part of a large EU-funded research project ENHANCE. ENHANCE aims to develop and analyse new ways to enhance society's resilience to catastrophic natural hazard impacts and develop supportive multi-sector partnerships (MSPs). The LCCP was established in 2002 as a centre for expertise on climate change adaptation and resilience to extreme weather in London. The partnership has focused on building resilience within and between sectors and is comprised of public, private and community sector organisations and actors engaged in preparing London for extreme weather and predicted climate change impacts. The paper presents findings from a survey and interviews with LCCP representatives and additional stakeholders, together with other data sources to reflect critically on the processes and barriers to developing effective and novel MSPs as required for tackling highly complex climate risks at multiple scales. Building on the case study findings, the paper reflects upon indicators for successful partnerships

and governance arrangements in improving resilience at multiple scales. Although empirical evidence is based on the specific London context, the key findings apply more widely to delta cities in the EU context and beyond.

DD 5.4-3

SPATIAL COST-BENEFIT ANALYSIS OF FLOOD-PROOFING BUILDINGS IN NEW YORK CITY

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In October 2012, Sandy wreaked havoc in New York City (NYC), causing billions of dollars damage to buildings in coastal zones of all boroughs due to flooding. In order to cope with this flood risk, there are conceptually two options: preventing flood waters from reaching the buildings (using surge barriers, levees, etc.), and/or minimizing the damage flood waters can cause by adjusting the buildings (i.e. flood proofing). Currently, NYC has little coastal defense structures to keep flood waters out, making building codes an important part of flood risk management in NYC.
To support this, we investigate in this paper the feasibility of water-proofing buildings in NYC in terms of costs and benefits.

Whereas costs of elevating a building do not depend on the geographic location, the actual flood risk (and thus potential reduced risk or benefit) does very considerably depending on the location. In addition, there are various water proofing measures possible (i.e. elevating, dry-proofing, wet-proofing), which can all be applied up to different heights (i.e. elevating 2 or 6 feet). Here, we therefore perform spatial cost-benefit analyses at the census-block level (~36000 units in NYC) for three types of measures (elevating, dry-proofing, wet-proofing) and three different heights (2, 4, 6 feet). We use a hazard and risk modeling framework based on ADCIRC and HAZUS consisting of 549 storms resulting in water levels and damages with different return periods to estimate flood risk and the benefit of the measures. Cost-wise, we estimate costs for adjusting the current building stock, but also perform spatial cost-benefit analyses related to implementing the measures for projected new buildings.
The results show the locations in NYC where it is cost-effective to implement flood proofing measures. Moreover, they illustrate where and which type (and height) of measure is most cost-effective. By aggregating this, a mix of measures can be derived that maximizes the potential of flood proofing measures in NYC and the total potential with respect to the total risk can be obtained.

DD 5.4-4

URBAN ADAPTATION TO CLIMATE CHANGE IN ROTTERDAM: FROM CITY TO NEIGHBOURHOOD

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Climate change is predicted to increase heat stress in cities in the Netherlands. This climate change effect adds to an already warmer urban environment due to the so called ‘urban heat island’ effect and the bad air quality in cities. Action is required to improve the quality of life of citizens, both in new and existing urban areas. However, policy

makers and urban designers are slow to integrate climate adaptation. To choose for certain climate adaptation measures a better understanding is needed of the options to intertwine measures with a specific urban structure.
The aim of this paper is to study the spatial implications climate adaptation measures have for various neighbourhood typologies in Rotterdam. First, the city of Rotterdam is analysed with the use of satellite imagery to identify areas where urban heat is accumulating. In the second step the selection of case study neighbourhoods is described based on their vulnerability to heat stress. The following third step contains an analysis of the type of land use which adds facades as an urban surface . For each neighbourhood typology the potential gains in thermal comfort are described based on the urban surface analyses and the building typology. Because humans tend to stay indoors for 90% of the day, we will be focussing on the role of the indoor experience in the way that people are exposed to urban heat.
The potential gains from the urban surface analyses are elaborated in an integral design. In the design process many hypothesis are considered and judged based on expert knowledge and links that become apparent. The paper provides a concise overview of approved climate adaptation measures from literature and includes: vegetation and water; light roofs and ventilation; and technical solutions like solar collectors.
Usually, thermal comfort is not considered the most important aspect of an urban redevelopment project. Therefore, relations with for example; parking, energy consumption and the water system are essential to realise climate adaptation measures. Especially the energy reduction that could be achieved with an adaptation measure is important for the financial feasibility. Therefore, energy consumption and production are calculated for each case study. The study will provide policy makers and urban designers with a clear indication which adaptation measures are most appropriate for a specific neighbourhood typology. The spatial implications and gains of some adaptation measures are made visible, which can convince people in the field to take action.

DD 5.4-5

TOWARD A COST-EFFECTIVE RESTORATION OF A VITAL COMMUNITY IN A SAFE DELTA, DESIGN OF THE 'NEW MEADOWLANDS', NEW JERSEY

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The metropolitan region of NY-NJ is a delta with the Hudson River, East River, Hackensack and Passaic all converging. This area was severely impacted during Hurricane Sandy in October 2012 with high damage to infrastructure, economic activities and society. The Meadowlands area emerged as highly impacted in a broad spectrum of vulnerabilities combining flood risk with social vulnerability, vital network vulnerability, pollution risk.
In a transatlantic consortium centered around MIT-CAU + ZUS + De Urbanisten, the 'New Meadowlands' design was developed. It articulates an integrated vision for protecting, connecting, and growing this critical asset to both New Jersey and the metropolitan area of New York.
Firstly, primary protection against flooding is realized. A green multi-purpose berm with occasional gates, along the edges of the Meadowlands and most of its developed areas will protect against flooding from storm surges. It will safely connect the various economical and urban centers and provide new public space structure for mediating

economical and societal growth (the Meadowband). Within the protected areas, substantial fresh-water basins will absorb rainwater, substantially reducing the storm water runoff into sewer lines, almost eliminating local flooding from sewer overflow. Outside the berm, nature will flourish and provide additional services to increase flood safety and ecosystem quality, in the line of Nature Based Flood Defense approaches implemented in the Netherlands (the Meadowpark).
The 'New Meadowlands' project will enhance the brand and identity of the basin, drive up the value of the land, and increase the ratable tax returns for the towns concerned. The cost-benefit analysis for this project yields a factor of 2 against a business as usual scenario. In each smaller scale area, the project will consist of a mix of actions within the opportunities created by the larger scale integrated vision, specifically (a) Meadowband berms and public space design and construction; (b) rezoning of functions to create Meadowpark; and (c) integration with other ongoing initiatives, based on substantive outreach efforts and involvement of stakeholders.

DD 5.5-2 FLOOD PROTECTION AND WATER RESILIENCY FOR CRITICAL FACILITIES IN THE NEW YORK CITY REGION

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Methodology
As a result of global urbanization of deltas and coastal areas, the value of real estate and waterfront infrastructure shows continues expansion. The New York City Region follows a trend comparable to delta and coastal cities like Singapore, Jakarta and Rotterdam. One of the key challenges for the New York City region relates to the optimum integration of short term (<5 years) measures to protect individual and critical facilities vs. longer term protection measures on a larger, regional scale.

Research approach
To analyse the impact of the surge on the telecommunication and large office buildings and hospital campuses and determine appropriate mitigation measures, ARCADIS is using the so called 'Design Cycle' with the following study steps:
- Evaluation of site conditions;
- Ranking of potential protection strategies;
- Incorporate top ranking strategies into an integrated solution.

The objective of the first steps is to understand the impact of the storm surge, by analysing wave loads and propagation of surface water, using hydrodynamic modeling such as FLOW-3D.

Research results and societal importance for stakeholders
The New York City Health and Hospital Corporation hospitals are located along the edge of Manhattan, at low lying parts close to the water. The recommended level of protection for hospitals relates to the 500 year flood elevation as given by the Federal Emergency Management Agency (FEMA). For the short term several individual flood protection measures are currently being evaluated and installed. For the long term larger scale collective strategies are being studied.
The Lower Manhattan utility and office buildings are located in one of the most densely built areas in the world. For the down town communication buildings, solution were found in the construction of aluminium panels that can be

connected to the façade of the building. For surrounding high level office buildings, the integration of flood protection with anti-terrorist bollards or potential closure of underground channels with surge gates leading to WTC is part of studies.
The Bay Park Sewage Treatment Plant (STP) - the Bay Park STP was put under a state of emergency and shut down for several months when the plant was flooded and the buildings were inundated with flood water from the nearby bay. In a series of technical memoranda, the vulnerability of the plant has been studied. This has led to a comprehensive strategy that will be constructed in 2014 along the STP.

DD 5.5-3 CLIMATE CHANGE IMPACT ON THE DRINKING WATER DISTRIBUTION NETWORK TEMPERATURE

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Health effects of exposure to heat waves are well known. However, the risks due to water quality deterioration in the drinking water distribution systems are less well known. The temperature of the urban soil around the drinking water distribution network , at ca. 1 meter depth, changes under influence of different factors. Blokker and Pieterse-Quirijns developed a micrometeorology model to predict the soil temperature at various depths as a function of weather and environmental conditions. They showed that the water in the drinking water distribution system approaches the surrounding soil temperature. Water temperature is an important determinant of water quality, since it influences physical and chemical processes, such as absorption of chemicals, and chlorine decay. In the Netherlands drinking water is distributed without additional residual disinfectant and the temperature of drinking water at the customers' tap is not allowed to exceed 25 °C. During a warm year, 0.1% of the routine water quality samples exceeded this value, and ca. 14 days reached a maximum soil temperature above 25°C. With increasing extreme weather events due to climate change and with more local variations due to the urban heat island effect, more samples may be expected to exceed this limit. Specifically in urban areas, with concentrated population and multiple heterogeneous land cover characteristics, tools are needed to monitor and predict drinking water temperature in the network at small spatial scales. The objective of this study is to extend the model to evaluate the impact of the urban heat island effect on soil temperature. Anthropogenic heat emissions and urban parameters were based on literature values based on the local climate zones. The study area is the city of Rotterdam in the Netherlands. The soil temperature for 2013 was simulated using data from the Dutch meteorological institute as an input. To calibrate and validate the model, soil temperature in two locations were measured during six weeks. A good correlation between the soil temperature simulated and the soil temperature measured was found. This paper demonstrates that it is possible to use meteorological information to predict urban soil temperature and therefore to estimate water temperature in the drinking water distribution network. The soil temperature model can be used to analyse the risk of exceeding the temperature limit, particularly during heat wave events and in highly urbanized areas. Moreover, the effect of mitigation measures such as green roofs can be also quantified.

DD 5.5-4 THE INFLUENCE OF ACTIVE GROUNDWATER MANAGEMENT ON THE CURRENT AND FUTURE WATER DEMAND OF URBAN AREAS

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Research question
There is a lack of knowledge about the influence of active groundwater management on the total urban water demand. The research question is: what is the water demand of urban areas in the Netherlands, now and in the future, and what is the additional water demand if active groundwater management would be introduced in urban lowland areas?

Methodology
To determine the land use of an average city in the Netherlands, a national land use analysis was done using GIS. An intersection was made between the National land use data and five categories of urbanity of Statistics Netherlands. An estimation of the urban water demand was made by investigating evaporation, urban water use and losses to the wastewater treatment. For a more detailed assessment, a daily time series model evaluation of the characteristics years of the Delta program was used under different climate scenarios and with various active groundwater management strategies.

Research results
The average yearly total water demand of urban areas in the Netherlands amounts to 4.2 km^3. With active groundwater management in the entire urban lowland area in the Netherlands, the additional water demand amounts to 0.16 km^3 in a dry year and 0.3 km^3 in a very dry year in the current climate. In a very dry year in the most extreme climate scenario this additional water demand may increase to 0.45 km^3. In practice, active groundwater management will only be applied in the vulnerable areas and the additional water demand will be lower. While the additional water demand is relatively small compared to the total urban water use, the additional demand will occur during dry spells when water availability is under pressure. Therefore, this additional water demand should not be neglected.

Societal importance for stakeholders
Climate change may lead to higher groundwater table fluctuations. In vulnerable lowland urban areas in the Netherlands, this will lead to damage to buildings, underground infrastructure and above ground infrastructure as wooden pile foundations will be exposed to oxygen if the groundwater levels are too low. Therefore in the Delta Program, there is a need to have more insight in the additional water demand that is needed to reduce groundwater level fluctuations. This study has contributed to this purpose by investigating the additional urban water demand as a result of active groundwater management in different climate scenarios.

DD 5.5-5 IS IT POSSIBLE TO DEVELOP A MODEL OF SUSTAINABLE URBAN WATER CYCLE?

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Cities impact the natural water cycle through modifications of the environment and through their water consumption and discharge. Toward sustainability-compatible urban water management, important factors are also: global and local climate changes, landscape changes, energy and transport systems, and the overall ecological footprint of the cities.

What should be the best way forward? Current analyses suggest that we need (i) a coherent systemic view on the interactions between environment, society and economy, and (ii) experimenting cross-sectorial innovation that is both system-relevant and efficient.

We propose an Urban Water Cycle Model that can be used as tool and reference for urban water system management. In order to deal with the limits of our knowledge, and to address the complexity and unpredictability of the natural and social systems, the model is grounded in several principles:

1. It is developed in analogy with the natural water cycle and accounts for the related biogeochemical cycles, so as to understand human impacts on natural processes and their implications for urban and environmental management.
2. It is cross-sector coherent but also an evolving model, with inbuilt flexibility ergo adaptability.
3. It is linked to the natural water cycle through water consumption and discharge.
4. It is striving to deal with the issue of knowledge fragmentation and data availability,
5. It is conceived as a versatile tool, which is (a) capable to absorb knowledge and experience coming from various case studies and projects and (b) serve back as a reference that can be utilized in new projects that aim at developing and testing new solutions for urban water management and urban sustainability in general.

The model consists in an operational definition of the interactions between the four main categories of urban water - white, gray, rain, and black water - along three phases: water use, water re-use and water discharge. This involves both quantitative estimations (based on available data) and background qualitative approaches - notably the assumptions used in computer models, and referring to data availability, individual/collective choices and social acceptability, technological readiness and economic relevance.

The model is tested with samples of proxy data from a series of European cities and we make recommendations for urban adaptation to climate change, and developments of future urban water infrastructure. We believe that this model can enable future smart water networks, and inform more coherent urban development scenarios for the local communities.

Two figures not shown / not allowed.

DD 5.6-1 CLIMATE PROOFING AND MASTERPLANNING OF DELTA CITIES: THE CASE OF BEIRA, MOZAMBIQUE

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Strategic challenges for Beira1. The goal of the Masterplan Beira 2035 is to make a significant contribution to a safe, prosperous and beautiful Beira. Beira essentially faces three challenges:

- To utilize the economic potential of the city, mainly due to its strategic location and at the end of an important transport corridor;
- To improve the poor living conditions of a large part of its inhabitants, mainly due to poor infrastructure and service coverage;
- To adapt to climate change and sustainably coexist with its natural environment. Beira is located in a delta and large parts of the built up areas are prone to flooding and are threatened by sea level rise and are prone to flooding.

An integrated and planned approach to meet these challenges has been prepared. In addition, a clear implementation and financing strategy was added which is an essential part of the approach.

Core strategic interventions have been selected as well as the necessary pre-conditions for the successful implementation of these interventions such as;

- Utilizing the economic potential of Beira
- Improving the living conditions and quality of life of the citizens of Beira
- Climate change adaptation and climate proofing

The following specific challenges were identified:

- Getting grip on future urban growth and land development.
- Parts of the city expansion areas need land preparation (leveling and elevation) and require huge amounts of sand which is a scare resource in Beira.
- How to finance new (road and railway) infrastructure?
- Financing capacity of the City of Beira is limited.
- How to guarantee reliability of infrastructure?
- How to create a basis for joint implementation and sustainable cooperation between relevant stakeholders?

The applied approach is a good example of the so-called Dutch approach for integrated planning and considers the following elements:

- Sharing ownership and stakeholder involvement.
- Where do we want to be in 25 years' time? - vision/strategy/political commitment.
- Enhance performance/catch up with autonomous development/1st things 1st
- Follow the money. Look for finance for improvement urban infrastructure and service delivery?
- How to deal with socio-economic and climate uncertainty? - short term/long term planning.
- Applying positive lessons learned in NL cities to African cities.

One of the core strategic interventions is will be the establishment of a Land Development Company. It will be explained in the presentation how this interventions responds to most of the challenges identified.

DD 5.6-2 ASSESSMENT OF NATURAL HAZARDS AFFECTING THE DELTA CITY OF JAKARTA

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Jakarta is the capital city of Indonesia with a population of about 9.5 million people, inhabiting an area of about 660 square-km. It is located within a deltaic plain and passes by 13 natural and artificial rivers flowing through it to Java sea. In the last three decades, urban development of Jakarta has grown very rapidly in the sectors of industry, trade, transportation, real estate and many others. This rapid urban development has caused several negative externalities, such as: extensive conversion of prime agricultural areas into residential and industrial areas, significant disturbance to main ecological function of the upland of Jakarta area as a water recharge area for Jakarta city, and increase in groundwater extraction due to development of industrial activities and the high population increase. In turns Jakarta is then prone toward a few natural hazards mainly land subsidence and flooding. The recent larges flooding in Jakarta occurred in 1996, 2002, 2007, 2013 and 2014.
The results obtained from leveling surveys, GPS surveys and InSAR technique over the period between 1982 and 2011 show that land subsidence in Jakarta has spatial and temporal variations. In general the observed subsidence rates are about 1 to 15 cm/year, and can be up to 20-25 cm/year at certain location and certain period. In general, the impacts of land subsidence in can usually be seen in the forms of cracking of permanent constructions and roads, changes in river canal and drain flow systems, wider expansion of coastal and/or inland flooding areas, and malfunction of drainage system.Several areas along the coast of Jakarta already have experienced tidal flooding during high tide periods. These coastal flooding usually occurs in the areas with relatively large subsidence rates. Subsidence in the areas along the rivers which are flowing throughout Jakarta, will also worsen the impacts of riverine flooding. The changes in river canal and drain flow systems and malfunction of drainage system due to land subsidence will also aggravate the flooding.
The economic, social and environmental losses due to these natural hazards in Jakarta are indeed enormous.
This paper analyses and discusses the risk and impacts of land subsidence, flooding, sea level rise and high tides phenomena in Jakarta; and the optimal (structural and cultural) measures and policies to minimize their impacts.

DD 5.6-3 A TALE OF TWO CITIES IN TIMES OF CHANGES: HONG KONG AND MACAU

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The Pearl River Delta (PRD) region in China has experienced fast urbanization since the late 1980s. Now it is one of the most densely urbanized regions in the world and one of the main manufacturing and industry regions to support China's economic growth. Under stress of the increasing new immigrants and urban sprawl, the future development of whole region is associated with environmental pressure. Due to global and regional climate change, a series of extreme weather events, rainfall patterns and higher temperature have been witnessed. They could highly affect local people's comfort and the public health condition. Thus, there is a need to adapt climate change and to create high-quality urban living environment for this region. Hong Kong and Macau are two important megacities in the PRD, which are selected to conduct a case study.
The paper first reviews the regional climate change trends and impacts on two high-density delta cities to get a holistic background understanding. Secondly, it explores the impact of urban development on the thermal and wind environment by using the Weather Research and Forecast (WRF) model simulations, and points out the climatic issues and problems. Thirdly, it employs Urban Climatic Map (UCMap) to evaluate the current climatic conditions under high density urban fabric. The results could provide a visual and spatial climatic information platform to local planners and policy maker. Lastly, it identifies adaptation measures from the view of climatic spatial planning for the two cities based on local climate change policy.

DD 5.6-5 FLOOD ADAPTIVE CITY: THE FUTURE OF MEKONG DELTA-CITIES

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Deltas are important natural and dynamic landscapes. However, deltas are vulnerable areas to change by natural forces and human activities. Moreover, the damages from natural hazards show an increasing trend in recent decades. Besides the reasons caused by the frequency or intensity of natural disasters, the trend in higher damages is also a consequence of increasing in population and higher economic investments. An emerged question is how to combine the goal of safety against flooding and the goals of improving quality of life, promoting economic development, and preserving ecological values of the delta.
Currently, flood risk management in the Mekong Delta is recognized by a two-stage process: self-protection and engineered defense. However, civil engineering is separated from urban design in which civil engineering mainly focused on the purpose of diminishing the danger of flooding and that of developing agricultural production; while urban design concerned with the composition of patterns, street systems and mainly focused on issues of land use. This study, therefore, relates to the question of what are the new balance between the natural character of the Mekong Delta, engineering interventions and possibilities of urban development. Two main issues will be concerned. Firstly, it is the solutions to integrate urban planning and design and flood risk management. Secondly, a cross-scales method of urban planning is conducted.

The paper firstly describes the process of urban development in the Mekong Delta. The research emphasizes the important role of the hydraulic infrastructure system in the changes of urban pattern. There are four types of the delta-city and town: river city, crossroad city, coastal town, and canal town. For each type, the relationship between city and flood control system will be analyzed. Secondly, base on possible scenarios of socio-economic development, population growth and climate change, the research presents different strategies of flood risk management at the regional level. Following each variation, the possibilities of urban development and spatial quality at the local scale are proposed. By interweaving of urban spatial and the hydraulic infrastructure system, diversifying function of open-space, and maintaining the waterways and floodable land for livelihood and living, we argue that the impacts of flooding can be avoided.

Keywords
Urbanizing Mekong Delta, flood adaptive cities, flood risk management, living with water.

Deltas in Depth Theme 6:

Rural development and food security

DD 6.1-1

PREDICTING VEGETATION PATTERNS UNDER FUTURE CLIMATIC CONDITIONS WITH A PROCESS-BASED ECO-HYDROLOGICAL MODEL

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Research question

Climate change may hamper the preservation and development of current nature targets, which are partly obligatory through European law. A timely response to climate change through adaptive measures can eliminate potential threats, while at the same time creating opportunities for nature development. Habitat distribution models (HDMs) play an important role in evaluating the effects of climate change and adaptive measures. Current HDMs, however, are likely inapplicable under changing climatic conditions, for instance because they use indirect empirical relationships between habitat factors and vegetation, based on measurements from the current climate.

Research results

By modeling habitat factors that directly impact on plant life - such as the availability of moisture, oxygen en nutrients in the root zone of plants - and by using robust relationships between these operational factors and plant traits, we are able to predict vegetation effects under different scenarios of climate change. Outputs are maps showing the occurrence probabilities of vegetation types and their associated conservation values. The model was applied to a small catchment of 270 km2 to forecast the effects on a 25 m resolution of a national climate scenario, related to the IPCC A2 and A1B scenarios. Severe loss was predicted for wet and mesotropic Junco-Molinion and Calthion palustris grasslands, while vegetation of dry and acidic soils appeared to profit. The results could not have been foreseen with sufficient knowledge and good reasoning, especially because of spatial hydrological interactions.

Societal importance for stakeholders

It is questionable whether nature targets, for example those formulated under the European Habitat Directive and the Water Framework Directive, are still attainable in changed climatic conditions. At present, focus in nature conservation is, as the name implies, on the conservation of existing distribution patterns of ecosystems and species. This can be done by carrying-out measures such as different planning of nature targets in the ecological networks, the creation of hydrological buffers against desiccation, and water storage in aquifers during wet periods. Climate change may, however, also asks for a more flexible approach, not only aiming at the conservation of existing patterns, but taking the opportunity to exploit potential future hotspots of biodiversity as well. To design adequate measures and spatial plans, and to avoid ineffective ones, policy makers, nature managers and spatial planners require information about the feasibility of nature targets under a future climate.

DD 6.1-2 IMPLEMENTING AN ECOLOGICAL NETWORK IN A DENSELY POPULATED AREA UNDER CONDITIONS OF GLOBAL CHANGE

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Like most large deltas, the Netherlands is densely populated, and pressure on land is high. Nevertheless, in the 1990's the country committed itself to the implementation of a National Ecological Network (NEN), in order to safeguard and promote biodiversity. The network was foreseen to be finalized in 2018, and would comprise 728,500 ha. Currently, the NEN has been implemented for only 55-60%; the remaining 185,000 ha (a reduction of 18 % of the initial ambition) is to be implemented within the coming 10 years.
However, both policy reform and global change may jeopardize further implementation. With policy reform we mean the abolition of an intermediary organisation that organizes land trades with the support of a national land bank. With global change we mean a combination of rising groundwater tables arising from climate change and improved economic prospects for farming. In order to evaluate the effects of these factors on future land acquisition for the NEN, we applied an agent-based model of the land market based on sales and purchases between farmers and nature organizations within a case study area. Our research questions were: How will land acquisitions for the NEN proceed until 2025, for two contrasting global change scenarios? How will these acquisitions relate to the official targets? What will be the effect of land purchases and expenditures if nature-organization agents increase their willingness to pay?
Our result demonstrate that future land acquisitions for the NEN are jeopardized by: (1) budget limitations, (2) the abolition of national land bank facilitating land trade, (3) strong competition for land by farmers, (4) a gradual loss of typical land-selling farms, and (5) the low willingness to pay for land by nature organizations. Climate change may alleviate the competition between farmers and nature managers, as higher groundwater tables result in parcels becoming too waterlogged for agricultural purposes, but of particular interest to nature organizations. Out of the five constraints listed above, 3 and 4 concern global or autonomous developments against which policymakers can do very little. The other three constraints can, however, be influenced by policy. Budget increases would be useful, but only if nature organizations display a higher willingness to pay. However, since this might involve undesired market distortions, addressing constraint 2 represents a better way forward. This would involve the re-establishment and maintenance of an intermediate party to organize land trades with the support of a national or provincial land bank.

DD 6.1-3 DRIVERS, CONSTRAINTS AND DYNAMICS OF WELLBEING FROM ECOSYSTEM SERVICES IN THE DELTAIC ENVIRONMENTS OF BANGLADESH

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Deltas are highly productive environments that provide a range of ecosystem services, but yet support some of the world's poorest populations. Recent research has responded to such paradoxes by determining where and when the contribution of ecosystem services to poverty alleviation is positive or negative and the processes that lead to that situation. In this paper, we argue that the wellbeing outcome of ecosystem service use is mediated by five dynamic factors: productivity of ecosystems including agriculture; climate variability and seasonality; mobility; social relations; and the nature and strength of property rights. While the importance of each of these factors has been acknowledged individually, this research analyses their aggregate and interaction effects. We investigate the shape of these effects across diverse social-ecological systems within delta environments through analysis in seven social-ecological systems in coastal regions of the Ganges-Meghna-Brahmaputra delta in Bangladesh including mangrove, fishery, char, aquaculture and agriculture-dominated systems. Interactions are identified from primary data from seventy-five semi-structured household interviews sampled across different systems, income levels and income types in Khulna and Barisal divisions. The results show that all five factors are important in transmitting wellbeing from ecosystem services but that each factor takes on a different importance and valence depending on the socio-ecological system in which it acts. The role of social relations and patron-client interactions are particularly fluid. Deltas are characterised by a diversity of ecosystem services provision. This socio-ecological systems approach acknowledges the interaction between the natural environment and the societies dependent on them. We suggest that the five factors are the principal determinants of wellbeing in delta environments, are currently under under-appreciated and a better understanding of them would lead to more effective poverty interventions in rural areas.

DD 6.1-4 COLLECTIVE IMPLEMENTATION OF AGRI-ENVIRONMENT CLIMATE MEASURES WITH A SPATIALLY EXPLICIT AGENT-BASED MODEL

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Introduction

This paper presents an analysis of the spatial, ecological and economic impact of farmers' cooperative decision-making for the European Commission's legislative proposals for the Common Agricultural Policy (CAP) 2014-2020 on farmers, their land use and their surroundings. The European Parliament and the Council explicitly included collective implementation of Ecological Focus Areas (EFAs) involving several farmers (Regulation no. 1307/2013). EFAs are meant to improve environment, climate and biodiversity on farms, such as buffer zones along water courses (Pillar I). The EFA should ensure that it contributes to general environmental performance of the agricultural holding, including

improvement of water quality and meeting climate mitigation and adaptation objectives. Also Pillar II includes payments for agricultural practices that are beneficial for the climate and the environment.

Research question
The main research question of this paper is: what is the impact applying collective approaches for both Pillar I greening measures and Pillar II agri-environment-climate measures linked to flood protection and fresh water management.

Research results
Results of experimentation with the model in the case study Oost-Groningen (arable farming) and the case study Winterswijk (dairy farming on sandy soils) show that farms will choose their less productive land to be EFAs directed at water and climate linked measures. These EFAs will be scattered around the area. Less productive land that is not sufficiently located in neighborhood of the farmstead will be under EFAs. The analysis is based on scenarios with a spatially explicit rural agent-based model (SERA) that explicitly models farmers, their socio-economic decision-making, their land use, and the landscape of which they are part.

Societal importance for stakeholders
We conclude that this approach is novel and holds promise as a way to explore the impact of environmental cooperative decision making on rural areas including regional and collective water arrangements. The modeling approach used in this study integrates both the natural environment and the socio-economic component at a detailed level. In this way insight is gained into the complex dynamics of rural areas while imposing different types of policy instruments with different types of management regimes to the (water) system. These insights can be valuable for policy makers and managers (farmers) to evaluate what the impact is of flood protection and fresh water management, and to gain insight into the impact of cooperative behavior, while aiming at creating sustainable development.

DD 6.1-5 ECONOMIC AND SOCIAL DRIVERS OF LAND USE CHANGE IN COASTAL BANGLADESH

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Bangladesh's coastal belt is characterized by high population growth, rapid land use intensification and change as well as regular occurrences of natural calamities. The situation is particularly sensitive due to salinity intrusion as a result of interception and withdrawal of surface water up-stream and sea-level rise from the south. However, the social and economic processes leading to land use change, land degradation and salinization are still not fully understood. For a better insight into these processes, our paper will present findings of explorative field work conducted in 2014 on 15 villages in six coastal districts, mainly employing semi-structured interviews.
Our findings confirm the existence of recent wide-spread changes in land use patterns. Increasing intensity of land utilization is mainly due to immediate economic demand. Overall, cropping has increased from single to double and from double to triple harvests per year, resulting in an overexploitation of surface and ground water. In many coastal villages, however, we rather observe a decrease in the number of harvests due to ongoing soil salinization. Some

farmers are able to close the production gap by using new high-yield rice varieties (HYV), improved technical skills, machines, and additional irrigation. Local and international development organizations support farmers particularly in those areas affected by the devastating 2007 and 2009 cyclones Sidr and Aila. The rapid transformation from natural forests and rice paddies to shrimp ponds in many coastal regions is not only triggered by domestic decision-making, but also by integration into global supply chains and the logics of external markets. This becomes particularly evident in the case of saltwater shrimp farming in the Khulna, Bagerhat and Satkhira districts and the related displacement of many traditional land users and small farmers. In long term, these processes may undermine indigenous coping, mitigation and adaptation strategies as well as social bonding which, in the past, have been important mechanisms for coping with floods, cyclones, and storm surges.

Our work is part of the larger Belmont Forum-funded BanD-AID research program 'Bangladesh Delta: Assessment of the causes of sea level rise hazards and integrated development of predictive modeling towards mitigation and adaptation'. The results of this research are relevant for a broad range of societal stakeholders, including administrators, NGOs, and farmers.

DD 6.2-1 OPTIMAL CROP PRODUCTION SUPPORTED BY CLIMATE-ADAPTIVE WATER MANAGEMENT

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Research question

Agricultural crop yield depends largely on the moisture conditions in the root zone; drought but especially an excess of water in the root zone and herewith limited availability of soil oxygen reduces crop yield. With recent climate change, more prolonged dry periods alternate with more intensive rainfall events, which changes soil moisture dynamics. With unaltered water management practices, reduced yield due to both drought and waterlogging will increase. Therefore, farmers and water boards need to be provided with possibilities to reduce risks of low yields. We provide a basis for and evaluate the application of a decision support system (DSS), which allows to optimize crop yield by timely anticipation on drought and waterlogging situations, and to minimize plant stress through automated drainage and irrigation management.

Research results

Our study comprises both the set-up and application of the DSS on three pilot plots in The Netherlands, in order to evaluate its implementation into daily agricultural practice. The DSS focusses on anticipatory water management at the field scale, i.e. the unit scale of interest to a farmer. We combine parallel field measurements ('observe'), process-based model simulations ('predict'), and the Climate Adaptive Drainage system (CAD) ('adjust') to optimize soil moisture conditions. The DSS has a core of the field-scale SWAP model (soil-water-atmosphere-plant), extended with a module for the simulation of oxygen stress for plant roots. Continuous measurements of soil moisture content, groundwater level and drainage level are used to calibrate the SWAP-model each day and to optimally reproduce the actual soil moisture conditions by data assimilation in the first step. During the next step, near-future (+5 days) soil moisture conditions and drought and oxygen stress are predicted. Finally, optimal drainage levels to minimize stress are simulated, which can be established by CAD. Using local-scale measurements, process-based models and

weather forecasts to anticipate on near-future conditions, optimizes not only field-scale water management but also regional surface water management by the water board in space and time.

Societal importance for stakeholders
In The Netherlands, agricultural production of crops represents a market exceeding 2 billion euro's annually. Given the increased variability in meteorological conditions and the resulting larger amplitudes in soil moisture contents, it is of large economic importance to provide farmers and water boards with tools to reduce risks of reduced crop yield by anticipatory water management at field and at regional scale.
Funding is provided for by Topsector Water/NL and FutureWater (SME).

DD 6.2-2 FUTURE TRENDS IN CROP PRODUCTION AND FOOD DEMAND AND SUPPLY IN THE LOWER MEKONG BASIN

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The majority of the population in the Lower Mekong Basin (LMB) lives in rural areas. Especially in the Mekong delta, agriculture is the most important economic sector, highly water-dependent and thus vulnerable to changes in water availability and water quality. At the same time, there is growing concern about the potential impacts of climate change on natural ecosystems, socio-economic structure and food security in the region. However, a comprehensible overview of expected changes under climate change and other drivers of change in crop production and food demand and supply in the LMB is still missing. Earlier initiatives were location specific, including only climate change as a driver of change, and not capturing the complex interactions that arise from the transboundary dimensions of food demand and supply. Most importantly, the majority of studies focussed solely on changes in crop yields (kg/ha), ignoring important aspects as changes in agricultural areas, food diets and imports and exports. Our study was based on the combination of two tools: AquaCrop and Food Balance Sheets. These tools were applied using the best available data currently, to explore the impact and potential adaptation options to climate change and population growth in the 15 sub-areas across the four member countries of the LMB. A key strength of the method and tools used is that they allow a smooth and direct interaction with stakeholders. From the three food components evaluated (energy, protein, fat) is the daily available fat intake the most problematic considering the recommended daily intake levels. The study concluded that appropriate measures should be taken to close the existing and future gaps between food demand and supply. The tools developed can be used to explore the effectiveness of potential adaptation measures.

DD 6.2-3 SALT-TOLERANCE MECHANISMS IN HALOPHYTES

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Salinity stress causes substantial losses of yield in agricultural production. Negative effects of salinity on plant yield are caused by the direct toxic effect of high salt concentrations and by the osmotic component of salinity. Breeding programs for salt tolerant crops have not been very successful to date, most likely because salt tolerance is a

multigenic trait of which not all aspects are known.
Plants have to maintain Na^+-homeostasis under saline conditions. Na^+-homeostasis relies on Na^+-transporters inside the plant. Halophytes, such as *Salicornia dolichostachya*, which naturally occur in highly saline habitats are capable of regulating Na^+-homeostasis and maintaining growth under saline conditions. These halophytes could serve as model species to indentify traits that are important in salt tolerance. This knowledge will be important for breeding for crops with improved tolerance.
We investigated the aspects of salt tolerance in the highly tolerant salt accumulating halophyte *S. dolichostachya*. We compared the expression of putative salt tolerance genes between S. dolichostachya and the phylogenetically related glycophyte S. oleracea. Moreover, we investigated the differences in proton translocating activities of the vacuolar H^+-pumps.
Our results suggest that high level salt tolerance in *S. dolichostachya* might be achieved be enhanced SOS1 expression in combination with suppression of HKT1;1. On a cellular level, a constitutive activity of the vacuolar H^+-pumps in combination with a constitutive functioning of the Na^+/H^+ exchanger likely contributes to the high salt accumulation in *S. dolichostachya* at low external salinities. At high external salinities, *S. dolichostachya* in comparison with *S. oleracea* probably better retains Na^+ inside the vacuole.
The findings of our studies stress the importance of research directed towards the understanding of salt tolerance in halophytes, with the goal of identification of targets that could be used in breeding programs for crops with improved salt tolerance.

DD 6.2-4 Climate change, food and water security in the coastal deltas: towards a sustainable transformation in Bangladesh

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Coastal delta of Bangladesh is highly vulnerable to climate change induced disaster and man-made intervention due to land use changes and water sources destruction e.g. conversion of agricultural land to shrimp farming. These adverse action leads to severe impacts mainly in water and agricultural facilities such as high saline content in drinking water sources and less agricultural production (e.g. rice, the main staple food) due to saline accumulation and seepage in the land and water logging in the land. The aim of this paper is to find out the vulnerabilities leading to food and water insecurity in the delta region and explore the way to minimize those vulnerabilities in a sustainable manner. In this paper, experiences have been shared from two implemented projects in coastal Bangladesh, (i) Disaster Prevention in the Context of Climate Change (DPCC) and (ii) Alternative Livelihood Program in the Context of Climate Change (ALPCC). Additionally Focus Group Discussion (FGD) has been carried out in the four villages. Result of the study reveals that access to safe drinking water and adequate food supply over the year is the main problem in this region. Most of the agricultural land has been converted to intensive shrimp farming, thus keeping it water logged with high saline content all over the year. Shrimp farming considered as less labor intensive practices, keeping landless people away from getting work like before during rice production. This study suggests community based drinking water supply management at small-scale and community based adaptation practices to create a social safety-net and minimize the adverse impact through enabling relevant stakeholders participation. Finally, for long term measures, a transformation to sustainable shrimp farming and self-sustaining agriculture is required to ensure food and water security in this vulnerable delta. A sustainable transformation framework has been developed and suggested for policy makers, practitioners and local level stakeholders.

DD 6.2-5

RURAL DEVELOPMENT AND FOOD INSECURITY IN THE GANGES BRAHMAPUTRA DELTA: CHALLENGES AND PROSPECTS

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Ensuring food security in Bangladesh has been amongst the country's greatest challenges and priorities since gaining independence (Faisal and Parveen, 2004, BCAS, 2010). The unique combination of socio-economic and environmental factors, including climate change, is likely to exacerbate the existing risks of food insecurity, especially in the densely populated Ganges-Brahmaputra Delta. The agriculture and fisheries sectors are particularly threatened in the southern coastal regions and the situation is likely to be aggravated due to increasing levels of salinity, siltation, cyclones, land degradation, and river bank erosion (Islam et al., 2011). In this context, the present study aims to investigate the state of food insecurity in this rural delta according to seven socio-ecological systems which have been developed using remote sensing technology.
Regression modelling is used to assess the impact of environmental and financial shocks and households' socio-economic conditions on food insecurity. The study makes use of the most recent 2010 Bangladesh Household Income and Expenditure Survey (HIES) focusing on nine administrative districts (zilas), all of which are located in the Khulna and Barisal administrative divisions, and forms part of the tidally active delta of Bangladesh. The methodology applied follows the approach suggested by Smith and Subandoro (2007) and focuses on two key indicators of food insecurity, i.e. insufficient calorie intake as defined by FAO and household expenditure on food items. The preliminary results show a considerable spatial variation in terms of food insecurity across the different socio-ecological systems of the Ganges-Brahmaputra Delta. Furthermore they suggest the poorest households as well as those which have experienced environmental shocks are at the highest risk of food insecurity. Given the geographical interconnectedness of the issues under investigation, the results are likely to be of interest to researchers and policy makers working on other delta regions and beyond.

DD 6.3-1

SUBSIDENCE & DEVELOPMENT IN THE GANGES-BRAHMAPUTRA-MEGHNA: PAST UNCERTAINTIES & FUTURE CHALLENGES

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As one of the world's largest and most populous delta, the Ganges-Brahmaputra-Meghna in Bangladesh and India provides scientific challenges in understanding its physical nature, and how it interacts with development at local to basin scales. As much of the delta is less than 1m above mean sea level, understanding spatial and temporal patterns of the rates and causes of subsidence is important, as this plays an important role in shaping the landscape and development, especially when combined with climate-induced sea-level rise. Yet, in this delta there is a lack

of consistent, good quality, well distributed measurements of past subsidence rates, let alone an understanding of possible future changes, the latter being essential for future planning and development purposes.
This research established a quantitative subsidence database by reviewing and synthesising the literature: nearly 150 records of subsidence in the delta and wider basin were analysed according to the methods used and their magnitude, spatial distribution, measurement method and age. For the basin, the mean rate of subsidence was 4mm/yr, with about 10% of measurements indicating subsidence greater than 10mm/yr. Spatially many higher values were found in the Sylhet Basin. Lower mean values of subsidence of 3mm/yr were recorded for West Bengal and West Bangladesh (Sundarbans). Despite some regional differences, local subsidence measurements were often more influenced by method employed rather than geographic pattern.
Societally, subsidence provides significant challenges for development, particularly in the light of climate change where changes to precipitation (and therefore river and sediment flow),sea-level rise and possibly more intense cyclones. Collectively, this could cause both salinisation in the rivers and groundwater massive losses of land unless there is a major defence-orientated adaptation effort. As a first step, it is fundamental to improve our understanding of both the present and future magnitude of subsidence, as well as analysing potential impacts and adaptation responses. The natural and human component of subsidence is important to distinguish as the responses differ - we must accept natural subsidence, while we might be able to mitigate and avoid human-induced subsidence by changing management approaches. In addition, future research could focus on a better long-term monitoring programme, with satellite and spot-measurements to provide a more solid record to better understand and project changes and causes in relative land level.

DD 6.3-2

CONTROLLED FLOODING TO ADAPT TO CLIMATE CHANGE: LESSONS LEARNT FROM COMPARTMENTALISATION IN BANGLADESH

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Controlled flooding in embanked polder areas (compartmentalisation) is a manner of regulating flood water levels with the help of inlet- and outlet structures. It enables a controlled way of water management for agriculture and aquaculture and is therefore believed to be a promising adaptive strategy to cope with climate change and reduce flood risks while simultaneously ensuring food security.
Compartmentalisation in combination with the formation of a community based system for flood protection and agricultural water management was tested between 1991 and 2000 in the rural areas of Tangail Sandar Upazilla, Bangladesh, under component 20 of the Flood Action Plan (FAP 20). The project is also known as the Compartmentalisation Pilot Project (CPP). In the current debate on the adaptation of agricultural systems to climate change in flood prone deltas, compartmentalisation is receiving increasing attention. CGIAR's WorldFish and the International Rice Research Institute (IRRI), for example, intend to test compartmentalisation by means of non-structural measures and a focus on improved drainage and on-farm-water-management in the Southern delta of Bangladesh.
This article provides a post-evaluation of the FAP 20 project outlining the social and biophysical complexity of the system and focusing on the research question: 'How did the interventions under FAP 20 change the area in relation to

land use, cropping patterns, spatial development, food production, fisheries and livelihoods?'
It is based on 1) field observations on the biophysical status; 2) interviews and group discussions with stakeholders about the current status and functioning of the scheme and the impact of the interventions on their livelihood; 3) an assessment of the system's functioning and maintenance using a simplified Rapid Water Management Appraisal; 4) data collection from governmental authorities and literature review by the first author in 2006 and 2011.
The article shows that though compartmentalisation can provide enhanced flood protection, implementation is relatively costly and not straightforward in complex social-physical delta systems. It can initiate various side- and counter impacts in the biophysical environment as well as in social-political configurations. The authors therefore argue that introducing controlled flooding in a new setting should be systematically assessed in different respects and not be pursued in isolation from other developmental interventions in relation to agriculture, fisheries, industries, housing and infrastructure.
The lessons learnt from this post evaluation are likely to be beneficial for future planning and development of controlled flooding strategies and measures in the light of climate change adaptation.

DD 6.3-3 CHANGING LIVELIHOOD STRATEGIES: ADAPTING TO HYDRO-CLIMATIC CHANGE IN THE SOUTHWEST COASTAL REGION IN BANGLADESH

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The natural resourcedependent societies of the coastal areas in Bangladesh have long been dealingwith vulnerabilities to extreme weather events. Marked changes in the coastalhydro-climatic environment in the way of increasing salinity intrusion, sealevel rise and tropical cyclones are causing drastical transformation on thecoastal landscape with serious impacts on environment, food production systemsand freshwater resources. As a result, coastal communities face the challengeof managing immediate livelihood threats and maintaining livelihood security inthe long term. Drawing on qualitative and quantitative data from a union(lowest local administrative unit) of a southwest coastal district inBangladesh, this study answer the research questions: i) how do local people involvedin shrimp aquaculture (dominant livelihood practice in the southwest coastaldistricts) cope with short-term climate disturbances? and ii) how do local people adapt their livelihoodstrategies in response to hydro-climate variability and change? Results suggestthat responsemeasures being employed in aquaculture are of intergradation of traditionalknowledge with current farming practices, providing new ways to deal withgrowing changes in climatic and environmental parameters. As adaptation to hydro-climaticstressors, households have diversified livelihoods, progressively changed livelihoodstrategy - mostly switching from agriculture to commercial brackish watershrimp aquaculture and business, gain access to agricultural land anddiversification of aquaculture sector through adoption of innovative practices. Drawing on this case study, there are clearwinner and losers of adaptive strategies because better-off households are ableto radically transform their livelihood strategies to exploit the opportunitiesresulting from changing environment and that provide ingredients to developrobust livelihood system. This research suggests that adaptations to climatechange to be effective in the coastal area of Bangladesh need to be combined specificstrategies in response to climate-related risks with strategies addressingunderlying causes of vulnerability that increase livelihood resilience in theface of multiple stresses.

Deltas in Depth Theme 7:

Port development and infrastructure

DD 7.1-1

DISCUSSION OF A FRAMEWORK FOR INTERDEPENDENT CRITICAL INFRASTRUCTURE VULNERABILITY ANALYSIS FROM A CLIMATE CHANGE PERSPECTIVE

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The services that technical infrastructures provide are essential for the function of the society, as highlighted by many infrastructure crises the last decades. Many of these crises was due to the impact of natural hazard, which future frequency and intensity characteristics might be hard to predict given possible climate change scenarios. Due to physical interdependencies between infrastructures, failures in one infrastructure can spread and cause disturbances in other infrastructures. Additionally, geographical interdependencies means that a given hazard can affect more than one infrastructure simultaneously. As such, hazard impact on infrastructures may give rise to unanticipated cascading consequences if not a system-of-system perspective is taken.
The common way to approach critical infrastructure protection is to start with addressing hazards that are likely to affect the system (i.e. a risk perspective). Based on the estimated frequency and intensity of these hazards, decisions are made regarding hazards to consider further. Hazards that have not been identified, or might be underestimated, in the identification phase will then not be addressed, which might be problematic given uncertainties in estimations. Here it is argued that it might be beneficiary to start in the other end by identifying systems' intrinsic vulnerabilities, i.e. the inability a system to withstand strains, before identifying how specific hazards might impact the system. Although no plausible hazard can currently be imagined, there might be reasons for reducing a particular vulnerability, since in good risk and safety management practice we ought also be well prepared for unknown or uncertain hazards.
The aim of this contribution is to twofold. Firstly, to present and discuss a previously developed modelling framework for interdependent infrastructures, inspired from both complexity science and engineering sciences, with special emphasis on ways to model how a system reacts to disturbances and consequences thereof. Secondly, to exemplify a generic geographical vulnerability analysis approach, which has the aim to provide a broad, initial identification of areas most vulnerable hazard impacts as input to decisions related to strengthen infrastructure resilience. Climate change related hazards that may exploit such geographical vulnerabilities include for example flooding, hurricanes, earthquakes, snowstorms, etc. which frequency, intensity or spatial orientation might be associated with great uncertainties. Examples of analysis is given from a previous case study of a railway system, located in southern Sweden. It as an interdependent infrastructure system composed of seven interdependent systems.

DD 7.1-2

A DECISION SUPPORT TOOLKIT FOR 'CLIMATE SMART' SEAPORTS

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In many countries, seaports are critical components of the infrastructure system, acting as vital 'hubs' that connect nations to regional and global supply chains. However, whilst there is considerable emphasis placed on the strategic importance of seaports, climate change will pose increasing challenges to the continuing successful operation of ports, and their associated infrastructure, over coming years and decades. However, despite these challenges,

comprehensive risk assessment, the identification of appropriate adaptation options, and mainstreaming into existing strategies and operations, in many instances remains lacking.
This presentation will highlight contemporary research activity that is developing and refining a user-friendly decision-support tool in support of 'climate smart' seaports. This web-based tool, building on original research on 'enhancing the resilience of Australia's ports to climate change', is currently being developed in close collaboration with key stakeholder partners. The initial iteration was funded by the Australian National Data Service (ANDS) for the Australian context, and follow up funding by USAID has enabled an extension to the focus through customising the support-tool for the Pacific Islands region. In the latter case, Fiji Ports, PNG Ports and Swire Shipping, are the main stakeholders. The tool is comprised of three main functions: the sourcing, refinement, and standardisation of multiple data sets needed for context specific climate change risk assessment; the integration of both primary and transformed data within a suitable data management framework; and, the development of software to provide an interactive interface for considering climate impacts and the prioritisation of areas within the port's functional and operational activities that require more in-depth analysis to identify appropriate adaptation options.
Output from the project includes the development of open-source software architecture that aims for ease of use by ports authorities, as well as facilitating the compilation of a broad climate risk assessment report for internal purposes. The presentation will discuss how iterative development of tool required addressing a range of uncertainties and complexities related to the integration of climate and non-climate data for assessment purposes. It will also showcase the latest version of the tool, and elaborate the potential for use beyond the seaports sector.

DD 7.1-3 THE HYBRID CRITICAL INFRASTRUCTURE ANALYSIS FRAMEWORK

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Research background
Delta areas rely on complex infrastructure systems. Ports, transport, energy, telecommunications and water supply infrastructure are crucial elements to remain prosperous. The relations and independencies between these critical infrastructures are increasing. This doesn't only asks for another way of designing and using the infrastructure system, it also means that a new way of working is needed considering policy making, decision making and stakeholder cooperation (Chang, 2013). There is only limited experience with the complete fall out of several parts of the infrastructure system in the Netherlands, but due to the changing context (climate change,increasing complexity of the system) there is reason to argue that the contemporary ways of managing infrastructures is not sufficient for the coming decades (Wall. 2013). Stakeholders become more and more dependent on each other and need to work together to create better, more efficient solutions.

Research objective
The most leading questions in this paper are, how in the perspective of extreme weather and climate change can the most important dependencies between critical infrastructures in delta regions be efficiently analyzed and how can relevant stakeholders be aided to create better policies and enforce better measures to improve the critical infrastructure system?

Research results

The hybrid framework tries to combine the benefits of existing qualitative and quantitative approaches while minimizing the disadvantages of both. The structure that is created can be used on several scale levels and in multiple kinds of situations to analyze the potential effects of extreme weather on the infrastructure system. And aids in finding feasible, implementable solutions to those effects. The results of the process are dependent of the input that is being used. The better the existing knowledge and the better stakeholders are able to work together the bigger is the chance of a successful outcome. Combining both quantitative and qualitative methods meet the demands and preferences of the different types of relevant stakeholders.

DD 7.1-4 FLOOD RISK ASSESSMENT OF INTERDEPENDENT NATIONAL INFRASTRUCTURES

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National infrastructures are constantly at risk due to exposure to large-scale shock events. In recent years extreme weather events have caused some of the biggest damages to infrastructures, leading to widespread economic losses and societal impacts. Amongst other extreme hazards, flooding events are a major cause of concern for national infrastructures located inland or along the coast. For an island like Great Britain, flooding risks are imminent as future climate projections indicate the likely increase in sea levels and frequent extreme rainfall events. As such for long-term planning for sustainable infrastructure a key research question arises: What are the risks of infrastructure failure due to extreme weather events and how can we adapt national infrastructure to make it more resilient?

This research addresses the above question by building spatial risk assessment frameworks to identify national infrastructure fragilities, disruptions, failure hotspot, all of which improves understanding of extreme risks. The risk assessment framework includes some key models for building: (i) scenarios and probabilities for extreme weather events and national infrastructure failures; (ii) interdependent infrastructure networks that capture the implications of interdependent failure propagation; (iii) spatial estimates of key vulnerabilities in national infrastructure networks; and (iv) demographic and economic consequences of national infrastructure failures. The overall framework captures the sensitivity of national infrastructure risks to multiple climate loading conditions and system failure states.

We provide a demonstration of the risk assessment framework through a flood risk analysis case study of interdependent national-scale energy and transport networks risk analysis for Great Britain. Such infrastructures include key installations such as waterway ports that are located in coastal areas. One of the key results showcase the importance of understanding interdependence among infrastructures, which leads to greater failure propagations. The analysis shows that several ports depend upon key electricity substations due to which there are interdependent customer disruption and economic loss effects if either infrastructure fails.

The work presented here makes important contributions of interest to stakeholders in research and practice. The National-scale infrastructure risk perspective provides useful tools for building large-scale interdependent spatial network models for national level risks and adaptation planning. Flooding, especially along coastal areas, is a major cause of concern in Great Britain, which makes the present research very useful for policy planner and industry stakeholders who are looking for updating the current understanding of large-scale risks. In the end we provide a useful tool for infrastructure planners and operators.

DD 7.2-1 ENHANCING THE RESILIENCE OF AUSTRALIAN SEAPORTS TO A CHANGING CLIMATE

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In Australia, direct climate impacts to sea ports from storm surge, cyclonic wind and flooding over the past decade have included damage to both land and marine infrastructure, loss of port operation time and affected maintenance regimes. A number of ports have also suffered indirect impacts resulting in loss of trade and operation time through damage to transport networks, impacts on electricity systems and on remote supply chain nodes. Of the two, the indirect impacts have been the most costly. However, ports have also operated as gateways to emergency shipping supply routes during major inland flooding. Research carried out between 2011 and 2013 (funded by the Australian National Climate Change Adaptation Facility) focused on the research question, 'how to improve the resilience of Australian seaports?' This paper will report on the results of that research.
The methodology used was a mix of quantitative and qualitative research techniques, guided by participatory approaches, augmented by communication with actors creating new knowledge, including: seaport personnel, climate scientists, and peak bodies (within transport networks, seaports, and engineering disciplines). Three ports (Botany, Kembla and Gladstone) on the eastern seaboard were used as case studies; other ports also contributed information over the life of the project. The research investigated both climate and non-climate risks across the port business and operations using a hybrid risk-assessment framework that was developed as part of the project. Research results indicated that ports are gradually adapting to the changing climate, through incremental change to extreme climate events, but were not planning for the transformational changes that would be needed in the next 50 to 100 years beyond building new berths to heights expected to accommodate global sea level rise. There were identifiable areas of port operations where adaptation actions were either implemented or planned and other areas where the need for adaptation planning had not been identified. The project created a synthesis report of the major findings crafted for uptake in policy and practice. The paper will discuss these learnings, including the development of an adaptation guidance document, which has relevance for many seaports around the globe and thus is of significant societal importance.

DD 7.2-2 MULTI-LEVEL VULNERABILITY ANALYSIS OF THE DUTCH ELECTRICITY INFRASTRUCTURE TO EXTREME WEATHER EVENTS

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Climate change projections for northwest Europe indicate a likely increase in the intensity of extreme hot temperatures, as well as increases in the occurrence of heavy precipitation events and extreme windspeeds. What might be the consequences of these long-term changes in weather extremes for the Dutch electricity infrastructure? Electricity is an essential service of modern society. Disruptions in electricity delivery can have significant economic and societal costs, and can effect the performance of other infrastructures such road, rail and wastewater. The electricity infrastructure is composed of generation facilities, transmission and distribution lines and substations, and other components. Each component of the infrastructure may demonstrate different extreme weather vulnerabilities,

depending on its geographical siting and technical properties. Thermal generation facilities may experience cooling water problems during heat waves and droughts, due to both regulatory and technical limitations. Overhead lines may fail during extreme wind events, due to conductor galloping, high-intensity winds or flying debris. Substations of the transmission and distribution infrastructure may be vulnerable to flooding, due to the moisture sensitivity of current-carrying equipment.
We present the results of a multi-level vulnerability analysis of the Dutch electricity infrastructure to flood and heat wave events. The first part of this study draws from an extensive dataset of the geographical locations and technical characteristics of Dutch infrastructure components. Combining this data with multi-scenario flood projections and estimates of the temperature sensitivity of different water bodies, we assess the vulnerability of electricity generation and transmission assets in the Netherlands. Results suggest limited vulnerability of these assets - many key transmission substations in flood prone areas have already been raised above anticipated flood levels, and most new power plants have been constructed in coastal locations with ample cooling water access.
The second part of the study involves an assessment of the flood vulnerability of a portion of the Rotterdam distribution grid. Using flood data from multiple dike breach scenarios and knowledge of the locations/characteristics of distribution grid substations, we assess the potential for flood-induced disturbances in the medium- and low-voltage grids. Building on this, we identify possibilities for failure cascades to other infrastructures - the wastewater, road, air and rail infrastructures. Results suggest that some assets of these infrastructures may be vulnerable to disruption due to failures of electricity infrastructure components.
We conclude by suggesting possible adaptation measures to alleviate these vulnerabilities, and by highlighting research needs.

DD 7.2-3 CLIMATE ADAPTATION STRATEGIES FOR INFRASTRUCTURE NETWORKS - CONNECTING SCIENCE AND POLICY

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Climate change is leading to an increase in extreme weather conditions. As a result infrastructure is exposed to more extreme weather conditions, which can lead to tremendous effects for the region. To reduce or even prevent damage, high repair costs and human injuries and losses of life, infrastructure networks should be resilient for extreme weather events. The challenge is to develop an integral solution to make infrastructure systems less vulnerable to climate change, by integrating interdisciplinary developed knowledge and make it applicable for infrastructure operators and policy makers. The experience is that there is a gap between scientific researchers and practitioners leading to difficulties in the implementation of scientific knowledge in policies.
The Research question is: <i>How to make scientific knowledge applicable for infrastructure operators and policy makers to reduce climate change vulnerability of infrastructure networks?
The research question is answered by developing an approach for a multi-disciplinary integral infrastructure network analysis. This approach is developed on the hand of a case study, Rotterdam North. Crucial steps in the development of this approach are: the connection of projects, integrating policy domains and research disciplines, sharing knowledge, knowledge exchange, matching knowledge demand and supply and science-policy interactions.
The key stakeholders, namely researchers, infrastructure operators and policy makers, came together during three workshops. The approach will be described in the presentation on the conference.

The Research result is an approach for a multi-disciplinary integral infrastructure network analysis. This leads to a higher probability of implementing adaptation strategies that are supported and aligned by infrastructure operators, scientists and policy makers.

DD 7.2-4 RESILIENCE OF HARBOUR COMPANIES TO FLOOD RISK

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Climate change could increase the risk of flooding. Therefore, on behalf of the Delta Programme, research was performed into the 'vulnerability' and 'adaptive capacity' of companies located outside of the dikes in Wadden harbours. In this study, the companies were asked what strategies they have to deal with floods. We also looked at the role of the government and we tried to calculate potential damage in areas outside the dikes.
The conclusion is that there is no reason to panic. The Wadden Sea port authorities already take measures to prevent flooding and to limit the consequences. Only in extreme cases the areas outside the dikes will flood and in those cases, companies can see it coming. In addition, many companies in the port have the means to act in the event of a flood. However, the companies and municipalities are often poorly informed about the risks. It is necessary to raise awareness and to provide better information, because not all the companies are aware of their location and formal responsibilities. In the provision of information the authorities have a role, even when companies are formally responsible for their own safety outside of the dikes. The companies themselves should not await an actual flood before they start to think about measures. Risk Prevention is almost always cheaper than the damage produced by an (unexpected) flood. Companies, port authorities and local governments have to cooperate more to develop early warning and crisis management options.

DD 7.2-5 IMPACT OF CLIMATE ON PIPE FAILURE: PREDICTIONS OF FAILURES FOR DRINKING WATER DISTRIBUTION SYSTEMS

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Underground water infrastructure is designed to withstand a variability of forces during its lifetime before failure occurs. As a result of variations in loads on and deterioration of the pipe, early failures may occur. Climate change may accelerate or decelerate these processes, and is therefore relevant for maintenance decisions on the drinking water distribution system (DWDS). There is a lack of knowledge on quantitative relationships between climate change and asset deterioration. Recently, we found that weather parameters temperature and drought were recognized as most influential on pipe failure. A model has been introduced to predict future pipe failure rates under changing weather conditions. In the current work, these results are used to assess the impact of climate change on pipe failure. Also, the effect of ageing of the pipes is considered in the modelling.
The different pipe materials react differently towards climate change. Since PVC, AC (asbestos-cement) and CI (cast iron) are the three most commonly used pipe materials (at least in the Netherlands), the increase in pipe failure as a result of climate change is modelled for these three materials. This has been done for the most severe climate

change scenario (W+) expected in the Netherlands in 2050 and 2100.The evolution of the network is determined from a specific replacement strategy (for example in The Netherlands, we assume that each year 0.5% of the AC and CI pipes are replaced by PVC). Ageing of the pipes is modelled as an exponential increase in pipe failure as a function of age, which was fit to historical failure data. The climate specific effect is combined with the evolution of the network to make predictions of pipe failures in future distribution networks. This has been worked out for the complete Dutch network. Failure frequencies increase up to 2050 due to ageing of the remaining AC and CI pipes, and the sensitivity of AC towards climate change. In 2100 failure frequencies will decrease as most of the network will consist of PVC, which has a lower absolute failure frequency and is almost insensitive towards climate change.
The presented analysis points out the vulnerability of existing and future DWDSs towards climate change. This analysis can be conducted for any DWDS, for which historical failure registrations and weather parameters are available. The proposed methodology can therefore assist in the construction and maintenance planning of DWDSs, particularly in the context of climate change adaptation.

Deltas in Depth Theme 8:

Disaster reduction and emergencies

DD 8.1-1 CRISIS MANAGEMENT IN FLANDERS, WATERPROOF ?

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Due to climate change and the accumulation of non-permeable surfaces, flood risks in Flanders (Northern Belgium) have increased and are expected to further do so in the future. Flanders has pushed up its efforts for flood protection and has developed a set of spatial planning instruments to impede further urbanisation of flood-prone areas. Awareness is rising, however, that the risk of future flooding cannot be fully eliminated and that flood policies should include awareness-raising and emergency planning measures.
The inclusion of emergency planning into flood policy designs forms a challenge for the region, since it does not have competences on this matter. Within the Belgian federal structure, spatial planning and water management have been assigned to the Regions (i.e. Flanders, Wallonia and Brussels) but emergency planning and crisis management are handled at the federal, provincial and municipal level. The starting hypothesis in our paper is that this fragmentation of competences might form a problem since growing flood risks require an integrated governance of flood protection, prevention, preparedness and recovery. As an additional challenge, Flanders does not have a well-developed culture of communal crisis response and flood risk awareness. Flemish citizens expect their authorities to protect them against potential flooding and to provide extensive care in case something would happen. The concept of community-resilience in emergency situations, whereby citizens are engaged in crisis response as volunteers and for communication purposes, is still underdeveloped in Flanders.
In the paper, our central question is whether the Region of Flanders is capable to respond to an external shock event without large societal losses. In order to answer this question, we will first assess what would be the advantage of integrating crisis management into the Flemish flood management arrangement. Secondly, we will investigate which policy actions could be taken to include local communities more into emergency planning and crisis management in order to enhance community-resilience.
Based on document analysis and semi-structured interviews with key actors, we will describe and reflect on the potential for improving the organisation of emergency planning and crisis management in Flanders.
With our presentation, we would like to make a contribution to DTCC's scientific session 8: Disaster reduction and emergencies. But we believe the upset of the paper allows as well to have a wider societal relevance, as an inspiration source for policy-makers to improve their resilience of crisis management.

DD 8.1-2 THE DISASTER MANAGEMENT GOVERNANCE FRAMEWORK OF BANGLADESH - A MODEL OF GOOD PRACTICE?

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The Ganges-Brahmaputra-Meghna (GBM) delta is one of the world's most significant deltas. It has however the unfortunate distinction of being one of the most disaster prone areas in the world. The delta is characterized by densely populated coastal lowlands and significant poverty. The well-being of delta inhabitants is increasingly impacted by global sea-level rise; unseasonal drought and flooding; subsidence, sediment starvation and salinization caused by up-stream activities and climate unpredictability linked to global climate change.

Research questions

This presentation asks the following questions:

- Is the Bangladeshi disaster management regulatory framework and its implementation adequate?
- How well is disaster preparedness, mitigation and post-disaster reconstruction coordinated?
- Is there sufficient integration of the disaster management framework into climate change responses? and
- To what extent can the disaster management governance framework provide a good practice model for other jurisdictions around the world as well as other sectors in Bangladesh?

Methods

A mixed-methods approach was used. The approach combined legal-doctrinal and institutional analysis with open-ended key-informant interviews. The legal and institutional research involved the systematic analysis of the rules and principles related to disaster management in Bangladesh and the identification of the relationships between the rules themselves and their implementing organs. This was supplemented by interviews with national-level stakeholders in Bangladesh including government, international agencies and NGO representatives.

Results

The regulatory framework for disaster management is one of the most comprehensive of any sector in Bangladesh. The Disaster Management Act is supplemented by comprehensive Standing Orders which provide a detailed description of the responsibilities of each Ministry and disaster management committees from the national to the local. The Act provides for the creation of a stand-alone Ministry of Disaster Management and Relief. This research identifies some of the reasons why this framework has been successful when other policy-driven efforts with respect to natural resource management in Bangladesh have not. It also sets out areas for improvement such as the better coordination with the Ministry of Environment and Forests and the implementation of its Climate Change Adaptation Strategy as well as the further mainstreaming of disaster management into other sectors.

Societal importance for stakeholders

This research is important for enhanced governance of disaster management in Bangladesh and beyond. It also provides a model for the management of other sectors within Bangladesh.

DD 8.1-3 FIRTHS OF FORTH AND TAY FLOOD WARNING SYSTEM AND THE STORMS OF 2012-2014

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The Firth of Forth is the estuary of River Forth where it flows into the North Sea. At some 88 km in length, with a maximum width of 31 km at its mouth, the Firth of Forth represents the most substantial estuary on the east coast of Scotland. The Firth of Tay is a neighbouring estuary separated by Fife, into which Scotland's largest river in terms of flow, the River Tay discharges.

Flood warning is at the heart of improved approaches to flood risk management in Scotland. The Scottish Environment Protection Agency (SEPA) is committed to reducing the impact of coastal flooding through the provision of reliable and timely flood warnings. The Firths of Forth and Tay have been identified by SEPA as some of Scotland's most vulnerable to coastal flooding.

'Could we provide reliable and timely coastal flood warnings to help local communities in saving lives and reducing flood damages?' With this desire in mind, in 2011, SEPA commissioned a project to develop a flood forecasting and warning system for the Firths. The system has been implemented into the Flood Early Warning System (FEWS) Scotland to contribute to the flood warning service from November 2012.
The approach to the flood forecasting system includes: the transformation of tidal surge forecasts from Leith to 28 warning sites along the Firths; the transformation of offshore wave forecasts to inshore locations; and the transformation of inshore wave forecasts to overtopping forecasts at six key communities at risk.
Since its operation, the British Isles have experienced severe coastal storms. In December 2012, some communities along the east coast of Scotland experienced their most severe flooding since the Great 1953 Storm. During the winter of 2013-14, the British Isles was affected by several winter storms. An analysis of pressure fields suggests this winter has had more severe wind storms than any other winter season since 1871. The Leith Tidal Gauge recorded a new maximum tide level on its 25 year record and resulted in flooding of communities in the Forth estuary.
This presentation will discuss how the flood forecasting system was developed and performed in real time during the recent storms. It will also discuss lessons learnt for the benefit of future development and roll-out of similar systems in Scotland. The authors would like to interact with the audience during presentation to share and learn experience from other countries in estuarine flood warning and dissemination.

DD 8.1-4 BEYOND OIL POLLUTION: THE NEXT BIG CHALLENGES IN NIGERIA'S COASTLINE

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The dynamics of Nigeria coastal zone are hinged on the growth and development of diverse socio-economic and environmental growth. Of recent, the crude oil exploitation, exploration, exportation and other associated developments have been driving the development along the coastal lines. The numerous and versatile crude oil related activities posed significant threats for over the years mostly on the impact of oil pollution and its effects on diverse human and endangered biological population. The current 21st Century environmental megatrends are raising the consciousness for the next big challenge in the Nigeria's coastal zone. As shorelines are some of the indication of changes in coastal zone, this study investigate the historical changes in shoreline positions within the vicinity of Ondo - Delta States coastline, southwest Nigeria between 1972 and 2014. The dynamic intertidal shore zone were investigated using the Digital Shoreline Analysis System (DSAS), an ArcGIS extension developed by the USGS. Specifically, the movements of Low Water (LW) and High Water (HW) shorelines were investigated. Multi-date remotely sensed data spanning 42 years of aerial images from Landsat and Nigeria Satellite Systems are examined. Shoreline features were digitised from each of the multiple images from which were calculated the Shoreline Change Envelope, Net Shoreline Movement and the yearly rate of movement(EPR). The results of the analysis show that Ondo - Delta State coastlines have experienced a progressive and unchecked landward movement over the last four decades. The nature of the shore zone erosion indicated that the issue of oil pollution, which are being tamed and addressed by the oil companies, may not be the next big thing when compared with the next phase of potential environmental hazards. The current prominent megatrends which drive intense erosion and has the potential of aggravating the challenge in the coastal zone include: the continuous wave attacks along the outer barrier beaches, the recent sea-level rise, storm surges with long shore current, increasing tide levels in the Atlantic Gulf of Benin, river canalisation which are known to reduce sediment transportation to coastal zone, and many anthropogenic interferences. This study calls for more of governmental intervention with different aspects of environmental monitoring of the coastal zone, adoption of

a holistic and long-term planning, conscious surveillance of the coastal zone -beyond strictly oil pollution surveillance, detailed mapping/development of emergency plan of future risks, exploration of sustainable ecosystems regeneration with the aim of addressing the anticipated future challenges.

DD 8.2-1 ECONOMIC BENEFITS OF DISASTER RISK REDUCTION - WHAT CAN WE LEARN FROM ADAPTATION?

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Economic disaster losses are averaging over $100bn a year and are projected to increase as our climate is changing and as more assets are clustered in areas exposed to natural hazards. Significant improvements on loss information, scenarios and a growing understanding of the magnitude of things to come in the context of climate change have led to an increased risk awareness - but to date these constructions have largely failed to convince ministries of planning or finance to invest in Disaster Risk Reduction (DRR). In a joint project, the Overseas Development Institute, London School of Economics and the Worldbank investigate the merit of shifting the narrative away from a singular focus on losses as a driver for action, towards the inclusion of DRR within growth and development. The project is targeted at Ministries of Finance and Economic Planning and is based on country and city case studies, surveys of government officials and a review of economic appraisal methods.

The economic case for DRR focuses largely on the measurement of costs and benefits; for every investment of a dollar in DRR, a certain amount is saved in terms of a reduction of losses and/or a reduction of expenditure on response. Economists have developed appraisal techniques and assessment methods to evaluate policies and investments for DRR, most prominently the calculation of the costs and benefits of a certain action. Acknowledging some well-known challenges of this approach we look beyond the rather narrow cost-benefit approach by investigating aspects such as:

- Examining exactly what key decision-makers need to know about the impacts of DRR on the economy, and how they need to receive that information.
- A focus on macro-economic changes in case study countries, including both the impact of disasters and the investments in DRR.
- A parallel set of econometric/statistical analyses of the impacts of shocks on sectoral and national aggregates for all case study countries.
- A review of public finances, disasters and investments in DRR in the context of a changing climate.

We investigate what can be learned from other areas, such as climate adaptation, where similar challenges exist. The project brings together the DRR and climate adaptation community, as well as economic development officials in order to consider how climate, disaster and development are linked and can be considered jointly. We outline preliminary findings and invite feedback from climate adaptation experts and others.

DD 8.2-2 GLOBAL DELTA VULNERABILITY INDICATOR DEVELOPMENT

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Background

In order to develop a Global Delta Vulnerability Index for worldwide delta assessments, vulnerability metrics need to be developed based on indicators that are quantifiable at the sub-regional scale, transferable in different delta contexts and account for elements often ignored in vulnerability assessments. For example, policy factors which are critical in shaping development trajectories of delta environments, but which also differ among various governance regimes, are often ignored in assessing delta vulnerability and need to be incorporated in vulnerability metrics. Emphasis also needs to be placed on capturing the interface between ecosystems and social systems through understanding and quantifying delta ecosystem services and how these can be altered by external (e.g., environmental hazards) and internal factors (e.g., induced by policy decisions). The main underlying assumption is that although each delta is unique, integrative vulnerability analysis frameworks that capture these coupled socio-ecological systems can be developed and adopted locally.

Research question

The work aims to define how a unified framework for assessing vulnerability could be developed as a combination of a global, top-down assessment approach with bottom-up approaches such as stakeholder consultations for sub-delta vulnerability assessments in order to achieve a dynamic and integrated assessment of delta vulnerability.

Research results

Based on a literature review of vulnerability frameworks and indicators, current and future risks, their probability and urgency, as well as current adaptive capacities, a list of indicators is currently developed which will be further developed during a series of local consultations in Vietnam and Bangladesh scheduled April-August 2014. The outcome of the local consultation will be an improved and weighted set of indicators for the delta vulnerability assessments. We will present the results of the global literature review, contrast these with the results obtained from the local consultations, highlighting points of agreements and departure, and propose a preliminary framework for delta and sub-delta vulnerability assessment.

Societal importance for stakeholders

This work is part of a global project on ‘Catalyzing action towards sustainability of deltaic systems (DELTAS)’ funded by the Belmont Forum and the forthcoming 2015 Sustainable Deltas Initiative, endorsed by ICSU. The work will complement other contributions from the DELTAS consortium that have been submitted for the Deltas in Depth sessions and the Deltas in Practice Workshops.

DD 8.2-4 RESTORATION OF COASTAL RESILIENCE THROUGH TIDAL RIVER MANAGEMENT

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The south-western (SW) coastal region of Bangladesh is exposed to multiple hazards such as regular tidal flood, frequent cyclonic storm surges and future sea level rise. In the early 1960s, a number of polders were constructed to protect the coast from regular tidal inundation. These polders confined the flows to the rivers resulting in siltation of the rivers. Consequently, the polders started to suffer from severe drainage congestion. In Khulna-Jessore area, local people proposed tidal river management (TRM) as a solution to the problem. After a thorough study, TRM was adopted as a semi-natural measure to solve the water logging problem on a sustainable basis.
Under TRM, hydraulic link between low lands in a polder, called tidal basin, and the river is restored. Siltation takes place on the low lands rather than the river keeping the river functional. Land of the tidal basin is gradually raised mimicking the delta building process. Tidal basins are rotated among feasible sites every 3-4 years. TRM started operating in the SW coast of Bangladesh since 2000 and so far, two rotations have been completed. The performance of TRM is very encouraging. However, during the TRM there were number of social and institutional issues which need to be resolved.
The resilience of the SW coast has been greatly compromised by the extensive polderization not only against tidal flooding but also against storm surges and sea level rises. Many of the polders could not be rehabilitated in time after the cyclone 'Aila' in 2009 as new channels were formed by the storm surges due to inability of the existing silted-up channels to covey the hydraulic loads. TRM has the potential of restoring the natural resilience of the coast by keeping the rivers functional. TRM has also great potential in mitigating the threats of sea level rise by raising lands. The research question of this paper is how far it is possible to restore the resilience of the coast through TRM.
The paper identifies the morphological changes because of the polderization and the storm surge of 'Aila'. The identification is based on review of secondary data, field level investigation and consultation with local people. Then the paper deliberates analytically on the potential of TRM in increasing resilience of SW region in the face of multiple hazards.

Deltas in Depth Theme 9:

Governance of adaptation

DD 9.1-1 CLIMATE CHANGE AND SECURITISATION OF NATURE

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Climate change is a powerful reminder of the interdependencies of human-nature relationship and the fallacy of the modernist assumption about our ability to tame nature for our exploitation with little or no consequences. However, this paper argues that such reflexivity is being subverted by the dominant discourses of climate change which portray: nature as risk, our relation to it in terms of security and, the quest for urban resilience as emergency planning. By construing nature as a threat to rather than an asset for cities, they signify a departure from sustainability discourses. They represent hark back to a pre-modern conception of human-nature relations that was centred on what nature does to us rather than what we do to nature. Seeing nature as risk ushers in deep concerns with security. The 'risk society' becomes entwined with security society. The paper examines the political implications of this discursive shift and argues that as securitization becomes the hegemonic discourse of our time, the postpolitics of hope, which underpinned sustainability, is giving way to the postpolitics of fear which underlies climate change. The methods used inlcude literature review and review of relevant climate change documents (international and UK). The paper is of societal importance because our perception of nature influences the value we attach to it and the progress we make towards climate change adaptation.

DD 9.1-2 HANDLING ADAPTATION GOVERNANCE CHOICES IN SWEDEN, GERMANY, THE UK AND THE NETHERLANDS

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Parallel to growth in climate change adaptation policies and procedures in Europe, so too has attention been increasing in academia towards the governance of adaptation, specifically how state and non-state actors have begun to define the adaptation 'problematique' and craft public policies to address it. Adaptation is defined as the "Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities". The challenge for governments has been in taking this rather vague concept and turning it into viable and implementable public policies. This implies that they have had to make certain choices as to the types of polices to create , the sectors they should cover (water, agriculture, transportation etc.?), ministerial jurisdictions, and how to fund activities. To date, much of the work on the governance of adaptation looks at what choices were made within a framework of "taking stock"of what has happened in particular countries; cataloging and comparing what exists and where. What the current studies do not do however is examine how, why and under what circumstances these choices were made. The purpose of this article is to move the discussion forward on adaptation governance, digging deeper into what choices various countries have made vis-à-vis the creation of adaptation policies and which choices in particular stand out as having significantly influenced adaptation

policy. Specifically it explores how countries have (1) defined the problem of adaptation, (2) the levels and scales they have applied it to, (3) the timing and sequencing of their activities, (4) the modes and instruments employed, (5) the costs and benefits, and (6) their means of implementation and enforcement. It focuses on four countries traditionally seen to be adaptation leaders: Germany, The Netherlands, Sweden, and the United Kingdom.

DD 9.1-3 GOVERNING ADAPTATION TO CLIMATE CHANGE: AN ANALYSIS OF ENGLAND'S NATIONAL ADAPTATION PROGRAMME

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The UK is often considered an international leader in climate change policy in both mitigation and adaptation. The Climate Change Act 2008 required the government to submit the National Adaptation Programme (NAP) to Parliament in 2013. Published in July 2013, England's NAP sets out what the government, businesses and society are doing to become more climate ready. This paper presents an analysis of England's NAP.
Our analysis shows a reframing of adaptation as resilience and a framing of adaptation as big business. The latter is based on two economic opportunities: 1) good management of climate risks saves money for businesses and other organisations; 2) the potential to export English expertise to help others to adapt is substantial. One key assumption made by the NAP is that market forces and self-interest of private and public actors will lead to appropriate adaptation. However, behavioural economics suggests that actors frequently fail to behave rationally and in their self-interest. The NAP's collaborative approach, the belief that adaptation will occur autonomously, and the removal of mandatory adaptation reporting powers by the Secretary of State, suggest a weaker commitment and willingness to exercise governmental powers to ensure effective adaptation. For example, the abolishment of National Indicator 188 could be considered as evidence of policy dismantling in governing adaptation. Many actions in the NAP are listed as aspirations rather than as concrete actions. This raises the question where does the responsibility and accountability for delivering adaptation lie and how is the evaluation and monitoring of the NAP to be done? We finally put the English NAP in a wider European context and note similarities with the Danish NAP, with its focus on collaboration, growth, 'localism' of adaptation and consequently the drive for individuals and business to take the lead on adaptation. This is in contrast with the NAPs from Germany and France for example which clearly emphasise the role of government and legislative and legal means to ensure the implementation of adaptive measures. The English NAP contains 126 actions addressing priority risks, however, the main foci of these actions are recommendations such as learning, guidance, capacity building, knowledge sharing awareness raising and many more 'good intentions'.
Our analysis raises the question of whether 'good intentions' and autonomous adaptation are sufficient to achieve the NAP's vision of 'a society that makes timely, far-sighted and well-informed decisions to address the risks and opportunities posed by a changing climate'.

DD 9.1-4

GOVERNANCE OF BOTTOM-UP ADAPTATION PROCESSES: THE CASE OF DROUGHT ADAPTATION IN NORTHWEST EUROPE

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Research question
In recent years, considerable progress was made with so-called 'top-down' adaptation approaches throughout Europe. A European strategy was adopted and national strategies are adopted or being developed in many countries. Also knowledge about climate impacts is expanding rapidly. In addition, actors at national and lower levels of governance increasingly start to look for ways to mainstream climate change into strategies, plans, programmes and projects. Such a bottom-up approach does, however, challenge existing governance structures. Within this context, our research question is: What governance issues are experienced in bottom-up adaptation processes and how can governance assessment support the implementation of these processes?

Methodology
Our analysis is based upon the preliminary results of governance assessments that are undertaken in a project called DROP - the benefit of governance in drought adaptation. This transnational collaboration project is implemented by eleven partners from five Northwest European countries. As part of the project, six water authorities develop and implement practical adaptation measures in their different regions. Moreover, five knowledge institutes assess - in close collaboration with these water authorities and other stakeholders - the supportiveness of the relevant governance contexts for drought adaptation. The assessment is guided by a method that was developed in a European research project and elaborated for drought and water scarcity. The presented results are based on the first rounds of visits by the transnational research team in 2013.

Results
The preliminary governance assessments from the DROP project show that droughts are not yet perceived as a significant climate adaptation issue. While all pilot regions regularly experience a shortage of freshwater, flood mitigation and adaptation is receiving much more attention. In various regions, strong stakeholder networks (good collaboration and mutual trust) have developed over time. These networks can be supportive but they can also be restrictive for drought adaptation since they do not always allow for the involvement or interaction with stakeholders outside these formal networks.

Societal importance
New insights are being developed regarding what kind of governance arrangements are emerging in different contexts, as well as what key factors restrict and support drought adaptation actions and interactions. The interactions between scientists, policymakers, practitioners and stakeholders in the DROP project is creating awareness about climate change and adaptation, and providing new insights into the critical challenges of adaptation governance in North West Europe. We conclude that governance assessments can enhance socio-institutional transformations that are needed for climate change adaptation.

DD 9.1-5 TACKLING CLIMATE CHANGE UNCERTAINTY WITH PLANNING APPROACHES FOR WATER MANAGEMENT

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Research question

Recently different planning approaches are proposed to adapt to climate change effects. In the Netherlands Adaptive Delta Management, based on scenario studies, tipping point analysis and construction of pathways, is used in determining long term strategies for water management. Its emphasis is on dealing with long term uncertainty and on adapting strategies during their implementation by built-in flexibility. In the USA the concept of Water Diplomacy, building upon scenario planning, joint fact finding, non-zero-sum consensus building and adaptive management, is designed to deal with, amongst others, uncertainty encountered in water management problems. In the face of climate change, and related uncertainty, both approaches claim solutions for the integration of technical solutions with social, economic and political choices. Since there are distinct differences, we investigate the question how this integration, the conceptualisation of uncertainty, and operationalization of flexibility to deal with uncertainty differs between both approaches and how both can be brought closer to each other.

Methodology & results

By taking a comparative case study approach, based on literature study and interviews with developers and users of the approaches in the US and the Netherlands, Water Diplomacy and Adaptive Delta Management are compared regarding their conceptualisation of, and operationalization to tackle uncertainty. We identify the needs and arguments for conceptualising uncertainty put forward in these approaches for dealing with complex water management problems and, in relation to this, climate change adaptation. Also, we identify strengths and weaknesses regarding the conceptualisation of uncertainty in each approach, in order to improve their operationalization to tackle prevailing uncertainty. Thus, operationalization of these approaches to deal with uncertainty in complex decision-making situations can be advanced.

Societal relevance

Scientific (re)conceptualization of planning approaches can inform the use of approaches by stakeholders and inform them how to tailor planning to the characteristics of uncertainties in water management. As such, it can provide insight in the approaches best able to tackle specific (sets of) uncertainty, such as those imposed by climate change. Thus, integration of climate change adaptation in planning processes can be improved. This can strengthen cost-effectiveness, save time during the planning process and lead to acceptance of the (im)possibilities of adaptive approaches.

DD 9.2-1 WHO GOVERNS URBAN CLIMATE ADAPTATION? A COMPARATIVE ANALYSIS OF GOVERNANCE ARRANGEMENTS IN URBAN AREAS

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Research question

Nowadays the need for adaptation to climate change is acknowledged by scientists and policy makers, certainly at the local urban level where the diverse impacts of climate change are directly felt. The issue of the division of responsibilities between the multiple public and private actors in dealing with the impacts of climate change in urban areas, however, has not yet been extensively addressed, and lack of clarity in this area is seen as an important barrier to adaptation planning and action. Empirical studies are scarce and have not yet been performed in a systematic manner. An interesting question, for instance, concerns which public and/or private actor(s) are most effective in tackling climate impacts. Besides effectiveness, other considerations such as legitimacy and fairness may also play a role in the allocation of responsibilities to certain public and/or private actors. This paper addresses the research question: "What are potential governance arrangements between public and private actors for urban climate adaptation, and how effective, legitimate and fair are these arrangements?"

Methodology

This paper offers a synthesis of three empirical studies in which governance arrangements between public and private actors were analyzed. Each study contained an in-depth comparative case-study analysis of arrangements for adaptation measures in frontrunner cities in Europe and North America: 1) green roofs for water retention purposes, 2) adaptive flood risk measures for water safety purposes, and 3) measures for reducing heat stress. In total, 10 cases were analyzed based on data derived from numerous policy documents; from 94 stakeholder interviews; and from two multi-stakeholder workshops. The meta-analysis offers a first evaluation of the performance of identified types of governance arrangements (hierarchical, market and interactive) in terms of effectiveness, legitimacy and fairness. Furthermore, it offers insights into emerging patterns of governance arrangements for urban climate adaptation.

Research results

Conclusions are drawn related to the types of responsibilities of local public authorities and of different types of private actors. A major outcome is that, contrary to what governance literature suggests, certain public responsibilities appear to be indispensable for the legitimacy and effectiveness of governance arrangements.

Societal importance for stakeholders

Practical guidance is offered for the design of local urban governance arrangements in terms of responsibility divisions in the different stages of the policy process.

DD 9.2-2 TEST DRIVING A POLICY INSTRUMENT FOR CLIMATE ADAPTATION: ANALYZING INSTITUTIONAL DYNAMICS USING SIMULATION GAMING

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A dominate stream in the scholarly research on climate adaptation asserts that the local level of government is fundamental insofar as policy-makers are well positioned to tailor responses to the unique characteristics of their institutional contexts. But how do policy-makers decide on whether a new type of financing instrument is appropriate or whether an existing instrument is sufficient in relation to adapting to climate change? What are the socio-political dynamics of the institutional context that underpin their choices? In this study simulation gaming is applied using a role play format to test the responses of Dutch planning practitioners and policy-makers to a novel financing instrument. This instrument could be used to facilitate investment in neighbourhood level climate adaptation relate public infrastructure. Seven workshops across the Netherlands were held (80 participants). 48% of the participants (48%) were employed by a level of government (39% municipal). Private sector planning practitioners represented 39%, and the remaining 13% were NGOactors. Data was collected through questionnaires (Likert Scale), audio recording of each 3 hour session, and a report written by participants.
The findings offer a number theoretical and methodology insights and implications for the policy development process. Despite differences in opinion about the degree to which a new financing instrument has potential to facilitate local level investment in public infrastructure, comparatively, the workshop results converged on the degree to which the local government should shoulder the investment risk and, more particularly, act as the primary driver of local adaptation. The findings also pointed to a strong correlation between the groups and individual participants that had a high degree of awareness and acceptance of climate adaptation as a pressing policy issue and interest in considering new financing instrument. The strategies that the groups adopted did not substantially exceed conventional values and socials norms, which can be described as achieved based on a logic of appropriateness.
By modeling a policy making process and using a highly interactive format, simulation gaming provides a decision-making environment in which practitioners can 'test drive' policy instruments without the risk of real-life failure or real institutional damage. For scientific research, it is method that provides an opportunity for researchers to analyze the social and political dimensions of policy instrument selection. In doing so, researchers can analyze actor responses and dynamics of the process and policy-makers and stakeholders can learn beyond the technical aspects that may help to reduce the adaptation implementation gap.

DD 9.2-3 WHAT STRATEGIES TRIGGER LOCAL RESPONSES TO CLIMATE ADAPTATION: WITH INSIGHTS FROM PHILADELPHIA, A BEST ADAPTER

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Mainstreaming involves the integration of information, policies and measures to address climate change into (existing) policy domains and planning processes. It is seen as making effective and efficient use of resources than designing

and managing policies separately from ongoing activities, i.e. is applying a dedicated approach (Uittenbroek et al. 2013). In order to achieve mainstreaming, strategies are needed to promote links between climate adaptation and existing objectives in the different policy domains (Ayers&Huq 2009). In adaptation literature, various barriers have been listed that complicate the design and implementation of (local/municipal) responses to climate adaptation, for example uncertainty about the risks and impacts, limited financial resources, little local expertise, a lack of political support, undefined role for local governments (Bulkeley& Betsill 2013, Moser&Ekstrom 2010, Amundsen et al. 2010, Sippel&Jenssen 2009). Several strategies have been suggested to overcome these barriers, such as strategic framing (e.g. McEvoy&Fünfgeld 2013; Dupuis&Knoepfel 2013), institutional entrepreneurship (e.g. Wejs et al. 2013; Carmin et al. 2012; Bulkeley 2010) and organizational learning (Storbjörk&Hedren 2011; Storbjörk 2010).
Limited empirical research has been conducted which illustrates the extent to which these strategies are indeed effective in promoting the mainstreaming of climate adaptation. Strategies are considered effective if there is performance - i.e. responses are explored, considered and/or consented with by policy makers in existing policy domains (Van Doren et al. 2013). Obtaining a more in-depth understanding when and why these strategies work or do not work could be beneficial for municipalities as it provides insight in the conditions that can facilitate the mainstreaming of climate adaptation. Extracting lessons from best practices could help other cities to develop strategies for adapting their urban systems to climate change risks.
The aim of this paper is to examine the use and effect of certain strategies to promote the mainstreaming of climate adaptation, empirically exemplified by an explorative case study: the City of Philadelphia, United States. The study is based on interviews with key actors responsible for local responses to climate adaptation, and analysis of policy documents. The research question that we address in this paper is: How do strategies, such as framing, entrepreneurship and organizational learning, trigger local responses to climate adaptation and to what extent has this led to the mainstreaming of climate adaptation in urban policy?

DD 9.2-4

USING CLIMATE IMPACT MODELS AS A TOOL FOR FINDING A CLIMATE ADAPTATION STRATEGY: A CASE STUDY IN THE BAAKSE BEEK

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Land use policy is increasingly confronted with uncertainties related to climate change. Integrated Assessments are a way to explore policy options under several future scenarios. To execute such Integrated Assessments, computer models are often deployed to understand the consequences of policy under several circumstances. Involving a diversity of stakeholders in the policy process is considered to contribute to finding robust solutions and contribute to how stakeholders value the models. The objective of this study is to better understand the role of computer models in changing perspectives of stakeholders on a climate adaptation strategy. The main research question for this research is: how do climate models function as tools for finding a strategy for climate adaptation? We aim to answer this question particularly for a participatory policy process in the 'Baakse Beek' area in The Netherlands, where scientists developed models to explore land use changes under various scenarios in the stakeholders' region. Four stakeholder meetings were organized, where stakeholders gave feedback on the presented model results. The final meeting included workshops where adaptation measures were discussed in terms of their value and impact for the area.
To determine the role of computer models in social learning, stakeholder perspectives on the situation in the Baakse

Beek area are assessed, as well as how these changed over time. A qualitative analysis of the discussions during the stakeholder meetings demonstrate how the model is discussed. Interviews with stakeholders are used to evaluate their perception on the models and the series of stakeholder meetings.
We found that stakeholders tend to change their perspectives over the course of a meeting, although this change can be very subtle. The analyses of discussions demonstrate that the type of questions and discussion during the meetings changes over time, depending on the phase of the model development. Discussion on adaptation measures during the final workshop were more referring to local knowledge than to output of the constructed models.
We conclude that the models produced during this project have brought more well-founded knowledge, and a good foundation to discuss the impact and effectiveness of adaptation measures from a less personal point of view.
Even though the expectations of stakeholders reached beyond model performance, the models gave much needed scientific input to next step: determining desirable adaptation measures together with the various stakeholders.

DD 9.3-1

CAUGHT IN THE MIDDLE: DEVELOPING COMPONENTS OF A STATE PROGRAM TO ASSIST LOUISIANA'S COMMUNITIES REDUCE FLOOD RISK

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To aggressively combat wetland loss and coastal erosion, the State of Louisiana legislature enacted the Coastal Protection and Restoration Authority (CPRA). The CPRA released the *Louisiana Master Plan for a Sustainable Coast* (Coastal Master Plan) in 2007, and its first 5-year update was completed in 2012. The updated Coastal Master Plan focuses on and contains a well laid-out 50-year plan for diversions, barriers, and wetland restoration projects. Measures such as flood-proofing, elevation, building codes, planning and zoning, adaptation, education, and acquisition of property are recognized as critically important for providing timely risk reduction and adaptation to risks but currently lack the programmatic details and policies to be efficiently and effectively implemented. To assist CPRA develop the programmatic details and policies, we researched current risk reduction efforts and needs at the local scale.
Using face-to-face interviews accompanied by a follow-up survey with elected officials and decision makers, and a public poll we gathered information on which measures work and do not work in Louisiana's coastal communities. The information gathered was analyzed for emerging themes, and we found that existing elevation and acquisition programs are largely uncoordinated within these communities; existing risk reduction programs and policies have created unintended negative consequences; available resources for reducing risks are dependent on disaster relief funds; and finally that decision makers and residents learn about their risk through experience.
An analysis of the findings confirmed a culture of strong aversion to regulation juxtaposed with the recognition that regulations are necessary to reduce risk. The findings were presented to an expert workgroup to further identify solutions and develop programmatic, policy and legislative recommendations to develop a strong program as part of Coastal Master Plan that addresses education, elevation, acquisition, land use, and coastal resilience planning. These recommendations include an extensive public education program aimed at risk education and available options for communities to reduce risk; extensive community planning around coordinated redevelopment, evacuation and relocation; and state-level support for measures taken by local communities to reduce their risk. The recommendations are aimed at assisting the CPRA in the development of policies and programs that are acceptable, embraced, and implemented by Louisiana's coastal communities.

DD 9.3-2 ORGANISING INTERACTIVE KNOWLEDGE DEVELOPMENT IN MULTIFUNCTIONAL COASTAL PROJECTS

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Coastal regions face environmental and spatial problems. In seeking solutions to these problems, decision makers have to deal with all kinds of uncertainties, ranging from knowledge uncertainties related to global climate change to competing interests of flood control, expanding cities, economic activities and nature protection. Responding to these issues requires the involvement of researchers, policy makers and stakeholders in knowledge production. We refer to such knowledge production as interactive knowledge development. The understanding of interactive knowledge development is mainly based on single case studies. Hence, a broader, generic understanding on how to organise such knowledge production is lacking. This paper therefore addresses the question 'How to organise interactive knowledge development in coastal projects?'

We analysed three cases of interactive knowledge development in multifunctional coastal projects. We selected most different cases to analyse cross-case patterns that may apply to other coastal projects. The cases are a Dutch dike reinforcement project, a US nature restoration project and a Dutch spatial development project. Interactive knowledge development is studied through the framework of project arrangements and knowledge arrangements. The project arrangement focuses on the overall project goals, how problems are defined, solutions are proposed and decisions are taken. The knowledge arrangement focuses on the process of knowledge production to find solutions for the problems defined in the project arrangement. Data were collected in each case through interviews (~11 per case), observations of project meetings (~4 per case) and project documents (numerous). Data were qualitatively analysed through a template coding approach.

The comparison reveals cross-case mechanisms that explain how interactive knowledge development functions. Some mechanisms reflect processes that are difficult to influence. For example how limited resources narrow the scope for knowledge production, or, how interactive knowledge development takes more time but also broadens societal support. Other mechanisms reveal processes that enable interactive knowledge development and are actively influenced by actors. Such as how easy understandable knowledge enables input from non-experts, or, how facilitation smoothens the process of interactive knowledge development.

This research contributes firm empirical substance to societal debates on co-creation of knowledge and joint fact finding. The studied cases provide building blocks for those who want to organise interactive knowledge development in a project. One lesson is that project solutions improve through interactive knowledge development because (1) feasibility increases and (2) societal support broadens. To foster these benefits project managers have to reserve time and money up front in the project.

DD 9.3-3 UNINTENDED CONSEQUENCES OF ADAPTATIONS TO CLIMATE CHANGE IN COASTAL AREAS

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Introduction

The drivers of change in coastal areas often act synergistically with complex non-linear feedbacks across spatial and temporal scales, between governance systems, users, resources and resource systems (Ostrom 2009). This can result in complex and unpredictable outcomes (Ludwig 2001) which vary from one context to another. Novel approaches to adaptation assessment are required (Moser et al. 2012) which acknowledge adaptation in coastal zones as a "wicked problem". While many adaptations have beneficial outcomes, some adaptations may result in unintended consequences for vulnerability, either for the decision makers themselves or for other stakeholders. While coastal adaptation plans have become increasingly popular, few if any of these plans have taken a multi-scale and multi-stakeholder perspective.

Research question

What are the feedbacks within and across scales that result in unintended consequences of climate change adaptation plans in coastal areas?

Research results

Adaptation plans that look exclusively at a single focal scale and context and do not consider their knock-on effects to other scales, stakeholders or areas frequently have unintended or unforeseen consequences beyond the focal context or focal scale of monitoring leading to new risks and vulnerabilities. In this paper, we view adaptation as a key *driver*, not just an outcome, of vulnerability. We adopt a social-ecological systems approach, with a focus on feedbacks and interactions between individual users, governance systems and resource systems and look beyond the immediate impacts of adaptive strategies. We take a step back to also assess the knock-on and longer term effects of adaptation plans, provide examples of the consequences of decisions for vulnerability, and describe the multi-scale feedbacks that occur when decisions taken in isolation have unintended negative consequences for social-ecological systems.

Societal importance for stakeholders

Climate change adaptation planners need to consider the potential impacts of their plans on social-ecological systems beyond the focal scale, proactively assess the knock-on effects of interventions, and engage in a learning process with stakeholders, instead of developing adaptation plans in isolation.

DD 9.3-4 RIVER AND URBAN SYSTEM GOVERNANCE IN PEARL RIVER DELTA: 1920- 2013

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Deltas have been one of the oldest and most prosperous territories for urbanization. 14 of the world's 19 largest cities are located in coastal areas and river deltas(UN-HABITAT 2012). The urbanization and related artificial intervention has increasingly influenced the natural process of this type of territory. With the most urban agglomerations over 10 million inhabitant in 2011, China will still hold the most complex and fastest urbanization process record till 2025(United Nations 2012). The Pearl River Delta has been the fastest urbanizing delta region with the two of the largest fast growing urban agglomerations: Guangzhou and Shenzhen, since 1970. The unprecedented scale and rate of urban expansion makes Pearl River Delta the most dynamic delta in both territory and governance transformation. More and more scholars realized that the human and nature intervention are closely related in the spatial quality and flood defense in delta regions. Both urban and hydrological scholars have focused on understanding, monitoring and evaluating the river system evolution and urbanization process in the delta. However, little studies have tried to link these two aspects. How the water and urban system interact during the fast development in the past 3 decades? And how effective is the governance in flood management and spatial quality in this delta?
This paper reviews the existing studies addressing the major territorial transformation during the past four decades with a spatial perspective. It investigates how policy influenced the spatial transformation with three cases: the large scale dike construction between 1920's to 1970's, the sand dredging between 1980's to 2010's, and the agricultural land lost since 1980's. Three insights draw from the study are: missing of morphological study in regional study, significant lag in the current top-down spatial governance and lack of multi-scale spatial perspective in studies and policy making. This paper calls for a more comprehensive inter-scalar design approach with quick react to land and water dynamics to maintain the sustainability in the Pearl River Delta. It suggests urban and regional design should play a more active role in this approach. The case of the Pearl River Delta is the most dynamic one in various aspects of delta urbanization. These insights could serve as an experimental experience in governance, science and design for the urbanizing deltas in the world.

DD 9.3-5 BRIDGING STATE AND NON-STATE DIVIDES IN VIETNAM'S TRANSFORMING ADAPTATION GOVERNANCE: LESSONS FROM THE MEKONG

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Research question
In order to facilitate effective adaptation governance in one of the most hazard-exposed deltas globally, the paper asks how the responsibilities and capacities for risk reduction and adaptation are negotiated and shared in selected urban risk hot-spots of the Mekong Delta, focusing in particular on the shifting roles of state vs. non-state actors within Vietnam's changing political economy.

Methodology

The analysis builds on a social-science oriented mixed methods approach and draws on first-hand empirical research comprising over 18 months of fieldwork. Data on state practices for adaptation were obtained from expert interviews with decision makers in the state bureaucracy, complemented by the analysis of governmental adaptation plans. Data on adaptation capacities, evaluations, decisions and action at household level was derived from in-depth household interviews and two household surveys.

Research results

The findings show that Vietnam's transformation process has not only contributed to significant changes in vulnerability profiles but also in the way risk management and adaptation is framed and attributed. Despite the continued paternalistic rhetoric of the party-state apparatus as care-taker, mismatches between state and non-state adaptation action are on the rise, potentially undermining the effectiveness of both realms. The subjective evaluation of different adaptation options by state vs. non-state actors shows discrepancies in a number of criteria often not considered in adaptation governance, including different perceptions on the efficacy of available options, the importance of cultural acceptance, the co-benefits implied by specific measures, the timeframe of implementation or the longevity of adaptation solutions. The paper therefore calls for a paradigm shift in Vietnam's urban disaster risk governance. Future approaches need to go beyond the leadership's current focus on top-down disaster contingencies and the adjustment of large-scale physical infrastructure. Rather, the continuing transformation and climate change necessitates that the institutional configuration of risk governance itself needs to be adapted. It needs to facilitate the integration of risk reduction measures of state and non-state actors which are shaped by divergent interests, motivations and capacities. Proposed changes relate, for instance, to financial mechanism, legal responsibilities or public participation in adaptation planning.

Societal importance for stakeholders

By addressing current institutional mismatches that hamper effective and inclusive adaptation governance, the results allow for the formulation of recommendations and institutional solutions. It is argued that the results are of great relevance also for other delta regions facing similar challenges in current adaptation governance.

DD 9.4-1

EXPERIMENTING FOR POLICY: AN IN-DEPTH LOOK AT HOW THE DESIGN OF EXPERIMENTS CAN ENABLE LEARNING IN CLIMATE ADAPTATION

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Experiments are increasingly considered a useful policy tool in the governance response to climate change. Touted as an opportunity to produce reliable knowledge and create space for policy innovations to emerge- while not committing to a permanent course of action- experimentation in the policy process allows us to address the uncertainty and complexity that stems from policy issues like climate adaptation. However, despite experimentation appearing in a number of academic fields the concept has had limited theoretical analysis. Moreover, how experimenting can enable learning outcomes is yet to be explored. This leads us to construct the research question: how can experiments be designed so they maximise learning opportunities? This paper seeks to reduce this knowledge gap by analyzing a selection of 25 experiments conducted in the Netherlands. The experiments originate from various types of environmental policy- water, agriculture, coastal, and nature management- and all have in

common a testing approach and relevance to governing the social-ecological system. The experiments are compared to better understand their social, bureaucratic, and political dynamics, as well as their success in enabling three sorts of learning- cognitive, normative, and relational learning effects. Learning outcomes in the policy network are also analysed. Statistical analysis tests claims made in the literature about how institutional factors increase learning outcomes. Learning is key in the construction of adaptable social-ecological systems and this paper produces robust findings about how it can be achieved in institutional arrangements such as experiments. Findings also include highlighting the political allergy that experiments face due to the risk of failure. Policy makers stand to benefit from the results due to the increasing pressure they face to be innovative and experiment- but is this what the state really wants?

DD 9.4-2 POSSIBILITIES AND RESTRICTIONS FOR TRANSBOUNDARY CLIMATE ADAPTATION GOVERNANCE FOR THE NETHERLANDS

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Climate change will impact various sectors and themes in catchment areas, such as the effects of floods, droughts and water temperatures changes that could affect navigation, agriculture et cetera. Climate change effects do not stop at man-made borders, thus climate change adaptation could be seen as a phenomena that transcends national borders. To complement and stimulate the development of national climate adaptation policies and to coordinate and stimulate cross border cooperation, the EU established an Adaptation Strategy in 2013. If we look at the Rhine and Meuse river basins, multiple transboundary cooperation structures exist, but integrative cross border cooperation is not for granted. For example, the Deltaprogramme Rivers is one of the nine sub-programmes of the Dutch Deltaprogramme and focuses primarily on water safety issues and flood protection in the Dutch fluvial region for the long term, while striving for an attractive catchment. Interim evaluations of the latest concept decisions revealed that the Deltaprogramme Rivers is struggling with the international dimension of river management. This struggle is related to the history of the Netherlands, the framing of climate adaptation as mainly a high water issue, political priorities et cetera. This is also caused by missing knowledge with regards to climate adaptation governance of neighbouring countries. In addition, a knowledge gap exist on ongoing transboundary cooperation structures and possibilities and barriers for integrative cross border climate adaptation. This research focuses on an inventory of potentially successful strategies for integrative transboundary cooperation in the Rhine and Meuse river basin in the light of both the EU adaptation strategy and the more domestically focused role of the Deltaprogramme Rivers. Finding strategies to deal with the international aspect of climate adaptation is relevant to protect the society in the future. In our research we firstly provide an overview of existing transboundary cooperation relationships to distinguish gaps in current Dutch cross border cooperation. A desk research and bilateral consultation will be applied for this exploration. Based on the established overview and identified gaps, we will derive more in-depth knowledge in the second research stage by applying a comparative case-study research of three exemplary cases of cross border cooperation, semi-structured interviews with experts and a content analysis of the implications of the EU adaptation strategy for the Netherlands and transboundary governance. In conclusion, possibilities and restrictions for transboundary climate adaptation cooperation from a Dutch perspective in the light of the EU Adaptation Strategy will be identified.

DD 9.4-3 SUSTAINABLE TRANSITION CHARACTERISTICS OF THE INTEGRAL AREA DEVELOPMENT ON WATER IN RIJNHAVEN ROTTERDAM

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Research question
What are characteristics of the planned sustainable integral area development on water in Rijnhaven Rotterdam from a Sustainable Transition perspective?

Research methodology
To gain insight in the policy, decisions and occurrences related to the current tender for sustainable area development on water in Rijnhaven Rotterdam, a literature study was conducted. Also, stakeholders in both the municipality and the private sector were interviewed. The outcomes of these studies were then compared to characteristics of sustainable transition described in literature of Transition Management, Water Sensitive Cities and Sustainable Area Development. The outcomes of this analysis were discussed with stakeholders en experts in workshops.

Research results
Up to this day there have hardly been any fully successful sustainable area transformations. The intended development of floating districts in former city ports could turn out to be a tipping point. The tender aims at realising a sustainable transition on niche-regime level, which indicates an acceleration of sustainable transition. The development of floating urban areas itself can be seen as a next phase in the transition towards water sensitive cities. The inducing role of the crisis, city-governmental movement towards regime change and commencing opportunities for private parties match with observations made in recent literature on Transition Dynamics.
However, the project can also be regarded as an experiment which outcome is yet uncertain. Some companies competing for the public tender are not so much interested in achieving a sustainable development of Rijnhaven Rotterdam as in developing technologies and working methods that can be commercially applied to other areas. Frontrunners in the municipality are trying out several new types of urban area development, one of which is Rijnhaven Rotterdam. Rules, regulations and working methods are still based on the old practice and might be an obstacle for this new form of area development. Furthermore, there is hardly any emphasis on community learning and citizen participation.

Societal importance for stakeholders
Rijnhaven Rotterdam is the first large scale integral sustainable area development on water in The Netherlands and arguably in the world. Gaining insight on its characteristics will help stakeholders to increase the success of this particular project and to facilitate similar projects in the future.

DD 9.4-4 WATERS WITH(OUT) BORDERS - THE HORIZONTAL COLLABORATION ON CLIMATE CHANGE ADAPTATION IN NORTH DENMARK

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Research question

Waters run across administrative borders and efforts in one municipality may course flooding in a neighbouring municipality if not coordinated. However, climate change adaptation is a new policy field and can be found in an institutional void where practices are still to be defined, leaving a new and interesting field for both research and practice. This research investigates the implications in coordinating climate change adaptation planning related to flooding from heavy rains, streams and inlets through horizontal collaboration between local authorities.

Methodology

The geographical area of this study is North Denmark, with the Limfjord cutting across the Jutland peninsular from the North Sea to Kattegat. The municipalities within this region border the Limfjord, several streams and/or the coast, and flooding incidents from these sources are increasing due to more heavy rains and storm surges. To investigate the current coordinating efforts to adapt to flooding, 10 semi-structured interviews have been carried out in the period from 11th March to 14th April 2013. The interviews have been conducted with relevant professionals from six local authorities, the North Denmark Region and three sewer utility companies.

Research results

Based on a conceptual framework dealing with centralisation and decentralisation, governing and governance, and structure and agency, this article discusses the implications for coordinating climate change adaptation across administrative borders. This article finds that a recent decentralising structural municipal reform and a privatisation of wastewater utilities hamper a coordinated climate change adaptation effort within North Denmark. The municipal structural reform demolished counties and left the main environmental and spatial responsibilities with the municipalities, and the privatisation of utility companies emphasises service and revenue over climate adaptation. The larger degree of decentralisation means that implicated actors act within a fragmented policy area, where network governance becomes essential. However, networks are first to be established and the lack of agency results in inaction, whereas the decentralisation seems to hinder climate change adaptation and calls for more regulation to secure action.

Societal importance for stakeholders

This research contributes with explanations of the current lack of implementation of climate adaptation action plans and activities related to flooding. It provides insights for practitioners in the importance of establishing networks for coordinating efforts when acting in larger degree of decentralisation.

Keywords

Climate change adaptation, municipalities, decentralisation, network governance, flooding.

DD 9.4-5 RESEARCH TRAINING ON THE BOUNDARY BETWEEN SCIENCE AND SOCIETY: DO TRANSDISCIPLINARY PHDS OBTAIN DIFFERENT SKILLS?

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Research question
Climate adaptation research has a rich history of involving non-academic stakeholders. A growing number of PhD researchers is trained and socialized within the context of such science-society interactions. It has been argued that these PhD researchers will become tomorrow's boundary workers and will tackle - in a transdisciplinary way - the grand societal challenges of contemporary society? To provide insight into the actual effect of such training trajectories, this presentation addresses the following research question:
'Does a research training in a transdisciplinary context result in a different set of skills?'

Methodology
To answer our research question, we conducted a survey among 415 sustainability PhDs in both transdisciplinary and traditional trajectories in the UK and in the Netherlands. The survey covered questions on research practices and the development on four types of skill: academic research skills, academic communication skills, translation & valorization skills, and transferable skills.

Preliminary results
Preliminary results indicate that PhDs in transdisciplinary projects are indeed more involved in stakeholder interactions and have more societal output (e.g. policy reports, popularizing lectures, stakeholder workshops). As these PhDs score better on the development of academic communication and valorization skills, it seems that involvement in science-society interactions has positive effects on these early career researchers. The data shows that two important requirements have to be met however. First, involvement in stakeholder interactions should be an add-on to academic activities, not a substitution. Academic activities have a very strong positive effect on the development of all four types of skills. Second, to benefit fully from the positive effects on academic communication and valorization skills, PhDs should be supervised by academics with experience with transdisciplinary research.

Societal importance
This research contributes to the current policy debate on the increasing number of PhD holders and the benefits for society. The results of this study provides means to diversify training trajectories and to increase their societal relevance. Non-academic employers and PhD students can benefit from the study as it provides insights into possibilities to increase PhD holders' employability outside academia. Finally, the study indicates that these training trajectories indeed result in a new cadre of PhD holders who possess strong ties to other sectors and professions. A cadre of tomorrow's problem solvers who will approach society's grand challenges in a transdisciplinary way.

DD 9.5-1 DESIGN PRINCIPLES FOR GOVERNANCE ARRANGEMENTS FOR CLIMATE ADAPTATION

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Research question
Adaptation to climate change poses some specific, particularly demanding governance challenges like: important uncertainties; long term perspective; fragmented policy contexts; cross scale dynamics; and complex science-policy relations. These specific complexities call for new advanced governance knowledge. Governance is defined as the interactions between public and/or private entities ultimately aiming at the realization of collective goals. A governance arrangement is the ensemble of rules, processes and instruments that structure these interactions. This paper addresses what kind of governance arrangements can contribute to realizing adaptation options, and increasing the adaptive capacity of society.

Methodology
The paper will present overarching insights of the Dutch governance of adaptation program (Knowledge for Climate; 2010-2014). The main research method was collaborative action research. This means that we took guidance from policymakers as the primary source of questions, dilemmas and empirical data, but also collaborate with them in testing insights and strategies, and evaluating their usefulness. Governance arrangements are operationalized in terms of policy frames, organisation of the decision making processes, responsibilities, steering instruments, normative principles, science-policy interfaces, scales and leadership. Effectiveness, legitimacy and resilience are the main criteria to evaluate these arrangements.

Research results
Most literature about climate adaption governance focusses on emphasizing the big long-term challenges of climate change, the many controversies, the need for participative approaches, the advantage of smart science-policy arrangement's, the importance of mainstreaming, etc. The insights resulting from the various research projects, however, show a more nuanced picture. Emphasising the enormous challenges of climate change can also result in leaning backwards, participation is not always effective, emphasizing controversies can result in deadlocks, science-policy arrangements can also result in less innovative approaches, drawing clear boundaries between (for example) the public and the private is as important as boundary spanning, and cherry-picking can sometimes be more effective than integrating and mainstreaming everything.

Societal importance for stakeholders
In the academic realm, there has been a sizeable growth in the number of publications on the governance of adaptation to climate change. However, many of proposed governance concepts and devices are rather abstract. Within governance systems, there is an urgent need to translate these theoretical concepts. This research provides policymakers and other governance actors with practical guidelines for designing governance arrangements.

DD 9.5-2 FLOOD GOVERNANCE OF JAKARTA, INDONESIA: IDENTIFYING SOCIETAL AND POLITICAL PROCESSES IN CLIMATE CHANGE ADAPTATION

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Jakarta, the capital city of Indonesia with 10.2 million population in 2014 (Bappeda Provinsi DKI Jakarta, 2014), is one of the most cities vulnerable to climate change in Southeast Asia (Fuchs, 2010; Yusuf and Fransisco, 2009). Particularly, the increasing sea level rise (PPKPL-ITB, 2007) and the ongoing land-subsidence (Abidin et al., 2010) have lead to a worsening state of floods (Ward et al., 2011). It is evident that the inundated areas in Jakarta increased significantly (BPBD DKI Jakarta, 2013). The densely occupation at the upstream and informal settlement at the reservoirs and along the canals added to the problems. Current adaptation mostly focuses on infrastructure development such as dikes, canals, reservoirs, and drainage systems. However, relocation of people in many areas linked with these programs still bear social economic problem. Additionally, political efforts for river basin management at the regional scale have not been satisfactory.

The paper is developed in scope of ongoing TWIN-SEA expert network joint activities (http://ehs.unu.edu/article/read/twin-sea-1) on disaster risk reduction (DRR) and climate change adaptation (CCA) in the coastal areas in South East Asia. Taking a case study of flood governance in Jakarta, it argues that the complex problem of adaptation is due to the interaction of physical, social, and political factors, and calls for a greater understanding of the governance processes, which underpin and influence future adaptation to climate change. It focuses on the question of 'what are ongoing societal and political processes that significantly influence the adaptation to increasing floods under climate change and land subsidence in Jakarta?' The paper assesses in particular relocation measures and livelihood opportunities of the vulnerable people as well as political context and stakeholders that influence the processes of adaptation to climate change.

The analysis is firstly based on a desk review of relevant existing studies (selected peer-reviewed papers as well as grey literature) and expert interviews with development and urban planning actors in Jakarta. The paper aims to provide a better understanding of why certain climate change adaptation measures work properly while others don't, and which societal and political processes allow for more effective implementation of climate change adaptation measures. By doing so, it provides insights for the relevant stakeholders in effectively and sustainably promoting formal and informal adaptation. Furthermore, it allows for better understanding on the identification of the key stakeholders' as well as their inter-relationships, which form and influence the governance processes for CCA in Jakarta.

DD 9.5-3 THE INFLUENCE OF TEMPORAL VARIETY ON THE DESIGN AND EFFECTIVENESS OF GOVERNANCE ARRANGEMENTS

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The implementation of climate adaptation is characterized by complex governance processes in which many actors are involved. They all have their own agenda, resources and strategies. But they also have their own time orientations. Their perceptions differ for example when it comes to the rhythm (when is the next opportunity for decision-making), the quantity (how much time do we have to realize a deal) and the horizons of time (do we need to realize our agenda now or later). Actors realizing adaptation strategies (like water authorities) do normally have long-term orientations, while private actors stick to short-term agendas.
Furthermore, this 'temporal variety' is not static but highly dynamic. Due to environmental influences time orientation of actors can change during the governance process. This can for example happen when financial resources for the short term dry up and ambitions have to be postponed.
This temporal variety may influence the design of governance arrangements (rules structuring interaction between actors). In situations with much dynamic and different time-orientations actors may be more willing to choose for flexible governance arrangements. In situations with less temporal variety actors may choose for stable and fixed governance arrangements. When both public and private actors do have short time horizons on which they have to realize their ambitions, they may feel strong drivers to stick to solid and fixated agreements that safeguard their agenda.
In our paper we answer the question how temporal variety impacts upon the design and effectiveness (in terms of realizing capacity) of arrangements for implementing adaptation measures. We answer this question by analyzing two climate adaptation projects in the Netherlands, the water husbandry Walcheren and the water cellar Waalblok. In these cases we reconstruct both the temporal variety and the chosen governance arrangement and analyze how different time orientations played a role in the choice and effectiveness of the ultimate arrangement.
From these case studies we can conclude that there are strong arguments to take temporal variety into account in the design of governance arrangements as it is an important condition for legitimate and effective implementation. The extent to which actors succeed in translating this variety in a governance arrangement contributes to the effectiveness of the arrangement. At the same time there are many barriers to come to tailor-made arrangements, due to a lack of trust, bureaucratic incapability and institutional barriers. We conclude with some insights how to deal with these barriers.

DD 9.5-4 MULTI-SCALE GOVERNANCE OF ECOSYSTEM SERVICES AND POVERTY IN THE GBM DELTA - THE RESILIENCE CHALLENGE

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The Ganges-Brahmaputra-Meghna (GBM) delta is one of the world's most significant deltas. The delta is characterized by densely populated coastal lowlands and significant poverty. The well-being of delta inhabitants is increasingly impacted by global sea-level rise; unseasonal drought and flooding; subsidence; sediment starvation and

salinization caused by up-stream activities; increased natural disasters and climate unpredictability linked to global climate change.
Government policy rarely pays sufficient attention to the management of ecosystem services. Decision-making processes often overlook the value of ecosystems and their role in alleviating poverty. This presentation aims to address this gap by providing an assessment of the legal, policy and institutional components for the governance of ecosystem services and of livelihoods in the GBM Delta in the context of global change.

Research questions
- How are ecosystem services and poverty affected by their governance environments?
- What are the challenges for adaptive management?
- How can governance interventions enhance the resilience of delta inhabitants?

Methods
A mixed-methods approach is used. The legal and institutional research methods involved the systematic analysis of the formal and customary law rules that relate to ecosystem service and poverty sectors in Bangladesh. The relationships between rules and their implementing organs were analysed. Interviews were conducted with transboundary, national and local level stakeholders.

Results
This research finds that building resilience in the GBM delta is hampered by a lack of cross-sectoral coordination, a polarized political climate, excessive executive power, the marginalization of the poor, an ineffective formal governance system and a lack of coordination of customary law with formal structures. This presentation details the challenges posed by local, national and transboundary power relationships and sets out how the shortcomings and inflexibility of the legal framework restricts adaptive management. Recommendations presented for building resilience include addressing governance and capacity limitations in the GBM delta; enhanced science-based approaches to law and policy; and the design of regulatory frameworks that are shaped to the GBM context.

Importance for stakeholders
This research will enable stakeholders to implement targeted governance interventions and supports the development of decision support tools that enable policy-makers in Bangladesh to evaluate the impact of policy decisions on environmental health and livelihoods. This research provides transferable lessons for stakeholders in other populous deltas to address current and future threats and pressures through multi-scale governance approaches.

DD 9.5-5 SCENARIO DEVELOPMENT FOR REACHING URBAN AND ENVIRONMENTAL PLANNING INTEGRATION IN THE CONTEXT OF CLIMATE CHANGE

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Scientific evidence of global climate change leads to predictions of increases in the recurrence and severity of extreme hydrological events, one of the main causes of flooding and other negative impacts over the territory and the communities. Urban development, especially in coastal cities, faces the challenges of continue growing in a planned way while guaranteeing a certain level of security against future events. Since the level of uncertainty remains high,

is possible to find some innovative strategies able to help decision makers to guide future expansion and design adaptation actions?
In this paper, a reflection on participatory processes is presented to address the potential of scenario development as a tool for integrating urban and environmental dimensions while withstanding the uncertainty of future climate changes and metropolitan growth. Through stakeholder interaction, scenarios were designed following a process of strategic foresight, adopting the SAS (Story-and-Simulation) approach to scenario development. The participatory process included the preliminary recognition of the main actors according to their role in the system (governmental agencies, NGOs, universities, producers, inhabitants, etc.), the construction of the first scenarios (represented as storylines) and the quantification of the storylines for mapping. The maps were developed using GIS (Geographical Information System) as a flexible and interactive tool for revisiting the possible future progressions in the fields of urban expansion (including changes in typologies and densities), environmental conservation, productive system and socio economic indicators.
The methodology was applied taking as an example the representative case of the Parana Delta (Argentina). The municipalities of Tigre and San Fernando, located in the lower section of the delta, face the pressures of the rapid growing processes of Buenos Aires Metropolitan Area and the uncertainty of strong climate changes in a context of lack of resources and social inequity. The fragmentation of the territorial, water and environmental management and the multiplicity of jurisdictional authorities and their conflicting visions on the area's role, turned the developed participatory processes an opportunity to build awareness and set networks of communication between the different categories of active stakeholders, which play a key role in the area.

DD 9.6-1 ROLES AND RESPONSIBILITIES OF RESIDENTS IN THE GOVERNANCE OF CLIMATE CHANGE ADAPTATION

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Research question
An emerging literature discusses roles and responsibilities of public and private actors in climate change adaptation. This literature has, hitherto, devoted relatively limited attention to the roles of residents in adaptation governance. Residents can, however, be expected to be important actors because they can take adaptation measures (e.g. adapt their behavior, decrease the amount of hardened surface in urban areas, make homes flood resilient) and their initiative or consent is often necessary for private property level measures. Furthermore, adaptation measures in public spaces might be more likely to be taken if they are (perceived to be) supported by residents. This article therefore addresses the following question: "which roles can residents take in the governance of climate change adaptation and what are the implications for governing actors that want to address residents in these roles?"

Methodology
Based on a review of literature from the fields of environmental governance and sustainable consumption, a categorization including nine potential roles has been developed. Each role has been illustrated with at least one empirical example from a European context.

Research results
Nine roles have been identified, three for each of the following three forms of commitment: (a) as citizens falling under the jurisdiction of various levels of government, (b) as consumers on the market and (c) as members of civil

society. All discussed roles offer the promise of advancing climate change adaptation measures. However, there are differences in the extent and ways in which governmental actors can address each of the specified roles. They can directly address people as citizens with individual rights and responsibilities. But with regard to the roles that are more market- or civil society oriented, governments' role will likely be that of a game keeper, partner or facilitator, for example, to stimulate that residents take private adaptation measures like installing a green roof (consumers) or set up local bottom-up initiatives (civil society members).

Societal importance for stakeholders
This paper provides ideas for societal actors, including governments, on how they could most fruitfully address residents in times in which governments often have to withdraw from taking immediate action. It can be shown that there is still unexploited potential for better involving residents in adaptation governance.

DD 9.6-2 THE ROLE OF SOLIDARITY IN DUTCH ADAPTATION STRATEGIES

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Adaptation strategies aim to reduce vulnerability and increase resilience to climate change. What differs is the choice of means to achieve this aim, because that depends on the local and social context. The question is what motivates this choice? We want to show that solidarity is a central concept to understand the choices made in Dutch adaptation strategies. In essence, solidarity means that one acts in order to support members of a particular community to which one believes oneself to belong. One acts out of rational self-interest in combination with the insight that achieving this common interest requires cooperation with other individuals. Solidarity also refers to helping unfortunate members of the group. Solidarity is not about sharing an equal burden, but about sharing a fair burden. It is not a universal obligation, but a particular and positive obligation.
We studied the governance process of improving navigation in the Westerschelde, water safety in the province of Groningen, water safety in Rotterdam and fresh water supply by Lake IJsselmeer. Our comparative case study analysis shows that solidarity plays an important role in various Dutch adaptation strategies. Based on 4 case studies, we conclude that a call for solidarity requires the operationalization of solidarity. Instead of focusing on the most efficient or effective adaptation measure, it is important to realize who needs to adapt and who will benefit from the adaptation measure and hence what the relevant group is and if it is possible that this group can act out of solidarity. Participation is important, because even though the government can force people to become solidary, protest will ensue when people do not want to be solidary. If the relevant group appears unable to realize an adaptation measure themselves, maybe they can realize a different measure. If taking an adaptation measure is in the general interest, then it should be considered whether and to what extent a wider group should be involved in the adaptation discussion - e.g. the residents in one or more water board districts or the entire Dutch society - to find out what kind of solidary assistance the wider group may want to give.

DD 9.6-3 AN ECO-BIO-SOCIAL APPROACH TO COASTAL ZONE FOR A BETTER GOVERNANCE ADAPTATION IN THE GULF OF ST. LAWRENCE, CANADA

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Research question

Coastal zones have 25% of the biological productivity of the planet, and 90% of the fisheries production in the world. They are dynamic ecosystems with strong diversity and variability due to the combination of salt and fresh water and their interactions between land, sea and atmosphere. Wilson et al. (2005) estimate that the value of ecosystem services represent more than 40% of the world value even if they are generated by a fraction of the earth's systems. These services include the processing of nutrients, the protection of the shore from stormy weather, the creation of habitats for aquatic life, food production, supply of raw materials and leisure. Thus, it is no surprise over 40% of the world's population is concentrated in littoral areas. The management of human activities and their impact on coastal zones represents one of the major challenges of the 21st century, that is further exacerbated by climate change. This paper will focus on how an eco-bio-social approach for governance adaption of coastal zones can offer a method for developing solutions to the complex dilemma posed by the pressures of human use of these areas and their degradation, that take into account the complex nature of internal and external factors of change and adaptation.

Research results

Over the past ten years, significant work has been undertaken in the different coastal zones of the Gulf of St. Lawrence in Atlantic Canada (Chouinard et al., 2006, 2008, 2011, 2012; Cousineau, 2011; Plante et al., 2011). Through these studies, partnerships between academics and local communities have emerged and helped to develop new knowledge for a better governance of adaptation. This eco-bio-social approach conceives the interaction of human communities as one element among others (such as animal and plant life) within the physical environment. In short, significant human activity and settlement within theses coastal zones ecosystems play a distinct role that needs to be studied and understood as such.

Societal importance for stakeholders

The participatory action research approach used is an important feature which gives a voice to local inhabitants and organizations in scientific study. By emphasizing the lessons learned from these studies and focussing on the process of knowing and doing, we will show how these will be applied in a new transdisciplinary action-research study focused on the Cocagne-Grande Digue region (Atlantic Canada) as part of the international project ARTISTICC funded by the Belmont Forum.

DD 9.6-4 THE USE OF INDIGENOUS KNOWLEDGE IN DEVELOPING CLIMATE CHANGE ADAPTATION STRATEGIES

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The strategies and capacities for climate change adaptation depend much on the location and specific context in which these strategies and capacities need to be developed. Indigenous knowledge is seen as critical and pivotal in all discussions on sustainable resources use and balanced development. Indigenous knowledge may provide an important part of the puzzle in developing strategies for adapting to climate change.
This paper reviews understandings, possibilities and limitations of the use of indigenous knowledge in climate change adaptation and analyzing indigenous ways of knowing and "knowledge-in-action"in the context of climate change by analyzing key literature of indigenous knowledge and adaptation concepts and their potential for designing climate change strategies. Two data bases were searched: the Web of Science® (WoS) and Google Scholar to also include niche papers and policy-reports not covered by WoS. The search descriptors included: indigenous knowledge, climate change adaptation, roles/contributions of indigenous knowledge in climate change adaptation, sustainable development in the context of climate change. Quotation marks were employed to search for phrases. The abstracts of the publications resulting from the foregoing search strategy were screened for relevancy. If the abstract provide insufficient information, then the full text was perused to determine whether or not the publication fit in the inclusion criteria.
An overview of the various uses or functions of indigenous knowledge in developing climate change adaptation strategies is provided. These uses include: contributions to the reduction impact of climate change; establishing legal incorporation of indigenous knowledge in existing practices and policies; enhanced community engagement; contributing to guiding principles for more sustainable development and, finally, the provision of a mechanism for strengthening participatory approaches. In our final analysis we conclude that incorporating indigenous knowledge into climate change and risk reduction policies can lead to the sustainable development by providing input for more effective and contextually appropriate adaptation strategies.

Keywords
Climate change, adaptation strategies, indigenous knowledge, sustainable development.

DD 9.7-1 GOVERNANCE CAPACITY FOR MULTILEVEL WATER GOVERNANCE. CAN PROGRAM APPROACHES ENABLE MULTILEVEL COLLABORATION?

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All over the world governments are struggling with the multilevel dimension of the challenges they are facing. The inability to organize effective collective action on a single level of governance is widely acknowledged. A variety of societal challenges are intrinsic multilevel of nature and require several actions on several levels of actions which have to be attuned in order to generate a substantial improvement of the situation.
The same holds true for climate change adaptation. Effective adaptation strategies are not primarily generated by a

single decision of a single authority on a specific level. The governance capacity to achieve effective and legitimate collective action depends heavily on the mutual strengthening between decisions taken on several levels. The scientific challenge is to increase our understanding of the system of multilevel governance as it is, the interactions between actions on different levels of government and the management strategies that can help to increase the reciprocal reinforcement of interactions. In this paper we will present a contribution to this scientific challenge.
In this paper we answer the question how a program management approach contributes to the governance capacity of the Dutch multilevel water domain in terms of realizing effective and legitimate climate change adaptation.
First we will indicate the characteristics of the multilevel governance system that is at action in the Dutch water domain. Secondly, we will describe the way how a specific government, in this case the national government initiates a program approach to deal with water-related climate challenges in the next decades. Thirdly, we will evaluate the effectiveness of this approach in terms of realizing climate change adaptation measures in a multilevel governance system.
In 2009 the Dutch Delta program started aimed to execute a fundamental exploration of the main challenges for the national water system and to prepare key long-term decisions and regional strategies in order to make the Dutch water system climate proof. Our research is based upon interviews with 30 key players in the Delta Program and a large-scale survey among 1400 respondents.
From our extensive material we conclude that the type of program management applied by the 'Delta Commissioner' is identified as a helpful device in enabling productive interaction among different governance levels. We conclude our paper with a couple of insights how to consolidate the capacity developed by the Delta Program for the coming years.

DD 9.7-2 AN EXPLORATION OF THE CONDITIONS FOR A SUCCESSFUL DIVERSIFICATION OF FLOOD RISK MANAGEMENT STRATEGIES

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Because of climate change, extreme weather events and urban sprawl, urban regions have to deal with increasing flood risks. It is argued, both in literature and in practice that these risks can no longer be dealt with by focusing solely on flood defenses (building dikes, dams, embankments etc.). Actors at various levels (international, European, national as well as regional) wish for and make efforts at a diversification of Flood Risk Management Strategies (FRMSs). The additional role flood prevention by pro-active spatial planning (building permits), flood retention, flood mitigation (e.g. urban green infrastructures, adaptive buildings), flood preparation and flood recovery can play in improving a region's resilience to flooding is widely debated. A diversification of FRMSs will result in governance challenges. Scientific literature so far has only addressed each shift - and the necessary institutional preconditions for establishing it - separately, but has failed to address them in combination. Addressing these challenges asks for an innovative vision and approach. It is however not clear under which conditions such an innovative vision and approach can be successful. Our study therefore aims to explore these conditions. Our exploration consists of the following steps. First we elaborate on the concept of diversification by making a distinction of 6 FRMSs. Second we clarify how these FRMSs are institutionally embedded in Flood Risk Governance Arrangements (FRGAs) in the Netherlands. We will refer to the discursive, the actor, the rules and the resources dimensions of the arrangements. Based on a literature review we present the implications a possible (de)intensification of FRMSs may have. In a next step we reflect on the way the Netherlands tries to the implement the idea of diversification by the Multilayered Safety Approach. By interviewing key informants we have identified the key conditions that might stimulate a successful

diversification. We have placed our results in a broader perspective by discussing them with some experts, that reflect on their generalizability or context specificity. The conditions identified need further specification, which can be based on future comparative empirical research. We therefore conclude with a research agenda.

DD 9.7-3 FROM FLOOD PREVENTION TO MULTI-LAYER SAFETY IN THE DUTCH DELTA - GOVERNANCE IMPLICATIONS

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The Netherlands has a long tradition of flood management, which mainly focussed on flood prevention via embankments. Spurred by near floods in 1993 and 1995 and the EU Flood Directive, the Dutch flood management is slowly moving towards a flood risk governance approach, called Multi-Layer Safety (MLS). The policy consists of three layers 1) prevention, 2) damage reduction through sustainable spatial planning and building codes, and 3) crisis control and evacuation.
MLS is currently been worked out in more detail, but faces considerable opposition especially from the traditional water agencies. As an integrated and area-specific flood risk approach, MLS will have large impacts on current governance arrangements. It implies a reallocation of responsibilities, costs and benefits from water authorities towards parties that currently have no, or a limited, role in flood management "' parties for who flood management is not the first priority.

Research question
Our research question is: what are the impacts of MLS on current governance arrangements? We will study this with the use of a conceptual framework with four main themes; reallocation of responsibilities, connectivity, frames and normative principles.

Research results
First results, based on an analysis of the current debate around MLS, show that connectivity between the involved governance levels, sectors and private parties need to be organised, in order to make sure that measures from each layer reinforce each other. Connectivity is hindered by differences in frames on flood safety (flood prevention or flood risk management), which include normative aspects such as solidarity and fairness (which might shift due to increasing differences in flood probability between regions). Water agencies "' who have invested so much (economically and emotionally) in flood prevention "' are concerned that other priorities might overrule flood prevention in spatial planning, thus increasing flood risks. They want to solely invest in embankments, which are seen as the most cost-effective measure.

Societal importance for stakeholders
Most studies on the governance of MLS have taken a single perspective, for instance focussing on the legal instruments or frames. Our research shows that in this complex discussion, a more diverse conceptual framework yields richer insights. On basis of the analysis with the conceptual framework we will sketch possible future governance arrangements for MLS, which can be used by policy and decision-makers involved in the ongoing discussion on MLS.

DD 9.7-4 A TYPOLOGY OF GOVERNANCE ARRANGEMENTS FOR THE CHALLENGES OF CLIMATE ADAPTATION POLICIES

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Despite the vast body of literature on climate change and the need for climate adaptation, less attention has been given to the actual implementation of climate adaptation strategies. We consider climate adaptation strategies as a specific category of policy implementation, since a) climate change impacts will occur on the long term, nonetheless in the near future decision have to be made on how to act, b) there is irreducible uncertainty on how and how fast the climate will change, c) therefore, the strategy needs to be adaptive and responsive to the actual change by keeping other adaptation options open, and d) as a result of the above reasons, climate change in itself is often not perceived as a strong enough driver alone for profound infrastructural investments and there should be other functions fulfilled as well. Hence, these features require specific governance arrangements. Therefore, our research question is: *what kind of governance arrangements are able to deal with these specific characteristics of climate adaptation policy?*
This article presents a typology of governance arrangements based on the magnitude of the adaptation challenge on the one hand and the expected frequency by which adjustments need to be made on the other. The typology has been applied to the case study of lake IJsselmeer in The Netherlands for which adaptation strategies have been developed within the Delta Programme. The presented governance arrangements consist of the set of stakeholders, actions, means and instruments to guide and facilitate the adaptation strategy. We have analysed to what extent the various arrangements can deal with high and low frequency adjustments in the policy, small and larger transformations and the notion of keeping options open to remain flexible.
The results of the study can help to implement the adaptation strategies in the Dutch Delta Program and contributes to the application and development of Adaptive (delta) management, the guiding concept in the Dutch Delta Program. Furthermore, it will contribute to the further scientific development of the Adaptation Tipping Points Approach (ATP's) (Kwadijk, et al. 2010), the adaptation pathways approach (Haasnoot et al 2011, 2012) and the institutional and socio-cultural analysis of adaptation pathways (Van der Brugge et al. 2013).

DD 9.7-5 EMERGENCE AND APPLICATION OF ADAPTIVE DELTA MANAGEMENT IN THE NETHERLANDS

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Adaptive approaches to governance of natural resources are needed to effectively and efficiently deal with uncertainty. In this respect, the government of the Netherlands is pro-actively taking an integrated approach to planning and governance of its water resources: it has adopted a Delta Act (2011) to manage flood and drought risks in the face of uncertainty; it assigned a Delta Commissioner and established a Delta Programme to develop adaptive strategies for the coming century; and it dedicated a Delta Fund for implementing these strategies.
Using scientific insights from adaptive policy-making, economic valuation and participatory decision-making, the Delta Programme has developed 'adaptive delta management' (ADM) as a method for developing these adaptive strategies through an optimization of cost-effectiveness, robustness and flexibility. Collaborative processes led to the development of 9 'preferential' strategies for the 9 area specific parts of the Delta Programme.

This paper presents the outcomes of an evaluation of the application of ADM in the Delta Programme. It presents a comparison between the initial expectations from ADM and the outcomes in terms of the 9 'preferential' strategies. Firstly, a literature review and interviews were conducted to analyse how and from what theoretical background ADM emerged. This led to the identification of the initial expectations from ADM. Secondly, a survey and interviews were conducted amongst the 9 parts of the Delta Programme to analyse the application of ADM and identify its achievements and its remaining practical challenges.
We conclude that application of ADM was instrumental for developing adaptive strategies, but that significant hurdles remain for securing these strategies on the long term. We discuss the implications of these hurdles and make suggestions for overcoming them. The insights of this research may be relevant for scientists, policy makers and planners who are interested in establishing more adaptive policy making practices.

Deltas in Depth Theme 10:

Economics and finance of adaptation

DD 10.1-1 99 CASE STUDIES OF THE UNFCCC PRIVATE SECTOR INITIATIVE: CAN THE PRIVATE SECTOR FINANCE ADAPTATION?

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The role of the private sector in climate finance is increasingly emphasised in political as well as scientific debates. The private sector's role in financing adaptation is however hardly studied and lags behind the understanding of their role in financing mitigation. To add relevance to preceding conceptional research, this paper analyses 99 case studies of private sector adaptation under the Private Sector Initiative (PSI) of the UNFCCC's Nairobi Work Programme. According to the UNFCCC, the PSI was launched to catalyze the involvement of the private sector in the wider adaptation community, through their 'unique expertise, its '*capacity to innovate and produce new technologies for adaptation*', and its 'FINANCIAL LEVERAGE'. In order to assess the private sector's role in adaptation finance, the 99 case studies are examined against ten indicators for adaptation finance that were distilled from UN climate negotiation outcomes.

This paper shows that the role of the private sector in adaptation is potentially large - case studies contribute to adaptation in all sectors and on all continents. However, private sector interventions only correspond to the UNFCCC's adaptation finance indicators '*adequate*', '*sustainable*' or '*predictable*' to a limited extent. The PSI contributions address, yet not '*prioritize the most vulnerable countries*', and they hardly fit under the adaptation finance indicator of '*transparency*'. Furthermore, it depends on the conceptualisation of adaptation whether PSI contributions to adaptation also constitute adaptation. This is an important difference particularly in the political debate on international climate finance.

This research is also important for policymakers and research for two other reasons. First, the case shows how the private sector itself frames adaptation and their role therein. This supplements frames from public actors and researchers, and provides insight in the way their activities correspond to expectations from the international climate negotiations. Second, the analysis of the variety of case studies explains the motivation of the private sector to engage in adaptation, and how they can reduce risks or explore the adaptation market opportunities. This helps to understand potential of private sector engagement in adaptation.

DD 10.1-2 FINANCING GREEN ADAPTATION STRATEGIES TO CLIMATE CHANGE: THE POTENTIAL OF PUBLIC-PRIVATE PARTNERSHIPS (PPP)

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The implementation of green adaptation measures is hindered by a number of procurement and financing barriers. We explored the possibilities and challenges ahead for these measures to be financed and implemented as PPP. As PPP's are a joint endeavor and not solely depend on a public authority; we opted for the use of collaborative modeling techniques.

Three sessions were organized with representatives of key decision makers: public client, project sponsors, and financiers. The case of mangrove restoration in Indonesia was chosen to allow for concrete recommendations and quantification of interdependencies. The first workshop focuses on understanding the complexities of natural

capital and the differences in behavior in terms of performance and costs of green versus grey option. In the second workshop the group worked in three assignments aimed at linking the stock of natural capital with the cash balance of the Special Purpose Vehicle implementing the project. Besides defining the required levels of services for the payment of 'availability fees' and defining cost drivers; the group explored ways to close the financial viability gap by capturing the positive externalities of mangrove restoration via taxes or via tariffs. All insights were brought together in a System Dynamics model and required conditions for bankable projects were explored.
The result is a script for effective collaboration of diverse stakeholders and disciplines to formulate a bankable project applicable to other green adaption measures.
The proposed methodology has been successful in dealing with one of the main barriers for the private financing of green adaptation, an unfounded perception of excessive risks . As measured by our survey, participants not only gained a better informed view of the risks of the project but were also more able to define the Internal Rate of Return (IRR) of the eco-engineering design.
The construction time and the cyclical performance of eco-engineering concepts require a different financing model than traditional grey infrastructure. When opting for PPP as project delivery method is of even greater importance to:

a. Define the right performance indicators and allow for more flexibility on level of services for the main service being provided by the project, in this case flood protection.
b. Adapt payment mechanisms so as to make possible a positive project IRR for these projects that take much longer construction periods and have a cyclical fluctuation in performance since they follow the dynamics of natural processes.
c. Implement risk sharing facilities.

DD 10.1-3 A COMPARISON OF FINANCIAL ARRANGEMENTS FOR REALISING ADAPTATION PROJECTS

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Adaptation receives much attention by policy and science, but implementation is lagging. A lack of understanding about adequate financial arrangements is often mentioned as one of challenges for the implementation of adaptation projects. Water management and maintenance of infrastructure assets typically fall under the responsibility of public sector and are typically facing budgetary constraints. The fact that many water infrastructure assets in many countries have long reached their technical lifespan illustrates the austerity of the sector, independent of the economic crisis. Over the last few years, scientists and policy makers in many developed countries have increasingly adopted approaches to synergistically link investments in water infrastructure with other developments, such as urban redevelopment or road infrastructure. These approaches typically aim to reduce the costs of adaptation by exploiting opportunities that emerge during infrastructure upgrades or urban redevelopment or to add value to society by combining infrastructure upgrades with the provision of additional functionalities.
This research aims to provide more insight in the effectiveness of financial arrangements for such synergetic adaptation approaches. Based on cases from the Netherlands and Australia, we analyse the strengths and weaknesses of public partnerships, public private partnerships and revolving investment funds in terms of linking adaptation measures with urban (re-)development and upgrades of other types of infrastructure. We have interviewed project managers and investment managers about what has been achieved through these financial arrangements and how this was done. In addition, we have questioned them about the applicability and limitations of their financial

arrangements under different conditions. One of the respondents nicely summarised the challenge of financing adaptation by using the metaphor of a motorcycle sidecar: '*there are currently many sidecars, but the motorcycle is nowhere to be seen*.' Hence, financial arrangements in which the investments can be earned back (as far as possible) seem most effective. Our research illustrates the potential of revolving funds for driving innovation for projects that have the ability to recover upfront investments. In addition, for the vast majority of adaptation projects that do not have this ability to recover upfront investments, our research shows how public and public private partnerships can play a role in optimising cost benefit ratios during the whole lifespan of assets. These findings can help steering adaptation in the fast lane.

DD 10.2-1 THE ECONOMIC-WIDE CONSEQUENCES OF LARGE-SCALE FLOODS. HOW RESILIENT IS THE EUROPEAN ECONOMY?

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For a successful adaptation strategy, it is necessary to have an in-depth understanding of the economic consequences of a flood. To assess the economic consequences of both large-scale coastal and river floods in Europe, we introduce an integrated direct and indirect risk model for the European economy as a whole. The proposed methodology consists of multiple steps. First, a direct loss assessment is conducted for multiple floods throughout Europe, based on simulated floods and past flood experiences. Second, the direct losses in capital and labor are translated into the loss in production per sector. Third, the recovery of this production shock is modeled using a hybrid interregional input-output model, combining non-linear programming and input-output modelling. This combination makes it possible to find (1) the possible production losses in the affected regions and other European regions, (2) the required production in Europe to satisfy additional reconstruction demands from the affected regions and (3) the required production in other regions that is necessary to take over lost production in the affected region. Consequently, when knowing how much production is lost (or gained) in each region, the economic consequences can be assessed. Finally, the model outcome is loss estimation expressed in terms of expected annual damage. To assess these consequences, interregional supply and use tables are used, consisting of 256 different European NUTS2 regions. This data makes it possible to model the indirect losses for both the affected region and the rest of Europe in detail. Results show that most of the regions outside the affected area are not affected by the natural disaster. Most of the regions gain benefits from the flood by taking over some of the lost production. Some regions suffered losses, mainly due to economic relations with the manufacturing sector in the affected region. Consequently, the overall consequences for the European Union are found to be positive for small-scale floods and negative for large-scale floods. Finally, a sensitivity analysis showed two important implications for disaster recovery. First, a certain level of overcapacity should always be possible to allow for a recovery of the area. Without any overcapacity, the area is impossible to recover without rationing, for instance, households or public services. Second, only a certain amount of reconstruction is possible at the same time due to insufficient capacity in the construction sector. This implies that a detailed reconstruction plan is required for an efficient recovery of the area.

DD 10.2-2 ECONOMIC IMPACT OF WATER SCARCITY FROM CLIMATE CHANGE AND DEPENDENCY ON SURFACE AND GROUNDWATER FOR IRRIGATION

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A number of climate change scenarios show an increased frequency and severity of droughts in Northwest Europe due to reduced precipitation and warming summer temperatures. If this would occur, the impact on the agricultural production would depend on the possibility of farmers to adapt by intensifying irrigation and changing cropping patterns. The majority of irrigation in Northwest-Europe is fully reliant on groundwater which has a limited supply and is also adversely affected by reduced precipitation. Areas close to rivers such as the low lying areas of the Netherlands can however, also be supplied by river water mainly from the Rhine. Access to river water to supplement ground water supplies for irrigation could make the Dutch agricultural producers less vulnerable to droughts in a warmer drier climate.

To determine the extent of the benefit of increased access to river water in times of water scarcity we employ the multi-regional computable general equilibrium model GTAP-W, which includes water as an explicit input in production, to capture the differing adaptation responses of agricultural producers who experience the same drought and participate in the same global markets for agricultural products. The model has been expanded to allow for differentiation between surface and groundwater endowments within individual regions in order to quantify the importance of increased surface water in irrigation as an adaptation response to climate change. The model has been applied to analyse the impact of a drier climate in Northwest Europe on the agricultural sector and the economy as a whole.

The results show that the extent of the benefit that the Netherlands would receive depends on the degree to which the Dutch agricultural producers can increase their share of river water to supplement groundwater for irrigation within the existing water distribution infrastructure.

The results on the influence of access to river water on the agricultural producers' adaptation response to drought can assist policy makers in anticipating the regional consequences of wider climate trends toward hotter drier summers as well as provide insight into the added value of expanding water distribution infrastructure to increase access to river water for irrigation.

DD 10.2-3 INCREASING STRESS ON DISASTER-RISK FINANCE DUE TO LARGE FLOODS

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Recent major flood disasters have shown that single extreme events can affect multiple countries simultaneously, which puts high pressure on trans-national risk reduction and risk transfer mechanisms. So far, little is known about such flood hazard interdependencies across regions and the corresponding joint risks at regional to continental scales. Reliable information on correlated loss probabilities is crucial for developing robust insurance schemes and public adaptation funds, and for enhancing our understanding of climate change impacts.
Here we show that extreme discharges are strongly correlated across European river basins. We present probabilistic trends in continental flood risk, and demonstrate that observed extreme flood losses could more than double in frequency by 2050 under future climate change and socio-economic development. We suggest that risk management for these increasing losses is largely feasible, and we demonstrate that risk can be shared by expanding risk transfer financing, reduced by investing in flood protection, or absorbed by enhanced solidarity between countries.
We conclude that these measures have vastly different efficiency, equity and acceptability implications, which need to be taken into account in broader consultation, for which our analysis provides a basis.

DD 10.3-1 ECONOMIC MODELLING FOR SELECTION OF FLOOD PROTECTION MEASURES IN JAKARTA: AN OPTIMIZATION APPROACH

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Jakarta is facing serious problems from coastal flooding and river flooding. There is an urgent need for implementing flood protection measures.
After the severe flooding in 2002, the Jakarta government and the national government have implemented various measures against flooding, such as polders, river normalization, and flood canals. However, severe floods still hit the city such as in 2007, 2013, and 2014. Currently, the government considers other flood protection measures, which can be built along the rivers from upstream to downstream. This requires a high investment budget, and hence selecting the appropriate measures that can reduce the damages, becomes an important issue.
This paper focuses on the economic analysis of choosing flood protection measures. Particularly, we develop an economic model, which enables us to select the optimal flood protection measures. The model has an objective function, which is to minimize the total costs including the costs for implementing flood protection measures and the damage costs. The model constraints include the budget constraint for implementing different measures. As such, the expected damage costs can be reduced. The model is solved by using GAMS. Solving the model provides the

information on the choice of optimal measures.
Our model includes the spatial and temporal dimension. Regarding the spatial issue, we consider Jakarta as part of Ciliwung River catchment areas. Implementing a flood protection measure upstream can contribute to reducing the damage costs in the downstream area. For the temporal issue, we take into account the construction period and the utilization period of flood protection measures. We calculate the net present value of the total costs including the measure costs and the damage costs. We take step-wise approach to illustrate how our model can be applied in three cases to identify the optimal choices of the flood prevention measures. In the first case, we study the three measures: polder, river normalization, and flood canal, and they are implemented in one area. In the second case, we extend the model to two areas, upstream and downstream. The measures in the first case represent the downstream measure, while the upstream measures include reservoirs and dams. Finally, in the third case, we consider the different time periods of the these measures for construction and their life time. Our primary results show that building flood canals can be the best option in case one, reservoirs and flood canals in case two and three.

DD 10.3-2 DESIGN OF ASSESSMENT FRAMEWORKS FOR DELTA ADAPTATIONS - EXPERIENCES FROM THE NETHERLANDS AND THE USA

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Research question
Delta adaptation requires a long term vision how to adapt to plausible futures regarding climate change as well as socioeconomic development. Promising strategies and measures need to be assessed and evaluated, providing essential information for decision making. However, relatively little knowledge exists how to design assessment frameworks that can handle the inherent uncertainty which comes with the long term character of adaptation strategies. Most existing evaluation frameworks such as CE or CBA are designed for investment plans and projects with a time horizon which is usually too short to encompass effects of climate change. Furthermore, delta adaptation strategies are of a very diverse nature, including but not limited to infrastructural investments, urban redesign, fiscal incentives, eco-engineering and green infrastructural designs. The question is therefore how to design assessment frameworks that can grasp this diversity as well as long time horizons.

Results
In this presentation the experiences of designing such assessment frameworks from both the Netherlands and the USA are presented. For the Netherlands an assessment framework was prepared upon request of the Dutch Delta Program. The Framework was developed during 2011 and 2012 in close interaction with analysts and members of the Delta Program and was tested in a number of regional trial sessions. The outcomes of these sessions were used to refine and improve the Framework. Recently, the Dutch experiences were used to prepare an Assessment Framework for application in the on-going Rebuild by Design contest aiming at providing a more resilient and adaptive coastal development in New Jersey and New York after Hurricane Sandy. An initial framework was tested during a workshop with the designers.
The core of the Framework includes a semi-quantitative scoring method on main criteria: goal realization (flood

risk reduction and/or freshwater supply), investment and maintenance costs as well as environmental, social and economic values. The Rebuild by Design scoring process has been embedded in a step-wise approach that includes defining a reference situation, stakeholder identification and robustness/flexibility tests as well as implementation and synergy opportunities.

Societal importance for stakeholders

The assessment Framework is used in an early stage to focus on most promising as well as feasible solutions. This reduces time wasted on less promising alternatives. Furthermore, the framework is flexible in the sense that different stakeholder perspectives can be presented (e.g. CBA perspective and a regional perspective). This enhances the acceptance of the method for a variety of stakeholders.

DD 10.3-3 COMPARING ECONOMIC TOOLS FOR EVALUATION OF ADAPTATION PATHWAYS TO SUPPORT CLIMATE ADAPTATION

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The exploration of adaptations pathways is gaining more and more interest as an approach to support decision making under uncertainty [1,2,3,4]. Until now, the economic evaluation of adaptation pathways is still underdeveloped. Although different economic evaluation methods are available, including cost-benefit analysis and real options analysis, applying these approaches for the evaluation of adaptation pathways and dealing with uncertainties is not straightforward. Some methods are over complex, while others (such as the regular cost-benefit analysis) miss a dynamic component needed for evaluating different adaptation pathways.
We are currently comparing and evaluating different economic evaluation methods to their strengths and weaknesses for evaluating adaptation pathways to support climate adaptation. For this purpose, we are applying the approaches of Cost Benefit Analysis, Multi Criteria Analysis and Real options to the same hypothetical case. This case is inspired by climate change impacts on a river reach in the Rhine delta of the Netherlands.
According to a first analysis, remarkable differences in preference for certain strategies become apparent when taking into account different assumptions and methods. This could indicate that the choice for certain economic evaluation methods will have a potentially high impact on decision making. Based on the results, we will give recommendations of tailoring the approaches, for them to be better applicable to adaptation pathways, and evaluate drawbacks and benefits of the different methods and approaches.

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DD 10.3-4 INTEREST OF AGENT-BASED VS MACROSCOPIC APPROACH TO EVALUATE ADAPATATION MEASURES OF PRIVATE SECTORS TO FLOODING

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Societal perspective.To reduce the impacts of climate change on society, adaptation is promoted at national and international levels. When coming to implementation of adaptation measures, decisions makers, at national or local levels, have to prioritize between different admissible options. Economic assessment is an adequate tool based on the efficiency criteria. Most of the economic models developed by the scientific community are macroeconomic approaches which provides a global idea of the efficiency of a whole program. However, they are based on implicit assumptions on asset vulnerability whereas local managers really need to comprehend vulnerability to propose adequate measures on their territory.Indeed, when adaptations measures concern private sectors, both business and individuals, they need to be designed at individual scale. To evaluate the efficiency of adaptation measures, both from a collective perspective (cost-benefit analysis) or from an individual perspective, this implies to have a good understanding of those measures at individual scales. But, even if they apply at individual scale, these measure may have impacts at a mesoscale due to interactions between agents. These kind of impacts are traditionally called indirect impacts and their propagation through a society is very poorly characterized. This raises the question of the interest of a bottom up approach such as agent-based modeling approaches to model damage (direct and indirect), in particular to evaluate adaptation measures.Research question. What are the insights, advantages and drawbacks of an agent-based modeling approach to evaluate adaptation measures in comparison to classical top down approaches?Research results. We propose a position paper based on literature review on the subject. We first analyze the compatibility and barriers to develop an agent-based modeling approaches considering damage assessment and vulnerability assessment literature.Then, we will propose several criteriato compare an agent-based and a macroeconomic approaches. Wecompare the interest and difficulties to use agent-based and a macroeconomic approaches to evaluate adaption measures. The kind of criteria analyzed are: modeling scale, characterization of input required and output produced by the model (level of aggregation, sensitivity of results). Finally, we propose a methodological framework to develop and use an agent-based modeling approach to evaluate damage and adaptation measures. In particular, we show how this approach enable to evaluate adaptation measures from a collective (economic) or individual (financial) perspective.

Deltas in Depth Theme 11:

Decision support tools and risk assessment

DD 11.1-1 EXPLORING CHANGES AND CHALLENGES: GLOBAL TRENDS IN FLOOD RISKS TOWARDS 2050 IN AN URBANIZING WORLD

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Research question

Today around 50% of the world population lives in an urban environment and it is expected that this percentage shall increase to 70% the coming decades. In this study the development of flood risks in urban and rural areas towards 2050 is analyzed with the objective of (i) assessing the possible development of annual expected impacts in terms of exposed population and exposed economic value; (ii), assessing these impacts in case protection standards are raised; and, (iii) identifying the most vulnerable cities.

Methodology

In order to explore future flood risk a global flood model is used in combination with a global demographic model. The combination of these models has been used to assess the increase in annual exposed population and GDP between 2010 and 2050, as well as to give a preliminary assessment of how much the overall risk could be reduced by improving flood protection standards. Using the same data, maps of cities vulnerable to flooding, ranging from less vulnerable to more vulnerable, in 2010 and 2050 are produced.

Research results

As urban areas expand, hundreds of trillions of dollars of assets are increasingly at risk from river floods and coastal floods, particularly in Asia. Following the baseline scenario, by 2050 there may be 670 cities that have 500,000 inhabitants or more, of which 88 count over 5 million inhabitants. Fifty percent of those cities fall in the highest vulnerability ranking with respect to flooding, based on exposed population and GDP per capita.
Comparing different flood protection levels shows that the annual exposed number of people and assets subject to flooding can be substantially reduced. When a safety level is applied of for instance a once in a thousand year flood (1:1000) for urban areas and 1:100 for rural regions, the expected annual exposed population by 2050 is lowered by more than 90% compared to an overall protection level of 1: 10.. This is also the case for economic assets based on GDP.

Societal importance for stakeholders

There is a wide range of measures available, and given the potentially large effect of flood risk reducing measures it seems no-regret and worthwhile for cities and countries to pay due attention to an appropriate flood risk strategy. Inclusive urban development and communication and involvement of stakeholders is an important governance challenge in flood risk strategies. Flood risk maps and figures can help to understand the challenges and explore solutions.

DD 11.1-2 HYDROLOGICAL VARIABILITY, TRANSBOUNDARY FLOODS AND INSTITUTIONS: ARE WE PREPARED FOR TOMORROW'S PROBLEMS?

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Research question

Floods are among the world's most frequent and damaging types of disasters and annually affect the lives of millions all over the globe. Over time, human exposure and vulnerability to floods has increased with a growing and increasingly urbanized population. The projected effects of climate change on hydrology, aggravated by a range of social, economic and political processes will continue to increase this vulnerability. Nonetheless, vulnerability of societies and their institutions to floods remains poorly understood. Using global data, this paper examines the nexus of transboundary flood events and social vulnerability: which international river basins have experienced transboundary floods, i.e. floods that affect two or more countries, in the past, and which are forecast to experience increased hydrological variability in the future, but lack institutional provisions, i.e. river basin organizations and/or treaties, to deal with these shared events?

Methodology

Current data and research on institutional capacity deriving from treaties as listed in the Transboundary Freshwater Dispute Database (TFDD; Yoffe, Ward and Wolf, 2000, De Stefano et al. 2012) will be refined by looking more specifically at the roles that river basin organization (RBO) functioning and treaty composition play in flood management. International river basins will be stratified by the type of climate-related stress they may face in terms of both hydrological change and the aspects of society most affected by flooding, such as urban areas and agriculture. Then, this updated information about international river basins and floods will be merged and weighted to produce a vulnerability ranking specific to floods and the institutions designed to manage them.

Research results

A global vulnerability ranking of international river basins when it comes to transboundary floods, climate-driven hydrological variability and institutional capacity.

Societal importance for stakeholders

The findings of this paper will significantly increase our current knowledge on transboundary flood events, projected variability regimes related to the shared waters between countries, and flood-related international institutional capacity. These insights will help policy-makers of tomorrow identify and evaluate potential vulnerability to transboundary river floods, which in turn can be used to bolster international water management institutions and increase international cooperation in managing and preparing for shared river floods in a changing climate.

DD 11.1-3 ASSESSING HEALTH, LIVELIHOODS, ECOSYSTEM SERVICES AND POVERTY ALLEVIATION IN POPULOUS DELTAS

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Deltas contain large populations who are often poor and live at high densities with a high dependence on ecosystem services. These areas are subject to multiple drivers, including climate change and subsidence, changing catchment management, and land use change and hence are likely to change dramatically in the coming decades. The ESPA Deltas Project aims to holistically describe the interaction between the coupled bio-physical environment and the livelihoods of these poor populations in coastal Bangladesh. It will further consider the prognosis for deltas ecosystem services and human well-being, including the role of policy intervention. The methodology is multi-disciplinary involving natural and social scientists, engineers, and policy experts and has a strong commitment to participatory approaches. It involves exploring and formalising relevant relationships based in data, models and stakeholder expertise and ultimately developing policy relevant information suitable for decision support.
The project started by identifying stakeholders and their issues of concern. This informed the issues we explore in biophysical and socio-economic terms, and further development of hypotheses on the use of ecosystem services and poverty. These are being further explored and quantified in analysis of the census as well as a dedicated social survey. This is collecting information from families over three seasons based on a sample of households across the study region. In parallel, a series of biophysical models are being developed for the delta and its surrounding areas (catchments, Bay of Bengal). These are being coupled as far as is reasonably possible, but full coupling is not feasible. Hence an integrated model on a common platform is also being developed using a system dynamics approach. To explore the future, exogenous scenarios such as sea-level rise or the global price of rice are developed by experts, while endogenous scenarios such as governance or flood management strategies are developed in a participatory manner with stakeholders. Thus the future socio-environmental trajectory of the study area can be explored through these scenarios and the model's output simulations can be assessed with stakeholders.
This leads to new suggestions of policy interventions which can again be simulated in the modelling system. Hence learning cycles of using this tool are envisaged and the resilience of policy options tested as an approach to handling uncertainty. This paper presents an overview of the project and its overall progress, while other papers at the conference examine more detailed aspects of the ESPA Deltas Project.

DD 11.1-4 INCREASE RESILIENCY WITH A NEW APPROACH TO COMMUNICATE FLOOD RISK TO FLOOD-PRONE COMMUNITIES

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Research question

Hurricane Sandy (2012) resulted in major flooding, extensive damage and loss of life. New York and New Jersey, some of the US most populous states, were hard hit by these storms. Thousands of individuals were displaced and millions lost power. Rebuild by Design, an initiative of the Hurricane Sandy Rebuilding Task Force, aims at addressing vulnerabilities that Hurricane Sandy exposed in communities and developing solutions to better protect residents from future climate events. Sandy illustrated that people who had a better understanding of the risk were in a better position in the storm's aftermath.

One of the most under-utilized, and yet simplest forms of resiliency opportunity is communication before, during and after a flood. There is limited understanding of the concept of flood risk amongst the public and decision makers. By actively reaching out to communities in flood-prone areas, increase their understanding of the risk of flooding and presenting complex information in an easy to comprehend way, the resiliency of this community is expected to improve significantly. Better information on flood risk improves resiliency because allows better, more informed, decision making, facilitates a more appropriate response to risk and better marshaling of resources. As part of Rebuild by Design a new approach in risk communication was developed by flood risk experts of Royal HaskoningDHV and researchers of OMA.

Research results

In anticipating flood it is essential for all stakeholders to share a common understanding of flood risk and its implications. Although efforts continue to be made at outreach and capacity building, more can be done to make information accessible. Based flood risk expertise and experiences of communities in flood-prone areas a 'flood risk 101' is developed. This encompasses hardcopy material to inform communities about flood events and explains flood risk in a straightforward way; risks are compared to events communities can relate to; flood probabilities are related to mortgage costs, poker hands and sport events. Moreover illustrations provide insight into the basic causes, probabilities and consequences of flooding and how to address those. The next step is to build an interactive environment to communicate this information; for example a mobile phone application.

Societal importance for stakeholders

Thinking of flood-prone communities as users and informing them on complex risk concepts was well received by communities which recently experienced a flood event. With minor modifications the 'flood risk 101' material can be used in vulnerable flood-prone communities world-wide.

DD 11.1-5 COUPLED ETHICAL-EPISTEMIC ISSUES IN ASSESSING AND MANAGING RISKS FROM SEA LEVEL RISE

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Scientists who assess how much sea levels will rise in the future have a difficult job. They need to take into account detailed information from several different scientific disciplines, evaluate contesting models and data within those disciplines, and foresee how future societies will act. In producing such assessments, scientists necessarily make choices, which can be seen as reflecting explicit or implicit value judgments. For example, there is a tension between the state of scientific knowledge on sea level rise and the demand for precise predictions, and this tension likely affects assessments of future sea level change. This study focuses on two related questions: 1) What value judgements do scientists make in producing assessments of future sea level change? 2) What effects do those value judgements have on decision making?

Following earlier work, we distinguish between epistemic values, which are related to the knowledge-seeking goals of science (e.g., scientists may strive towards findings that are as accurate and precise as possible) and social values, which are related to ethical, economical or practical considerations (e.g., assessed sea level rise projections may have ethical consequences, if such assessments lead to inefficient decisions). We use this distinction as a tool to analyze recent, prominent assessments of future sea level rise.

We point out that the 'correct' future sea level to plan for depends on local factors, including sensitivity to flooding and the marginal costs associated with planning for too much or too little sea level rise. Thus, decision makers may wish to consider the vulnerabilities of their particular system, in addition to examining scientific assessments of future sea level change. Recently, 'robust' or 'adaptive' decision frameworks have been developed to help decision makers carry out these tasks. These decision support methods create a demand for scientific assessments that explore the range of potential futures, rather than simply giving a best estimate or narrow range. Given this tight coupling between ethical and epistemic values, scientific assessments of future sea level rise may need to account for the differing values held by decision makers, just as such assessments account for other sources of uncertainty.

Our work adds to understanding of the influence of social and epistemic values on assessing and managing the risks of future sea level rise. We anticipate that this work will help to make scientific assessments of future sea level rise more relevant for decision making and will lead to better adaptation decisions.

DD 11.2-1 EXPLORING, EVALUATING AND UPSCALING ADAPTATION PATHWAYS FOR EUROPE

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The EU research project 'Bottom-Up Climate Adaptation Strategies for a Sustainable Europe' (BASE) aims to increase local knowledge of adaptation pathways, and integrate this bottom-up knowledge with top-down knowledge to assess the effectiveness of costs and benefits of adaptation strategies at different scales in order to support action for sustainable climate change adaptation in Europe. BASE seeks to improve estimates of costs and benefits of climate change adaptation and to upscale and integrate them at the sectoral and EU-level.
In this paper, we will outline the development, evaluation and upscaling of adaptation pathways for prospective cases using a decision analysis framework for adaptation planning and decision-making. The cases are based on the RCP 4.5 & 8.5 and the SSP2 & 5 scenarios to handle uncertainty and to maintain comparability. An interdisciplinary assessment of costs, benefits, effectiveness, challenges and opportunities of adaptation across urban, rural, water, agriculture and health sectors will be carried out to evaluate and improve the adaptation pathways.
The upscaling of climate adaptation information is an activity in which information on a smaller spatial scale is translated into information for a larger spatial scale. The information to be upscaled is drawn from case studies and consists of adaptation pathways and its characteristics, costs of impacts and adaptation, and adaptation benefits. For example, the benefits of a flood risk reduction action, studied in detail at the local scale for a specific catchment, can be translated by using the models developed and applied in BASE, to the European scale, for catchments where a similar action could be relevant. Upscaling also involves the development of generic pathways for different sectors and areas based on the case-specific pathways. First results show that is possible to develop such generic pathways and summarize them in a generic adaptation map. For example, for flood risk management a set of generic actions and pathways were identified for river floodplains and coastal areas. The timing of an adaptation action will then not only depend on the scenarios but also on the case the pathways is tailored to.

DD 11.2-2 RESPONSES TO COASTAL CLIMATE CHANGE: INNOVATIVE STRATEGIES UNDER AN UNCERTAIN FUTURE

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The RISES-AM- project deals with the projections of impacts for vulnerable coastal systems under climatic variations. Starting from global scenarios we shall use regional projections for sea level rise, waves and storm surges together with some consistent socio-economic pathways. The project will employ an advanced set of models to assess impacts, focussing on flooding and erosion for the physical component and on coastal land uses and population migration for the socio-economic component. The development of such impacts in time will allow introducing conventional and novel coastal interventions for adaptation. The error bars in drivers and responses will introduce a significant uncertainty level that must be explicitly considered when developing an adaptive pathway, if it is to be seriously considered by the corresponding policy and decision makers.

Our main **research question** is whether the unavoidable limits in knowledge and accuracy may hinder decision making for vulnerable coastal zones that often require urgent choices even under present conditions.

Our **research results** will explore the feasibility of using a risk-based approach to assess coastal vulnerability and to compare the present adaptation deficit with that expected under future scenarios, particularly the high-end ones. The assessment will combine the long term (averaged) evolution with the occurrence of extreme (storm) events and their corresponding uncertainties, incorporating both of them into the analysis. The obtained adaptation pathways will address the effectiveness of novel (flexible) coastal engineering interventions, aiming to establish their performance under present and future conditions. This will be done for a number of case studies at local, regional and global scales and covering the defend/retreat/accommodate set of options so that the derived assessments contribute at various scales to climate change adaptation over time.

These results are considered to be relevant (**societal implications**) for the climate community, the coastal community and also for those involved in decisions related to the sustainability of the coast. This applies to present conditions (e.g. of coastal authorities deciding on coastal works) and to future conditions (land planning) and climate agreements.

DD 11.2-3 TWO SIDES OF THE SAME COIN? INTEGRATING RESILIENCE AND TRANSITIONS THINKING FOR CLIMATE CHANGE GOVERNANCE

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Human-induced climate change represents a major issue that societies will have to face in the 21st century. Due to the failure to significantly decrease greenhouse gas (GHG) emissions, extreme climate scenarios and related significant adverse consequences become increasingly plausible. However, although projected impacts of climate change inevitably include increased flooding and sea level rise, drought, decrease in glaciers and loss of biodiversity, science will consistently be unable to provide reliable and precise predictions about the extent to which climate will change and about the timing, magnitude and severity of impacts. This is because of complex feedback mechanisms between drivers and impacts, which play out across temporal and geographical scales and interact with change dynamics across social, economic, political and biophysical dimensions. To exacerbate issues further, changes are likely to be non-linear, rapid and fundamental, creating deep uncertainties. Solutions to address these impacts are urgently needed; even more so as the challenges are not solely ecological but also affect social systems and wellbeing in adverse ways. They essentially represent governance challenges as governance systems of public and private actors and bodies set the foundation for the capacity of societies to deal with climate change. However, attempts to tackle climate change have thus far succeeded in neither reducing greenhouse gas emissions nor adapting to climate change impacts, because of a mismatch between the problem characteristics and traditional decision-making paradigms based on short-term and blueprint planning, compartmentalising, path dependencies and risk aversion. New approaches for climate change governance are urgently needed that enable societies to manage the intricacies of the problem and to formulate solutions that divert society from extreme scenarios and enable it to respond to (deeply uncertain, extreme) climate change impacts. Solutions need to integrate mitigation of climate change drivers and adaptation to its impacts as well as balance system adaptations and transformations. A growing number of novel governance arrangements that aim to tend to addressing complex sustainability problems build on notions of adaptive governance. Adaptive governance presupposes that more inclusive and participatory decision-making is required to address the multi-scale and multi-temporal dimensions of sustainability issues, and that due to the nature of complex adaptive systems, which are in constant and often uncertain change, responses need to be flexible and build on learning in order to make the system more adaptive to changes. However, these approaches still feature one-sided foci, not addressing drivers and impacts of change in unison and emphasising either adaptation or transformation. Therefore, the main question this paper seeks to answer centres on the establishment of governance guidelines that enable an integrated approach to mitigation of climate change drivers and adaptation to climate change impacts as well as system adaptation and transformation.

Resilience scholarship and transitions thinking are examples of elaborate propositions of alternative governance approaches that are thus far limited in their focus. While the former focuses attention on the capacity of human systems to continue functioning in the face of (severe and rapid) disturbances, the latter attends to the anthropogenic drivers of sustainability challenges such as climate change and hence the need for radical changes in the way society is organised (structures), values services and amenities (cultures) and operates (practices) to address persistent unsustainability problems is transition management. This paper reviews resilience and transition literature and argues for an integration of their respective approaches to system change. Despite seemingly diverging foci on resilience and transitions, both scholarships share several similarities, such as their focus on change in complex adaptive systems (social-ecological and socio-technical, respectively). Thus far, prominent concepts of both scholarships, such as transformation and adaptation, resilience and vulnerability, seem related yet have not been strongly linked to each

other conceptually. Crosspollination between resilience and transitions thinking is particularly interesting with regard to the recognition of negative resilience and thus desired system transformations by resilience scholars. Questions are raised as to how a system can respond to change and simultaneously try to influence its pace and directions, how adaptation is distinct from transformation, and thus adaptability from transformability. The integration of these concepts enables to derive novel governance guidelines for achieving a better fit between governance practice and problem characteristics. More specifically, it will inform a governance framework that accounts for deep future uncertainties and historical path dependencies in order to enhance the capacity of societies to deal with (radical) changes and build a sustainable future.

The integrated approach to change bases upon the following elements: (1) a system operation space in which the system moves between a high level of vulnerability and a high level of resilience through adaptation and transformation; (2) the magnitude of change that a system can undergo in terms of adaptation and transformation; (3) an integrated time-scale focus on historical path dependencies and lock-ins and future uncertainties and potential impacts; (4) the importance of timing and seizing momentum in initiating adaptation or transformation; and (5) the role of agency in determining the ability of the system to move between vulnerability and resilience via its capacities to adapt and transform.

This enables to draw implications for governance with relation to time and time-scale dependent agency strategies in relation to adaptation and transformation in order to essentially manage resilience by building and disrupting it. These implications will inform the stakeholder-led decision-making methodology established within the IMPRESSIONS-project (Impacts and Risks from High-End Scenarios: Strategies for Innovative Solutions). The EU FP7 project aims to contribute to scholarly and practical understanding of extreme climate change impacts and to support participatory decision-making in the face of deep uncertainties. The insights generated in this paper provide new inputs for scientific discussions in both resilience and transitions literature through providing conceptual developments as well as for decision-making practice in the face of climate change.

DD 11.3-1

COASTAL VULNERABILITY ASSESSMENT: A CASE STUDY IN KIEN GIANG, WESTERN PART OF THE MEKONG RIVER DELTA IN VIETNAM

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The Mekong River Delta in Vietnam plays a crucial role for the region in terms of food security and socio-economic development; however, it is one of the most low-lying and densely populated areas worldwide. It is vulnerable to flood, seawater incursion, and shoreline change, exacerbated as a consequence of sea-level rise (SLR) related to climate change. Therefore, management of these effects is a priority at all levels in Vietnam, particularly the local level. This study examined the Kien Giang (KGI) coast in the western part of the delta, comprising seven coastal districts (namely Ha Tien, Kien Luong, Hon Dat, Rach Gia, Chau Thanh, An Bien, and An Minh), the economy of which is important in terms of agriculture and aquaculture.

The Analytical Hierarchical Process (AHP) method of multi-criteria decision making was integrated directly into Geographic Information Systems (GIS) to derive a composite vulnerability index that indicated the areas most likely to be vulnerable to SLR. The hierarchical structure comprised three key components: exposure (E), sensitivity (S), and adaptive capacity (A), at level 1. At the next level, 8 sub-components were mapped: flood inundation, seawater incursion, shoreline change, population characteristics, land use/land cover, and socio-economic, infrastructure,

and technological capability, beyond which a further 22 variables (level 3) and 24 sub-variables (level 4) related to vulnerability were also mapped. Based on the weights of variables derived from AHP pair-wise comparisons, a final map was generated to visualize areas where the relative vulnerability was very low, low, moderate, high and very high. Several regional patterns emerged. First, relatively high exposure to flooding and inundation, salinity, and moderate loss of mangroves characterized the coastal fringe of each district. Second, those areas found to be most sensitive tended to have moderate population density, generally with a large rural population and high numbers of ethnic households with limited availability of agricultural land. Third, many aspects of adaptive capacity could only be represented at district scale, with the least adaptable areas consisting of high numbers of poor households, low income, and moderate densities of transport, irrigation and drainage systems.
Finally, most coastal districts were determined to be of relatively moderate vulnerability, with scattered hotspots along the KGI coast, particularly in An Bien district.The results obtained, enable identification and prioritization of the areas most likely to be vulnerable, for which site-specific assessments might further assist the local authorities and communities in better coastal management and conservation.

DD 11.3-2 ASSESSMENT OF ADAPTATION SCENARIOS OF COASTAL PROTECTIONS UNDER GLOBAL WARMING, IN CASE OF MEKONG DELTA

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In case rising in sea-level and change in intensity of tropical cyclone strongly, storm surges must become higher and cause heavy coastal floods. Our simple question is how we should construct dykes to adapt the heights and reduce a hazard of the coastal flood. The authors have been developing assessment method of these adaptations (Nobuoka and Mimura, 2011; Nobuoka et al. 2013). This study presents higher accuracy results of the assessment of adaptation scenario in Mekong-delta, Viet-Nam.
Base parts of the presented assessment method are the same as method by Nobuoka and Mimura (2011). The future dykes construction scenarios are set by GDP per capita and population density. In years of one category of GDP per capita, the dyke are constructed from areas where population density is higher in the country. The heights of these dykes are chosen, which can prevent overflow due to the height of a return period of storm surges. The heights of return periods were calculated by use of hind cast of storm surges about in last 60 years. Each category of GDP per capita has the one height of return period. As the category of GDP per capita and the height of return period is scenario, we can call that these are scenarios of coastal dyke adaptation. The future information of GDP per capita, population and sea level follow SRES scenario, provided by CIESIN (2002). Calculations of Coastal flood in lands was improved by use of the numerical simulation based of the non-linear shallow water equation instead of level comparison method. Typhoon track information is same as the Typhoon Linda in 1998, which was the strongest typhoon in Mekong delta during last 60 years. Intensity of typhoon only changes to fit the height of the return periods. The spatial resolution of present analysis is higher as 15 arc-seconds. The base digital elevation model is Vietnamese original model of which resolution is higher than that by present analysis.
The assessment results of the adaptation scenarios show the difference of hazard areas and affected populations. These results of variety in the same year can be said as uncertainty. In case results are precise except the scenarios, these quantitative information must support decision making.

Reference : H. Nobuoka and N. Mimura (2011), Assessments of Early Adaptations due to Sea-Level Rises and Storm Surges in Asian and Oceanic Coastal Zones, Coastal Structure 2011, Yokohama, pp.120-129.

DD 11.3-3 EVALUATION OF ADAPTATION TO WATER-RELATED RISK IN THE MEKONG DELTA - A MULTI-CRITERIA ANALYSIS OF RESPONSE DECISIONS

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Research question
Which underlying drivers shape stakeholders' evaluation of adaptation measures in different risk-settings of the Mekong Delta and how can divergent adaptation options be assessed in a strategic evaluation combining subjective and 'objective' criteria?

Methodology
The authors build on a social-science oriented mixed-method research design for a multi-criteria analysis. To understand the drivers of local risks and adaptation in the Mekong Delta, qualitative interviews and focus group discussions were conducted in a first phase. These findings informed a strategic survey-based assessment of stakeholder-specific evaluations (state and non-state actors) of different adaptation mechanisms in different risk contexts.

Research results
The empirical findings show that a comprehensive evaluation of actors' climate change adaptation options and decisions needs to consider three components: (1) the risk context, (2) the cognitive premises of individual decision-making and (3) the resulting evaluation frames that are applied to judge different adaptation options. Representing different degrees of subjectivity, a number of key criteria could be identified many of which are largely ignored in standard evaluation procedures. These include cultural acceptance, the longevity of a measure, the opportunity costs or the synergies and conflicts with more general development aspirations. In addition, significant differences between the various risk contexts could be brought to light. Agricultural communities, for instance, tend to place greater emphasis on a strategy's monetary aspects while households in urban areas rather emphasized impacts in terms of opportunity costs and quality of life. The study thereby explains differences in the prioritization of adaptation action and indicates, amongst others, low acceptance of various strategies which had "objectively"been defined as promising and vice versa. Overall, the findings point at the importance of including issues of individual decision-making and risk perception in evaluation as people's action is guided by multiple goals which are not equally relevant and attainable. Evaluation approaches should thus not only look at various criteria and stakeholders to judge a specific strategy but also consider socio-cognitive aspects and the wider risk context in which adaptation takes place.

Societal importance for stakeholders
The strategic evaluation and comparison of different adaptation options is of key relevance in social-ecological systems which experience high adaptation pressure but are bound in limited resources. It is argued that the developed framework helps broadening the understanding of adaptation judgments and decisions and, hence, allows

for the identification of mismatches in adaptation goals, priorities and potentials between different stakeholder groups (e.g. state and non-state actors).

DD 11.3-4 CONSTRUCTING SCENARIO ANALYSES FOR ASSESSING FLOODING RISK IN THE BANGLADESH DELTA

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Approximately 46% of the Bangladeshi population, about 62 million people, resides in the low elevation coastal zone. It has been estimated that a one meter rise in sea-level would inundate 18% of the country's total land mass and directly threaten 11% of the population. Additionally, Bangladesh faces increasing soil salinity, coastal erosion/ subsidence, as well as frequent natural disasters. Cyclone Sidr exposed 3.45 million households to inundation in 2007, and a potential 10 year return cyclone in 2050 could expose 9.7 million people to more than 3 meters of inundation.

Here we describe our use of qualitative scenario analysis to generate projections of the vulnerable coastal population at 10, 20, 30 and 50 years into the future, under a variety of socio-political circumstances. This analysis is supported by several interlinked research programs. First, we will conduct a quantitative analysis of micro-level adaptation to climate risk, focusing on out-migration - both short- and long-term - as a potential coping mechanism. Our methodology utilizes economic modeling and econometric estimation to incorporate other aspects of the migration decision, such as local environmental conditions, wage and job growth in cities, and transportation costs. Second, we will consider the evolution of underlying demographic trends related to fertility and aging, identifying social patterns and trends unique to the coastal areas. Third, we estimate the resilience of coastal villages in terms of their ability to respond to flooding from cyclone Sidr by maintaining population and economic activity. We then use linear projection taking these factors into account plus estimated sea-level rise to project the vulnerable population at different spatial scales over the next 10, 20, 30 and 50 years. Finally, we will examine the role of local governance and the potential efficacy of local institutions in mitigating climate risk via a survey of village leaders and key informants (government officials, NGO leaders, farmer's association leaders, local water management groups, etc.).

We will then integrate these components to generate projections based on stable (linear) trends; a "most probable"scenario based on our assessment of economic, social and political trends; alternate scenarios based on potential crises, such as a major cyclone disaster; and worst- and best-case scenarios. Additionally, we assess the likelihood of these various alternatives, with the goal of identifying possible points of intervention where coastal management strategies and adaptation could make a difference while optimizing cost-effectiveness.

DD 11.3-5 INTEGRATION OF BIO-PHYSICAL AND LIVELIHOOD DYNAMICS FOR ANALYSIS OF POVERTY IN COASTAL BANGLADESH

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Deltas are one of the most densely populated areas in the world that is especially true for the coastal zone of Bangladesh where more than a thousand people live in each square kilometre of land. Livelihood, food security and poverty in Bangladesh are strongly dependent on natural resources affected by several factors including climate variability and change, upstream river flow modifications, commercial fish catches in the Bay of Bengal, and governance interventions. The scarcity of fresh water, saline water intrusion and natural disasters (e.g. river flooding, cyclones and storm surges) have detrimental impact on drinking water availability and crop irrigation possibilities; thus severely affect land use and livelihood opportunities of the coastal population. However, the poorest people are highly dependent on natural resources and live generally on less than US$1.50 per day.
The ESPA Deltas project aims to holistically examine the interaction between the coupled bio-physical environment and the livelihoods of these poor populations in coastal Bangladesh. Here we describe a new integrated model that allows the long-term analysis of the possible changes in this system by linking projected changes in physical processes (e.g. river flows, nutrients), with productivity (e.g. fish, rice), social processes (e.g. access, property rights, migration) and governance (e.g. fisheries, agriculture, water and land use management). This integrated approach is designed to provide Bangladeshi policy makers with science-based evidence of possible development trajectories over timescales up to 50 years including the likely robustness of different governance options on natural resource conservation and poverty levels. This presentation describes the model framework and shows some preliminary results for demographical changes, river flow and soil salinity trends, and their interlinked implications for agriculture productivity and livelihood in coastal Bangladesh. Early results highlight the far reaching implications of sustainable resource use and international cooperation to secure livelihoods and ensure a sustainable environment in coastal Bangladesh.

DD 11.4-1 DUTCH DELTA SCENARIOS

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Introduction
Urbanised deltas represent some of the most densely populated, economically vital and ecologically vibrant areas in the world. At the same time, they belong the most fragile areas, plagued by flooding, land subsidence, and storms. One of the most difficult challenges for policymakers (and stakeholders) is to adapt the delta to possible future developments that might have an impact on the area, like climate change, globalisation, and energy transitions. In 2008 the Dutch government launched the Delta Programme, a policy programme preparing the Netherlands for the impacts of climate change. The Delta Programme commissioned Deltares, PBL, KNMI, CPB, and Wageningen UR to build scenarios in order to support strategic decisions to be taken in the programme.

Research question
The Delta Scenarios were published in 2013. They answered the following question: 'Which climate changes and socioeconomic developments may occur in the long-term and what are their expected impacts on water safety and the provision of freshwater in the Netherlands?

Method
Various techniques were applied to build the scenarios. By doing this, various sources of insight into the future were mobilised and mutually checked. Model calculations were made in order to explore future economic, demographic, climate and other changes, their impacts on land-uses like agriculture, nature, and urbanisation, and the challenges this may generate for water management on the national and regional level. Literature was reviewed to integrate insights from various existing scenario studies and to develop storylines about the future. Designs were made to visualize the most important land-use changes and to better communicate the scenarios. The results were integrated by group-model building, logical thinking, and discussing the outcomes with a user-group.

Results
The scenarios explore the possible future courses of economic, demographic, energy and climate changes together with their impacts on various land-uses and the challenges this may generate for water safety and the provision of freshwater in the Netherlands. The scenarios are presented in words (story-lines) as well as images (sketched maps, artists impressions) and figures (GIS-maps, databases).

Societal impacts
The Delta Scenarios play an important role in the Delta Programme. They raise awareness among policymakers for the long term. They inspire strategy development related to water management and land-use planning. They help to test alternative strategies on their robustness and flexibility for future developments. And they facilitate communication among policymakers.

DD 11.4-2 SAFE DIKE HEIGHTS AT MINIMAL COSTS - AN INTEGER PROGRAMMING APPROACH

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Optimal dike heights are of crucial importance to the Netherlands as almost 60% of its surface is under threat of flooding from sea, lakes, or rivers. This area is protected by more than 3,500 kilometres of dunes and dikes. These dunes and dikes require substantial yearly investments of more than 1 billion euro.
In this paper we propose an integer programming model for a cost-benefit analysis to determine the optimal dike heights. We improve upon the model proposed by Brekelmans et al. (2012), which in turn is an improvement of the model by Van Dantzig (1956). Recently, the model of Brekelmans et al. (2012) has been used to assess new, economically optimal water safety standards for virtually all dike rings in the Netherlands: Cost-benefit analysis of water safety in the 21st century by Deltares.
Our approach has three important advantages in comparison with Brekelmans et al. (2012):

1. Almost complete flexibility towards input-parameters and functional specifications for flood probabilities, damage costs and investments costs for dike heightening. This flexibility facilitates the inclusion of more location specific safety measures and is crucial for the acceptance of the model results by policy makers.

2. Proven optimal solutions are found for all problem instances.
3. The model is easy to implement with the use of standard software. Ease of implementation is not only important for the use of our results in Dutch practice, but also for the dissimilation of our results to less wealthy countries.

The integer programming method has been implemented and tested for recent data on flood probabilities, damage and investment costs that are presently being used by the Dutch government to determine how the safety standards in the Dutch Water Act should be changed. The solution algorithm was able to generate the proven optimal solution for all problem instances within a minute. This is faster than the heuristic solution procedure by Brekelmans et al. (2012).

DD 11.4-3 ANTICIPATING CHANGE BY EXPLORING ADAPTATION PATHWAYS FOR THE RHINE DELTA

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Decisions on whether or not to adapt to possible future change are complicated by the high uncertainty in projections of the future and knowledge about the system. The Dynamic Adaptive Policy Pathways (DAPP) method aims to support the development of adaptive strategies that can cope with changing, uncertain future conditions [1]. Exploring adaptation pathways offers the possibility to evaluate the performance of a policy choice in the course of time, and under changing conditions. Using pathways planners can develop 'future-proof' policies that maximise robustness by designing actions that perform well in multiple plausible futures, and have sufficient flexibility to avoid 'lock-ins' and keeping options open where and when possible.

In order to assess whether the recently developed DAPP approach can be applied to real-world cases, we used it to simulate policy planning in the Dutch Rhine delta and analyse how it is applied in practice. For this, we developed a fast, integrated model and used the approach in stakeholder consultations. Pathways were explored across multiple scenarios, using an ensemble of possible climate realisations. Promising pathways were checked for consistency for multiple policy objectives. The case study demonstrates that the approach can be applied to a real-world decision making problem.

The DAPP approach inspired the Dutch government in the development and application of the concept of Adaptive Delta Management (ADM), that is directed towards safety and socio-economic targets, but flexible in how and when to implement management interventions [2,3]. ADM is now a key strategy in the Delta Programme, a nation-wide programme to prepare the Netherlands for climate change, and includes the development of adaptation pathways. In this presentation, we illustrate the DAPP approach with an application for the Rhine delta, give examples about how it is being applied in the Delta Programme and evaluate how the approach can be applied in designing robust and flexible actions that help to prepare the Rhine delta for uncertain future conditions.

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DD 11.4-4 A MONITORING AND EVALUATION FRAMEWORK TO SUPPORT THE NEW NATIONAL CLIMATE ADAPTATION STRATEGY IN THE NETHERLANDS

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Adaptation to climate change has become of greater prominence in the European Union (EU) and its member states since the launch of the EU Adaptation Strategy in 2013. Many member states are currently working on the development and adoption of National Adaptation Strategies. Adaptive management is key to addressing the long time horizons and range of uncertainties associated with climate change and its impacts, and provides an effective means of tackling climate-related risks and opportunities in the longer term. Good adaptive management requires adaptation policies, adaptation option appraisals, flexible and transformative measures, and integrated and mainstreamed actions within and across policy areas and sectors.

Good adaptive management also necessitates a robust approach to monitoring and evaluating (M&E) the effectiveness of National Adaptation Strategies and the policies, measures and actions upon which these are based: "*are we doing the right things?*" refers to (long-term) strategic policy decisions and their consequences; "*are we doing the things right?*" links to the implementation of these policies and subsequent actions. The authors of this abstract have been commissioned to establish a monitoring and evaluation framework to support the new Dutch National Adaptation Strategy, which will be launched by 2017. The project not only builds on their respective knowledge and experience of monitoring and evaluating adaptation and related indicator development, but also draws on the lessons learned from a range of approaches to monitoring and evaluating adaptation that have been developed both for the EU and in its member states.

The Dutch framework embraces the principles of good adaptive management and includes indicators to track progress with adaptation. The indicators cover both the 'processes' associated with the development of adaptation policies and delivery of adaptation measures and the 'outcomes' of adaptation actions at successive stages in the adaptive management cycle. These indicators will, therefore, provide data from which to identify any adjustments that might be needed to policies, measures and actions. The framework also includes governance structures that set out governmental, sectoral, and stakeholder roles and responsibilities.

The framework will firstly be designed for use in the Dutch Delta Programme, where it will encompass the domains of flood protection, fresh water supply and the urban environment. It will then be developed further for use in other domains relevant to the National Adaptation Strategy (e.g. agriculture, biodiversity, energy, health, transport and infrastructure, and ICT).

DD 11.4-5 SIMULATING LAND USE CHANGE TO EXPLORE SUSTAINABLE URBAN RENEWAL STRATEGIES IN THE CONTEXT OF FLOOD RISK

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In highly developed countries like the Netherlands, strategies aimed at reducing flood risk have hitherto focused on reducing the chances of flooding, e.g., by building extensive flood defense systems (levies etc.). These systems, however, are never completely flood-proof. Further increasing their defensive capacities is getting increasingly difficult. At the same time, the economic value behind many of these barriers is growing. Depending on the (political) question of what chances and damage would be 'acceptable', this might justify a shift of focus from minimizing (regional) chances of flooding to adaptation to its potential (local) effects. The question is how much, where, and at what costs damage reduction could thus be achieved. The focus of this paper is on the reduction of potential flood damage to houses, particularly through 'flood proof urban (re)development', e.g., by constructing new houses on poles or other elevated constructions like parking garages.
The potential damage reduction that could thus be attained is very uncertain, especially on the local scale. It depends on a wide range of interrelated processes, most importantly those driving future urbanization. This paper introduces a land use model framework which is able to simulate urbanization on a 100 x 100 meter scale, including residential density changes occurring within urban areas. The specific policy instruments which' effects can be explored are, amongst others, regional urban intensification targets and local zoning. The strength of the model framework lies in the fact that it is able to integrate model specifications related to different processes (e.g., housing markets, land markets) operating on different spatial and temporal scales, and visualize their ultimate spatial-temporal consequences in a 100 x 100 m grids, in time steps of one year, allowing both the consistency (input) and validity/ plausibility (output) to be checked rigorously.
The paper demonstrates that spatial policies could indeed significantly reduce potential flood damage to houses. It shows that most damage reduction could be attained in scenarios of high socio-economic growth. In this scenario, if urban intensification measures and zoning measures would be combined, total damage could drop by almost one third from 2008 to 2050. All in all, the paper shows that the model framework can be a useful tool to help planners explore where, to what extent, and under which specific circumstances (scenario's, policy packages) potential flood damage to housing could be reduced.

DD 11.5-1 COMPARING ROBUST DECISION MAKING AND ADAPTATION PATHWAYS FOR SUPPORTING CLIMATE ADAPTATION

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There is an emerging consensus that adapting to climate change requires an adaptation strategy that is flexibly and can be adapted over time in response to how the future unfolds and what has been learned over time. A wide variety of analytical approaches are being suggested for supporting the design of such strategies. These analytical

approaches however are only rarely compared and contrasted. Such a comparison is useful for a variety of reasons. It can assist decisionmakers and analysts in choosing an appropriate analytical approach. It can offer guidance in employing these approaches effectively. It can also guide future research on further improving these approaches. In this paper we compare Robust Decision Making (RDM) (Lempert 2002) with the Adaptation Pathway (AOP) approach as developed in the Netherlands (Haasnoot et al. 2013) and practices in the Dutch Delta Program.
The aim of the comparison is to create insight into the types of tools and information that are needed to perform each approach, the types of uncertainties that can be considered, the type of information that is being generated, and the implications of applying either approach on the resulting adaptation strategy.
In order to compare the approaches, we apply both RDM AP to the same case. We use a hypothetical case inspired by a river reach in the Rhine delta of the Netherlands. As most existing computational hydrological impact models demand too much computing time for simulating the dynamics of adaptation pathways, we use an Integrated Assessment Meta-Model (IAMM) based on more complex detailed models.
The results indicate that RDM and AP are complementary. RDM offers insights into scenarios under which problems occur, and makes trade-offs transparent. AP emphasizes the dynamic adaptation over time and thus offers a natural way for handling the vulnerabilities identified through RDM. The application also made clear that RDM is open ended: there are many choices an analyst has to make over the course of an RDM study, for which RDM offers no clear guidance.
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DD 11.5-2 USING DATA AND TECHNOLOGY FOR DECISION SUPPORT AND RISK MANAGEMENT

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It is common for hydrological, statistical, technological, operational and crisis management expertise in the water domain to develop in isolation of each other in most countries. As a consequence, often it is only during crisis that crucial challenges pertaining to water management come to light, and these challenges can prove to be major hindrances in management of water resources during crises.
Some of the challenges include:
- Deal with uncertainty of potential risks and domino effects and impacts of decisions.
- Provide prompt and intuitive feedback for decision makers facing uncertainties.
- Make most appropriate actions in reaction to the development of risks.

Data and technology can play a central role in addressing these challenges. We can build a single comprehensive view of the water situation in real time without drowning in data, which allows us making sense of predictions and forecasts, planning forward and managing risks and crises.
We developed and implemented an open architecture that consists of the following key functions:
- The data-gathering network collects information from many sources, including various sensors, databases and open data sources, including the web and social networks.
- Robust modeling framework that enables the integration of modeling and simulation software.

- Advanced analytics to process and convert collected data into a comprehensive, constantly updated picture of the environment - a Unified Situational Awareness Picture (USAP).
- Crisis management with pre-determined procedures and recommendations to automatically guide people quickly through the process in case of incident.

The modeling framework and simulation allow performing various 'what if' analysis in near real time based on sensor input as well as historical data, which reduces uncertainty. The USAP based on Geographical Information Systems (GIS) provides intuitive information to decision makers quickly without requiring them to in-depth domain knowledge. The pre-determined procedures and recommendations allow most appropriate actions by comparing different 'what if' scenarios.

The real-world implementation - our ReadyMIND system - has been successfully deployed in a number of projects in the countries like Netherlands and China.

Our approach integrates operational experience on action plans with academic expertise on collecting data, modeling & forecasting. The integrated approach provides an all-in-one water resource management platform, as well as the ability to split between water management and generic crisis management. By acting on the information in real time, operators can potentially prevent incidents, but definitely accelerate their response time and make better-informed decisions.

DD 11.5-3 A RISK-BASED APPROACH FOR FRESH WATER MANAGEMENT: SUPPORTING DECISION MAKING IN TIMES OF WATER SCARCITY?

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Already in the present situation, delta regions world-wide encounter problems resulting from fresh water scarcity. Climate change and socio-economic developments make delta societies even more susceptible to consequences arising from drought events. This is also the case in the Netherlands, where fresh water availability will be more and more under pressure, due to the predicted effects of climate change. In the Rhine-Meuse Estuary, for instance, the joint occurrence of large consecutive periods of low discharges, severe salt-water intrusion from the sea side and limited water storage in open surface water and/or in soil water (due to dry periods prior to the occurrence of the low river discharges), may result in fresh water deficits. Consequently, the availability of fresh water required for drinking, agriculture, industries, ecosystems and subsistence uses is at stake, bringing along large economic consequences. Various counter-measures to cope with water scarcity and reduce drought-damages are currently under investigation. It is however rather unclear whether these measures compensate drought-damage in a cost-efficient way. A management instrument is therefore required to evaluate the impact of climate variability on drought related risks for the various end-users, but also to assess the cost-efficiency of counter-measures to better cope with water scarcity. To that end, a risk assessment & management instrument has been developed for fresh water allocation and salt intrusion in times of water scarcity. This instrument jointly considers the probability of drought-related hazard events and the consequences of these hazard events for the various end-users. Drought-related risks, defined as the product of the probability of a drought event happening multiplied by the consequences of this event, can then be determined using the instrument. The resulting information about drought-related risks enables us to prioritise and predicate decisions. It can help to assess the cost-efficiency of measures to cope with droughts and define cost-efficient solutions through a cost benefit analysis.

The potential of this instrument is demonstrated for a case study of the Rhine-Meuse Estuary in the Netherlands. It is shown, that the instrument enables a rigid evaluation of cross-sectoral and cross-regional impacts of water allocation options. The resulting risk profile serves as a starting point for new management strategies for risk adaptation and mitigation. The total risks resulting from drought-related hazard events can be reduced by measures at river basin scale, at regional scale (regional water system) or by the end users.

DD 11.5-4 TOWARDS IMPLEMENTATION OF THE DELTA APPROACH: THE ADDED VALUE OF STRATEGIC ENVIRONMENTAL ASSESSMENT

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This paper aims to discuss the added value of Strategic Environmental Assessment (SEA) to the further practical development and effective implementation of the Delta Approach developed by the Netherlands Delta Alliance. For this purpose the Delta alliance and the Netherlands Commission for Environmental Assessment have joind forces to prepare a paper. This paper intends to inform on-going delta planning and management processes on the potential added value of SEA in the implementation of their programmes.
The Delta Alliance developed the concept of adaptive delta managemnt as a means to deal with the uncertainties of climate change and socio-economic development in delta areas. Significant experience has been gained in this field by the Netherlands in its Delta Programme and related new approaches are emrging in several dealtas around the world for example the Mekong delta and the delta area of Jakarta.
SEA is a family of decision support tools that identifies and addresses the environmental consequences and stakeholder concerns in the development of government policies and plans. SEA has a legal basis in about fifty countries and this number is rapidly increasing. Moreover, international finance institutes such as the World Bank increasingly require SEAs for funding of plans in low income countries that have a potential negative environmental and social impact. The Netherlands Commission for Environmental Assessment has supported governments in Indonesia, Mozambique and Kenya in implementing SEA for policy-making in Delta areas.
In this paper the Delta approach and SEA are compared and it is concluded that there is a clear overlap between the two approaches. Three models of a combined SEA - delta approach are distinguished and briefly described. The suitability for application of one of these models is dependent on the institutional context, institutional capacity and the legal requirement to execute an SEA in a country. The new approach will, most likely, be tested in Bangladesh. The new approach will assist decison-makers in making effective use of the added value of SEA for delta planning.

DD 11.6-1 FLOOD DAMAGE MODELLING ON BASIS OF URBAN STRUCTURE MAPPING USING HIGH-RESOLUTION REMOTE SENSING DATA

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The modelling of flood damage is an important component for risk analyses, which are the basis for risk-oriented flood management, risk mapping, and financial appraisals. Multi-parameter models that take several damage influencing factors into account improve the reliability of flood damage modelling. Such models consider beside the water depth many other flood loss influencing factors like building characteristics, and precautionary measures. To improve the applicability of multi-parameter damage models on the meso-scale an automatic urban structure type mapping approach on a land use / land cover classification generated from multispectral IKONOS data and LiDAR data was developed. The multi-parameter damage models FLEMOps and regression-tree models are adapted to the information derived from remote sensing and are applied on basis of the urban structure map. The urban structure mapping approach that was applied on multispectral IKONOS data delivered a map with a good accuracy and on this basis modelled flood losses for the Elbe flood in 2002 in Dresden are in the same order of magnitude as official damage data. Thus, remote sensing methods have a high potential to further improve flood damage modelling and risk assessments.

DD 11.6-2 CONSTRUCTING VULNERABILITY MAPS OF MATERIAL AND ENERGY PATHWAYS IN DELTAS

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Background

Water, sediment, and nutrient fluxes that nourish and sustain deltaic systems are delivered throughout its 'body' via multiple pathways some of them natural and some of them human engineered. Demands on water and energy upstream are satisfied thanks to dams and divergence structures, while multiple dykes, embankments and sluice gates are constructed downstream mainly for irrigation purposes and to control floods and salinity intrusion. Research question: To maintain a desired socio-ecological state of a delta, material and energy fluxes must be delivered to its body and to its coastal zone in a way that 'malnourishment' is avoided, as this would compromise system integrity, which often is not local but propagates to larger areas.

Research results

We have developed a methodology by which a deltaic system is mapped into a complex set of inter-connected pathways (network) of material and energy fluxes, setting the dynamic template over which alternative scenarios of management can be tested. Dam construction can be emulated by reducing water and sediment downstream by

a given fraction, the location and operation of irrigation dykes can be varied, and different alternative management options can be evaluated in a simple yet extensive framework. A vulnerability map is constructed wherein sediment and water delivery to the coastal zone outlets is mapped against hundreds of upstream nodes. This enables us to evaluate which nodes and what management scenarios would most influence (positively or negatively) flux delivery to the coastal nodes. Localized or more spatial extensive interventions can be explored and a whole systems approach to management can be developed.

Societal importance for stakeholders

We demonstrate the proposed framework on selected deltas and build 'Vulnerability Signature' maps to varying scenarios of development. Having such maps pinpoints connectivities and propagation of changes from local to more regional scales in ways not obvious in such complex systems but which are absolutely necessary for bringing scientists and managers on the same page for sustainable management of these threatened systems.

This work is part of a global project on 'Catalyzing action towards sustainability of deltaic systems (DELTAS)' funded by the Belmont Forum and the forthcoming 2015 'Sustainable Deltas Initiative' endorsed by ICSU. The work will complement other contributions from the DELTAS consortium that have been submitted for the Deltas in Depth sessions and the Deltas in Practice Workshops.

DD 11.6-3 A STORM SURGE ATLAS FOR LOW-LYING DELTAS WITH PILOT APPLICATION FOR THE NORTH SEA

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Large-scale flood disasters in low-lying deltas around the world occur frequently. Well-known examples are Hurricane Sandy in New York/New Jersey (2012) and the battering North Sea storm in the United Kingdom (2013). A key aspect for mitigating flood risk is to forecast storm surge events timely and accurately, in order to get good insight into which locations are at risk and what effective emergency measures can be taken. Real-time storm surge forecasting has often been proposed and also successfully implemented. However, challenges of these real-time systems are the reliability of the ICT infrastructure during extreme events, sufficient time/flexibility for scenario analysis and the computational time of the detailed models, and implementation and maintenance costs.

To cope with these challenges, this paper proposes an alternative concept for storm surge forecasting with a pilot application to the North Sea. The objective is to have quick but still reasonably accurate storm surge predictions for 10-day ensemble weather forecasts. The idea for this Storm Surge Atlas has been based on good experiences with a similar type of tool developed for New Orleans after Hurricane Katrina. For this pilot, a 500-year data set of ECWMF weather predictions have been processed with a detailed storm surge model for the North Sea. The pressure fields for every forecast step are intercompared with the 500-year database. The analogue is found by looking for the field with the most identical EOF eigenvalues of the pressure fields. The realized surge in the analogue is assumed to occur similarly in the forecast.

The pilot version of the Storm Surge Atlas for the North Sea is able to very quickly (a few minutes) produce a 10-day storm surge forecast using the ensemble members of the weather forecast. First validation runs show that the model is able to match the observed peak surges within reasonable accuracy. Next to real-time models, it is envisioned that

this tool can be valuable in that it produces quickly insight in the potential storm surge hazard for coastal regions. The concept is globally applicable and can also be a cost-effective solution for areas with limited resources.
The development of the Storm Atlas for the North Sea has been partly funded by The Collaboratorium Climate and Weather. The authors gratefully acknowledge the support from this foundation. Also, the project WTI2017 - Hydraulic Loads project commissioned by the Dutch Ministry of Infrastructure and the Environment is acknowledged for matching funds.

DD 11.6-4 IMAGINE THE IMPACT: A GUIDELINE TO VISUALISE CLIMATE INFORMATION

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For effective adaptation, relevant climate impact information is necessary. Policy and decision makers endorse the value of maps in the decision making process on adaptation. However each phase demands a specific visualisation approach. The aim of this paper is (1) to investigate visualisation approaches regarding different phases of the planning process and (2) to identify relevant visualisation approaches.
In the scope of these objectives three visualisation approaches, differing in information load and interface, were developed to visualise local information on climate impacts. We define impact as a function of exposure and sensitivity. The *geoportal* contains detailed information on the exposure of climate change. Information is provided for the current situation, four climate scenarios and three time horizons (13 maps in total). Differences between maps are shown via map pairs. The *interactive climate impact atlas* provides information on exposure and sensitivity. Information is summarised in four themes. Two climate scenarios and a single time horizon can be compared to the current situation via an interactive display. The *single climate impact map* displays only the major impacts in less detail via a single static view. Only one time horizon is displayed and differences between scenarios cannot be recognised.
These visualisation approaches were applied for 20 case studies. Structured interviews and online surveys are performed to [1] analyse the decision-making process, [2] identify the role of maps and [3] evaluate the applied visualisation approach. The case study analysis reveal [ad 1] that the development of the decision-making process and sequences of the different phases highly depends on the stimuli evoking the decision. [Ad 2] *Analyse* was a common map use goal in the assessment phase when a decision making process was forced by a problem and explicit identification of the problem was needed. Analyse also turned out to be crucial in the evaluation phase to underpin an adaptation plan when the decision was evoked by an opportunity. When the emphasis was on design and decision was evoked by an opportunity maps were used to *synthesise* information. In the agenda setting phase the map use goal varied from *exploration* to *presentation*. Exploration was needed to match stimuli, presentation to finally set the agenda. [Ad 3] The geoportal was preferred for exploration. The interactive climate impact atlas and single impact map were preferred for respectively analyse and synthesise. Based on the results we offer a guideline to visualise impact information for different decision-making processes.

DD 11.6-5 USING GEODESIGN TOOLS IN ADAPTATION WORKSHOPS

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Research question
Climate adaptation planning requires combining spatial information with stakeholder values. This study demonstrates the use of geodesign tools as a mean to integrate spatial analysis with stakeholder interests. The aim is to investigate the influence of tool selection on group decision processes.

Methodology
Four geodesign tools were evaluated in two interactive pilot workshops. The pilot workshops allowed for systematic testing of the tools. The first workshop was organized for researchers and the second for planners. During each workshop the participants were set around an interactive mapping device to design spatial adaptation measures supported by each of the tools. The four tools were based on distinctive rationalities. The groups were asked to apply spatial adaptation measures to improve one objective value while at the same time minimize the decrease in other objective values. The resulting maps were evaluated by the amount of changes and the correspondence of the measures with tool information. In addition, variations in the group decision processes were observed such as the time spent on tool interpretation and on the allocation of measures.

Research results
Comparison of the maps revealed that each tool influenced the group decision processes differently resulting in different spatial designs. Careful consideration is recommended on which tool is used for what type of decision task. The participants emphasized the need for a professional operator. They also requested additional explanation on the exact interpretation of each tool. Furthermore, suggestions for tool improvements were to include filters to reduce the amount of information in the maps, to add scenarios of measures and the integration of the tools with a user-friendly interface. Improvements of geodesign tools as well as the users learning process must be seen as an interactive and iterative process.

Societal importance for stakeholders
The development of adaptation strategies can benefit from the use of geodesign tools as the tools provide interactive feedback on multiple objectives and interests. All participants indicated that the tools were easy to use and that the tools supported the design of adaptation measures successfully.

Posters

P 001

UNDERSTANDING THE RELATION BETWEEN EXTREME PRECIPITATION INTENSITIES AND TEMPERATURE USING A CONCEPTUAL MODEL

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Events of extreme precipitation are highly disruptive to society, and are likely to intensify with global warming. When sufficient moisture is available, precipitation extremes are expected to be related to surface temperature through the Clausius-Clapeyron (CC) relation of a ~7%/°C increase. However, several processes may influence precipitation intensity leading to deviations from CC scaling. Previously observed twice Clausius-Clapeyron (2CC) scaling for extreme precipitation at hourly timescales has led to discussions about its origin.
We have assessed the robustness of this scaling by analyzing a sub-hourly dataset of 10-minute resolution over the Netherlands. The results confirm the validity of the previously found 2CC scaling for extreme convective precipitation. In this presentation we will focus on the processes leading to this invigorated scaling.
Using an entraining plume model, we analyze extreme precipitation scaling from a frequently used relation based on the column condensation rate. With a robust increase of ~10% per degree, the plume model successfully simulates a steady precipitation increase that is greater than Clausius-Clapeyron scaling (super-CC scaling), albeit lower than the observed 2CC scaling.Precipitation intensity increase is shown to be controlled by a flux of moisture through the cloud base, and in-cloud lateral moisture convergence. Decomposition of this scaling relation into a dominant thermodynamic and additional dynamic component, allows for better understanding of the scaling, and demonstrates the importance of vertical velocity in both dynamic and thermodynamic scaling.

P 002

SPATIAL PRECIPITATION PATTERNS AND TRENDS IN THE NETHERLANDS DURING 1951-2009

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Research questions
Have there been relevant trends in precipitation in the Netherlands? Where did the changes take place? And can the changes be attributed to (changes in) surface characteristics?

Methodology
We use homogenised daily precipitation measurements from 240 KNMI stations (Buishand etal. 2013). Trends are calculated using a linear regression model, independently for regions based on surface characteristics and zones at certain distances from the coast. Stations with more than 25% urban area (based on the Corine land use map) within a 5 km radius are marked as urban. We investigate differences in trends, occurrence and frequency of precipitation.

Research results

Mean precipitation in the Netherlands has increased with more than 15% over the period 1951-2009. This increases is significant in almost 90% of the stations and not homogeneous in time or space. Stations along the coast have on average become 25% wetter, while stations further inland receive about 10% more precipitation. In addition, the increase in precipitation mostly takes place in the months October to June. While the largest difference between coastal and inland stations occurs in the months April to June and October to January. We do not find significant differences between urban and rural stations and between regions based on surface characteristics. We conclude that changes in sea water temperature have had the largest effect on precipitation trends in the Netherlands. It is however complicated to project these findings into the future as circulation pattern and the absolute temperature difference between land and sea have large impact. It is clear, on the other hand, that precipitation changes have not been uniform in the past and will not be in the future.

Societal importance for stakeholders

Precipitation intensity and timing is of importance for the whole of society, especially for agriculture, water managers and urban planners. Our research shows an increase in both the frequency of occurrence and the intensity of precipitation. This affects the design capacity for rivers and sewage systems and the safety level for inland dikes for example. For farmers it is important to know if there will be less precipitation in drought sensitive periods of their crops and if more frequent precipitation will increase the risk of pest and disease.

Buishand, T. A., G. De Martino, J. N. Spreeuw, and T. Brandsma, 2013: Homogeneity of precipitation series in the Netherlands and their trends in the past century. International Journal of Climatology, 33, 815-833.

P 003

THE CORRELATION OF CLIMATE CHANGE ON HEALTH: RAINFALL VS DENGUE HEMORRHAGIC FEVER INCIDENCE IN PHUKET

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Dengue Hemorrhagic Fever (DHF) is a common vector-born disease in Thailand caused by mosquito Aedes sp., and at times leads to death. In the past 10 years, climate change has led to an increase in rainfall in Phuket, along with an increase in mosquito breeding sites and the incidence of DHF in Phuket. This study was carried out to determine the correlation between the annual rainfall in Phuket and the DHF incidence in City of Phuket and in Phuket province. Ten years (2004-2013) retrospective study for the annual rainfall and the DHF incidence in City of Phuket and in Phuket province has been reviewed; Mean, Median, Standard Deviation(SD) and Pearson Product-Moment Correlation Coefficient were used for data analysis. The results revealed that the annual rainfall in Phuket ranged from 1,516.7 (in 2005) to 2,788.3mm. (in 2012) with a median of 2,372mm, and a mean of 2,287.54mm. (SD 350.71). The DHF incidence per 100,000 population in City of Phuket ranged from 19.9 (in 2006) to 296.1 (in 2013) with a median of 60.95, a mean of 83.7 (SD 81.99), while the DHF incidence per 100,000 population in Phuket province ranged from 40.1 (in 2004) to 623.16 (in 2013) with a median of 102.05, and a mean of 167.27 (SD 176.23). Nevertheless, there was no correlation between the annual rainfall with the DHF incidence either in City of Phuket or in Phuket province, however, the correlation between the DHF incidence in City of Phuket and in Phuket province exists at p value 0.01(r = 0.99).

P 006

A STRATEGIC APPROACH TO AN OPTIMAL FLOOD RISK STRATEGY FOR THE RHINE ESTUARY-DRECHTSTEDEN DELTA

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The delta 'Rijnmond-Drechtsteden' is a vulnerable area where the sea and the rivers meet. Moreover, this densely populated area with the harbour of Rotterdam is the economical heart of the Netherlands and is surrounded by green polders with agriculture, nature and recreation areas. It is utmost important that the delta will remain protected from high water – now and in the future. The delta is vulnerable with respect to climate change and continuous and fast soil subsidence. New and more severe standards against flooding have to be met. Outside the primary water defences there are large unembanked areas with a large population and chemical industry. Flood risk strategies must not only be robust and economically efficient, they must also be adaptive (no-regret) and be lined up with spatial planning programs.

As a part of the Dutch Delta programme, the government parties in this region developed a new strategic approach that is both effective and adaptive. This approach addresses the question how to properly link the issue of flood risk management to the goals for economic development, nature, the landscape, living and recreation? To achieve this, we developed a chain of new 'models' covering 3 aspects of decision making:
- Protection against floods: models on flood risks and new safety standards, based on high water levels in the delta;
- Costs and benefits: time specific models on costs and benefits, from now until 2100;
- Governance: programme management, joint-fact finding process, new approach on adaptive spatial planning.

The integration of these 3 aspects was challenging but also essential for the success of the approach. The derivation of an optimal economic flood-risk management strategy is obtained from a quantitative benefit-cost analysis based on probabilistic modelling of water levels and waves, cost of infrastructure, elementary dike cost functions and flood-damage functions. An adjustment of this benefit-cost analysis with respect to demands from spatial quality (nature, recreation, etc.) and from regional organizations ("soft requirements from governance") is done as well.

Adaptive spatial planning is based on four spatial perspectives in accordance with the characteristics of the distinctive areas. These are deep polders with subsiding but populated dikes, strong urban dikes, islands with high dikes from clay and areas with room for the river measures. Essential is that the strategy was obtained by joint fact finding and that decision making was done in a board of local authorities.

This poster focusses on the 3 aspects of decision making and their integration.

P 007

RECONCILIATION AND TRADE-OFFS OF A RESILIENCE AND CONTROL RATIONALE FOR FLOOD RISK MANAGEMENT

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Research question

In the scientific literature we find two main rationales to manage flood risks. In a control rationale, the aim is to increase system predictability through modifying activities or events that may lead to adverse consequences, thus reducing the probability of these events occurring. The approach focuses on expected conditions and enhances system efficiency. In a resilience rationale, the aim is to manage the capacity of a system to cope with, adapt to and shape change, thus reducing the consequences of adverse events taking place. The approach focuses on response to surprise, based on the notion of incomplete knowledge and inevitability of these surprises. The research tracks of resilience and control often do not meet. We aim to increase insight in what managing for both control and resilience means and to what extent it is possible, showing reconciliation and trade-offs of both rationales for policy.

Research results

We developed an overview of system attributes (properties of a system) favored in both rationales and applied this to a case of Dutch flood management. We specifically single out the Delta dike: a very high, broad or strong multifunctional flood defense advocated in Dutch flood management. The Delta dike combines elements of resilience and control. From a control perspective, the dikes make flood defenses more robust for expected future developments of climate change and beyond, thus increasing system predictability and reducing flood probability. From a resilience perspective, over-dimensioning (reserves) is favored for handling surprise. However, when the dike is not flexible for adaptation or further confines natural dynamics - two other system attributes of resilience - it also reduces system resilience. This is the case for extra high dikes (confining dynamics) combined with permanent high investment functions such as parking garages (inflexibility for adaptation). In contrast, an extra wide design combined with parks and low investment roads is more favorable. The example illustrates that reconciliation of rationales requires tailor-made solutions.

Societal importance for stakeholders

The main purpose of the framework is to facilitate discussion amongst stakeholders in terms of desired policy. Although scholars of resilience and control rationales operate rather isolated, policy often reflects elements of both. The framework provides a ‘language’ for discussing policy in terms of resilience and control attributes, comparing policies and matching policy with a desired rationale. A thoughtful consideration of risk management in policy development may result in better anticipation of future developments and more appropriate responses.

P 008

FACTORS INFLUENCING ADOPTION OF RISK INFORMATION WITHIN THE FLOOD PRONE COMMUNITIES: OKAVANGO DELTA, BOTSWANA

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Natural disasters such as earthquakes, windstorms, and floods havebecome more frequent nowadays. Extreme weather events have resulted in massivefloods affecting communities and their socio-economic livelihoods. These eventshave necessitated for flood risk management strategies, with flood riskcommunication at the core of these strategies. Literature has suggested thateffective flood risk communication interventions should consider thesocio-cultural environments and other factors that will facilitate desiredresponses to flood risk information by the public. The current studyassessed the factors influencing the adoption of flood risk information in theflood prone communities of the Okavango Delta, in north-western Botswana. Thestudy will inform the risk communicators and disaster management institutionsin the formulation of effective policies, mitigation strategies, and communicationinterventions with regard to the practice and the performance of effectiveflood risk communication. The study was guided by the trust determination andrisk perception models. A total of 95 respondents participated in the study,following a stratified random sampling (two strata) of households, one beingclose and the other far off the floodplains. Data was collected from keyinformants, focus groups and respondents through interviews usingsemi-structured questionnaires and interview schedule. Data was analysed usingdescriptive statistics, ANOVA and chi-square. The results indicated that peoplehave negative attitudes towards floods and flood risks, and have highperception of flood risks (M= 1.82; SD = .73, n = 95) within their localities,though no significant differential effect were found for the level of riskperception on the adoption of flood risk information [F(4,90) =.22, p= .93].Communities and risk communicators used a multi-mix of channels, approaches,and strategies to maximize flood warning messages' reach and impact. Factors identified which impeded adoption of flood risk information were,amongst others, timing of the message and dependence on the riparian naturalresources for livelihoods. The study recommended that flood risk communicationshould be a continuous activity within the flood prone communities of theOkavango delta, mainly as the floods in the delta are pulsed, as opposed toepisodic floods. It is also recommended that land authorities should undertakea thorough assessment of land suitability prior to designating areas forresidential purposes. Areas prone to floods and flooding should be avoided whenit comes to planning for residential areas

P 009

ASSESSING FLOOD RISKS AND FLOOD-PROOFING MEASURES FOR THE CRITICAL INFRASTRUCTURES IN DORDRECHT

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Research question

Recent flood events in England, Germany and France have shown that flood damages are not confined to the affected communities and areas, but that floods will impact society and economy at large due to the failure of critical infrastructures, such as electricity and natural gas. The city of Dordrecht, amongst other cities in the Netherlands (e.g. Amsterdam and Rotterdam), wants to gain more insight into the exposure, susceptibility and failure impacts of critical infrastructures, and also to identify cost-effective options for modifying network designs and/or flood-proofing individual objects (so-called hot spots). The research question is: What are the flood risks and cost-effective flood-proofing measures for critical infrastructures on the Island of Dordrecht?

Methodology

A map of critical infrastructure was composed from existing data on the networks and hot spots on the Island of Dordrecht. Furthermore, new data was gathered from interviews with network administrators and from field visits. Further analysis and assessments have been carried out by applying two decision making tools, developed under the European FloodProBE project. The Hotspot Flood Proofing toolbox and the Quick Scan method present a workflow to analyse and assess flood risks and flood-proofing measures for critical infrastructures for achieving high cost-effectiveness. Also for each critical infrastructure in Dordrecht a framework was developed to illustrate their working principles and how they are affected by a flood.

Research results

Electricity is essential for the functioning of almost all critical infrastructures on the Island of Dordrecht. The network itself depends on supply from outside the island. The electricity hotspots at risk can be flood-proofed at modest cost, to enable the continuous functioning of electricity supply during (relatively extreme) high water situations. The total flood-proofing cost ranges from some ten thousand Euros for temporary measures, like sandbags, to some hundred thousand Euros for permanent measures, like floodwalls. Furthermore, close cooperation with network administrators is necessary for further implementation.

Societal importance for stakeholders

Critical infrastructure failures due to flooding and other causes can disrupt society and economy at large. Awareness of and acting upon flood risks is therefore essential for cities all over the world. For Dordrecht specifically, not only for its vulnerable geographic location, but also because large-scale, preventive evacuation off the island is not feasible. The decision support tools from FloodProBE provide stakeholders with the means for identifying critical infrastructures at risk from flooding and for assessing feasible and cost-effective flood-proofing measures.

P 010

CALLING FOR RAIN: RAINFALL MAPS FROM CELLULAR COMMUNICATION NETWORKS

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Research question

Various studies have shown that microwave links from operational cellular telecommunication networks may be employed for rainfall monitoring. Although this new potential source of rainfall information is promising, its quality needs to be demonstrated more extensively. For this purpose, approximately 1500 microwave links are used to obtain rainfall maps for an entire country, the Netherlands (~ 35000 square kilometers), over a two-year period.

Research results

The basic principle of rainfall monitoring using microwave links is as follows. Rainfall attenuates the electromagnetic signals transmitted from one telephone tower to another. By measuring the received power at one end of a microwave link as a function of time, the path-integrated attenuation due to rainfall can be calculated. Previous studies have shown that average rainfall intensities over the length of a link can be derived from the path-integrated attenuation. This is particularly interesting for those countries where few surface rainfall observations are available. Here we present country-wide rainfall maps employing cellular communication networks.The data set from a commercial microwave link network over the Netherlands is analyzed. Fifteen-minute and daily rainfall maps (1 km spatial resolution) are derived from the microwave link data and compared to maps from a gauge-adjusted radar data set. Validation is performed based on two years of data. We show that such a network can be used to provide accurate precipitation estimates, down to scales of individual storms.

Societal importance for stakeholders

Rainfall has a large impact on society. Extreme rainfall can lead to loss of life and property by causing land slides or flooding due to dike breach or dam failure. In urban areas flooding is often caused by short high-intensity rainfall of limited spatial extent. Accurate rainfall measurements are therefore important to prevent these damages, for instance, by improving flood forecasts, and can also improve our understanding of the climate system of the earth. However, the majority of the land surface of the earth lacks accurate rainfall information and the number of rain gauges is even severely declining in Europe, South-America, and Africa. This calls for alternative sources of rainfall information. Cellular communication networks cover 20% of the land surface of the earth and have a high density, especially in urban areas. Hence, these networks have potential for global land-surface rainfall monitoring, which is highly relevant for climate monitoring as well as ground validation of satellite-based precipitation estimates.

P 011

A FLOOD RISK ASSESSMENT AND ECONOMIC OPTIMUM SAFETY LEVEL FOR HOBOKEN (NJ, USA)

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The impact of hurricane Sandy (2012) on the high-density built environment in New York and New Jersey illustrated the region's vulnerability to storm surges. For Hoboken (New Jersey) - a 50,000 people community along the Hudson River and severely flooded during hurricane Sandy - a flood risk assessment is conducted, illustrating an approach to determine an appropriate safety level and highlighting the importance of increased flood protection. The study provides an example for comparable communities in the region and a motivation for flood risk assessments for high-asset flood-prone areas world-wide.

Parts of Hoboken were historically marshes along the Hudson River. This geography combined with storm surge- and extreme rainfall events led to severe flooding of the lower lying areas of Hoboken. This flood risk needs to be addressed comprehensively and therefore an appropriated level of protection is studied. Within Rebuild by Design, a design competition for a more resilient Sandy-affected region, a comprehensive strategy for flood risk reduction for Hoboken is proposed. The conceptual design of this strategy is built upon this flood risk assessment.

Determining a safety level for flood protection is ultimately a political choice. It is the question how much safety a society desires at which costs. By monetizing investments in flood protection and determining the corresponding present value of risk reduction, an economic optimum level of protection can be determined (Jonkman et al., 2009; Kind, 2013). To conduct this analysis, the hydraulic boundary conditions for Hoboken are obtained from different sources (Lin et al., 2012 and NOAA, 2013), potential investments in flood protection measures are derived based on expert judgment and coastal defense cost estimates (Hillen et al., 2010; Jonkman et al., 2013) and a damage assessment is conducted, based on private and public damage (Hudson County Tax, 2012) and a mark-up to include indirect damages and the concept of risk-aversion. These parameters determine a safety level with best value for money.

Following a preliminary analysis a 500-year safety level for flood defenses to address storm surges is concerned to be an economic optimum. With this level of protection the risk reduction significantly outweighs the investment in flood defenses. Hereby a new standard for Hoboken is proposed, protecting the city against Sandy-like surge events. This level of protection is considered achievable in the US setting, can be funded with the ongoing grant programs and provides a case for improved flood risk reduction measures for comparable communities.

P 012

THE NIGERIA FLOOD OF 2012: IMPACTS IN THE NIGER DELTA AND LESSONS LEARNED

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The Nigeria flood of 2012 has been described as the most severe and devastating in the history of modern Nigeria. The Niger Delta region suffered the most extensive devastation because of its location in the lowest part of Nigeria where the Niger and Benue rivers empty their waters into the Atlantic Ocean.

The main research questions discussed in this paper are; (a) what were the magnitude and negative environmental

and socio-economic impacts of the flood in the Niger Delta?; (b) what are the lessons learned and how can flood mitigation strategy, preparedness, response, recovery and integrated management be improved in the region? Results of field measurement and analysis of published data revealed that the flood affected over seven million people, displaced 2.3 million people, killed over 363 persons and damaged about 597,476 houses nation-wide. The combined economic losses have been estimated to be approximately US$16.9 billion. Flood heights attained maximum of 3.68m at several floodplain observation stations within the Niger Delta whilst those taken at the centres of major rivers range between 6.46m to 7.88m above the normal seasonal water levels. Most parts of Niger Delta were inundated for 6-8 weeks causing severe negative impact to flora and fauna. Chemical wastes from oil industry disposal sites were carried by the flood waters which contaminated surface and groundwater resources within communities. People were exposed to hazardous wastes and this was compounded by social pressures arising from displacement and migration. In spite of the tremendous negative impact of the flood disaster, not much has changed in terms of flood mitigation strategy, preparedness, response, recovery and integrated management.

P 013

TIMES OF CHANGE - THE INSTITUTIONAL DYNAMICS IN DUTCH FLOOD RISK MANAGEMENT

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This presentation analyses the institutional dynamics of flood risk management (FRM) in the Netherlands. Flood risk is increasing, due to changes in the socio-economic and hydrological systems, and the climate. To adapt to these developments in a more appropriate way, efforts are undertaken to broaden flood risk strategies (FRS), also stimulated by the EU Flood Directive. That means that several strategies, e.g. structural defence measures, emergency management, or green infrastructure are implemented simultaneously. The broadening of flood risk strategies is accompanied by a change in governance practices around strategies often in order to increase legitimacy, effectiveness and efficiency of FRM.

The presentation will analyse the situation in the Netherlands. The Netherlands is a highly flood-prone country that traditionally relies on a technical approach to FRM. However, efforts to broaden FRS are visible. This presentation will address the following questions: (1) How are FRS institutionally embedded in the Netherlands, and what are the historical dynamics thereof? (2) Which governance practices surrounding particular strategies can be identified? (3) What are the factors of change and stability for changing FRS?

Qualitative research, including desk research and semi-structured interviews with stakeholders, yielded the following findings. The main pillar of flood risk management in the Netherlands is still probability reduction of floods by resisting the water (defence). However, also other strategies are increasingly institutionalised, e.g. strategies with the aim to accommodate more water or to reduce the exposure to flooding (integrated FRM). Also crisis management is recently distinctly stabilised in institutions by the formation of security regions. Insurance against fluvial flooding is more and more discussed but not institutionalised yet.

The governance practices surrounding particular strategies differ. Defence is still state dominated, with a growing role of market actors. Integrated FRM is an interactive governance arrangement, whereby different levels of governmental and non-governmental actors collaborate. Emergency management tends to be mainly the responsibility of decentralised governmental actors. The governance practice surrounding insurance practices is characterised by self-governance, with a negligible role of governmental actors.

The factors explaining change and stability are multiple. It is often the interaction of factors that initiates, facilitates and accelerates policy change. The factors explaining change and stability reach from structural and agency-related

factors to physical circumstances, social and physical infrastructure as well as shock events.
Based on this results the presentation will offer valuable insights on governance in FRM, as well as barriers and chances for policy change.

P 015

SUSTAINABLE DEVELOPMENT CHALLENGES AT SOUTHERN MEDITERRANEAN COASTLINES

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Research question
The Nile Delta has been subjected recently to the added impacts of the climate changes as witnessed by the progressive coastal flooding since 2003. Flooding of the lowland zones (-2.0 to +1.0m) at several locations around Rosetta headland and the adjacent Abu-Qir bay commonly are occurring at major storms as seen in 2010 by the strong winds, exacerbated by heavy precipitation, up to 60 km/hr with a surge of over 1.0m and more than 5.5m wave height. There is an urgent need to proceed promptly with the second phase II of adaptation strategies, and innovative coastal defenses, that are not only needed, but also environmentally acceptable. This new phase, should address the needed remedies to offset the adverse impacts of coastal hard structures, such as groin systems placed on Rosetta headland according to the Nile Delta CZM Master Plan I, initiated in 1981. Impacts of Climatic Changes on coastal design are introduced.

Research results
The Rosetta headland is currently protected by two flanking seawalls since 1990 according to the Nile Delta Master Plan formulated in 1981-1986. Furthermore two sets of groins have been constructed in the last decades on both sides of Rosetta headland seawalls to slow down the down drift erosion. In this research phase, several alternatives, for the mitigation and adaptation measures to protect the coastal regions around Rosetta headland between the coastline and the coastal road, have been investigated. Use has been made of the modified ImSedTran-2D model and the design standards of EurOtop (2011) to determine the maximum future estimates of wave heights, wave runup and overtopping in the inland zones. The proposed systems include, beach nourishment between the groins, joint use of submmerged geotextiles sand bags with individual groins, and creating marshland along the coastal strip.

Societal importance
The proposed coastal defense systems will enhance the resilience of the coastal strip of the Nile Delta west of Rosetta headland. This study contributes to coastal urban planning including including fostering eco-tourism.

P 016

A PRACTICAL INNOVATIVE DESIGN TO PROTECT JAKARTA FROM INCREASING YEARLY FLOODS

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Research question

The current coastal defense of Jakarta does not provide sufficient flood protection. Every year larger areas of Greater Jakarta are flooded. Flood risks have increased in recent years due to rapid land subsidence of the region. The region has subsided in the last decades and is expected to continue subsiding with an average rate of 7.5cm per year. This causes larger areas to sink deeper below sea level making flood risks in the coastal zone unacceptably high.
If no measures are taken, a large part of the coastal zone, with over 4.5 million residents, is under threat of permanent inundation as soon as 2022. How to protect the lives of the people and the economy in this region?

Research results

Drainage systems and protection systems are unstructured. Measures are normally taken on an ad-hoc base; no long term plan is present. No design conditions and design standards are in place. No reliable long term datasets are available. And the rapid land subsidence makes it even harder.
The first step is to understand the underlying mechanisms and determine design conditions and horizons. Existing plans provide insight in the coastal zone development and possible future inundations and weak links.
The second step is to combine the available data and determine an overall short term action plan. As large areas of the coastal zone are or will become below sea level, the implementation of a polder-like system with dike rings and pumping stations, is a must.
The third step is to translate the plan into a conceptual design where local needs and customs are incorporated. And last the design should enable future connections with offshore developments and future long term protections.
This research resulted in a practical design where the region will be protected from inundation. The solution is adaptable and can be improved without having to go back to the drawing board when design conditions were too optimistic. It minimizes social impact and provides added value for coastal communities.

Societal importance for stakeholders

Most residents are people from weaker social groups. When these people are moved, social connections and relations are lost and often moving also implies the loss of economic relations. People continue to live along the coast: they get better facilities, more green space, better flood protections, etc. The residents also keep their economic links with the water and through innovative spatial designs maintain ties with their market.

P 017

FLOOD DAMAGE INFLUENCING FACTORS FOR RESIDENTIAL BUILDING IN CAN THO CITY, MEKONG DELTA

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Floods in the Mekong delta occur on a recurring basis during the flood season from July to November. In line with the projected rise in sea level and the estimated increase in precipitation during the wet season, which is expected to be especially pronounced in the south of Vietnam (MONRE, 2009), flood hazards could increase considerably in the Mekong Delta. In Can Tho city, the biggest city in the Mekong delta, extreme floods like the one during the flood season in 2011, cause significant damage to buildings, businesses and infrastructure. Comprehensive risk and damage assessments are essential for an efficient flood management. To improve the knowledge about flood losses and the loss-influencing factors, 858 households and small businesses affected by the flood in 2011 in Can Tho city were interviewed.
The important flood damage influencing factors for residential building were identified by multi-variate statistics. Preliminary results revealed that surprisingly inundation duration seems to be much more important than water depth. The importance of various factors influencing flood damage will be presented and the consequences for flood damage modelling will be discussed.

References

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P 018

FLOOD RETENTION AND FORESTRY - AN EXAMPLE OF WATER FRIENDLY LAND MANAGEMENT IN THE HÖRDT FLOODPLAIN

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Research question

Rhineland-Palatinate (Germany) started to build an emergency polder on the river Rhine, designed for extreme flood events exceeding that of a 1:200 years flood. As the area is partly operated as a commercial forest the objective is to successfully combine efficient flood retention and cost effective forestry.

Research results

Hard wood like common beech, Norway maple and sycamore maple usually provides good yields in forestry but do not tolerate long lasting flood events or high water levels. As the common ash, normally a typical floodplain species is expected to disappear due to ash dieback, it is cut together with harvestable trees of non-flood tolerant species and substituted by flood-tolerant species that can withstand floods up to three months. Beside common oak, other typical floodplain species like Turkish hazel and the European white elm are planted as well. Both were widely spread in the Balkan Peninsula and the Danube floodplains but due high demand on hard wood were nearly extinct. Especially

white elm is a clear alternative to field elm as it is fairly resistant to the Dutch elm disease caused by a microscopically small fungus transmitted by the elm bark beetle. Supplemented with yew trees, formally widely but scarcely spread in natural floodplain forests, these species contribute to restructuration of the local forest.
Since the cut off from the river Rhine flood events affect the area only indirectly and very slightly in form of varying groundwater levels. The ecosystem developed from a former floodplain towards land ecosystems with only minimal influence of water. Therefore ecological flooding was designed to reconnect the retention area to the natural river discharge up to a certain level. The objective is to improve the groundwater level and to initiate a long-term adaption and natural restructuring of the forest within the retention area.

Societal importance for stakeholders
An improved water supply due to ecological flooding will promote typical flood tolerant species and minimizes the danger of summer droughts. Individual species and the whole ecosystem are able to adapt to higher water levels. Forest conversion and ecological flooding can help to minimise the potential damage on nature and forestry due to a retention events thus leading to a future increase the flood safety along the Upper Rhine.

P 019

THE POTENTIAL OF MOBILE SERVICES FOR EARLY WARNING AND FOOD SECURITY IN BANGLADESH

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The impact of the increasing mobile services has been enormous on life in developing countries. Mobile services are causes for improvements in financial independence, health, government-citizen interaction, education, gender equality, environment and of course monitoring and warning. In this project the potential of using mobile services for early warning of natural hazards and for food security was investigated for the Embassy of the Kingdom of the Netherlands in Bangladesh. How does one provide early warning and communicate the imminent danger of a natural hazard such as a flood or a tropical cyclone to isolated, poor rural communities?
The potential for mobile services was assessed through a series of interviews with stake-holders, such as certain departments of the Government of Bangladesh, various NGO's and humanitarian organisations, several meteorological and hydrological organisations, a number of research organisations, and a local village community in southern Bangladesh. A great number of pilot projects using mobile services have been set up in Bangladesh. This paper presents the challenges that are faced when developing such ideas in practice into sustainable business models that will help rural communities.

P 020

MULTI LAYER SAFETY IN THE WADDEN AREA

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The Dutch National Water Plan introduced the concept of multi-layer water safety in 2009. Within the concept of multi-layer safety three layers can be distinguished: flood prevention, sustainable spatial planning and disaster management. This study provides an overview of the opportunities to bring the concept of multi -layer safety in practice in the Wadden Area: the mainland coast of Friesland and Groningen and the Frisian Islands.
The study consisted of several sub projects that each consisted of literature study, interviews and workshops. Next to this models were used to calculate costs and benefits of different measures.
The first safety layer is not future-proof yet. At the mainland coast the maintenance of the dykes is of great importance. Ongoing research should show whether dike concepts can combine the protective function with natural and / or recreational functions. Around the Frisian Islands the method of sand nourishment is important. The study how sand nourishment can best be applied should be intensified.
Studies elsewhere in the Netherlands have shown that the second layer measures are generally less cost-effective than the first layer measures. Probably, this also applies in the Wadden area. Large-scale second layer measures with old 'sleeper' dikes appear unprofitable. However, more local measures could be useful. In particular, the Eemsdelta is an interesting area for second layer measures. In this coastal area a possible dike breach has serious consequences, because the gas fields (30 % of the Dutch energy supply comes from here), the city of Groningen and other municipalities are directly threatened. That is why a design study was carried out. Three preliminary designs were presented to several stakeholders in the area.
Regarding the third layer safety the conclusion is that the relationship between the Delta Programme and the regional safety organizations should be strengthened. There has been much discussion about evacuation strategies and how to standardize this. Two strategies are distinguished: horizontal evacuation (leaving the flooded area) and vertical evacuation (remain in the flooded area at a high place). Risk awareness of citizens has to improve. The Frisian Islands are particularly vulnerable because manpower and expertise will be lacking during a disaster. Local residents on the islands should be well informed and in an emergency they should have the capacity to help tourists.

P 021

WHAT CAN THE NETHERLANDS LEARN FROM GERMANY AND THE UK ABOUT FLOOD RESILIENCE?

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Research question
The Netherlands is not an innovative country in living with floods. Experiences date from 1953. Since then society focussed on reducing risks with dikes and innovative waterworks. A huge success. The other side is that presumptuousness leaks in. A tendency 'to fall asleep behind dykes'. While climate change combined with massive

land subsidence is posing huge challenges from behind. Experiences in Germany and the UK might help. Countries facing numerous floods and even catastrophes in the last decade. More inclined to adapt. Amazed to hear that Dutch farmers call The Hague to complain about a shortage of water after a few weeks of drought. Or about questions in parliament on precipitation causing water on the pavement in a town. Overtaking the market for technical solutions to get water out, to prevent it from coming in or to insure yourself against it. What can the Dutch learn on flood resilience from the UK and Germany in facing climate change?

Methodology and research results

Robert, Peter and Marnix, having worked on flooding and adaptation issues for many years, believe that new solutions often build up on listening to other experiences and cultures. They have shared their observations and their creativity to develop visions for new approaches. They will present to the audience a pallet of creative possibilities for amphibious housing, calamity polders, options for insurance, technical means to get water out of the house, stakeholder sensitivity, carbon neutral floating structures, etcetera. In a potpourri of opportunities it becomes clear that there is absolutely no ground for business as usual in regard to adapt to the impacts of climate change. On the contrary: it is about time to share knowledge with our neighbours for the mutual benefit.

Societal importance for stakeholders

Robert, Peter and Marnix will deliver a catalogue for the conference participants combining their common creativity to the benefit of people from both their respective countries and elsewhere. Besides they will show them a way for an adaptation strategy that comprises all steps to turn problems, through challenges to actual benefits for both economy and ecology. Of course we can!

P 022

VARIATIONS IN THE ISOTOPES IN GROUNDWATER FROM RAS JBEL AND GUENNICHE AQUIFERS DUE TO ARTIFICIAL RECHARGE

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Isotopes in both surface and groundwater studies is a relatively recent field of scientific investigation. This paper deals with isotope analyses of more than 140 samples which were monitored 2 times in the course of 2008 (April and November 2008) into Ras Jbel and Guenniche watertables. Oxygen and hydrogen isotopic investigation was undertaken to characterise the isotopic nature of the groundwater in both watertables and provide basic framework for future hydrological studies and this on the basis of observations from several wells and piezometers. The application of stable isotope analyses (oxygen-18, deuterium and carbon-13) for the description of groundwaters in the study areas is of a particular interest. In fact, these two watertables not only provides the dominant water supply for residents, but also because they are representative of a common semi-arid environment where natural recharge is dominated only in rainy season, the high sub-exploitation of Ras Jbel and Guenniche groundwaters, both for domestic human use and irrigation, made an artificial recharge a necessity, by contact with the Mediterranean sea for the Ras Jbel watertable and with Bizerte lagoon for the Guenniche one.

In the present study, we describe the groundwater isotopic content and we determine the modifications induced by the artificial recharge. This study shows that: (1) The shallow groundwater of Ras Jbel and Guenniche watertables collected in rainy season retains the isotopic signature of the local precipitation averaged over a few tens of years. (2) Samples collected in the first survey have distinctly depleted isotopic composition compared to those collected in the second survey.

P 023

MODELLING RAINFALL-RUNOFF PROCESSES IN LOWLANDS WITH WALRUS (WAGENINGEN LOWLAND RUNOFF SIMULATOR)

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Lowlands exist all over the world (often in river deltas), and are characterized by shallow water tables. These shallow water tables affect both runoff generation and evapotranspiration: groundwater and unsaturated zone are coupled, plant water stress is limited, the catchment wetness determines flowroutes, feedbacks exist between groundwater and surface water, and seepage and surface water supply and extraction are common.

Research question
How can these processes and feedbacks be incorporated in a new rainfall-runoff model to fill the gap between complex, spatially distributed models which are often used in lowland catchments and simple, parametric models which have mostly been developed for mountainous catchments?

Methodology
To develop this new rainfall-runoff model, we used data and experience obtained in two contrasting Dutch catchments: the slightly sloping, freely draining Hupsel Brook catchment and the flat Cabauw polder with controlled water levels.

Research results
The end product of this research project is the Wageningen Lowland Runoff Simulator (WALRUS), a new parametric rainfall-runoff model (Brauer 2014a, 2014b). In both catchments, WALRUS performs well during calibration, validation, extremely wet (flash flood in the Hupsel Brook catchment in August 2010) and dry (summer 1976) periods. WALRUS is computationally efficient, which allows operational forecasting and uncertainty estimation using ensembles. It can be used for multi-year water balance studies as well as detailed analyses of individual flood peaks.

Societal importance for stakeholders
WALRUS can be used all over the world. The main advantages for end-users are that WALRUS (1) is applicable to both freely draining lowland catchments and polders, (2) is computationally efficient, (3) has few parameters which require calibration, (4) has a clear (qualitative) relation between model states and measureable variables, (5) has default options for initial conditions and (6) is open source and freeware. WALRUS can be used by water managers for (1) operational forecasting of floods and droughts, (2) real-time control, (3) input for a hydraulic model, (4) risk assessment, (5) infrastructure design and (6) filling data gaps. Stakeholders are involved in the continued development of WALRUS: we are currently working together with four water boards in a project which aims at preparing WALRUS for operational use.
Brauer et al. (2014a): The Wageningen Lowland Runoff Simulator (WALRUS): a lumped rainfall-runoff model for

catchments with shallow groundwater, Geoscientific Model Development Discussions
Brauer et al. (2014b): The Wageningen Lowland Runoff Simulator (WALRUS): application to the Hupsel Brook catchment and Cabauw polder, Hydrology and Earth System Sciences Discussions

P 024

THE IMPACTS OF FLOATING URBAN DEVELOPMENT ON WATER QUALITY AND ECOLOGY

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Research question
What are the negative and positive impacts of floating urban development on water quality and ecology?

Methodology
A literature survey was executed to collect information from scientific and technical publications. In addition, expert workshops with different stakeholders as water authorities and construction companies were organized to access experience knowledge in dealing with water quality in floating construction projects. Finally, site visits, surveys and water quality measurements and aquatic ecoscans were done to collect location specific knowledge.

Research results
There is a lack of knowledge on water quality and ecological impacts of floating urban developments. Based on the results and measurement data that were gathered in this study, it seems that the current small scale projects do not have a significant influence on water quality. However, this might be different in the future if the scale and number of projects increase. The results from the expert workshops indicate that water authorities do not have a uniform approach in to permit and regulate floating construction projects. Therefore, a tool is developed to exchange and access the available information on this topic. In addition, floating projects could be combined with creating floating wetlands and ecological structures to improve water quality and ecological habitat.

Societal importance for stakeholders
Floating urbanization is a flexible and climate adaptive form of urban development. Potentially, it combines the objectives of housing and water retention by implementing multifunctional use of space. The objective of water authorities to create more water storage in urban areas could become economically feasible if creating water retention is combined with floating urban development. However, the water quality and ecological impacts of floating urban development are largely unknown. This creates a difficulty for water authorities and municipalities to regulate and facilitate the development of construction projects. Therefore more knowledge is needed in order to create a policy framework.

P 025

ADAPTATION PROGRAM ON CLIMATE RESILIENT INFRASTRUCTURES IN COASTAL ZONE OF BANGLADESH

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The coastal zone in southern Bangladesh adjoining the Bay of Bengal is a low lying area. Since 1960s, the construction of a system of polders where earth embankments prevent flooding of the low lying lands (1-2m above MSL) during the highest tides is now an established feature. The ability to drain the land during low tide that occurs twice a day has made it possible to build 139 polders wherein 1.2 million hectares of new land are now under permanent agriculture.
The cyclonic storms have caused much destruction in the coastal zone of Bangladesh. At present, there have been unintended consequences of the coastal project due to climate change. The polder system had also been affected by siltation of the river system triggered by the massive interference with tidal volumes consequent to the prevention of tidal flooding in the delta. The embankment system was designed originally to keep out the highest tides, without any consideration of possible storm surges. Recent cyclonic storm damages and the anticipation of worse future situations on account of climate change, has caused this strategy to be revised. Coastal Embankment Improvement Programme will provide protection against anticipated long term impacts of sea level rise and increased cyclone intensity predicted in climate change projections. This paper describes the first phase of this programme.
The paper describes the use of a cyclone model in the Bay of Bengal and drainage models in individual polders to design a new system that takes into account future storm surge heights, wave run-up and land subsidence in the design of embankment and the redesign of drainage systems to counter sea level rise as well as changes in precipitation. In this paper climate change scenario for 2050 has been developed considering sea level rise of 0.5 m and 10% increase in maximum wind speed of cyclone. The maximum surge height was obtained from 106 pre-selected locations in the model domain, for each cyclone of the 38 cyclone simulations. In addition, the continuing subsidence of all protected lands in the coastal zone and the resulting uncertainty with regard to the existing standard leveling grid and the crest levels of existing embankments required that a new carefully devised strategy is adopted for design of both the new drainage systems and in setting the embankment crest levels as also described in the paper.

Keywords
Storm Surge, Climate Change, Wave Run-up, Embankment Design, Land Subsidence.

P 026

RIVER SALINITY ON A MEGA-DELTA, AN UNSTRUCTURED GRID MODEL APPROACH

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With an average freshwater discharge of around 40,000 m^3/s the BGM (Brahmaputra Ganges and Meghna) river system has the third largest discharge worldwide. The BGM river delta is a low-lying fertile area covering over 100,000 km^2 mainly in India and Bangladesh. Approximately two-thirds of the Bangladesh people work in agriculture and

these local livelihoods depend on freshwater sources directly linked to river salinity.The finite volume coastal ocean model (FVCOM) has been applied to the BGM delta in order to simulate river salinity under present and future climate conditions. Forced by a combination of regional climate model predictions, and a basin-wide river catchment model, the 3D baroclinic delta model can determine river salinity under the current climate, and make predictions for future wet and dry years. The river salinity demonstrates a strong seasonal and tidal cycle, making it important for the model to be able to capture a wide range of timescales.The unstructured mesh approach used in FVCOM is required to properly represent the delta's structure; a complex network of interconnected river channels. The model extends 250 km inland in order to capture the full extent of the tidal influence and grid resolutions of 10s of metres are required to represent narrow inland river channels. The use of FVCOM to simulate flows so far inland is a novel challenge, which also requires knowledge of the shape and cross-section of the river channels.

P 027

WETLAND DEVELOPMENT AND EFFECTS OF SAND ENGINE AT THE COAST OF LAKE IJSSEL - AN IMPORTANCE FOR ECOLOGICAL RESTORATION

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In this case study we explored a potential to enhance coastal wetlands resilience to rising lake water level, by applying sand supplementation. exploring the factors driving the vegetation development and the soil stability was equally important. We investigated if creating a natural foreland with the sand supplementation results in: (1) enhancing coastal dynamics, (2) improving local coastal resilience due to enhancing the vegetation development; and (3) improving the ecological values of the area. An experimental sand supplementation was applied along the coast of Workum, in the province of Frysland. Sand was supplied 200 meters off the coast in shallow water. Plant species composition of wetlands and wet meadows was monitored before and after application of experimental measures. Plants were used as indicators of abiotic conditions in the study area and they marked processes that shape these wetlands. Also other characteristics of the vegetation were studied, in order to get insight in the system functioning. Only initial effects of sand supplementation could be investigated, due to a short-term monitoring. The system is relatively dynamic, due to erosion processes and re-deposition of sediment. We found zonation in the vegetation, that was related to wave erosion, local hydrology and management practices (grazing). The soil stability and erosion prevention potential were related to this gradient in the vegetation. A high ecological value of the study area is most likely related to the gradient in the vegetation as well. First results indicated enhanced sand movement in the direction of the coast, but no effects on the vegetation were observed in the short-term. For successfully ecological restoration, which is a process of assisting the natural recovery of a system, we need to first understand the relevant processes effecting coastal wetlands development. The experiment has a high impact on stakeholder involvement and learning: it demonstrated climate adaptations measures 'in the field', but also pointed out their limitations and contributed to better insight in the ecology of the study area.

P 029

UNDERSTANDING SEDIMENT DELIVERY TO DELTAS UNDER FUTURE ENVIRONMENTAL CHANGE

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This research aims to answer the question of how future environmental changes will influence fluvial sediment delivery to deltas, thereby contributing to our understanding of relative sea level change projections for deltas. Relative sea level change is affected by eustatic change, crustal movements, compaction, and aggradation. The flux of sediment supplied by the catchments feeding deltas exerts a first order control on delta aggradation and thus the potential for the surface elevation of a delta to rise relative to sea level.

In this research the environmental changes which will affect sediment delivery to deltas will be identified and their potential ranges established. The key environmental changes include reservoir construction, channel engineering, and land use e.g. agricultural practices and vegetation cover. To evaluate the effects of these catchment changes on fluvial sediment delivery, catchment numerical models will be calibrated for a selection of major vulnerable deltas. This calibration exercise involves the use of historical reference data for each delta.

The results of this research are able to inform the identification of a range of factors affecting delta elevation change relative to sea level. Further research will focus on using these data to refine definitions of delta vulnerability and identifying proxies for environmental changes which affect delta aggradation, such as land use change and channel engineering.

Relative sea level change is an important predictor for land loss, degradation, and flooding. With a resident population of roughly 500 million people worldwide, this research will assist in prognosis for vulnerable delta areas and inform their short- and long-term management. As some aspects of delta sustainability are under anthropogenic control or influence the projections will indicate the consequences of various actions affecting delta elevation. While this could give forewarning for the residents and managers of unsustainable deltas, it could also be used as an argument for or against various anthropogenic activities.

P 030

GLOBAL LEARNING FOR LOCAL SOLUTIONS: REDUCING VULNERABILITY OF MARINE-DEPENDENT COASTAL COMMUNITIES

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The project 'Global learning for local solutions: Reducing vulnerability of marine-dependent coastal communities' or GULLS is an international project within the Belmont Forum and G8 Research Councils Initiative on Multilateral Research Funding. Participants include teams from nine countries: Australia, Brazil, India, Madagascar, Mozambique, New Zealand, South Africa, the United Kingdom and the United States of America.

The project goal is to encourage and assist coastal communities to adapt to climate change and climate variability

through a comparative and trans-disciplinary whole-system approach to the characterization, assessment and prediction of the future of coastal-marine resources. It will identify adaptation options and strategies for enhancing coastal resilience at the local level and in doing so will contribute to capacity building and local empowerment. The trade-offs implicit in the need to address food security and conservation goals simultaneously will be assessed.
The focus is on regional 'hotspots' of climate and social change, defined as fast-warming marine areas and areas experiencing social tensions as a result of change. These areas require most urgent attention and can also be seen as providing natural laboratories for observing change and developing adaptation options and management strategies that can also be applied to other regions. The five marine and coastal hotspot areas selected for study are in the Southern Hemisphere and include south-east Australia, Brazil, India, South Africa, and the Mozambique Channel and adjacent countries of Mozambique and Madagascar.
Each of the five coastal marine hotspots, including deltas in some countries, will be characterized by identifying primary drivers of change, the associated risks and the current status of adaptation. The similarities and differences between them and the implications of these for global efforts to facilitate adaptation and strengthen resilience in marine and coastal social-ecological systems will be described. A standardized vulnerability assessment framework will be developed based on an array of system models and will be used to assist in understanding the complex processes driving coastal change and the responses to those changes in the hotspot areas.
The assessment framework will be used to integrate results from natural, social and economic studies through a multi-sectoral process, and to assist in identifying scenarios for management and options for policy reform. The presentation will describe the tools, how they are being applied in the different regions and progress towards achieving the project goals.

P 031

REGIONAL SEA LEVEL TRENDS IN THE BAY OF BENGAL: PRELIMINARY RESULTS FROM A GRACE AND JASON-1/-2 JOINT INVERSION

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Sea level rise and its acceleration is a major global challenge of the 21st century. Besides the uniform increase, the rise of sea level exhibits considerable regional variations.Consequently, coastal vulnerability isbecoming an increasingly important issue for many countries all over the world.
In Bangladesh, large areas of the country lie just above the sea level. Here, sea level rise in combination with land subsidence resulting from groundwater pumping, sediment load or tectonic motion, poses a major threat to the coastal regions,which are the home of about 30 million inhabitants. As part of the Belmont-project "Bangladesh Delta: Assessment of the Causes of Sea-level Rise Hazards and Integrated Development of Predictive Modeling Towards Mitigation and Adaptation" (BanD-AID) a joint inversion method is employed to estimate the different contributors to sea level rise, such as melting of mountain glaciers/ice caps and Greenland and Antarctica ice-sheets, hydrology, glacial isostatic adjustment, and steric sea level changes.
In the joint inversion method, spatial patterns (fingerprints) are forward computed for each of the contributors, utilizing the sea level equation formass fingerprints, e.g.individual ice-sheets and glaciers anda Principal Component Analysis for steric fingerprints derived from ARGO float data. Temporal GRACE gravity data and along-track Jason-1 and -2 altimetry data is combined to estimatethe time variable amplitudes of these individual fingerprints, which allow the computation of individual sea level trends.

We provide preliminary results for the Bangladesh region as performed within the framework of the BanD-AID project. Results from a global solution of the inversion are compared to local measurements for offshore Bangladesh. Estimated sea level trends are compared to trends derived from tide gauge data and their differences are interpreted in terms of unmodeled regional effects, such as land subsidence. The initial results give an indication on the magnitude of the contributions from the different sources at the coast of Bangladesh; e.g. the contribution from the Greenland ice-sheets between 2003 and 2011 (0.69 mm/yr) is significantly larger compared to that of the ice-sheets in Antarctica (0.15 mm/yr), but the biggest effect results from steric sea level changes (-1.5 to 6 mm/yr).
In upcoming stages of the BanD-AID project, the knowledge of the influence from the individual contributors to sea level rise and its combination with other regional effects will aid in a roboust prediction of future sea level rise and resulting social and socio-economic impacts in the Bangladesh region.

P 032

BAND-AID: COASTAL BANGLADESH VULNERABILITY DUE TO SEA-LEVEL RISE: AN INTEGRATED NATURAL & SOCIAL SCIENCE FRAMEWORK

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Approximately half of the world's population or 3.2 billion people lives within 200 km of coastlines and many of them in the world's deltaic plains. Sea-level rise, widely recognized as one of consequences resulting from anthropogenic climate change, has induced substantial coastal vulnerability globally and in particular, in the deltaic regions, such as coastal Bangladesh, and Yangtze Delta. Bangladesh, a low-lying, one of the most densely populated countries in the world located at the Bay of Bengal, is prone to transboundary monsoonal flooding, potentially aggravated by more frequent and intensified cyclones resulting from anthropogenic climate change. Sea-level rise, along with tectonic, sediment load and groundwater extraction induced land uplift/subsidence, have exacerbated Bangladesh's coastal vulnerability. Here we describe our integrated approach and initial results based on both physical and social sciences to address the adaption and potential mitigation of coastal Bangladesh vulnerability. We propose to build a robust Belmont Challenge identified Earth System Analysis & Prediction System (ESAPS) for coastal Bangladesh, to adapt/mitigate the detrimental hazards including sea-level rise. We will establish an advanced observation system based on contemporary space geodetic sensors to quantify causes of sea-level rise and land motion and their robust vertical datum link, and improve our understanding of human interactions that governs coastal vulnerability in Bangladesh. This knowledge will be used for the integrated development of a natural and social science framework employing robust predictive modeling towards the adaption of sea-level rise and other hazards in coastal Bangladesh. Our ultimate goal is to conduct physically based robust projection of relative sea-level change at the end of the 21st century for the Bangladesh Delta to enable quantitative measures of social science based adaption and possible mitigation.

P 033

MODELING THE IMPACTS OF RELATIVE SEA-LEVEL RISE ON DELTAIC RICE FIELDS

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River deltas are of paramount importance in terms of ecological and economic values. They are characterized as having fertile soils, and are consequently well-endowed for agricultural production. A significant portion of rice is produced in deltaic areas, especially in Southeast Asia and the Mediterranean. Deltas are particularly sensitive to global climate change effects (primarily sea level rise, SLR, to which land subsidence has to be added) by increasing the risk of coastal flooding, salt stress and shoreline retreat leading to wetland loss, crop damage and infrastructure destruction. This study focuses on the Ebro Delta (NW Mediterranean), an example of a subsiding delta subject to significant erosion, mainly caused by flow regulation and the large sediment deficit due to its retention in lower basin reservoirs. Most of the delta plain (320 km^2) is devoted to rice production (ca. 65 % of the total surface), being the main economic activity. Rice production is negatively affected by salt intrusion and elevation loss, and is likely going to decrease in SLR scenario.
As part of the European project RISES-AM (*Responses to coastal climate change: Innovative Strategies for high End Scenarios - Adaptation and Mitigation*), we developed a model to forecast the dynamics of rice production in the Ebro Delta under different SLR scenarios, according to IPCC predictions. The yield production model couples data form Geographic Information Systems with Generalized Linear Models. Several GIS datasets were included, such as digitalized geology, altitude, water bodies or shore-line, and used for deriving model parameters that exhibit considerable spatial variability within the delta. Additionally we obtained soil salinity data from over 1400 different agricultural parcels. The relationship of soil salinity to GIS data was analyzed with GLM, which was also used to predict soil salinity and yield production across the delta rice fields. Spatial data treatment, analysis and subsequent simulation were performed with QGIS and R.
Results indicated that altitude (negatively), soil geology and river distance (positively) were the most important factors for estimating soil salinity. Geologic units mostly consisting of clay and peat were less susceptible to soil salinity. The model predicts a reduction in rice production related to an increase in soil salinity under a SLR scenario. The impact of SLR in the Ebro Delta economy is discussed, as well as the applicability of the model in other deltas, and its utility for land users, rice farmers and decision makers.

P 034

OYSTER REEFS: OPPORTUNITIES FOR COASTAL PROTECTION AND AQUATIC FOOD PRODUCTION

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Coastal erosion represents a serious problem to many coastlines around the globe. One of the most striking examples of severe erosion is found in the near shore islands of Bangladesh. Loss of stretches of land puts the environment and

community livelihood in those areas under immense stress. To adequately deal with these threats innovative, cost-efficient and sustainable methods are required. The collaborative Dutch–Bangladesh project (ECOBAS) is exploring the use of ecosystem engineers (i.e., organisms that create or modify habitats) especially oysters in solving coastal erosion problems in Bangladesh.
Four different types of substrates i.e., stone, live oyster, windowpane shell and oyster shell were used to analyze oyster spat availability in the coastal waters of Moheshkhali and Kutubdia Islands (southeast coast of Bangladesh) and ecological parameters were monitored at regular intervals. Windowpane shell was found most suitable substrate for oyster spat settlement followed by live oyster, oyster shell and stone. Though environmental conditions were favourable for oyster growth and survival but siltation, water current and tidal energy were the threats to maintain reef substrates during the monsoon months. In this connection, 50 m long and 2 m wide concrete rings with 75 cm vertical relief was deployed on the lower intertidal mudflat to influence sediment deposition, stabilization and consolidation in Kutobdia Island. Monthly monitoring of eco-morphological effects indicate that sediment accumulation rate is promising and significant in the reef site with positive role on mangrove generation and salt marsh succession as well as habitat facilitation for fishes, shrimps, crabs and other invertebrates in the reef area. Moreover, the potential additional harvest of adult oyster from the reef development initiatives could make an important contribution to the overall food supply. More oyster harvest promotes household consumption and island dwellers to have more per capita protein intake. An enhanced harvesting, therefore, generates employment, fetches more cash and save malnutrition as well as ensure sound health. In addition, a comparative scenario will be drawn with the ongoing building with nature study on the use of oysters as eco-engineers for coastal defense in the Oosterschelde (NL), which will provide new information on the use of eco-engineers for economic use in combination with climate adaptation at two different geographical settings in Bangladesh and the Netherlands.

P 035

HOW COASTAL AND RIVERINE WETLANDS CAN ADAPTIVELY REDUCE FLOOD HAZARD

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Several recent studies point at the role that wetlands can play in decreasing flood hazard for many densely populated delta areas in the light of climate change. These studies emphasize the adaptive capacity of ecosystems as a key feature that makes them suitable for flood risk mitigation under unpredictable or highly varying future conditions. Yet, adaptive capability is mainly defined as the capacity of ecosystems to accrete sediment or organic matter under rising water levels and their ability to self-repair. Here we present a third adaptive feature that has not yet been acknowledged; the ability of ecosystems to reduce wave height to a fixed level irrespective of water level and incoming wave height. An important implication of these findings is that combined flood defenses with a coastal or riverine ecosystem situated in front of the levee, do not require immediate upgrading with changing hydraulic boundary conditions, e.g. water levels and wave height. This can result in substantial savings on construction and maintenance of infrastructural works in the future.

P 036

DYNAMICS OF THE TIDAL CREEKS OF BANGLADESH SUNDARBAN: AN INDICATOR OF SEA LEVEL RISE?

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Bangladesh Sunderbans delta formed at the confluence of Ganges-Brahmaputra-Meghna river system is a mixed river and tide dominated delta, with extensive low lying flood plains, mangrove swamps and saline creek system. The present day morpho-dynamics of the delta is largely controlled by the interplay of enormous sediment laden fresh water flow, strong tidal currents of a macro-tidal estuary , deltaic subsidence and rising sea level. Erosion and accretion in coastal areas and 'char-lands' are of common concern in the populous delta . The present paper aims to explore evolution of shape complexity of this deltaic margin over a time span of three decades through geomorphic investigation using Remote Sensing techniques. The research deals with the question whether the deltaic fringe irregularities are controlled by changing creek density in the region. Following the inductive reasoning system, it is observed, that the shape of the islands changes with the changing creek length and creek density in the mangrove swamp and adjoining area which in turn might be influenced by the local Sea Level Rise. The changes in the creek densities over three decades in the Bangladesh -Sundarban Delta have been estimated using multi temporal optical satellite imageries of the same spatial and optical resolution. With rising sea level , derived from tide gauge data and satellite altimetry, a steady increase of creek density and creek area has been observed in the islands of Bangladesh Sundarban delta, effecting the increasing trend of shape complexity of this tidally active region .

P 037

EROSION AND SUBMERGENCE OF NEW MOORE ISLAND FROM SUNDARBAN DELTA

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Rising sea level and loss of small islands is currently a matter of concern to the researchers involved in Global Change Studies. Loss of two small estuarine islands, Lohachara and Suparibhanga has been reported earlier from the Indian Sundarban, northern Bay of Bengal. The present paper reports the loss of another off shore island, New Moore, popularly known as Purbasha at the border of India and Bangladesh. The island first reported after a cyclone in 1970, was a matter of controversy between India and Bangladesh government over decades. The study reveals loss of New Moore Island within the time period of 1985 to 2000 from analysis of multi-temporal satellite images. The rate of erosion, of two other offshore islands Jambu Dwip and Maya Dwip situated along the similar latitude of New Moore, were also estimated within the same time period. A close relationship was found between the rate of erosion of small islands and the rate of rising sea level in the region as measured from the tide data at the Sagar Island and other observatories during the study period. The sea surface temperature analysis of the period 1990 to 1998 shows the increasing trend, indicating the thermal expansion of the sea surface. Also the sea surface height analyzed during the period 1993-2000 using satellite altimeter data of TOPEX/POSEIDON which showing a steady increase 1.229 cm/year sea level acceleration.

P 039

LONG-TERM SEA LEVEL VARIABILITY ALONG WESTERN AUSTRALIA AND ITS IMPACT ON LINEAR SEA LEVEL TREND ESTIMATES

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Prediction of near future sea level change in coastal areas often relies on linear trend estimates from past sea level records such as given through long-term tide gauge records. However, due to the presence of long-term variability such as decadal and multi-decadal variations and strong sporadic events, linear trend estimates can be seriously biased depending on the time period considered. This study quantifies the impact of long-term sea level variability on linear sea level trend estimates along the Western Australian coastline. Highly impacted by climate variability in the Pacific Ocean, Western Australian sea level is known to be influenced by considerable multi-decadal variability and strong sporadic events, thus making it an ideal study area within the South-East Indian Ocean. Based on the Fremantle tide gauge record, extending over more than one century, biases in linear sea level trend estimates are quantified through the comparison of short-term trend estimates with the long-term trend estimate taken over the entire 116 year record. Compared to a secular sea level trend of 1.5 mm/year relative biases (maximum difference divided by the secular trend) can be almost 100% (60%) for trends based on 40 (60) year records. This demonstrates the need to remove or model long-term sea level variability before estimating robust short-term linear trends taken as estimates for long-term trends (e.g. near future predictions). Further, comparing Fremantle sea level with other records along the Western Australian coast and beyond provides information on how representative are long-term sea level changes at Fremantle for other regions within the South-East Indian Ocean. This is a preliminary study within the Belmont Forum/IGFA Project BanD-AID (Bangladesh Delta: Assessment of the Causes of Sea-Level Rise Hazards and Integrated Development of Predictive Modelling Towards Mitigation and Adaptation) to be extended over the entire Indian Ocean including the Bay of Bengal and Bangladesh Delta.

P 040

SEDIMENT RE-CIRCULATION IN THE GANGES-BRAHMA PUTRA-MEGHNA ESTUARIES AND ITS IMPLICATIONS FOR ECOSYSTEM SERVICES

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The Ganges-Brahmaputra-Meghna (GBM) delta is home to about 100 million people who depend on the ecosystem services supported by this rich deltaic environment. The deltaic environment is largely influenced by the amount of

sediment coming into the system and the way these sediments are distributed within the estuarine systems of the GBM delta. In this paper, we compute the incoming volume of suspended sediments to the GBM delta and the way these sediments are re-distributed among the estuaries using the Delft 3D and HEC RAS unsteady flow models. The implications of flow/ sediment parameters on the ecosystem services(for example: fisheries) along each of the estuaries is also established.
The available estimates(FAP1993)indicate that the annual total sediment volume (including sand and silt/clay) reaching the GBM system is ~960 million tonnes, of which around 60% are comprised of silt/clay and 40% are sand. The sand fraction is important for delta building processes, whereas the silt fraction contributes to reshaping the estuarine system and supporting ecosystem services through re-circulation processes. Using the measured suspended sediment concentration data and simulated water discharge (from the 1D HEC RAS model)in the major rivers, the yearly average suspended sediment transport has been estimated. It is found that the annual volume of suspended sediment reaching the GBM system is around 580 million tonnes, which is very similar to the estimated values in FAP studies during 1990's, lending a degree of confidence to our model simulations.
The model resultsof water and sediment flow within the GBM estuarine system show that the clockwise recirculation processthrough which the incoming fluvial sediments (suspended)in the Meghna estuary (eastern most) are being redistributed into each of the estuarine systems (through clockwise recirculation)are the primary source of nutrients that underpin key ecosystem services. It is found that a deep estuary with a high flow velocity and low sediment concentrationattracts bigger fish species with less species diversity. On the other hand, a shallow estuary with low velocity but higher sediment concentrationattracts smaller fish species with high species diversity. Any change of this hydro-morphological regime due to either climatic or human activities will have significant impacts on fishery resources and species diversity.

P 041

SALINE CONSTRUCTED WETLANDS MAY ACCOMMODATE BIODIVERSITY DEMANDS UNDER CLIMATE CHANGE IN COASTAL AREAS

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Research question
Natural saline wetlands occur in settings ranging from coastal salt marshes to estuarine tidal marshes, shallow lagoons and mangrove swamps. Wetlands are nature's water purifiers, filtering water, regulating flow to allow sedimentation and removing nutrients and other pollutants. In the Netherlands, the delta functions are often sharply divided with dikes, with on one side the estuary with high biodiversity of fauna and flora (protected by Natura 2000), and on the other side intensively used agricultural and urban hinterland. Natural or constructed wetlands can serve as a bridge between these functions. Constructed wetlands utilize the ecosystem service of wetlands as water purifier and are used worldwide to purify a wide range of waste water sources, from freshwater, brackish and saline sources. We investigated the potential of saline constructed wetlands in temperate deltas (such as the Netherlands), and compared the nutrient removal efficiency of three salt tolerant plant species in a greenhouse experiment.

Research results
A major ecological benefit of constructed saline wetlands is that it can make up for losses of salt marsh and mangrove habitat worldwide due to land reclamation and embankment activities. However, despite the large body of knowledge on functioning and optimizing freshwater treatment wetlands, little is known on saline treatment wetlands,

especially for temperature regions. We investigated the removal efficiencies of three common Dutch salt tolerant plant species in a greenhouse experiment, *Aster tripolium, Bolboschoenus maritimus* subsp. *compactus* and *Spartina anglica*. This showed that of these three species, *Spartina* and *Bolboschoenus* had the highest nutrient removal. If a location is more saline, *Aster* is better suited, and for locations with large tidal influence, *Spartina* is the best choice.

Societal importance for stakeholders

We have combined these results with a general framework designed to optimize the choice for implementation of saline constructed wetlands in different application scenarios. One application is to implement constructed saline wetlands in land-based mariculture practices. The other application is to incorporate constructed wetlands as part of the transition zone from salt to freshwater, integrating various functions such as nature, water purifying, biomass production, water safety. Especially the second application can be of large importance for deltas in times of climate change and can provide a significant contribution to a sustainable delta management.

P 042

WATER RESOURCES CHANGE AND FOOD SECURITY: AN INTEGRATED STUDY FOR SUSTAINABLE DEVELOPMENT IN THE COASTAL AREAS

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The surface water resources of the Vietnamese Mekong Delta are highly complex due to the dense river network in conjunction with the operation of the existing hydraulic constructions and different requirements of land cover patterns (agriculture vs. shrimp farming systems). In addition, climate change is an ongoing and exaggerated phenomenon, leading to significant changes of the surface water resources and livelihood of local residents, especially those who are living in the coastal areas of the Vietnamese Mekong Delta. In this paper, water resources changes, given impacts of rainfall changes, sea level rise and hydraulic construction operation in the coastal areas of the Vietnamese Mekong Delta are evaluated. The existing and projected agro-ecological zones are presented as a strong base for agriculture land use plan in the study area. Consequent impacts of agro-ecological changes on yields of different rice farming systems in the area are also studied, providing decision-makers (at the provincial level) projected impacts of the climate change and in-situ hydraulic construction operation on the food security issues.

P 043

TIDAL RANGE VULNERABILITY OF THE BANGLADESH COAST

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Tidal Range of the Bengal Delta was calculated using tide-gauge data.
A significant variation in tidal ranges was observed. The highest and the lowest ranges were observed at the coast of Sandwip Island and along the Sundarbans coast respectively. Tidal range along the Sandwip Island was 6.01 m and Hiron Point station in the Sundarbans was found as 2.95 m. The second highest range was 4.48 m that was observed at the Sadarghat station in the Chittagong. Tidal ranges at Khepupara (Patuakhali), Char Changa (Hatia), Cox's Bazar

and Shahpuri Island (Teknaf) were assessed as 3.73 m, 3.56 m, 3.85 m and 3.37 m, respectively for the specific period. Sensitivity of the Bengal Delta Bangladesh coast was assessed on the basis of tidal range. Thus, the coast of the Bengal Delta was divided into five vulnerability classes of Very high, High, Moderate, Low and Very low, with tidal range of <3.5 m, 3.5-4.0 m, 4.0-4.5 m, 4.5-5.0 m and >5.0 m respectively. As a general pattern, northern part of the coast showed very low vulnerability and the southern part as very high vulnerable. A total of 203 km of the shoreline covering the Sundarbans Coastal Zone and part of Cox's Bazar Coastal Zone was identified as very high vulnerable coast. The whole of the Barguna Patuakhali Coastal Zone, part of Bhola Coastal Zone, part of Hatiya and Kutubdia islands and a significant part of the Cox's Bazar Coastal Zone were identified as high vulnerable coast. A total of 419 km of the shoreline was identified as highly vulnerable coast. The length of moderately vulnerable coast is 124 km that covers a small section in Bhola coastal zone, northern part of Hatiya Island, northern part of Kutubdia Island, a small section from the Chittagong coastal zone and a small section of the Cox's Bazar coastal zone. A length of only 75 km of the shoreline was identified as low vulnerability coast that covers almost half of the Noakhali Feni coastal zone and a big part of the Chittagong coastal zone. Very low vulnerable coast was identified along half of the Noakhali Feni coastal zone, half of the mainland Chittagong coast and the whole of Sandwip Island. Total length of very low vulnerable coast is about 115 km.Understanding tidal range variation will help for a better management of the delta that will faciliate 47 million population along the Bangladesh coast.

P 044

THE EBRE RIVER DELTA (NW MEDITERRANEAN): A CASE STUDY FOR CLIMATE CHANGE VS ANTHROPIC MANAGEMENT

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The Ebre River Delta (Biosphere Reserve since 2013) is one of the largest wetland areas (over 300 km^2) in the North-Western Mediterranean region. It is a flat area characterised mostly by rice fields, which is the main agricultural activity of the area, together with natural lagoons and marshes along the shoreline.
The Ebre River Delta is a typically temporary-flooded wetland. Rice culture management in this area requires maintaining the paddies flooded after rice harvesting to provide habitat for migrating birds and only just before rice seeding the soil is left non-puddled. These water management practices in the Ebre River Delta agro-ecosystem play an important role in the temporal and spatial variability of the atmospheric greenhouse gases (GHGs) sources and sinks.
A GHGs measurement station has been established at the Ebre River Delta Natural Park with the aim of studying climate interactions between land-surface and atmosphere by the Institut Català de Ciències del Clima (IC3) within the framework of the ClimaDat project, founded by the 'Obra Social la Caixa' (www.climadat.es). The station (DEC3) provides infrastructure for the study of atmospheric regional influences with a tower sampling point, as well as for the study of fluxes by open and close path eddy-covariance analyses over the natural wetland.
Since May 2012, the station (DEC3; 40º 44' 38' N, 0º 47' 12' E) continuously measures atmospheric greenhouse gases and tracers concentrations (CO2, CH4, CO and N2O), along with atmospheric concentrations of the natural radioactive gas 222Rn and meteorological variables (i.e. temperature, relative humidity, wind speed and wind direction). Air masses are sampled at a height of 11 m a.s.l, dried at dewpoint of -56 ºC and analyzed using: (i) a Picarro analyzer G2301 which measures concentrations of CO2, CH4 and H2O; (ii) a modified gas chromatography system (based on Agilent 6890N) which measures concentrations of CO2, CH4, CO and N2O; (iii) an atmospheric radon monitor (ARMON) for 222Rn measurements.

Data from the station are open, and they are included in the InGOS project. The main relevance of the DEC3 station is giving novel knowledge of the Ebre River Delta system as it is affected by the coupling/uncoupling of natural systems with human activities. Climate processes and water management from both the local activities and the watershed uses beat the rhythm of the integral biogeochemistry and metabolism of the land-surface vs atmosphere relationships. The DEC3 station was designed for the study of their variability.

P 045

OYSTER REEFS (CRASSOSTREA GIGAS) STABILIZE ERODING TIDAL FLATS UNDER THEIR FOOTPRINT

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The realization of a storm surge barrier and two secondary dams not only changed the hydrodynamics, but also the geomorphological characteristics of the Oosterschelde estuary (The Netherlands), creating a disequilibrium between erosion and sedimentation processes. Over the past 25 years, this has led to erosion of the tidal flats.

Due to this erosional trend habitat for intertidal soft-bottom benthic fauna slowly disappears, and with it, foraging grounds and food sources for estuarine birds. Furthermore, intertidal areas play a role in wave energy dissipation. As a consequence, disappearance of adjacent tidal flats will increase the risk of dike failures and flooding during storm surges, since dikes will become more exposed to wave action.

The Pacific oyster (Crassostrea gigas) is an ecosystem engineer that forms large dense reefs in the intertidal area in the Oosterschelde estuary. Recently, the potential of this ecosystem engineer as a coastal protection method for sediment stabilization and wave attenuation is being investigated. In this study we investigate erosion and sedimentation rates of intertidal areas covered by oyster reefs (i.e. under the footprint of the reef area) compared to bare tidal flats. Erosion and sedimentation rates were calculated using detailed long-term (1987 - till present) bathymetry transects.

Overall, intertidal flats in the Oosterschelde show a mean erosion of 0,012 m year-1. Whereas intertidal areas covered by oyster reefs show a mean sedimentation of 0,007 m year-1. A switch from erosion to sedimentation was observed on transects that over time switched from bare tidal flat to an area covered by oysters. The stabilizing effect that oyster reefs have on tidal flats, stress their importance as ecosystem engineers in an estuary that is dominated by erosion. Conservation of oyster reefs as well as construction of artificial reefs could be an important management tool for tidal flat protection and conservation.

P 046

HUMAN-MODIFIED VS. NATURAL LANDSCAPE DYNAMICS IN THE GANGES-BRAHMAPUTRA TIDAL DELTA PLAIN

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Research question

The most sediment starved regions of the Ganges Brahmaputra delta are located at the interface of the river- and tide-dominated portions of the delta, where the transport energy of small distributaries and the upper tidal zone approach zero. These regions are considered highly vulnerable to flooding from summer monsoon rains, peak astronomical tides, and tropical storm surges. Compounding the slow rates of sedimentation, these regions have been strongly affected by the construction of embankments (polders) that further starve the land surface of sediment, artificially de-water and compact shallow soils, and accelerate organic decomposition during the dry season. Elevation surveys and sediment cores, along with geotechnical and GIS analyses, were used to quantify land surface dynamics in natural and human-modified environments in these regions of southwest Bangladesh.

Key findings

Embanked landscapes have experienced a net elevation loss of more than 1 m relative to local water levels and the natural environment since construction in the 1960s and 1970s. Observed elevation differences have resulted from: (i) impeded sedimentation, (ii) enhanced compaction and consolidation of poldered soils during the dry season (30% loss in water, 50% consolidation), and (iii) removal and oxidation of mangrove wood following deforestation (attributing up to 20 cm elevation loss). In addition, analysis of the channel networks in the tidal delta plain reveal that constructed embankments have significantly decreased the density of naturally functioning tidal channels (-47%), inducing locally rapid bank migration and affiliated changes in sinuosity. These rapid landscape changes suggest that there has been a resultant change in hydrodynamics of the tidal delta plain following widespread construction of the embankments.

Societal importance

The acute effects of elevation offset were felt in 2009 when the embankments of several large islands in southwest Bangladesh breached during Cyclone Aila, flooding the landscape for ~10 hours/day (compared to ~2 hr/day in the natural landscape). Many failures were located where recent tidal channel migration had occurred. The assessment of landscape vulnerability to environmental change has resulted in renewed efforts to rehabilitate and stabilize embankments. In addition, practices to restore natural tidal exchange and sedimentation during the monsoon season (locally called Tidal River Management) are gaining traction in certain regions, yet remain controversial. Our results inform local stakeholders and decision makers of natural landscape dynamics and those persisting in the human-modified environment, in the hopes of supporting successful and sustainable coastal defense initiatives.

P 047

HUMAN PRESSURES AND PERCEPTIONS OF THE ADVERSE IMPACTS OF WATER POLLUTION IN THE SEMI-ENCLOSED BAY OF KALLONI, GREECE

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Fishermen communities are vulnerable to the adverse impacts of water pollution in the semi-enclosed shallow bay of Kalloni, Greece (Lesvos island, N-E Aegean Sea). DPSIR analysis revealed that land use changes (increase 10% of urban areas and 8% of agricultural areas) in the past 50 years (1961-2011), free grazing (3,380 ton BOD5 annually emission loads) and fishing practices in combination to low water renewal rates have gradually deteriorated the water quality and the biodiversity of the bay. Fishery (1,500 ton/yr) and shellfish (262 ton/yr) landing may facing problems due to increased pollution and reduction of freshwater influx. MOHID modeling system was coupled to the Soil and Water Assessment Tool (SWAT), a physically distributed model to assess the human impacts on water quality and predict the possible effect of the planned reservoir construction (12 Mm3 storage capacity) on freshwater influx in the bay. We surveyed Kalloni users such as farmers and fishermen and found that even though bay pollution is of high priority for them, only around 4% of them attribute it to their activities. The knowledge gained from this study is essential to researchers and policy makers in identifying potentially effective adaptation and mitigation policies and measures.

P 048

URBMOBI - A MOBILE MEASUREMENT DEVICE FOR URBAN ENVIRONMENTAL MONITORING

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Due to anthropogenic climate change the urban population is exposed to increasing air temperatures and reduced air quality. To plan adequate adaption and mitigation measures, detailed knowledge of thermal and air quality hot spots is required. Therefore, in different fields of urban research and administration - such as urban planning - spatially and temporally high resolution environmental data are important. Usually, data of fixed stations is interpolated and downscaled to show e.g. the structure of the urban heat island, not taking into consideration that environmental data within a city are highly variable in time and space.
Within the Urbmobi research project, a novel mobile measurement unit is developed. This unit integrates state-of-the-art sensors for environmental variables embedded in a system that allows mobile usage and easy data handling based on geo-location technology and data transmission by telecommunication networks. In its first version, measurements will include air temperature, relative humidity and solar radiation. The unit might be operated on vehicles of public transport systems like buses, trams, taxis or other private or public operated vehicles cruising urban areas. Urbmobi fulfills the need for monitoring various locations without the large costs for deploying a large number of fixed meteorological stations.
Integration of the Urbmobi measurements into climate and air quality models (WRF, SWIFT) will provide climate services and environmental data for a wide range of applications, for instance for public health issues, urban and regional planning, and real estate development. Possible applications are: mapping the urban heat island effect, identifying hot spots and comfortable neighborhoods, predicting heat stress situations and warning vulnerable

citizens, improving urban weather forecasts and developing and evaluating climate-proof urban plans and designs. Special focus of Urbmobi is on the spatial variability of thermal comfort within cities, since thermal comfort is a variable that is more relevant with respect to heat-related effects and health issues than air temperature.
Urbmobi is a new project of the European Institute of Technology (EIT) Knowledge and Innovation Centre (KIC) related to climate issues that started in August 2013. Within Climate-KIC the Urbmobi consortia is constituted by the Department of Geography of RWTH Aachen University, the Technical University of Budapest, TNO from the Netherlands, and two companies, ARIA from Paris, France and MEEO from Ferrara, Italy.

P 049

THE IMPACT OF URBAN GREEN SPACES ON RESIDENTS' OUTDOOR THERMAL COMFORT - A PSYCHOLOGICAL AND PHYSICAL APPROACH

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Green infrastructure has the ability to improve thermal comfort in outdoor urban spaces in moderate climates such as in The Netherlands. Green spaces, like parks, act as 'cool islands' within cities and are thermally comfortable places for outdoor activities on warm summer days. Up to now, the impact of greenery on thermal comfort, however, was only studied in physical terms, using meteorological variables and human-biometeorological indices. Little is known about the role of green spaces on people's behaviour and generally perceived outdoor thermal comfort. Therefore, we studied the impact of green spaces both from a psychological and a physical perspective. We obtained comprehensive insights into the impact of green spaces on outdoor thermal comfort through answering the following research questions

(1.) How do people generally perceive green places in urban environments during warm summer days with respect to thermal conditions?

(2.) What are the physical thermal comfort conditions in urban green areas (during daytime on warm summer days)?

To identify impacts of green spaces on perceived thermal comfort we investigated inhabitants' long-term perception of thermal comfort on warm summer days in three Dutch cities in 2011/ 2012. In order to find evidence for people's perception in the urban environment, we additionally examined the daytime cooling effect of green spaces in Utrecht. To do so, we used bicycles equipped with micrometeorological sensors in summer 2012. We compared thermal conditions of 13 parks with conditions in the city centre and in the open grassland outside the city and analysed dependences with spatial variables of parks (size, tree canopy, upwind vegetation cover).
Our results demonstrate that green spaces generally enhances perceived thermal comfort. People evaluate green urban spaces as the most thermally comfortable spaces. The physical data we obtained show that the physiological equivalent temperatures (PET) in parks are on average 1.9 K lower than in the city center and 5 K lower than in the surrounding grasslands during the hottest period of the day. Thermal variation between the parks is significantly

related to tree canopy cover and upwind vegetation cover. In contrast, no significant relationship with park size is found. In general, our study indicates that there is a good fit between people's perception of urban green and its physical impact on thermal conditions. Our results emphasize the need to preserve, maintain and develop green infrastructure in cities, to ensure residents' thermal comfort in present and future urban environments.

P 050

ASSESSMENT OF IMPLEMENTATION STRATEGIES FOR CLIMATE ADAPTATION MEASURES IN DUTCH SOCIAL HOUSING

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Abstract
Housing providers have to keep adapting their building stock to keep pace with the dynamic changes in the urban environment. One of the main drivers of adaptation is climate change, caused primarily by the accumulation of human-induced greenhouse gases. In urban areas, the main impacts of climate change are drought, flooding from extreme precipitation, and heat stress. Climate change not only threatens the building stock, but also the quality of life of people living and working in urban environments. In the Netherlands, housing associations have strong interests in and responsibilities for managing the social housing stock and maintaining quality of life, but they seem scarcely aware of the challenge that lies ahead in terms of adapting their stock to make it resilient to the exigencies of climate change. This paper focuses on physical adaptations to the housing stock and discusses the likelihood of five implementation strategies for climate adaptation measures as assessed by decision-makers in Dutch housing associations in an online survey. The strategies combine the conceptual approaches policy making, involvement by external players and carrying out construction projects in a partnering approach, added with one extra strategy that assigns a central position to the occupant of the dwellings.

Research question
Which strategies do housing association employees regard as most likely to lead to the implementation of climate change adaptation measures?

Results
None of these strategies offered strong prospects for effectiveness for the whole population of housing associations. Nevertheless, a large number of housing associations do see opportunities in this domain.

Societal importance
The housing associations that assessed the implementation strategies positively are the ones to focus on in the next step towards making the social housing stock climate-proof. Moreover, governance arrangements for the implementation of climate change adaptation measures that focus on a combination of development of policy guidelines, involvement by external players, partnering in construction and assigning a central position to the tenant are have the potential to start up a movement towards making the social housing stock climate-proof.

P 051

OUTDOOR THERMAL COMFORT WITHIN THE ROTTERDAM AGGLOMERATION AS INFLUENCED BY CITY DESIGN

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Societal importance

In the next 50 years, sustainable urban planning faces two major challenges: first, addressing the impact of urbanization and second, that of climate change. Both developments will significantly influence future urban climate conditions, thermal comfort of citizens and liveability of urban areas. The results of the present study give important insight in the potential effectiveness of adaptation measures to mitigate the impact of climate change on UHI and outdoor thermal comfort in urban areas in the Netherlands.

Research questions

We examine the temporal and spatial variability of climate and outdoor human thermal comfort within the Rotterdam agglomeration. The main research questions are: 1) how large is the intra-urban variability in climate and thermal comfort, and 2) to what extent is this variability determined by local features? We analyse three years of meteorological observations (2010-2012) obtained from a monitoring network that is operational since 2009 and consists of 14 Automatic Weather Stations. To get an indication about the impact on human thermal comfort, the Physiologically Equivalent Temperature (PET) is calculated from the meteorological data. Subsequently, we assess the dependency of intra-urban variability in local climate and in PET on urban land-use descriptors and geometric characteristics.

Results

Our results show that during a large part of the year nocturnal UHI intensities in the densely built areas can be considerable, under calm and clear (cloudless) weather conditions. The highest maximum UHI values are found in late spring and summer, with 95 percentile values ranging from 4.3 K to more than 8 K, depending on the location. In winter UHI intensities are generally lower. The intra-urban variability in maximum UHI intensity is considerable, indicating that local features have an important influence. It is found to be significantly related to the building, impervious and green surface fractions, respectively, as well as to aspect ratio and mean building height.
In summer, urban areas show a larger number of discomfort hours (PET >23 °C) as compared to the reference rural area. Our results indicate that this is mainly related to the much lower wind velocities in urban areas. Also the intra-urban variability in thermal comfort during the day appears to be mainly related to differences in wind velocity. After sunset, the UHI effect plays a more prominent role and hence thermal comfort is more determined by this phenomenon.

P 052

OPPORTUNISTIC ADAPTATION OF ARCHITECTURE AND URBANISM

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Adaptation is more and more conceived as a bottom-up socio-economic process rather than as a set of stand-alone adjustments, taking a more dynamic view of adaptation by combining climate change with socio-economic drivers. This has been referred to as 'adaptation mainstreaming'.This research provides insight into the potentials of mainstream adaptation with renewal cycles of components of the urban fabric by assessing the adaptation rate and potential for adaptive measures across different spatial scale levels (individual building, block and neighborhood level). Instead of the traditional top down and stand alone adaptation interventions, synchronizing mainstream adaptation at neighborhood level provides opportunities to consider the urban services in an integrated way and to identify multiple benefits which will lead to an improvement of the urban performance as a whole.
The questions arise: what are the potentials in practice for opportunistic adaptation on the building block, and neighborhood level in typical Western and Asian cities? Is there a large differentiation in the expected end of the lifespan or can clusters of assets be identified that reach the end of life cycle at the same point in time? Can a catalogue of adaptation measures be developed for different groups of assets (e.g. 2 houses, house-street, house-street-square, block, block-street, etc.)? Can the measures in this catalogue be flexible (or generic) enough, such that they would become models that can be applied to an existing? Opportunistic adaptation calls for strategic planning and long-term thinking. What are the future scenarios when applying such measures while using a scenario that: a) uses a strict end of life cycle approach b) relaxes the constraints so groups of assets can be adapted at the same future point in time c) relaxes the constraints even more to provide opportunities for the future adaptation of the complete neighborhood?
We use future projections (of lifecycle and urban growth modeling) to analyze the potentials for opportunistic adaptation and to assess alternatives of adaptation interventions of the building and infrastructure in the urban flood risk area. These interventions are important factors impacting the form and space of the urban fabric as well as the urban performance as a whole, e.g. adaptation measures, scale of measurement, protection standard and multiple benefits.

P 053

URBAN TRANSPORTATION, WEATHER AND CLIMATE CHANGE

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Transportation and travel demand are strongly affected by weather. Accordingly, a long-term weather pattern change, i.e. climate change is expected to impact transportation, transportation infrastructure and travel demand. At first, we estimate the weathers' effect on cycling, car use and car speed according to a 12 year data set for Rotterdam. Afterwards, we use the estimates to predict the impact of the IPCC climate change scenarios on urban travel for the next 20 years. The results are mixed. An increase in the occurrence of adverse weather would temporarily reduce travel demand, especially for cycling, and might increase welfare reducing road congestion. In comparison, we expect a mean temperature increase to increase travel demand. However, we suspect that other travel determinants such as transportation policy, technology, demographic and social factors rival the predicted impact of climate change.

P 054

THE POTENTIAL OF MODULAR FLOATING URBANIZATION FOR FUTURE URBAN SPACE

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What are the practical options for incrementally developing floating urban space on coastal waters that can expand into larger neighborhoods and eventually become cities, taking into account environmental influences such as wave behavior, bathymetry, and climate?
Design objectives first assessed constraints of developing modular floating structures including movability, dynamic geography, seakeeping, water experience, growth development, and safety. A site location was arbitrarily selected for the exercise of assessing local conditions including bathymetry, tides and currents, waves, wind, climate, precipitation, ocean energy production, and available nutrients. Taking into account the aforementioned variables, platform sizes, building sizes and construction materials were evaluated. Sustainability and ecological betterment were considered. Finally, a cost model was developed and growth strategy and growth dynamics were articulated. The results include a concept design of how modular components consisting of 50M sided squares and pentagons with three-story buildings and 20% open space could develop from a few platforms in protected waters with 10s of people to a small village with hundreds of residents, to a large city on the open ocean with tens of thousands residents. Taking into account many constructions variables, we estimate that real estate could be developed at the case study site for approximately 4,019 euros/M^2, comparable to major metropolises in developed nations. It was concluded that a village of 11 platforms housing 225-300 residents at the case study location, could operate sustainably by harvesting rainwater and generating energy through a solar powered micro-grid. Concrete was chosen as the best material to build the foundations considering costs, durability, and life expectancy. In order to eventually move the city to the open ocean, a floating breakwater would need to be constructed that could encircle the city; a model to finance the development of the breakwater was developed.
Currently about 40% of the world's population lives within 100 kilometers of the coast. Delta and coastal cities are facing rapid urbanization, with an increase of population and economic activity. Cities that have no more possibilities to grow or only have locations too far away from the city centers often turn to land reclamation. Floating urbanization can offer a more sustainable and climate adaptive way to expand, and expansion to the open ocean can offer humanity a new frontier experiment with new societal structures. Important findings for urban planners and politicians are that it is technically and economically feasible in locations such as our case study.

P 055

EXPANDING COASTAL ADAPTATION IN NEW YORK CITY: A FRAMEWORK FOR FLOATING STRUCTURES AND ITS CO-BENEFITS

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Research question
How can New York City's regulatory framework regarding waterfront development be expanded to increase the role of floating structures in coastal adaptation?

Methodology
A literature review was conducted of city, state and federal climate adaptation plans and coastal regulations in order to understand the existing pathways and frameworks for coastal development, adaptation and resiliency. Interviews with government officials and policy makers were conducted to further nuance the bureaucratic relationship between the varying frameworks of governmental agencies - identifying points of conflict and synergy. The feasibility of realizing certain co-benefits was analyzed against these results.

Research results
Currently, there is no regulatory framework or permitting mechanism for floating structures in New York City. The development of floating wetlands has been identified as a strategy for coastal adaptation, but the current jurisdictional complexity and regulation impedes the implementation of water based construction projects. However, by making targeted changes at points of conflict between policy and regulation, floating structures, and their co-benefits, could become a viable component of coastal adaptation in New York City.

Societal importance for stakeholders
By identifying inhabitable floating structures as a piece of the long term vision for New York Harbor, the City can take incremental and strategic steps to form the necessary building blocks of this vision. Creating regulatory space that allows for the implementation of floating wetlands is the initial step towards the eventual permitting of floating structures that support a more robust set of services. Pursuing floating urbanity creates a new opportunity for the City to address the chronic affordable housing shortage, need for community facilities, lack of waterfront access, as well as facilitate the realization of goals outlined in Vision 2020 and PlaNYC, two long-term sustainability plans for New York City. The resulting development from the creation of this framework would allow for a new real estate paradigm, based on the leasing of city-owned water plots. This new revenue stream could be reinvested into the resiliency, community development, and environmental justice needs of adjacent communities. Additionally, floating structures can create a transitional boundary at the urban edge, where integrated and complementary elements of hard and soft infrastructure create synergies that benefit both human and ecological habitats.

P 056

URBAN CLIMATE MAPS AND MICRO CLIMATE ADAPTION STRATEGIES TO REDUCE SOCIAL VULNERABILITY CAUSED BY CLIMATE IMPACTS

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The ongoing climate change is influencing our environment, but the effects caused are not always the same. Especially urban and dense populated areas are highly affected, and the developed existing social structures as well as the built-up areas can act like a multiplier for the intense of the climate change.
To detect and generate a climate footprint it is necessary to elaborate an Urban Climate Map (UCM) in the Geographic Information System (GIS) to define different (not functional land use bound) climatopes, which first can be used to estimate overheating potential and second describe the possible climate functions of the plots. Together with demographic and social data, geo-statistical analysis establish the linkages to high-risk groups of the community and vulnerable urban parts.
However this meso scaled view is only one part of the game. By reaching this stage, it is possible to focus closer on the micro climate level, because micro- and meso climate aspects are clinged together by direct and indirect correlations. This means that it is important to reflect the meso scale level to avoid mistakes when analysing and evaluating the microclimate. To reduce the gap between meso and micro an interim step seems to be helpful. On local scale the bigger parts of the urban area are analysed in GIS. Away from the meso scale, factors like ventilation, solar radiation, greenery and shadowing are objects of investigation.
When focusing on the microclimate conditions it is useful to leave back the GI-System and use numerical simulation models like ENVI-met. Limited to a ‘small’ manageable research area this model is in touch to simulate realistic microclimate conditions by using physical correct equations. In spite of this, it won’t be possible to model and simulate reality, but very close to it. At this level hotspot analysis are done and new scenarios will be simulated to evaluate the effect.
In summary, the declaration of intent has to start at the whole urban area. Here the urban climate maps are needed to give and guide planning strategies for social vulnerable high-risk groups and future development. After this first step, zooming to the important quarters and modelling hotspots will be one way to solve and reduce climate stress hotspots. Take the climate and the climate change into account for future urban planning aspects to increase the climate resilience of the community and decrease the future social costs.

P 057

MODELING THE INFLUENCE OF OPEN WATER SURFACES ON THE SUMMERTIME TEMPERATURE AND THERMAL COMFORT IN THE CITY

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Due to the combination of rapid global urbanization and climate change, urban climate issues are becoming relatively more important and are gaining interest. Compared to rural areas, the temperature in cities is higher (the urban heat island effect) due to the modifications in the surface radiation and energy balances. This study hypothesizes that the

urban heat island can be mitigated by introducing open surface water in urban design. In order to test this, we use the WRF mesoscale meteorological model in which an idealized circular city is designed. Herein, the surface water cover, its size, spatial configuration, and temperature are varied. Model results indicate that the cooling effect of water bodies depends nonlinearly on the fractional water cover, size, and distribution of individual lakes within the city with respect to wind direction. Relatively large lakes show a high temperature effect close to their edges and in downwind areas. Several smaller lakes equally distributed within the urban area have a smaller temperature effect, but influence a larger area of the city. Evaporation from open water bodies may lower the temperature, but on the other hand also increases the humidity, which dampens the positive effect on thermal comfort. In addition, when the water is warmer than the air temperature (during autumn or night), the water body has an adverse effect on thermal comfort. In those cases, the water body eventually limits the cooling and thermal comfort in the surrounding city, and thus diverges from the original intention of the intervention.

P 059

QUANTIFYING LOCAL IMPACTS OF REGIONAL ADAPTATION MEASURES IN THE URBAN ENVIRONMENT

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According to present-day climate projections the atmospheric temperature (both maximum and minimum) will rise, and precipitation is expected to change as well compared to the current climate. These changes will have a major impact in the urban environment. The focus on this paper will move from the transient effects of climate change to the changes in extremes in both temperature and precipitation.
It it hypothesized that land use in the surroundings of major cities influences the urban environment and will therefore be an interesting adaptation measure. A fine-scale atmospheric model (RAMS) coupled with an urban parameterization scheme (TEB) is used to investigate the impact of temperature and precipitation in the urban environment of the city of Rotterdam. The possible role of land use in the region surrounding the city on urban meteorology is investigated. To that end, the model is run with different configurations of land use. The analysis will focus on the sensitivity of temperature and precipitation extremes to changes in the land use from grasslands (dominant land use at present) to forest. Results from earlier studies for Paris showed that the effect of a change in land use may be in the order of 2-3 degrees Celsius.

P 060

CLIMATE CHANGE AND WATER CONSERVATION EFFECTS ON VEGETATION PATTERNS IN A STREAM CATCHMENT

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Research question

What are the effects of climate warming and precipitation changes on water quantity, quality and vegetation patterns in a stream catchment, and how are these effects influenced by water conservation measures?

Methodology & results

We performed an integrated hydrology-vegetation modeling study. We analyzed two climate change scenarios (W and W^+) and one water conservation scenario. The climate change scenarios represent a global temperature increase of 2 °C. In one scenario the amount of precipitation increases (W scenario), while in the other the precipitation increases in winter, but decreases in summer (W^+). For the water conservation measures the groundwater level around the stream was increased to ensure sufficient water availability for agriculture and nature, while preventing flooding in urban areas. Both scenario types were combined to test whether water conservation measures could reduce the potential negative effects of climate change.

There were large spatial differences in the changes of water quantity and quality. Groundwater tables and seepage flux increased in the W scenario, while both decreased in the W^+ scenario. The water conservation measures led to an increase of the groundwater levels while the seepage flux decreased. In some parts of the stream the seepage flux switched to an infiltration flux. The W scenario enhanced the water conservation effects, where the groundwater level increased even more, although the seepage flux decreased less. In the W^+ scenario the groundwater level rise was reduced and the seepage flux decreased even further.

The W scenario without water measures had little impact on the vegetation communities. In the W^+ scenario, wet herbaceous vegetation communities decreased, while dry herbaceous communities increased. The water conservation effects increased the semi-terrestrial vegetation types and decreased moist forest and dry herbaceous vegetation types. The increase of semi-terrestrial vegetation was even higher in the W scenario with water conservation measures. In the W^+ scenario there were large spatial differences, were both semi-terrestrial vegetation types increased, as well as dry forest types.

Societal importance

Our integrated hydrology-vegetation modeling approach allows to simultaneously assess impacts of water quantity and quality on vegetation patterns, which is required to implement the right nature management in a future climate. This study shows that water conservation effects are effective in increasing water availability in a catchment, although these effects are influenced by climate change. This requires developing climate robust water conservation measures (‘no-regret’ options) that can be effective in multiple climate scenarios.

P 061

SPATIAL MODELLING OF THE ASSOCIATION BETWEEN AGRICULTURAL LAND USE AND POVERTY IN THE GANGES-BRAHMAPUTRA DELTA

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Within the broader integrated aims of the Ecosystem Services Poverty Alleviation in Deltas project (ESPA Deltas/DFID/NERC/ESRC) a key project aims is to explore and elucidate the potential associative spatial linkages between *spatial poverty* variables and a range of *ecosystem services* provision within the defined coastal study site of south western Bangladesh Delta. This approach involves the development of an associative model elucidating spatial statistical associative relationships between land cover (as a proxy for ecosystem services and food security) and poverty outcomes as defined by an index of census variables. This work specifically examines the 2010 Bangladesh census survey in the light of contemporary 2010 land cover mapping. The study aims to adopt robust geospatial statistical techniques to converge on a clear set of strategic level rules that address such questions as what levels of relative poverty are associated with specific land use food provisioning types which have a relevance to food provisioning (e.g. mangrove or irrigated agriculture) and does infrastructure and environmental degradation (e.g. Salinity) have a specific association with the spatial distribution of poverty.

This paper employs spatial autocorrelation and spatial regression techniques to examine the independent relationship between such variables in the coastal regions of Bangladesh, accounting for important land use and socioeconomic factors with spatial autocorrelation techniques used to measure the degree of spatial heterogeneity of poverty within and between the Unions (i.e. the smallest planning unit) in this region. Tests of spatial autocorrelation are used to investigate significant differences in the clustering of poverty. Geographically Weighted Regression (GWR) techniques are then used to examine the adjusted effect of land cover on poverty, accounting for other important predictors, conditioned on the spatial location of the Unions in the analysis.

This work represents the first stand alone outputs in a strategic process to develop a rule base between the land cover/provisioning characteristics of the study area and the associations with poverty outcomes in order to feed into a broader policy support process to allow decision makers to consider climate change adaptation and food security options on the delta. The intention would be to then validate this rule base utilising historical data sets of the census and land cover for 2001 and 1991.

P 062

LIVELIHOODS IN TRANSFORMED FLOODPLAIN: A CASE OF FLOOD POLDER IN SOUTHWEST BANGLADESH

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Uses of ecosystem services for sustainable livelihoods are drawn attention of political and academic world in the recent juncture of paradigm shift of education and development intervention processes. Optic of interdisciplinary education and research is well accepted in the processes of paradigm shift. This article provides explorations of

sustainable livelihoods practices using ecosystem services in a polderized floodplain of southwest Bangladesh. This polderization was created during 1960s to protect the tidal floodplains from saline water intrusion and storm surge. The polderized tidal floodplains were brought under intensive rice cultivation. Farmers were benefitted from increased yielding up to 200 - 300%.
But, after a decade of polderization, the large farmers, and the businessmen introduced shrimp farming in the polder because export market of shrimp was lucrative. Over a period of 10/12 years, most of the polderized areas were brought under shrimp farming by displacing rice. This shrimp farming has generated transformation in biophysical and social processes. This article elucidates the forms of livelihoods practices in transformed biophysical and social landscapes. Our interdisciplinary research explored that the interplays in biophysical and social processes in polderized area are constructed in conflicts, contestations and counter-development. Livelihoods practices are socially constructed in indigenous and local knowledge of the social actors. Uses of ecosystem services in reshaped biophysical processes are practiced by applying knowledge interface.
This article provides social and biophysical complexities in using ecosystem services of polderized area. The article suggests that though the flood polders can provide enhanced flood protection, but causes destruction to ecosystem services. Local initiatives bring options of addressing the complex of social-physical delta systems towards efficient and effective uses of ecosystem services for sustainable livelihoods.
This research was conducted during 2012 and 2013 in polder no. 28/2, which is located under Dumuria Upazila of Khulna district. The central research question was how transformation practices shape ecosystem services and livelihoods practices in a polderized tidal floodplains. How local people's initiatives are constructed in changing deltas for their sustainable livelihoods.
Literature review was done in this research. In-depth interview, group discussion, focus group discussion, transect walk, and observation method were used to collect primary data.

Keywords
Flood polders, tidal floodplains, ecosystem services, sustainable livelihoods, and counter-development.

P 064

AUTOMATED ASSESSMENT OF ROAD STABILITY FOLLOWING FLOODING OR EXTREME RAINFALL

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Losses to the European transport system due to extreme weather conditions are estimated at least 15 billion Euros annually. Ensuring safety under all weather conditions and improving reliability and availability will help reducing fatalities, injuries and economic losses. Changing climate conditions will require transport infrastructure to adapt to the impacts.
It will not be possible to make a road or transport system totally resilient to climatic events by physical changes to the infrastructure, and certainly not at an acceptable economic cost. Alternative strategies may include risk based adaptation (apply measures only where needed), early warning systems (providing real-time assessment of road integrity and trafficability) and improving post-event management (real-time assessment and prediction of availability). This paper presents a key single component of such system for road infrastructure, a computer model for the real-time and automated assessment of stability of embankments threatened by flooding, extreme rainfall or drought. The assessment is based on prediction of the time-dependent effects of forecasts of precipitation and flooding and provides updating of the prediction model in response to observations from remote sensors.

The model was developed in the Dutch Knowledge for Climate research program as part of the Infrastructure Networks Climate Adaptation & Hotspots (INCAH) project. The model couples an agro-meteorological model to a groundwater flow model. The calculated water pressure fields support a stability analysis of the embankment slopes and the analysis of bearing capacity of pavement and verges. The model also allows the prediction of effects of drought such as desiccation cracking. The assessment model can be linked into the flood early warning FEWS, which provides a tool for scenario studies and real-time assessment.
The paper will describe the modular architecture of the model, the embedded models for wetting-drying, groundwater flow, stability and bearing capacity, and the updating procedure on the basis of input of remote sensors. The model is demonstrated in a section of the road network in the Rotterdam area.
The paper will also explore options for future development of the model, including integration in systems for vulnerability assessment, early warning and post-event management and extension to other climate change impacts. The reliability and versatility of the model may be improved by considering alternative inputs from multiple sensors, remote sensing and in-car systems. Requirements for the development of software architecture and user interfaces will be identified, based on experiences in the development of similar systems for Dutch flood protection.

P 065

THE PRESENT AND FUTURE SITUATION OF LAND SUBSIDENCE IN MEKONG DELTA

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Research question
Mekong delta is one of the high vulnerable regions due to global climate change and global warming. Especially, expanding inundation region due to sea-level rise and the other factors related to global climate change will be the most severe problem. In addition, it is known that land subsidence has taken place in Mekong delta but it is unknown how amount of settlement has cause in the region. The purpose of this study is to understand the present and future situation of land subsidence in Mekong delta, quantitatively.

Methodology
In order to investigate land subsidence in Mekong delta, InSAR (Interferometry Synthetic Aperture Radar) technology has been used. Computer software SIGMA-SAR (M. Shimada, 1999) has been used for analysis of observed variation of the ground surface in this study. Dataset of InSAR has been used JERS-1 image data received by the December 28, 1993 and January 1, 1997, and modified SRTM3 as DEM (Digital Elevation Model) because original SRTM3 has been modified because it has included some unexpected values. Land subsidence map has been represented from the InSAR results and representative land subsidence regions in Mekong delta have been identified. Finally, the future settlements in the representative regions have been predicted by using observational prediction method (S. Murakami et. al, 2000).

Research results
Land subsidence map by InSAR shows severe settlements have taken place in Ho Chi Minh City (HCM), My Tho, and Can Tho. Settlement rate is around 5-10mm/year in HCM and around 15-20mm/year in My Tho and Can Tho from 1996 to 1998. The future situations of land subsidence in the representative region of HCM, My Tho and Can Tho until 2100 are different from each other. Settlement in HMC continue to progress in 2100. On the other hand, future settlement in My Tho and Can Tho will come to an end.

Societal importance for stakeholders
Land subsidence accelerates due to human activities such as excessive abstraction of ground water, construction of heavy building and so on. So, it is important for thinking suitable adaptation to global climate change to observe the settlements and related information over time because inundation damage due to sea-level rise and the other factors related to global climate change increases with progress of land subsidence.

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P 066

CLIMATE CHANGE AND ITS EFFECT FOR DRINKING WATER IN THE MEKONG DELTA IN VIETNAM

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Research questions
The Mekong Delta is facing the consequences of climate change, making the available rains more volatile, contributing to a rise of the sea level and increased salinity. Also subsidence of the soils due to the use of wells is a serious problem in HCMC. The Mekong River Basin is also prone to seasonal droughts, a risk that may be further exacerbated by climate change. Some utilities face problems with their current wells, which are not producing enough, or polluted and often too salty water. One alternative is using surface water, which is being pushed by higher levels of government and further subsidence through pumping could be prevented by regulating the use of ground water, for example through metering and imposing a charge or by eventually not allowing it any more, Given the length of Vietnam's coast and the number of cities on the coast the salinity of the drinking water resources is considered the biggest problem.

Research results
The paper reviews the climate adaptation plans of Vietnamese utilities (SWC, 2013). Climate change adaptation plans should be available early 2014. Not much attention has been given to governance issues in climate change. Grumbine et al. (2012) argue that the extensive hydropower program under way in the upper Mekong will transform the Mekong by altering the natural flow patterns and disrupting eco system services. They link these developments to ongoing regional governance issues and suggest how decision making in a complex setting can be improved. The same concern is expressed by Bass and Nguyen (2013: 171) which mention: ''issues of jurisdiction and coordination (which) mean that huge infrastructure projects will take a long time". Similar problems are expected for the utilities, when trying to implement their adaptation plans.

Societal importance for stakeholders
More adaptive water management strategies are needed to deal with uncertainty and the increasing number of stakeholders. They may not always fit into the existing urban governance structures (Van Dijk, 2012).

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P 067 CLIMATE CHANGE COMPLIANCE FOR MOBILITY BY SNCF

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In the field of rail transport, climate change raises very concrete challenges. The infrastructure is already under heavy stress and suffers from waves of heat that distort the rails and from floods that can disrupt traffic. Passenger comfort raises additional problems. How can we adapt to these changes? How can we anticipate them? SNCF has think about these problems for several years and are beginning to design new strategies of action on the short, medium and long term.

SNCF has taken part in this reflection by creating a working group that brings together specialists from different areas of the firm while involving external professionals and experts.
Rather than making a specific study for each of the components of the rail system, we have chosen to implement a systemic approach. A central issue was to define strategic directions for the adaptation of activities. The six key steps described in The Economics of Adaptation to Climate Change by Christian de Pertuis (2010) served as reference.
After an initial phase of identification of the impacts of climate change, their timeframe and of the vulnerability of zones, it was necessary to identify priority adaptation measures based on the identified impacts. An assessment of the priority measures and the selection of these measures, consistently with the overall strategy, helped finalize the study phase before moving to the operational phase.
By taking into account these different examples, SNCF has built its adaptation strategy. The heart of this strategy is based on a series of “no regret”measures, that is to say measures whose cost/benefit balance remains positive independently from the pace of climate change.
The whole set of measures is divided into three parts:
- the creation of a knowledge base to refine the measurement of risks and associated losses to assess better the feasibility and cost of technical solutions.
- the development of tools for support to the different relevant timeframes: crisis management in emergency situations, prevention plans and investments on the medium term.
- the mobilization of internal and external stakeholders without which SNCF cannot take action: staff, organizing authorities, public authorities, customers.

Technical solutions are already known - although newer, and more efficient, solutions could emerge thanks to technological advances. These solutions are already implemented by the operators present in countries with a harsher climate than ours; they are also implemented as crisis management solutions by SNCF during extreme weather events.

P 068

ADAPTATION OR MAL-ADAPTATION TO A CHANGING CLIMATE: GOVERNANCE OF CLIMATE ADAPTATION IN THE HILLS OF RURAL NEPAL

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Autonomous adaptation and coping strategies to reduce vulnerability or to enhance resilience are used by rural households and communities in response to the adverse impacts of climate change. Planning for adaptation requires a long-term strategy and coping strategies responding to short-term climate variability may not always contribute to long-term adaptation, but rather increase vulnerability and contribute to mal-adaptation. Some scholars also recognise a need for transformational adaptation rather than incremental adaptation that requires critical re-evaluation of existing structures, institutions, normative behaviours and institutional priorities in regard to risks and vulnerabilities from climate change.

Local knowledge on adaptation strategies provides insights to better inform adaptation theory, policies and strategies. Local knowledge of climate change, strategies, policies and governance has been researched in a socially heterogeneous and hierchial rural agriculture based farming communities in Nepal. The study explored how: (i) rural communities were practicing individual and collective actions to adapt to climate change impacts; (ii) local adaptation practices were of benefit to different well-being groups; and (iii) how policies, governance arrangements and institutions were equipping households and communities to adapt to climate change.

Research findings revealed that adaptation strategies practiced by households and local communities varied according to their access to resources, information, education, and abilities and skills, all determined largely by households' well-being status. The autonomous and reactive nature of strategies adopted at community was found to not always be beneficial. Autonomous adaptation in these hierarchical and heterogeneous communities appeared to provide greatest benefit to the wealthy elites and be particularly focused on the short term. The resultant mal-adaptation practices were observed to lead to: (i) environmental consequences - e.g. excessive use of chemicals to control pests and diseases, (ii) socio-demographic consequences, e.g. unplanned migration and its implications in both source and destination communities; and (iii) socio-political consequences, e.g. increased taking of loans and indebtedness in favour of local elites, increasing dependency, social inequity, promoting unequal power relations, and influencing governance of local resource management systems.

The findings have provided in-depth and micro level knowledge on the social and governance implications of unplanned mal-adaptation practices. The implications for climate change policies indicated that well-being status of households in the communities largely determine their ability to adapt, and policies are required that protect the poor and marginalised in managing vulnerability and the risks of climate change into the future.

P 069

COST-BENEFIT ANALYSIS AS A MAJOR TOOL FOR DUTCH MULTI-LEVEL WATER GOVERNANCE

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For a century, major decisions on waterworks in the Netherlands, like the Zuiderzee-works, the Delta-works, official safety norms for Dutch dikes, More room for rivers and the Deltaplan for the next century, have been accommodated by cost-benefit analysis based upon welfare/economic theory. This paper provides an overview of the evolution of this cost-benefit practice in terms of scope, technique and role in the Dutch political decision-making process. It illustrates that cost-benefit analysis can be a major tool for overcoming the various implementation gaps of water policy identified by OECD, e.g., administrative and policy gaps due to fragmentation of tasks between different parts of national and local government, funding gaps and lack of information and technical and scientific capacity. We also identify lessons for how cost-benefit analysis can be used as an effective tool for multi-level water governance.

P 070

LAND-USE CHANGE CHRONICLE- CALLING FOR CHANGE IN SOLUTION AND POLICY: CASE STUDY OF 2011 THAILAND FLOODS

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The 2011 Major flood in Thailand was estimated as the 4th costliest damage disaster by World Bank. There were three main causes for damage: climate change, water mismanagement and land-use change. This research focuses on the land-use change on Thailand's upstream and downstream. Upstream sent massive of runoff to flood downstream on Choa Praya River Basin. Downstream area is the fertile delta suitable for agriculture, but the land became industrial parks and suburb residential zone.

Methods
First, the research starts with searching aerial and satellite images from the past, 1950s until now, and compare land-use changing on the upstream and downstream. On the upstream, Mae Wong River Watershed was selected as a sample area because it was the controversy area of Thai government want to build a dam in National Park for flood protection project. On the downstream side, two sample areas were selected, the first area is Rojana Industrial Park where sent stunning images of factories under water. Second area is Sai Ma, Bangkok suburb, where is suburb villages spored into flood plain and sunk under water in 2011. Both areas was the reason of the costly flood damage. The second step is finding the reasons of land use-change by interviewing the local people and local government on the three selected sample site, and reviewing for the state and international policy that influenced to the land use decision.

Results
After reviewing the aerial and satellite images, the upstream is clearly seeing the changing from forest into farmland. The reasons related to the timber concession and agriculture land reform policies during 1970s until 1980s. The downstream was also dramatically changed from fruit grove and rice field into industrial and residential zone. These

changing related to the aiming to be NICs (Newly Industrialized Countries) since 1980s and real estate bubble during 1990s.

Societal importance for stakeholders

The upstream land-use changing is the floods because of generating massive of surface runoff. Meanwhile, downstream land-use changing increases flood vulnerable because of the settlement on the flood plain. However, the flood solutions by Thai government were focused only on built mega-infrastructure projects.

In the future, under the climate change situation, if the government still sticks to the same solution as before and no sign of adaptation in mind-set and policy, the flood damages would be severe. Moreover, the budget that invest in the water resource management would be useless or make worst.

P 071

ADAPTATION RESEARCH A TRANSDISCIPLINARY TRANSNATIONAL COMMUNITY AND POLICY CENTRED APPROACH

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The purpose of this presentation is to present the approach that is currently being developed in the course of the Belmont Forum IOF funded project ARTisticc. ARTisticc's goal is to apply innovative standardized transdisciplinary approaches to develop robust, socially, culturally and scientifically, community centred adaptation strategies as well as a series of associated policy briefs. The approach used in the project is based on the strong understanding that adaptation is:

(a) still 'a concept of uncertain form";

(b) a concept dealing with uncertainty;

(c) a concept that calls for an analysis that goes beyond the traditional disciplinary organization of science, and;

(d) an unconventional process in the realm of science and policy integration.

The project is centered on case studies in France, Greenland, Russia, India, Canada, Alaska, and Senegal. In every site we analyze how natural science can be used in order to better adapt in the future, how society adapt to current changes and how memories of past adaptations frames current and future processes. ARTISTICC is thus a project fundamentally centered on coastal communities.

These analyses allow for a better understanding of adaptation as a scientific, social, economic and cultural practice in coastal settings. In order to share these results with local communities and policy makers, this in a way that respects cultural specificities while empowering stakeholders, ARTISTICC translates these "real life experiments"into stories and artwork that are meaningful to those affected by climate change. ARTISTICC is thus a research project that is profoundly culturally mediated.

The scientific results and the culturally mediated productions will thereafter be used in order to co-construct, with NGOs and policy makers, policy briefs, i.e. robust and scientifically legitimate policy recommendations regarding

coastal adaptation. This co-construction process will be in itself analysed with the goal of increasing science's performative functions in the universe of evidence-based policy making.
The project involves scientists from natural sciences, the social sciences and the humanities, working in France, Senegal, India, Russia, Greenland, Alaska, and Canada

P 072

COMMUNITY RESILIENCE AS ADAPTIVE GOVERNANCE ARRANGEMENT; A COMPARISON OF A US AND DUTCH DELTA

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Introduction
Resilience is discussed as guiding concept for adaptive governance arrangements to support communities in dealing with climate change. As posed by Termeer et al. (2011:197), good governance of climate adaptation requires arrangements to be not only legitimate and effective, but also resilient. We compare our findings about community resilience in the US and the Netherlands and discuss how to embed community resilience in governance arrangements.

Research question
Community resilience is highly dynamic and context dependent, meaning it requires adaptive governance arrangements. We aim to bring forward the main indicators of community resilience in both the Mississippi and Southwestern Delta, to provide insight in community resilience dynamics and to discuss its meaning for governance arrangements. This brings us to our research question:
What are main differences and similarities of community resilience in the Mississippi and Southwestern Delta and how to adapt governance arrangements to community resilience within their regional context?

Methodology
The research combines a quantitative analysis and an action research process. Both approaches are embedded in a Soft-System-Methodology approach (Checkland et al., 2006). The quantitative analysis builds upon the Resilience-Interference-Monitor (RIM) as developed by LSU University after hurricanes Katrina and Rita (Reams et al., 2012). In the action research process local communities and safety professionals are brought together in design studios to validate the model and to co-create governance capacity. A complex systems approach is applied to analyze vulnerabilities emerging from interdependencies between involved systems and to interpret the implications for governance arrangements.

Research results
The US RIM is customized to derive a resilience index of the Southwestern Delta. In part 1 we present results of the Dutch RIM, which identifies and quantifies a resilience index of local communities in the Southwestern Delta. Part 2 argues about differences and similarities between the US and Dutch RIM and their meaning for context-specific governance arrangements. Part 3 shows which adaptations (like rules, processes, instruments) in governance arrangements are required to support community resilience.

Societal importance for stakeholders

We search for more effective governance of crisis management and simultaneously support resilience of communities in the Southwestern Delta to deal with climate change. The RIM provides a common ground for policy makers, professionals and interested participants to gain insight in resilience of local communities. The design studios directly support safety professionals, local authorities and citizens to take collective responsibility for embedding community resilience into governance arrangements.

P 073

INFLUENCING 'SOCIAL NORMS' TO PROMOTE GREATER CLIMATE CHANGE ADAPTION MEASURES TO MINIMIZE LOCALIZED FLOODING

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Research question

This poster draws on a PhD project and specifically addresses changing people's attitudes, beliefs and values so that socially sustainable behaviour is adopted instead of 'collective conservatism' (Thaler & Sunstein, 2008), promoting climate change adaption measures in the form of rain gardens, under the umbrella of climate change neighbourhoods. By examining current methods of climate change adaption, and via a thorough understanding of community action, and the social norm approach, this research provides a contribution to the broader discussion around social nudges, assessing whether they are effective at shifting attitudes to encourage citizens to adopt socially beneficial behaviour, ultimately increasing participation in and responsibility for the environment.

The poster will illustrate how the use of social nudges when presented within engagement methodologies applying knowledge transfer, avoids provoking defensive reactions which currently restrict the implementation of LID measures and instead, by reframing the issues perceived around climate change utilizing 'libertarian paternalism', encourages shifts in behaviour to enable greater adoption of localized climate change adaption in the form of rain gardens.

Qualitative and quantitative research methods were selected so that understandings, attitudes, norms and behaviours could be observed to highlight how respondants reacted to social nudges (Thaler & Sunstein, 2008). The results shall be analyzed utilizing ground research theory (Strauss & Corbin, 2008).

Focus groups in particular shall be used observing interaction within neighborhood forums, providing key insights into language use, values and beliefs (Kitzinger, 1994) appropriate for exploring socially-shared knowledge (Markova et al., 2007) aiding the development of further social nudges that influence behaviour.

Research results

The research looks at how social nudges can be used to influence people's choices to adopt behaviour that promotes LID measures for flood prevention and climate change adaption in the UK and Europe. The initial findings that will be illustrated on the poster will show the potential for this approach and highlight extended testing which could further refine the results, demonstrating key nudges that could be adopted wider promoting greater LID measures for flood prevention by local organizations.

Societal importance for stakeholders

The research, drawing upon social practice theory associated with behavioural economics and choice architecture, illustrates how subtle shifts in communication and engagement utilizing social nudges, encourages more socially

sustainable behaviour. By altering the social norms away from 'collective conservatism' bottom-up climate change adaption to localized flooding through rain garden delivery as LID measures can be promoted.

P 074

BRIDGING THE GAP: EFFECTIVE COLLABORATION AND DECISION-SUPPORT FOR ADAPTATION PLANNING

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Uncertainty and competing interests are just two of the factors that make climate change adaptation as much a governance challenge as it is a technical matter. Compounding these challenges, adaptation typically does not fit nicely into existing institutional arrangements, necessitating new ways of bringing stakeholders together to wrestle with information and make effective decisions.

This presentation will share lessons learned from the Knowledge for Climate-funded *Harboring Uncertainty* research project. The project is working with transportation infrastructure stakeholders in Rotterdam, Singapore and New York to explore the following research questions:

- Does the explicit recognition of multiple possible futures alter how decision-makers approach infrastructure planning? If so, how can scenarios best be incorporated into decision-making and their limitations overcome? In general, how can groups successfully adopt new decision support tools?
- Does face-to-face collaboration among decision-makers and other stakeholders improve adaptation planning? How can effective collaboration be fostered and supported?
- How do different institutional arrangements influence the ways in which adaptation planning is approached?

Participants are engaged via a role-play simulation exercise (i.e., '*serious game*'). The exercise allows both researchers and participants to explore the above questions in a safe, relatively low-cost simulated environment. Participants benefit from the opportunity to experiment and draw connections back to their own situations.

Preliminary findings suggest that collaborative processes can add significant value. However, attention must be paid to process design. One challenge is that a great deal of planning happens informally among actors that have relatively strong institutional connections. These relationships must be extended, formally and informally, if different stakeholders are going to effectively engage.

Officials need to find ways to mediate between multiple sources of knowledge that do not use the same terminology, metrics and epistemological standards. Best practices in '*joint fact-finding*' and '*collaborative adaptive management*' can help here.

Scenarios are often praised because they help groups think about multiple possible futures. Unfortunately, users regularly gravitate towards the forecasts that best match their own perceptions of the future and ignore the others. It is not enough to inject decision support tools like scenario planning; we need to find ways to ensure that they are integrated into the evaluation of options in practice.

This presentation will share the lessons learned from this project and what they suggest about improving practice. It will also introduce how role-play simulation exercises can be used to facilitate individual and group learning, foster action, and conduct research.

P 075

A BOTTOM-UP EMPOWERMENT AND CAPACITY BUILDING IMPLEMENT FOR COASTAL SUBSIDED AREA OF TAIWAN UNDER CLIMATE THREAT

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The inhabitants of west coast of Taiwan has been identified as the first climate refugees due to the land subsidence in the past 25 years. With the climate change, the phenomenon of sea level rising has worsened the problem of flooding in that area. Besides land subsidence and flooding, water shortage, water pollution, industrial decline, infrastructure deterioration and young population migration are also the critical problems in the area. Therefore, how to build the adaptive capacity of the inhabitants to communicate with the government and corporations for enhancing the wellbeing of the locals becomes a pivotal issue in the recent years.
A group of researchers started the action approach to build up local adaptive capacity for that region since year 2006. From 2006-2008, local influential stakeholders were interviewed for a better understanding of the problems people faced in that area. Government related offices were also mobilized by the needs of people. The preliminary task group was formed by three pillars of inhabitants, professionals and government staffs in this stage. From 2009-2011, different types of community activities and classes have been implemented. The locals learned the related knowledge and express their own opinions through the above channels. In order to contact the most vulnerable people who are the poorest and disable group, the face-to-face interviews were conducted at their houses. This out-reach approach helped the connection with those who seldom make their voice heard in public. There were seven common visions formed in the end of this stage.
Since 2012, the implement stepped into the third phase. A people's association in local community was legally set up to strengthen the long-term relationship between the locals and the task team. Through more comprehensive community contacts and activities, it is believed that the locals' adaptive capacity can be built up and the future directions of community development can be specified. This bottom-up empowerment implement not only provides various communication channels but also raises the awareness of climate changes of the locals. More actions will be taken for reaching the consensus goals step by step during the third phase.

P 076

ADDRESSING LIVELIHOOD INSECURITY THROUGH ACCESSING LOCAL RESOURCES TO MINIMIZE VULNERABILITY IN BANGLADESH DELTA

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Coastal deltas of southern part of Bangladesh is day by day facing so many challenges due to severe impact imposed by climate change induced calamities and man-made disaster. The study been done to analyse whether alternative livelihood adaptation strategies can support livelihood security in this region or not? and how these options can be familiarized among the vulnerable people? This study has been carried out in two villages of Khulna district in Bangladesh where livelihood security is under threatening condition. In total two focus group discussion (FGD)

has been done with local people in the study area (one in each villages). The study finds that higher risk of natural disasters especially cyclone, high population growth and increasing number of landless marginal farmer (LMFs) are actually worsening the existing impacts of climate change. In 2007 and 2009 two disastrous cyclones 'Sidr' and 'Aila' devastated this region that clearly shows higher frequency and intensity of natural disaster. Although most of population are agro-based farmers but have no lands to do farming practices on their own. Because of reduced agricultural production most of the land owners do their own farming by employing daily basis labour only during sowing and harvesting time without giving land to LMFs for shared cropping. Ultimate cause is temporary migration of vulnerable people to city areas for short term work to support their family in the villages, sometime even for longer periods depending on household capital. The flow of people creates conflicts in sharing common pool resources in urban territory and also increasing number of unhygienic slums. This paper finds that existing strategies are inadequate to support the vulnerable people due to failure of local resilience capacity, thus suggests new strategies to boost up existing NGOs action to support community based adaptation projects and seek for government allocation in accessing barren lands to the vulnerable community in order to empower local people and improve local resilience.

P 077

MIGRATION AS AN ADAPTION TO CLIMATE CHANGE: CASE STUDY VOLTA DELTA, GHANA

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Climate change impacts such as droughts, fluvial flooding, salinization and sea-level rise has the potential to affect sources of livelihoods of over 380,000 residents in the Volta delta in Ghana. Flooding has displaced residents in the delta, while drought has resulted in crop failure, livestock losses, malnutrition, and increased health risks. Available adaptive strategies may exacerbate gender inequalities and not adequately cope with changes associated with climate change. Hence, large movements of people are often projected from deltas under climate change. This study aims at identifying when migration could be used as an adaptation strategy in the Volta delta. The methodology includes survey, participatory research and economic methods to analyse the impacts of climate change, and associated vulnerabilities in the Volta delta. The study forms part of the DECCMA project involving four deltas in Ghana, Egypt, Bangladesh and India in collaboration with the University of Southampton with funding from IDRC. It is expected that the study will encourage appropriate gender-sensitive policy responses to ensure that the most vulnerable in deltas are able to adapt, and how adaptation policy effectiveness can be maximised. This paper will present results on the demographic situation and trends as well as a comprehensive assessment of climate change impact in the Volta Delta.

P 078

TRANSLATION IN THE CLOUD: THE EVOLUTION AND CIRCULATION OF CLIMATE CHANGE KNOWLEDGE AMONG NGOS IN THE MEKONG DELTA

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While scholars have addressed the challenges of translating scientific knowledge about climate change into local action, less attention has been paid to the role of NGOs as translators of this knowledge, communicating projected outcomes and defining appropriate response strategies. This paper examines how the discourse around climate change adaptation in the Mekong Delta of Vietnam circulates and evolves within networks of NGOs on the World Wide Web. Identified as one of the regions at greatest risk to the effects of a changing global climate, particularly rising sea levels and saltwater intrusion, the Mekong Delta is also a center of national economic growth and significant international development attention. This research asks: Which international organizations are most influential in shaping knowledge about climate change impacts in the Mekong Delta and the adaptation strategies that are pursued? How do they frame the issues, whether problems or solutions, challenges or opportunities? I use the Issue Crawler tool to trace the evolution and circulation of this discourse among networks of organizations on the Web, and then analyze their Webpages for patterns in the content and framing of this knowledge. The results of such analysis are presented as a useful starting point for comparing the translation of knowledge in 'the cloud' to levels of awareness, experiences, and specific practices of people on the ground, which will be the aim of future ethnographic research in Vietnam. Better understanding the role of NGOs as vehicles for the translation and dissemination of knowledge about climate change will assist both practitioners and local people in devising effective and equitable responses to its impacts.

P 079

PARTICIPATORY MONITORING AS INSTRUMENT TO ACHIEVE INTERMEDIATE OUTCOMES IN STAKEHOLDER PARTICIPATION PROCESSES

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Introduction

Evaluation of participatory programs and projects is necessary to assess whether these objectives are being achieved and to identify how participatory programs and projects can be improved. Intermediary outcome evaluation has been given less attention than other forms of evaluation but can identify some real achievements and side benefits that emerge through participation, such as interaction, network development and trust. A specific type of participation is participative monitoring: the repetitive conductance of measurements by citizens.

Research question

In this paper, we explore how participatory monitoring of water levels in the context of a water management adaptation, helped increase trust between the water manager and stakeholders.

Methodology
In the recreational area of Loosdrecht (the Netherlands), an innovative way of water management was introduced, by allowing the water level to fluctuate more than before. The purpose of this flexible water staging is to increase resilience to extreme weather events and to improve the ecological situation in the area.
Local inhabitants were worried about the effects of the projected water level fluctuations on their properties, and the possibilities for recreation. They were involved in the design of the monitoring of the water levels, and actually did the measurements themselves. The data and model results were jointly (by stakeholders, waterboard staff and researchers) compared and discussed in four meetings in two years. The participating citizens and waterboard staff were interviewed right after the first year in which the monitoring was intensive and half-way the second year in which the monitoring and especially the discussion was much less intensive.

Research results
The monitoring by citizens contributed to more understanding of the natural system by the citizens as well as the water managers and the researchers and also contributed to growth in mutual trust.

Societal importance for stakeholders
For stakeholders like farmers, recreational entrepreneurs and other citizens, active participation in monitoring of, in this case, water levels, created an understanding of the water system that they did not have before. This enabled them to evaluate their own position regarding the water management, as well as the position of the water manager. The trust building that took place alongside the monitoring enabled the citizens as well as the staff of the water board to effectively communicate with each other. These are two aspects that are highly relevant in water management in general.

P 080

CONTESTED GOVERNANCE OF ECOSYSTEM SERVICES FOR POVERTY ALLEVIATION IN SOUTHWEST BANGLADESH

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Good governance plays a vital role in the process of alleviating poverty through ecosystem services. Accountability, transparency, coordination and monitoring are among the key elements of good governance. Other elements like institutional capacity, service delivery, technology, financial management, participation, equity and inclusiveness are also important. A strategic and adaptive legislative, institutional and policy framework is essential. However, it is not easy to evaluate the state of ecosystemgovernance as it is a multidimensional issue. This presentation consists of an evaluation of existing legislative, policy, and strategic framework of governance of ecosystem services for poverty alleviation in the Southwest region of Bangladesh. The presentation attempts to carry out a mapping of livelihoods practices which are ecosystem dependent.

Research question
Which ecosystems services are impacted by a contested governance context and are shaped by practices in the processes of rural economy, food production, livelihoods and poverty alleviation?

Methods

The methods used included a literature review, interviews with stakeholders at various levels, group discussions, and two local level participatory workshops in the Bagerhat and Khulna districts of South West Bangladesh.

Results & Societal Importance for Stakeholders

Results from the two local level participatory workshops show high positive rank correlation (0.89). This suggeststhat the two districts of South West Bangladesh have similar governance problems. Results from the two locations combined showthatrule of law/justice/level of enforcement has deteriorated the most(Rank 1), followed by irregularities/corruption (Rank 2), inaction of agencies concerned (Rank 3), coordination/monitoring (Rank 4) and accountability/transparency (Rank 5). Overall, public participation and the capacity of institutions (human, financial, legal and technology) were found to have slightly improved compared to 10-12 years ago.

Keywords

Ecosystem Services, Governance, Livelihoods, Poverty Alleviation, Food Production, South West Bangladesh.

P 081

CHALLENGES OF SYSTEMIC INNOVATION: CITIES AS EXPERIMENTATION UNITS?

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In the systemic view on sustainability, the interactions between factors are best described in terms of complex systems theory - non-linear dynamics (thresholds, criticality) and emergent properties, which lead us to acknowledging the limitations of planning. How then to proceed with our adaptation to climate and wider environmental changes? Hereby, I address a set of questions already opened in an earlier article (Ciumasu 2013a) as common as several scales (street, city district, city, nation, continent, world):

- What are the technological choices?
- How to integrate economics with environmental and social issues?
- How to govern complex projects and investments?
- How to manage the unexpected?
- What are the costs and the applicable burden-sharing agreements?
- How to integrate dynamics between scales?

Based on a literature review and drawing on the results from recent pioneering projects for urban sustainability, I propose that the best strategy of adaptation to environmental changes is through systemic innovation experimentation and I identify the city as the best unit and scale for it. The central idea of the argument is that a city is a natural mid-way point in terms of both scale and governance: it represents (a) the highest scale of experimentation that is manageable in practice and (b) the lowest scale of relevance for system dynamics.

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P 082

THE ECONOMICS OF SALINIZATION DUE TO CLIMATE CHANGE AND POSSIBLE ADAPTATION INVESTMENTS

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This is a quantitative study based on literature which provides knowledge on the economic impact of salinization due to climate change on agriculture and possible adaptation measures. Bangladesh, with the 'Ganges-Brahmaputra-Meghna Delta', has been taken as a case study as it is one the most vulnerable countries to climate change and copes with high soil salt concentrations already. A methodology has been developed to compare different scenarios and measures.

Research question
How can adaptation and mitigation investments on a private as on a public level be compared regarding the economic impact of climate change on agriculture?

Methodology
This is a quantitative research based on literature. This means relations have been quantified and information will solely be secondary data. Besides literature, data and consultation have been provided by experts from LEI and Wageningen UR. The goal of this dissertation has been to find a method to approach this and similar cases. A case study of Bangladesh has been worked out to prove its functionality.

Research results
The rising sea level will cause salt intrusion to increase in the future. Higher salinity levels will cause rice yields and therefore income to decrease. This continues until it is beneficial to switch to private adaptation/mitigation measures. Measures which have been researched are shrimp cultivation, drainage and salt tolerant crop varieties. Depending on the effect of these private measures a continuing public mitigation strategy has been researched. Repair and maintenance of existing coastal polders is the public mitigation strategy applied. The study shows that different measures would lead to different costs and effects and that it would depend on the policy goal (salinity decrease or private profit maximization) which measures would be most suitable.

Societal importance for stakeholders
As a method to compare different adaptation/mitigation measures of different current and future salt concentration levels to reduce costs has not been found, this dissertation has focussed on that issue. The methodology to approaching this issue could function as a guideline for future salt intrusion projects increasing time efficiency for similar cases. Therefore this methodology is important for stakeholders.

P 083

COST-EFFECTIVE ADAPTATION TO CLIMATE CHANGE UNDER A LONG-TERM SYSTEM RELIABILITY STANDARD

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Climate-sensitive infrastructure must be timely adapted to ensure that system reliability standards, or flood risk standards, are met.

Research question
In this paper, we study the impacts of natural variability and climate change uncertainty on cost-effective adaptation to climate change for systems that have to comply with a system reliability standard.

Methods
We develop a model and a solution method to identify cost-effective investment strategies for surface or urban drainage system adaptations. Runoff and water levels are simulated with rainfall from stationary rainfall distributions for a range of system configurations, and annual rainfall maxima are simulated over time based on a climate scenario. Cost-effective investment strategies are computed with dynamic programming.

Results
As a ‘proof of concept’, we evaluate the volume of a water storage basin in a polder in the Netherlands. We determine the cost-effective volume of the storage basin, and find that it is larger if the compliance period is longer.

Societal importance
Long-run reliability/ flood risk standards may be preferred over short-run standards, which can be used to reduce the probability of costly re-investment, and increase the robustness of climate-sensitive infrastructure. Flood risk management strategies, furthermore, may be seriously flawed if the impacts of weather variability on the cost-effectiveness of investments are ignored.

P 084

FLOOD PROTECTION AND ENDOGENOUS SORTING OF HOUSEHOLDS: THE ROLE OF CREDIT CONSTRAINTS

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Migration is increasingly seen as a promising climate change adaptation strategy. The purpose of this paper is to investigate how spatial differences in flood risk, due to differences in flood protection, reduce the mobility of vulnerable households through a credit constraint mechanism. Using an equilibrium model with two households and endogenous sorting, we show how spatial differences in flood protection lead to clustering of vulnerable households in risky regions.

P 086

THE ROLE OF WATER PRICES IN AGRICULTURAL WATER DEMAND: TWO CASE STUDIES

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Introduction

Due to climate changes in time, the Netherlands face serious challenges with respect to achieving the objectives of water quality (Water Framework Directive) and water quantity (Deltaproram) policies. As the periods of droughts will prolong, the water quality of surface waters has to improve, and the availability of freshwater for all users have to be secured in order to reach the policy objectives.

The agricultural sector plays an important role in the achievements of the Dutch water policy objectives. On the one hand, the sector can contribute to improved water quality by lowering the impact of nutrients and pesticides pollution to water. On the other hand, the sector benefits from the availability of freshwater for irrigation at the right moments of the growing season of crops.

The implementation of new water efficient technologies is not common yet. Farmers have to be convinced with the advantages of the new technologies. The price for water is one of the crucial factors of implementing new technologies in agriculture. Higher prices are an incentive for more efficient use of water. Additionally, a higher water price will also have a positive impact on the implementation and distribution of water efficiency innovations in agriculture.

Research question

Before we can address the question how these water efficiency innovations in agriculture are implemented, and how they affect agricultural production, we first ask the question how do farmers respond to higher prices for water (higher tap water levies or paid fresh water provision in the Zeeland province)?

Preliminary results

With the Dutch Farm Accounting Data, we will test the impact of prices of water in two case studies using econometric analyses. In the first case study, we will test whether open-air fruit farming in the 'Zuid-Beveland' area

has higher yields due to the fact that they have a fresh water provision than similar farming in other Dutch areas. In the second case study, we will determine the price elasticity of tap water demand for farmers due to the substantial increase of the tap water levies since January 2014.

Societal importance

Farmers are likely to switch to alternatives such as ground or surface water demand. With the implementation of the WFD, both sources of water become more serious alternatives for the demand for tap water of farmers. We expect the price elasticity of tap water demand to be significant. This will contribute to more implementation of new technologies.

P 087

DEALING WITH UNCERTAINTY IN THE DUTCH DELTAPROGRAMME

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Dealing with uncertainty in decision making on long term strategies, lessons learned in the Dutch Delta Programme
Pieter Bloemen, Jos van Alphen, staff delta programme commissioner
On 1 February 2010 the Delta Programme Commissioner was installed, in order to elaborate and implement a rolling-on Delta programme[1]). The objective of this Delta programme is to adapt flood risk management and fresh water supply to a changing climate. This is considered crucial for securing the Netherlands as an attractive place to live and work this century.
The Delta Programme has produced proposals for updated standards for flood protection, a strategy regarding fresh water supply and a policy-framework regarding flood-proof urban (re)development. The programme also includes the necessary measures for the short term (maintenance, improvement of “aging infrastructure”), framing these measures into the long-term perspective.
Long term planning implies dealing with uncertainty. The Delta program adopts a comprehensive approach in which different types of uncertainty are dealt with in a dedicated way:
Uncertainties due to lack of knowledge of the present system (local characteristics, large scale system behaviour, response to interventions) are reduced by research and pilots, by including a robustness margin in the design of measures and by performing a sensitivity analysis.
The Deltaprogramme deals with uncertainties related to the future by Adaptive Deltamanagement. This method combines monitoring of the physical and socio- economic environment with an adaptive way of planning, that seeks to maximise flexibility, keep options open and avoid “lock in”. Uncertainties related to the actual implementation of the selected strategies and measures. Commitment of relevant stakeholders is crucial and is enhanced by merging strategies with ambitions in other fields, like nature and inland shipping. Therefore, policy development is organized is a multi-governmental setting. The Delta Commissioner directs this process (and subsequent implementation), monitors progress, reports to Parliament every year in September and takes the necessary steps when problems arise. From 2020 onwards, a Delta Fund of about 1 billion euros per year will provide stability in financial resources, reducing dependency on economic developments and continuous political attention. The new Delta Act forms the legal basis for the implementation of the programme, the responsibilities of the Commissioner and the Delta Fund.
A monitoring and evaluation programme is being developed to secure the effectuation of the decisions taken and the adaptive character of the proposed strategies.
2 www.deltacommissaris.nl/english

P 088

THE INFORMATION ENRICHMENT CHAIN: INDICATOR AND VISUALISATION SUPPORT FOR LOCAL CLIMATE ADAPTION PLANNING

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By 2050 75% of the world's population will live in cities and the occurrence of heat-wave events might have doubled. Mapping the climate and land use change impact for urban heat events should set the agenda for adaptation planning at the local scale. Translating and tailoring impact information to policy-relevant and usable science is needed to meet the user needs. Literature on urban heat mapping does not reveal a clear indicator to visualise the urban heat impacts that includes consequences of land use and climate changes for planning purposes. This paper aims at translating scientific information on urban heat into policy-relevant and usable information to support local adaptation planning processes. The research questions addressed in this paper are:
- What policy relevant urban heat indicator for local climate adaptation planning processes can be constructed?
- How can such an urban heat indicator be visualized?
- Do such indicator and map meet the information and communication needs of policy makers?
We introduce the information enrichment chain as a stepwise approach to develop a single complex indicator to map the urban heat impact for local climate adaptation planning processes. First, indicator and its visualisation requirements are defined based by user needs. Information on climatic drivers and land use characteristics are combined and projected for future land use and climate change impacts. Next, several visualisation techniques are developed to investigate which techniques are most effective to visualise complex information with multiple variables in one visualisation. Finally it was investigated how indicator and map meet the information and communication needs of policy makers. The approach was applied for a case study area and usability tests were performed during different stages of the planning process. Our findings reveal that it was crucial to add information on future impacts, caused by climate and land use change, to set the agenda for adaptation planning at the local scale. A sequential map presentation has proven to be effective to map complex information and fulfil most of the identified information needs. The information enrichment chain seems a promising approach to support local adaptation planning. It improves the information exchange between science and policy makers by making information accessible, useful and relevant.

P 089

THE NATIONAL ECOSYSTEM ASSESSMENT OF THE NETHERLANDS: A DIGITAL ATLAS OF OUR NATURAL CAPITAL

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Introduction

By the end of 2014, the Netherlands will have a first version of a Digital Atlas of its Natural Capital: DANK. This atlas will show the state of our natural capital en give insights in the possibilities to utilize that capital in a better and more sustainable way. DANK is the implementation of Action 5 of the EU Biodiversity Strategy in the Netherlands, which

was accepted by European Parliament in 2012. Main objectives of the Biodiversity Strategy concern the safeguarding of ecosystems ('no net loss'), promoting the application of ecosystem services, and restore 15% of degraded ecosystems. As stated in the national Implementation Agenda Natural Capital, DANK should also serve as the primary source of information for the TEEB project and the system of Natural Capital Accounting. DANK is developed by the Ministry of Infrastructure and the Environment and RIVM.

Research question
The main objectives of the project are the identification and disclosure of relevant information as well as obtaining consensus on the mapping, assessment and valuation of our natural capital and ecosystem services.

Research results
First results concerning the identification of relevant information, consensus building and a first idea (screen dumps or demo version) of the digital atlas will be presented at the conference.

Societal importance
Our natural capital includes everything of value supplied by nature, such as food and drinking water. It includes also the services that nature provides us of which we are not aware of e.g. production of oxygen by trees, dunes protecting us from flooding, bees that pollinate our crops and soils that capture & purify the water for our agriculture and industries. Our natural capital is currently not properly mapped and valuated. It is the aim to fully map and assess the natural capital of the Netherlands by 2020. By then, its value and benefits should have been defined and should be included in decisions by government, NGO's and businesses. At the national scale, DANK will support societal-cost benefit analysis, environmental impact analysis and the National Policy Strategy for Soil and Sub-soil. It may be taken into account in deciding on spatial developments, such as the construction of new roads, new residential and industrial areas, development of water storage areas or management of agricultural areas. Valuation of our natural capital and the services nature supplies will facilitate a more sustainable use of our living environment.

P 090 THE EUROPEAN CLIMATE ADAPTATION PLATFORM

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Research question
Information and knowledge on climate change adaptation has increased but sharing across Europe can be improved. In March 2012 the European Commission launched the web-based European Climate Adaptation Platform (Climate-ADAPT), hosted and maintained afterwards by the European Environment Agency, supported by the European Topic Centre on climate change impacts, vulnerability and adaptation. It is designed to support policy-makers at the EU, (trans-) national and local levels to develop and implement adaptation strategies and actions. In 2013 an 'EU Strategy on Adaptation to Climate Change' was adopted, supporting actions in countries, mainstreaming adaptation in EU policies, providing funding and enhancing research and information-sharing. It mentions the further development of Climate-ADAPT supporting the strategy objectives.

Methodology
Climate-ADAPT presents comprehensive information on adaptation for the EEA 33 member countries. It contains information on observed and expected climate change in Europe; vulnerability of regions and sectors at present

and in the future; transnational, national and city level adaptation strategies and actions; cases of adaptation and adaptation options; tools that support adaptation planning and implementation and an overview of EU policy frameworks and processes. Information is included from many sources including EU research, Interreg (European Territorial Cooperation) and LIFE+ projects. Metadata is included in the Climate-ADAPT database in a comparable way while the quality assurance of the underlying information is done by the relevant project, through peer review processes. Countries provide information on their legal framework, assessments, priority sectors and local action regularly on a voluntary basis to EEA. Climate-ADAPT is complementary to national climate change adaptation platforms that were launched the past years. These platforms are in the national language and support implementation of national actions.

Research results

The platform is used by many, but continuous efforts are needed to keep the information up to date and tailored to the needs of the target audience. Next steps include updating of transnational information; improved connections with Climate Services and Disaster Risk Reduction platforms; inclusion of EU funding options and the outputs from more EU research projects and improving case studies.

Societal importance for stakeholders

The platform has already supported (sub-) national adaptation policy and action. 3600 unique visitors per month use the platform and it is one of the most visited thematic EEA websites. The most visited pages are the countries pages and the adaptation support tool, which delivers guidance on impacts of climate change, adaptation planning/ implementation and monitoring/evaluation.

P 091

ESTIMATION OF FLOOD DAMAGE AND ITS COMPARISON WITH A GIS STUDY IN PESANGGRAHAN RIVER JAKARTA

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Flooding is a serious problem in Jakarta. During the last two decades, four big floods attacked Jakarta in 1996, 2007, 2012, and 2013. Assessing flood damages is important for the region to develop its flood policy, which enables us to estimate the benefits of implementing flood protection measures.

The objectives of this study are to estimate the actual flood damages (AFD) in the residential and business sector, and to compare them with those from GIS. Specifically, we estimated the direct and the indirect tangible flood damages. Interviews were undertaken to the flood-affected households and the business units to collect data on economic losses from the flood event in January 2013 along Pesanggrahan River. We interviewed 300 households and 150 business units located in six villages, where 1,706 houses were inundated. We regressed the AFD as the dependent variable with five independent variables including flood characteristics (flood depth and flood duration) and socio-economic factors (income, area, and distance to river). Based on this, we estimated the annual actual flood damages to be USD 525,103 for the residential sector and USD 698,089 for the business sector.

GIS damage map was obtained by using the damagescanner model, which employs three inputs: (1) flood hazard,

represented by the flood depth and extent map, (2) flood exposure, represented by a land use map with associated value in each land use class, and (3) flood vulnerability, represented by flood-damage curve. Information on flood hazard was based on the SOBEK model while flood exposure and vulnerability were obtained from the experts. The map covers 12 land use classes. It shows that the annual actual flood damages to USD 1,318,235 for the residential sector and USD 9,248,201 for the business sector.
Comparing the two methods, we found that the damage estimation based on regression analysis were lower than the GIS analysis. The following reasons could explain the differences in estimation. First, the survey directly collected the damage data from the samples that really affected by flooding, while GIS estimated damage by expert views. Second, the survey investigated only two areas, namely high-density urban villages, and commercial-business areas, while the GIS does not make any distinction between density of population. Third, the survey covered the direct and indirect flood damage, while the GIS estimated only the direct damage. Finally, the survey samples consisted of small and medium business units, while the GIS covered small, medium, and big business units.

P 092

A FRAMEWORK FOR THE INTEGRATED ASSESSMENT OF VULNERABILITY OF DELTAS SYSTEMS

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Deltas are complex socio-ecological systems vulnerable to multiple global pressures, ranging from natural to human factors, including climate change. The combined effect of the resulting pressures increases vulnerability and results in risks to the preservation of the environment, the functioning of the ecosystem as well as to the social and economic development of Deltas. The use of indicators to understand complex processes can make an important contribution to assess and manage Deltaic ecosystems.

Research question
'*What are the symptoms of river and coastal syndromes that make Deltas vulnerable?*' was the research question used to select the key indicators for the assessment of Deltas vulnerability.

Methodology
Factors contributing to the vulnerability of Deltas, including natural, physical, biological and socio-ecological features were critically reviewed and the indicators and indices that can be useful to cope with complex issues in Deltas were cross-checked. Then, a selection of multi-criterion indicators able to answer the research question is proposed.

Research results
In order to encompass the multiple environmental and human changes in Deltas, the selected indicators were divided in 6 categories: Natural hazards, morphological, hydrological, ecological, ecosystem services and social-economic indicators. The assessment of the locally relevant indicators in each category can integrate the indicators using a multi-criterion index based on the planetary boundaries concept, with the locally appropriate numerical boundaries to the classifications on a scale continuum between resilience and vulnerability. The set of indicators should be locally adapted to the individual Delta, thereby providing a useful tool for the understanding of complex phenomena in a particular case study.

Societal importance for stakeholders

The proposed index is a simple and visual tool that summarizes a large amount of scientific data in a way that is easy to communicate to stakeholders. The framework offers an opportunity to share and exchange the scientific knowledge of complex processes in socio-ecological systems with decision makers and managers in order to produce sustainable and effective management decisions and, increase the resilience of Deltaic ecosystems.

P 093

ANALYSING CLIMATE CHANGE IMPACTS ON LOCAL ECONOMIC PERFORMANCE OF DUTCH AGRICULTURAL SYSTEMS

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The economic profitability of agricultural systems depends on a complex combination of economic, technological and political factors operating within particular socio-cultural contexts, and according to the opportunities and constraints set by spatial factors such as biophysical features and transport networks. Since the biophysical environment is spatially heterogeneous, location is a key factor in describing the economic profitability of agricultural systems. Future climate change impacts are likely to affect the crop suitability and, consequently, the economic profitability of current agricultural systems. Yet, there is limited understanding of the interplay between local production capabilities, regional climatic changes and more general socio-economic conditions that determine the profitability of current agricultural systems.

A method is hereby proposed to map local changes in the economic performance of agricultural systems resulting from climate change. Changes in the expected net present value of current agricultural systems are assessed in a spatially explicit way by measuring time series of cash flows, taking into account local changes in crop suitability resulting from climate change impacts such as an increase in temperature, changes in hydrological conditions, and increased frequency of pests, diseases and extreme weather events (e.g. heat waves, heavy rainfall). The economic feasibility of a number of adaptation measures is also assessed, by taking into account the investment and annual costs of adaptation measures and their effectiveness in reducing crop damage.

The Netherlands, a country with an advanced agricultural sector with a high value per hectare, is used as a case study. The proposed method will allow:

- mapping the impacts of climate change on the variation in economic performance of current agricultural systems;
- mapping the economic feasibility of different climate adaptation measures;
- identifying the regions in which current agricultural systems are able to remain economically profitable, with and without the adoption of adaptation measures;
- identifying the regions in which the economic profitability of current agricultural systems is expected to be most severally undermined by climate change impacts.

The findings of this research will allow informing decision-makers and stakeholders (e.g. farmers associations) on the magnitude of long-term economic impacts in agricultural systems resulting from climate change, as well as pinpointing which regions might require the design and implementation of robust adaptation strategies.

P 095

LONG TERM REINVESTMENT PLANNING FOR THE REPLACEMENT OF HYDRAULIC STRUCTURES - GENERAL METHODOLOGY AND CASE STUDY

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Research question

During the last century many structures were built within the main water systems of the Netherlands to facilitate a number of important societal functions. As a result the main water system nowadays provides safety against flooding, sufficient and clean water and a thriving navigational network. The main water system consists of a complex network of waterways with approximately 650 major hydraulic structures. These structures were designed to last for 80 or 100 years. In the decades to come, due to ageing, an increasing amount of structures need to be replaced or renovated to meet new and future societal requirements. Changes in the physical and social environment of the structures, resulting from climate change and socio-economic developments, influence the need and the timing of replacement and the desired functional and performance requirements for the redesign of a structure. Furthermore, the mentioned structures operate in complex networks, with many functions and stakeholders. The question is twofold:

1) How to determine the effect of climate and socio-economic changes to the estimated 'end of life' of hydraulic structures (based on the year of construction and the original design life time)?
2) What are the key-features of a replacement strategy, taking into account the many uncertainties, stakeholders and possible adaptive pathways?

Methodology

For estimating the technical end of lifetime several types of data are used: First, there is generic information such as the type of construction, the year of construction, the design lifetime (80 or 100 years), the geographical location, etc. Second, each structure is periodically given a quality score based on a visual inspection. Third, some structures have been studied using a fault-tree analysis which gives detailed information on failure modes. Finally, experts may give estimates of the remaining life of individual structures. The several types of data and information are be combined using a probabilistic approach. The replacement strategy process has been explored with stakeholders on the basis of an existing case-study: pumping station and outlet sluice 'IJmuiden'.

Research results

General methodology: probabilistic distribution functions of the technical end of the functional lifetime for each of the 650 hydraulic structures, including more methodical findings on the basis of the case study.

Societal importance for stakeholders

The method enables cost-effective replacement of structures, in order to remain the important societal functions of the water systems for the coming century.

P 096

CONTRIBUTION TO SUSTAINABLE RIVER BASIN MANAGEMENT FOR A COASTAL ZONE OF SOUTHERN VIETNAM - INTERMEDIATE RESULTS

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Remark

The paper represents the research project 'Environmental and Water Protection Technologies of Coastal Zones in Vietnam EWATEC-COAST' (funded by: German Ministry of Research and Education (BMBF); Vietnam National University of Ho-Chi-Minh-City) with 20 partners from Germany and Vietnam working closely together.
The project runs for a period of 3 years and will end in August 2015. Results shown at this point in time are still preliminary and further work is in progress.

Research question

Rapid growth of economy put massive environmental pressure on river catchments in Vietnam, which resulted in a massive decline for the fishing industry in the river landscape of the Thi-Vai-River (South-Vietnam). This led to serious threats to the economic performance and furthermore to severe restrictions for the usage of riverwater.
At the same time storm surges are among the most hazardous geophysical risks in coastal regions and are often associated with significant losses of life and property. This is why coastal defenses need to be meticulously estimated to offer an appropriate level of protection over the lifetime of the structure. Together with expected sea level rise, this poses a challenge to food security and protection of coastal population and assets.

Target research results

The overall objective of the research project is the development, supply and use of water and environmental technologies and service tools in the framework of a management system.
A further development of these basic technologies and tools towards a Decision Support System (DSS) will be capable to manage the treated water discharge in time and place, so that more water in a better quality can be discharged while river water will be preserved.
If coastal protection should be realized, it is of utmost importance to reproduce consistent water level time series from the middle of the 20th century until the present day.

Societal importance

Decision makers need both, technology to increase water quality by optimising treated water discharge and proper management tools to preserve water quality in the river networks.
The target system offers the capability of sustainable improvement of the environmental and living conditions of the designated coastal zone in South-Vietnam. The project takes into account the anthropogenic influences, the natural climate variability and future climate change.
In addition, the project aims to the transferability of the EWATEC-COAST concept in the target country and other countries on capacity building, as well as the economic valuation of the management strategy.

P 097

COASTAL STATE INDICATORS INTERDEPENDENCIES: BOTTOM UP VS BOTTOM DOWN PERSPECTIVES

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Research question

Coastal systems offer a range of important services. Coastal state indicators (CSIs) are a reduced set of quantifiable parameters used by coastal managers at the operational level as benchmarks and intervention triggers to guarantee the most important/critical service, such as flood protection, good water quality, etc. Future scenarios represent the high-level policy strategy and consist of a number of requirements (e.g. tolerable risk levels, minimum water quality standards…) and allotted trade-offs with other coastal systems services. The ecosystem services framework (e.g. Millennium Ecosystem Assessment framework) provides a bottom down approach to identify these trades-offs that can be linked to a core set of CSIs. In contrast, risk assessment frameworks (e.g. Source-Pathway-Receptor) provide a bottom up approach that links CSIs with high level policy strategies. Here we explore if the interdependencies between CSIs identified by the different approaches are equivalent, analysing six existing sources of CSIs (EUROSION, DEDUCE, CONSCIENCE, DELTA ALLIANCE, TE2100, PEGASO).

Research results

The structure and interdependencies between CSIs are found to be sensitive to the integration approach. CSIs at the operational level are often identified by the bottom up approach while at the policy level the ecosystem services bottom down approach is preferred. Some of the CSIs derived from the bottom up approach are missing from the set derived from the bottom down perspective. This is due to a number of relevant coastal attributes such as navigability and harbour downtime that are not directly related to the ecosystem services but to the built environment.

Societal importance for stakeholders

This result is of particular importance for decisions that have very long-term implications, such as those related to long lived infrastructure and spatial planning. Identification of the coastal state indicators and related stakeholders is the first step of integrated coastal management planning. Failure to identify the interdependencies among indicators could induce unexpected/unwanted consequences. Such consequences can be regarded as lock in processes, where human interventions further limit the portfolio of adaptation pathways over time, or failure to balance the trade-off between different services.

P 099

QUICK SCAN OF URBAN HEAT STRESS

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Cities in Western Europe have not been designed and built to endure heat waves and draught. As the urban design determines living conditions in a city for a long time, it is logical to take climate change into account. Differences in surface temperatures have been mapped using satellite images, but those maps don't show what might happen in the future and don't predict the effect of measures. For that purpose a model is needed that covers the whole city on a scale similar to detailed satellite imaginary and which expresses the effects in air or comfort temperatures. Therefore we have developed a relatively simple model which shows (on a highly detailed map) the expected temperature differences in a city during a heat wave. We are currently expanding the model to predict the effect of measures increasing the resilience of a city.

Research questions

How can we help municipalities in deciding on actions on urban heat stress? Is a relative simple model sufficient? What elements need to be in this simplified model? Is a thermal comfort index a better indicator than the air temperature and is this sufficiently understood by the stakeholders?

The concept of a relatively simple model has been developed for the city of Eindhoven. Several recently finished research projects have been used to underpin the setup of the model. The model results have been compared with satellite images and with on-site measurement data. In order to test if this model helps municipalities in deciding on climate adaptation actions we have done workshops with relevant stakeholders, discussed the approach and asked for further input.

Research results

Using such maps during stakeholder workshops learned that the computed heat maps proved useful to raise attention for the issue of climate change impacts and to discuss possible measures. The fact that the maps use and show accurate local data, results in relevant discussions. We learned that technical stakeholders want to involve the public health department in this discussion and that the stakeholders appreciate the simplified model as a valuable start and see it as a way of triage for more accurate analyses for specific locations..

Societal importance for stakeholders

The model helps municipalities to decide if and what actions to reduce climate change impacts are needed. It supports municipalities deciding which stakeholders (urban planners, managers of water and green in cities, public health services, housing corporations) need to be involved.

P 100

A USER-DRIVEN ATLAS OF WATERPOORT ENABLING A PARADIGM SHIFT TOWARDS WATER SENSITIVE AREA DEVELOPMENT

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Introduction
Water systems are an important driver for local dynamics, especially in delta areas. Although, in contrast with contemporary integrated area development processes, the water sector is strongly focused on scientific data, including associated frameworks and standards. Due to increasing cost and climate change challenges water management is in need for a paradigm shift: with less governmental interference and more self-sufficiency and ingenuity by the local community towards water sensitive area development. We present a new tool to develop user-driven knowledge: the Atlas of Waterpoort.

Research question
In this search for a new water management approach the region Waterpoort is used as case study. Waterpoort is the region surrounding lake Volkerak in the Southwest of the Netherlands. By the construction of the Deltaworks this area lost its strong connection with the water and was transformed from a salt delta area into a fresh water 'aquarium'. This has led, next to the problems with the toxic algae in lake Volkerak, to problems with the livability of the region. Now a decision has to be taken on the salinization of lake Volkerak to eliminate toxic algae, there lie great opportunities to incorporate the local dynamics of Waterpoort in the area development process.
In this research we answer the question: *How can an user-driven Atlas of Waterpoort support decision making in water sensitive area development? And how does this contribute to adaptation of local communities in times of climate changes?*

Methodology
The research makes use of a joint-fact-finding analysis, embedded in a complex-system approach via soft-systems-methodology. In the joint-fact-finding we make use of explorative research, like field-visits and in-depth interviews to compose a clear overview of the local water system assembled in the 'Atlas of Waterpoort'.

Research results
In the first part of the Atlas we present an overview of how the local community interacts with water system and the interdependencies between the users. In the second part we show which adaptations in the water system can be arranged to support the ingenuity of the local community to enhance the livability of the area.

Societal importance for stakeholders
The Atlas approach literally images the conditions and requirements of users of the water system in area development. By mapping and visualizing the water system in cohesion with the local community, the Atlas of Waterpoort functions as communication tool to support policymakers to incorporate local dynamics in water sensitive area development.

P 101

MONITORING OF ADAPTATION AT THE LOCAL LEVEL

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At the European, national and local level strategies and policies for adaptation to climate change are formulated. Monitoring and evaluation can help to inform on the effectiveness of adaptation policies and measures. Several countries have developed methods at the national scale, although it is still a search process how to measure adaptation. Not much is known about monitoring of adaptation at local and regional scales.
We performed two case studies to find out how monitoring of climate change adaptation can be put into practice; in the Haaglanden region and the Rotterdam region, both in the Netherlands. The research was guided by a framework with five building blocks; general requirements, system of interest, indicators, responsible organization and procedures. Information on these building blocks was obtained by literature study, interviews with stakeholders and several workshops.
A general requirements list for monitoring of adaptation was derived from the literature. On the system of interest we can say that spatial scales and time scales are of great importance, however, still a lot is unknown about how urban climate works. Monitoring should ideally start with a clear adaptation strategy. In Haaglanden this was the case and a preliminary set of indicators could be obtained. If no strategy is present, like in many municipalities in the Rotterdam region, it is often too early to talk about procedures and specific indicators. It can still be useful to start monitoring in the absence of a strategy, but then for the purpose of revealing vulnerabilities and to work on creating awareness. The discussion about the monitoring responsibilities was not difficult as municipalities already have experience with monitoring in other fields in both regions. Adaptation monitoring can most likely be implemented within existing regional arrangements.

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RISK-BASED ACTION UNDER DATA SCARCITY: USE OF GLOBAL RAINFALL AND HYDROLOGICAL INFORMATION TO ANTICIPATE DISASTERS

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Research question
With climate change, we expect that heavy and unusual rainfall events will increase in many locations around the world, thus greatly increasing the importance of disaster early warning systems. With existing technologies, we can already anticipate periods of heightened flood risk around the world, using satellite rainfall measurements, dynamical rainfall forecasts, and global hydrological models. However, this information is not currently operational within the

humanitarian sector, where it could allow disaster managers to anticipate flood risk and take preventative action. Here, we develop a mechanism to use existing global datasets to assess flood risk in data scarce regions of the developing world, and estimate potential avoided losses if humanitarian action was taken systematically at times of heightened flood risk.

Methodology

We select three types of global information that are associated with flood risk: observed satellite rainfall, hydrological modeled discharge forced by daily rainfall, and forecasted rainfall amounts. For each, we identify two global datasets that can be used in data-scarce environments, and verify them with observed floods as recorded by Desinventar and Red Cross in northeast Uganda. For each dataset, we calculate the hit rate and the confidence rate that would be achieved by using a threshold to trigger humanitarian action.

Research results

Based on these results, we estimate the value of humanitarian action triggered by global rainfall and hydrological information for northeast Uganda. While there is a substantial loss of skill with the use of unadulterated forecasted rainfall, modeled discharge based on forecasted or observed rainfall for this region is an excellent proxy for disaster. Depending on the threshold selected, disaster managers can anticipate the majority of all floods in this region using only globally available datasets.

Societal importance for stakeholders

With such a system in place, flood risk reduction actions can be taken systemically in this flood-prone region to reduce the impact of disaster. Several options for risk reduction actions will be presented, with an estimation of the societal benefits of action triggered by existing information on flood risk.

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GLOBAL QUICK SCAN OF THE VULNERABILITY OF GROUNDWATER TO TSUNAMIS

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Major tsunami events struck the coasts around the world in last decade with fatal consequences in terms of human casualties and material damage. While effects of a tsunami are clearly visible and well documented on the surface, little is known about the impacts on groundwater resources in the inundated areas. We have developed a quick scan modeling tool to find the most vulnerable areas worldwide to groundwater salinization caused by tsunami inundation. First, a topographical vulnerability index is calculated using information from the SRTM90m dataset (DEM of the world). Thereafter, a global tsunami hazard study by Løvholt et al. helps to choose only areas with potential high risk of tsunami. At last, regions with income below poverty line (1$/day per capita) are picked as the most vulnerable, due to no availability of alternative freshwater resources. Once these areas are selected, a search for parameter statistics such as soil type and precipitation is performed using a method of raster masking (overlay). Parameter statistics help to create ranges of values which are then used during a modeling process of salinization of fresh groundwater aquifers due to tsunami inundation. Conceptual 2D models are created with total length of 5km and depth of 50m, each model simulation has a unique combination of parameter values. The severity of salinization is quantified as time necessary for a specific area to restore a freshwater concentration in more than 95% of its extent. The method proposed in this study gives a lot of opportunities for vulnerability assessment to different hazards on a global scale.

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AN ABM FRAMEWORK FOR MODELLING CLIMATE CHANGE IMPACTS ON ROAD INFRASTRUCTURE IN COASTAL AREAS

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Climate-change poses an inevitable risk to many aspects of humankind and it's supporting infrastructure services. Some of the climate-change impacts witnessed in the recent past are increased incidences of rain, snow, floods, rising sea-levels and temperatures. For delta regions of the world, two climate impacts that are of importance include sea level rise and flooding, and additionally, increased wet weather in case of The Netherlands. These impacts cause increased salinity levels in water resources either because of the salt surfacing with rising groundwater level, or with increase in brackishness from rising sea levels. This increase in salinity levels present serious risks to water quality, agriculture and damage of infrastructure. Infrastructure of specific interest to this study is the road pavements and sewer pipes in coastal areas.

Asset management is a domain that mainly focuses on maintenance and management of infrastructure assets over their entire life cycle. With climate-change impacts and risks discussed above, asset management can play an important role in managing and minimizing them. Many studies that deal with asset management of infrastructure more often than not, consider one asset category and thus avoid the possibility of studying simultaneous effects of events on multiple-category of assets.

In this study we propose an agent-based modeling (ABM) framework that helps in studying interactions between interconnected infrastructures. The ABM paradigm allows for modeling system components at an individual level and observe the outcome of their interactions at a system level, over a period of time. Here the interactions of infrastructure are with asset managers and varying groundwater levels and rising sea levels. We model each infrastructure asset and the climate event as an agent layer and integrate them logically in the framework. The framework is currently being used for a case study in Noord Rotterdam to study cascading effects of infrastructure due to a dike breach. We extend this model to include effects of salinity on sewer and transportation infrastructure and study their deterioration for risk profiling. The model framework includes agents: asset manager, traffic, road segments, and sewer network together with groundwater and sea level scenarios. The advantages of such a framework include long term valuations of asset behavior with an insight into cumulative impacts on the asset over the years. We expect this tool to form a decision support system that can help asset managers in answering many when-and-where questions and in rectifying their investment profiles over a long term.

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