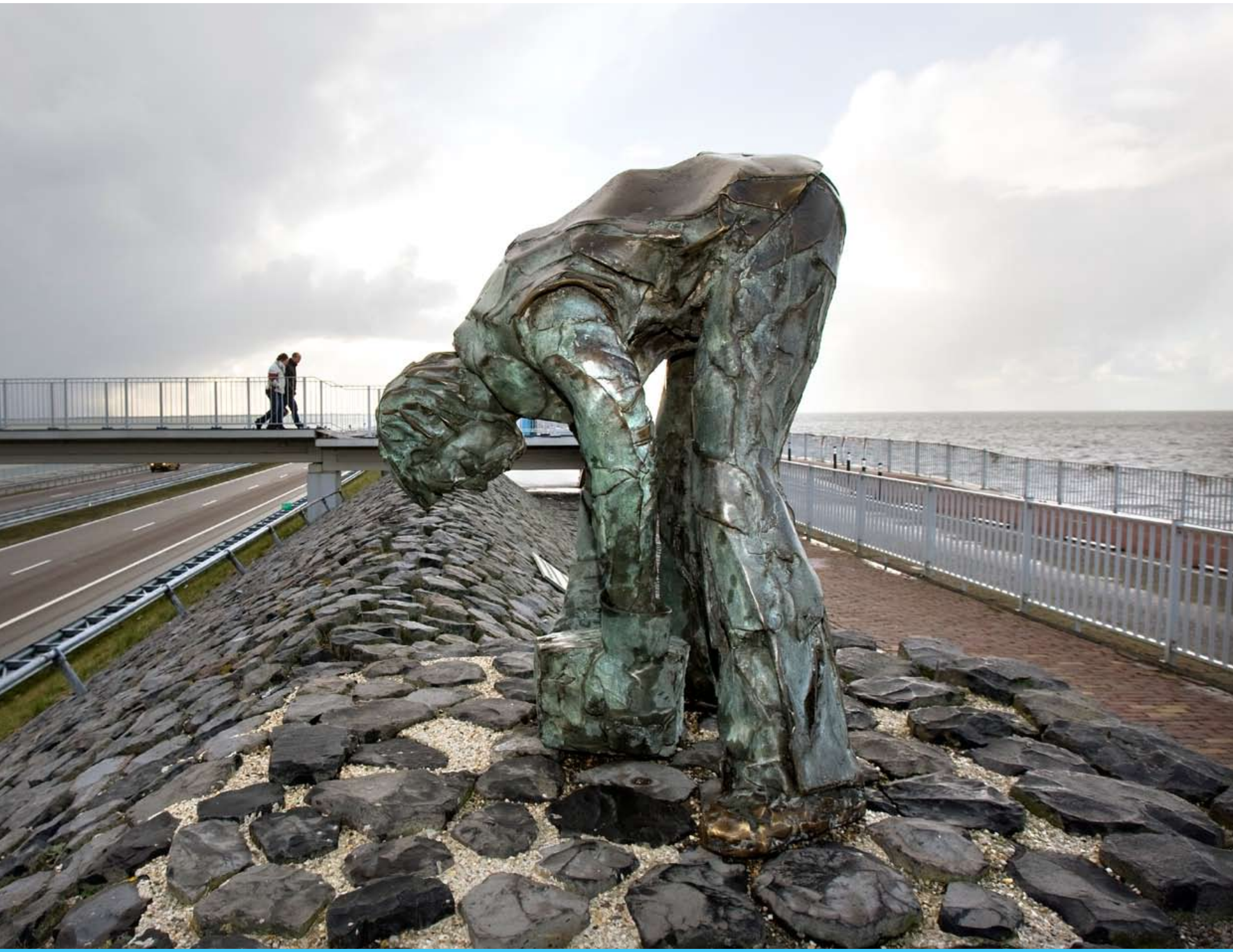
Climate Research Netherlands

A PUBLICATION OF THE RESEARCH PROGRAMMES
CLIMATE CHANGES SPATIAL PLANNING
AND KNOWLEDGE FOR CLIMATE | DECEMBER 2009

Research Highlights



COLOPHON

Climate Research Netherlands – Research Highlights s a publication of the research programmes Climate changes Spatial Planning and Knowledge for Climate This issue offers a broad spectrum of Dutch Climate Change research. It highlights the topics we work on, results so far and ongoing research.

This publication online
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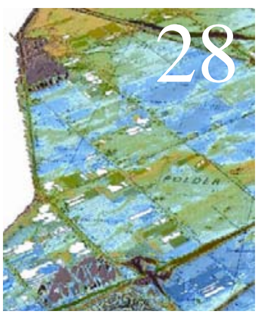

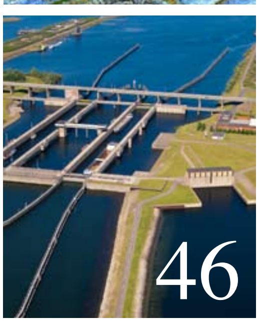

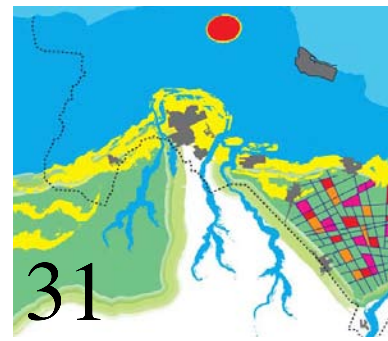

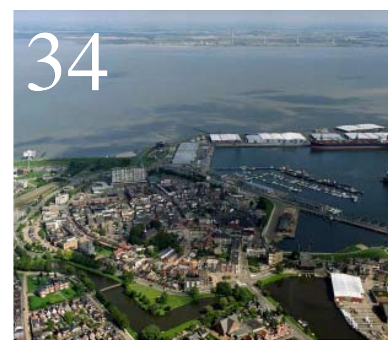

Editorial

CLIMATE CHANGE is one of the major environmental issues for the coming years, both globally and regionally. The Intergovernmental Panel on Climate Change (IPCC) concludes that since 1900 the global mean temperature has increased on average by 0.8°C. In the past 30 years
this warming was mainly anthropogenic, which means up to large extent attributable to human activities. Global climate scenarios for 21st century show a range of warming which is of a large concern for many regions around the world. We can no longer assume that the future climate will be a statistical replica of the past. Scientific evidence is mounting that frequencies and magnitude of climate extremes in the future are increasing as a consequence of anthropogenic climate change.

In the Netherlands the temperature has risen, on average, by 1.6°C since 1900. Regional climate scenarios for the 21st century developed by the Dutch Royal Meteorological Institute [1] show that temperature in the Netherlands will continue to rise and mild winters and hot summers will become more common. On average winters will become wetter and extreme precipitation amounts will increase. The intensity of extreme rain showers in summer will increase and the sea level will continue to rise.
Changing climate will affect all segments and sectors of the society and the economy of the Netherlands, but it also brings new opportunities for major innovations. Examples are opportunities for emission low (re)development of country spatial infrastructure, to enhance land-use opportunities with respect to sources and sinks of greenhouse gases, to increase adaptive capacity in the management of, amongst others, agriculture, natural resources and water, and to enhance the protection of our infrastructure and thus the safety of our people. Meeting this challenge calls for a major investment in knowledge development and knowledge infrastructure. For the period between 2005 and 2014, two large research programmes have been initiated and funded in the Netherlands in response to this challenge: "Climate *changes* Spatial Planning" (CcSP) and "Knowledge for Climate". Both programmes are supported by the Dutch Government from a so called Economic Structure Enhancing Fund (FES), providing funding of 90 million Euro, and by participating organizations and stakeholders, which bring up an additional 110 million Euro.
The programmes are built around the principles of "Climate proofing" [2]. Climate proof development does not mean a zero-risk, which would not be a realistic or economically viable approach for any country or region in the world. Our programmes embrace the climate proofing concept as a combination of (i) targeted, new "hard" infrastructural adaptation measures as well as mainstreaming climate change into other infrastructural developments, (ii) risk management and coping strategies which rely on mainly the "soft" sectors and measures, like the bank/insurers, legislation schemes, governance and institutional transitions,

PROF PAVEL KABAT
Scientific Director and Chair Programme Council, "Climate *changes* Spatial Planning"

PROF PETER DRIESSEN
Scientific Director "Knowledge for Climate"

transitions in spatial planning, and (iii) opportunities for technological, institutional and societal innovations

Both knowledge programmes aim to generate internationally competitive scientific results. At the same time, a major goal of both programmes is to enhance joint-learning between science and practice in coping with climate issues in local, regional and (inter)national developments, both in public and private domains. Both programmes recognize that the benefits of climate research arise from direct engagement and applications by the stakeholders. Governmental organizations (central government, provinces, municipalities and water boards) and businesses, actively participate in research projects.

A special feature of both programmes are so called hotspots: places or regions where science and practice meet and collaborate during the entire cycle of a project, from its definition phase through to its execution and final valorization of outcomes in terms of prototyping and implementing climate proof solutions. Hotspots are chosen based on (i) economic importance and the importance of the investment agenda, (ii) expected impact of climate change, (iii) ambitions relating to innovation and adaptation and (iv) national and international transferability. In order to ensure that research activities are demand-driven, a mixed team from the local authorities and business and science communities is put together for each hotspot project. Selected hotspots include major infrastructural and economic pillars of the Netherlands, such as Schiphol Mainport and the Port of Rotterdam. "Climate *changes* Spatial Planning" (CcSP) and "Knowledge for Climate" focus on exploiting new adaptation strategies in the Netherlands to alleviate negative effects due to climate change and climate variability and at the same time support sustainable use of our space. The programmes aim at implementing an integral approach where science, governmental organizations and private companies jointly invest and operate to develop adaptive strategies supported by high quality technology. These guiding principles and initial results of our research have already found their way into some of the major strategies and decisions on future infrastructure of the Netherlands[3].

In this brochure , a small selection of our projects and some results are presented. We welcome and encourage the reader to visit our webpages to learn more about our programmes, or to contact us for more information.

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PROJECTS
CS02: The CESAR Observatory: climate monitoring and process studies
CS03: Representation of soil moisture and root water uptake in climate models
CS04: The regional climate impact of aerosols
CS05: Remote influences on European climate
CS06: Refinement and application of a regio-nal atmospheric model for climate scenario calculations for Europe
CS07: Tailoring climate information for impact assessment

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Update on the KNMI Regional Climate Model RACMO

Regional Climate Models (RCM) are increasingly used for downscaling global climate model projections to refine spatial and temporal resolutions. The challenge is to develop modules that improve the representation of small-scale features in the Regional Climate Models.

Large scale atmospheric features such as weather systems or long-lasting episodes of excessive precipitation or drought are typically inherited from the lateral boundary conditions and reproduced fairly well by adequately configured RCMs. It is information on small-scale features such as intense precipitation events, gradients across coastlines and mountains, or conditions where the surface is strongly decoupled from the overlying atmosphere, where RCMs can add skill to the coarse scale climate projection[1].

The modeling group at the Dutch KNMI institute has devoted more than a decade of research to building the Regional Atmospheric Climate Model (RACMO). This model is performing very well in European projects (PRUDENCE, ENSEMBLES), where RCMs are confronted with a range of observations[2]. It reproduces summertime precipitation and temperature variability very well and captures the main climatic gradients. There are, however, several areas that need improvement.
A systematic warm bias in high latitude winters persists, as well as a wet winter bias in mid-latitudes[3], among other structural shortcomings.
In addition, many improvements to components of the model have only been guided by empirical evidence, such as the deepening of the soil layer to mitigate a summer warm and dry bias[4]. Finally, some processes, which have a clear and important impact on the regional climate, such as direct and indirect effects of temporally variable aerosols, are lacking in the model.
Ongoing research activities continuously lead to further improvements of the model. This paper highlights a few developments that may lead to significant changes in future projections applied with the RACMO model. They cover the areas of coastal precipitation effects, land surface hydrology, turbulent mixing and aerosols.

Coastal precipitation effects in summer and autumn

The temperature of the North Sea has a significant impact on the spatial distribution of precipitation in the Netherlands. During July 2006 the temperature in large parts of North-West Europe was more than 3K warmer than normal, and it was excessively dry in the Netherlands and surroundings. During August 2006 the atmospheric circulation changed and transported large amounts of moist air from the North Sea into the country, and record breaking precipitation events occurred in the coastal zone of the Netherlands. Partially in

The modeling group at the Dutch KNMI institute has devoted more than a decade of research to building the Regional Atmospheric Climate Model (RACMO).

The integration of turbulence and convection and the inclusion of an equation for the Turbulent Kinetic Energy (TKE) enhances the synergy and robustness of the model formulation.

the context of climate change projections, it was found that in late summer and autumn the coastal precipitation increases at a rate of 14 % per degree temperature rise of the North Sea when cold and unstable air is transported from the North Sea. The temperature increase of the North Sea appears to exceed the global mean temperature rise during the past decades. This is associated to the observed increase in coastal precipitation relative to the main land area. High resolution RACMO simulations carried out for this 2006 episode[5] confirm the correlation between sea surface temperature and coastal precipitation (see figure 1). Coarse resolution simulations with low resolution sea surface temperatures (left panel) are unable to generate the strong precipitation gradient across the coastal area. The high resolution version of RACMO, however, shows a good simulation with realistic sea surface temperatures (right panel). Increased resolution, and inclusion of realistic sea surface temperature calculations are components of a future version of RACMO, which will lead to a better representation of important spatial features.

Land surface hydrology

In an earlier version of RACMO, used for early European climate integrations, a typical problem emerged: during summertime, continental areas in Eastern and Southeastern Europe showed a strong warm and dry bias, caused by a rapid depletion of the soil water reservoir and positive feedbacks reinforcing this dry-down. The cause of this bias is probably a mixture of coarse resolution, errors in the representation of land surface and precipitation processes, and a soil water reservoir that is too shallow. This latter feature was corrected for by extending the soil depth arbitrarily, indeed leading to a better summer climate over continental Europe[6]. However, the procedure followed was not very satisfying, as no clear physical evidence was given to support the increase in soil depth.

In a later evaluation study, Wipfler et al[7] used a mix of satellite observations and model versions to identify an optimal and realistic configuration of the soil-root system. Straight incorporation of soil depth data from an external source (FAO) did not lead to an improved model performance, as this soil depth data generally showed shallower root zones than already present in RACMO, thus reinforcing the bias problem. Apparently additional processes are in place that constrain the hydrological cycle in that area.

Example: Evaporation in the Danube Region

Comparison with remotely sensed evaporation data covering a major part of the Hungarian Danube region revealed an interesting feature (figure 2): large areas are shown where the annual evaporation exceeds the annual precipitation amount, pointing at non-local sources of water. These areas include major irrigation fields bordering the Danube river, and the large Lake Balaton, both not represented well in the RACMO model. Inclusion of these processes in future versions of RACMO are underway, and will probably lead to improved representation of continental scale hydrological processes.

Turbulent mixing

Near surface temperatures are highly controlled by turbulent mixing of air in the lowest atmospheric layers. Turbulent mixing, in turn, is very efficient when the air is heated from below, such as during summer days with fair weather conditions. But for cases where the surface is cooler than the atmosphere, such as nighttime or (high latitude) winter conditions, turbulence is very inefficient and strong vertical temperature gradients can occur. It is under these conditions that large systematic (positive) biases occur in the modeled temperature in many model configurations, including the older versions of RACMO. To complicate the picture further, mixing also occurs under conditions of small-scale organized convection: parcels heated from below (or cooled from above) tend to rise (or sink) in organized cells, leading to for instance scattered clouds in areas with rising air and clear skies in the areas with descending air in between. In many models including RACMO the effect of small-scale organized convection is represented in a separate module using a so-called mass-flux approach.

DualM-TKE formulation

A suite of alternative formulations in the representation of mixing have been examined using the RACMO model. The optimal configuration is attained with the so-called "dualM-TKE" formulation (see figure 3). In this representation mixing by turbulence and mixing by organized convection are integrated into a single module rather than treated separately. The integration of turbulence and convection and the inclusion of an equation for the Turbulent Kinetic Energy (TKE) enhances the synergy and robustness of the model formulation. The new module leads to a significant improvement of temperature under conditions which are typically difficult to represent: nocturnal

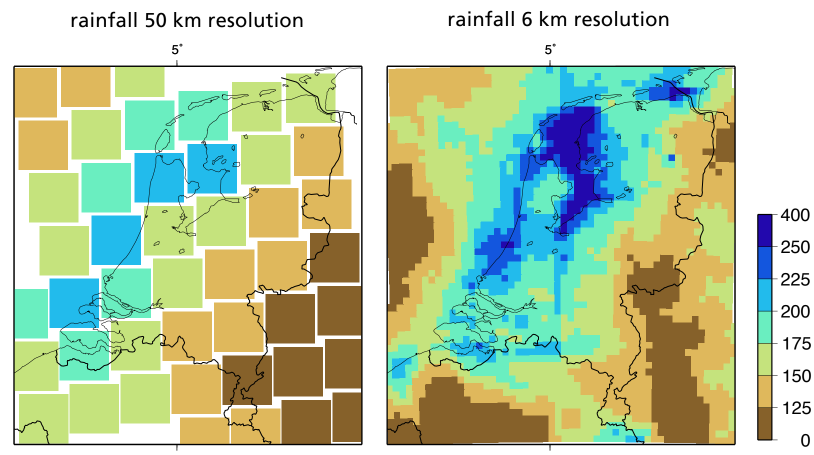


FIGURE 1: RACMO calculations of monthly rainfall in August 2006. Left panel: simulation at 50 km resolution forced with low resolution North Sea surface temperatures. Right panel: 6km resolution simulation with high resolution satellite inferred sea surface temperatures (Lenderink et al, 2009).

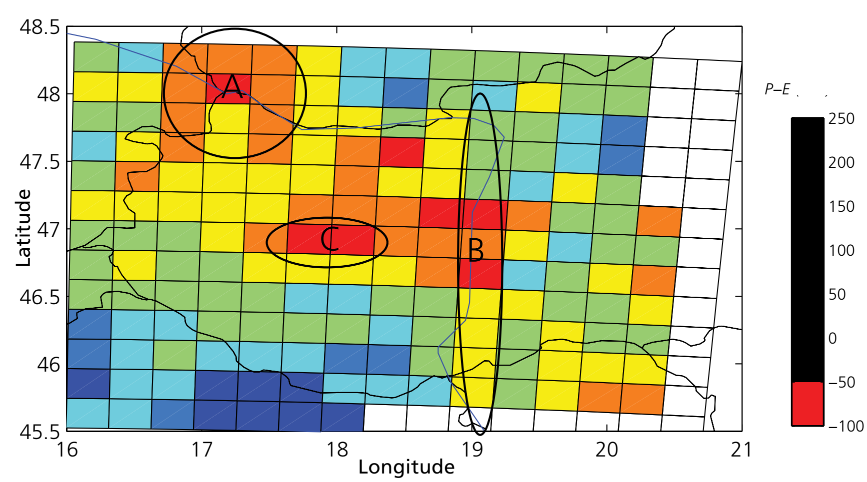
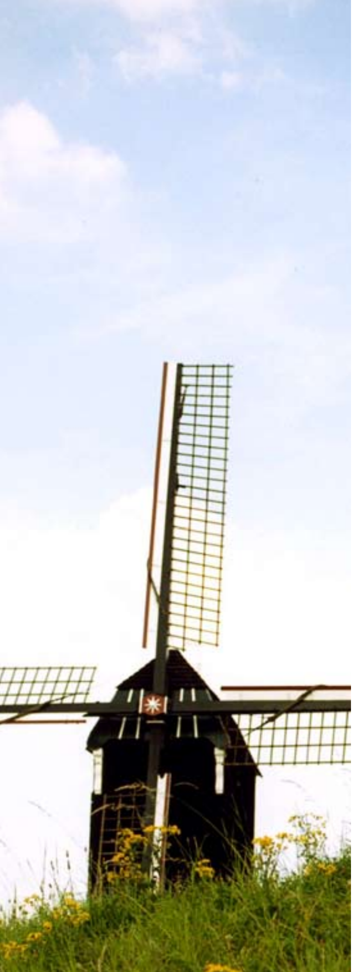


FIGURE 2: Annual balance of precipitation (P) minus evaporation (E) for the Hungarian Danube area. Both P and E are estimated from satellite data. Negative values of P-E (dark blue shading) denote non-local water sources to sustain evaporation. Regions A and B are irrigation areas, and C is Lake Balaton.



and/or (high latitude) cold season temperatures have a much smaller systematic positive bias. Also this change will significantly increase the realism of projected temperature changes in future model simulations.

Aerosols

The representation of direct and indirect effects of aerosols is a very active field of research. Direct effects of aerosols include changes in the reflection of shortwave radiation by changes in the aerosol composition of the clear sky atmosphere, thereby affecting the surface energy balance. The indirect aerosol effects refer to the interaction between aerosols and clouds. They include the increase of the number of particles that allow cloud water droplets to be formed by condensation, the so-called Cloud Condensation Nuclei (CCN). Changes in cloud droplet size and number considerably alter the reflection of shortwave radiation and, to a lesser extent, the cloud emissivity affecting the longwave radiation (Figure 4). In addition, the onset of precipitation and the lifetime of clouds depends on CCN, causing another indirect effect of aerosols.

In the reference version of RACMO the effects of aerosols and CCN are implemented in a very indirect way. Cloud formation processes and atmospheric reflection properties are "tuned" to account for aerosol effects, and the spatial distribution of aerosols is typically prescribed and does not respond to temporal or spatial changes in aerosol emissions or chemical processes in the atmosphere that change the aerosol distribution. A chain of research activities is currently underway to implement aerosols in a much more interactive way, by coupling aerosol distributions generated by an offline chemistry/transport model (LOTOS) to the actual cloud and radiation modules in RACMO. This coupling is both scientifically and technically very complex. Scientifically, because a lack of observations and basic understanding of the relevant processes makes it difficult to constrain

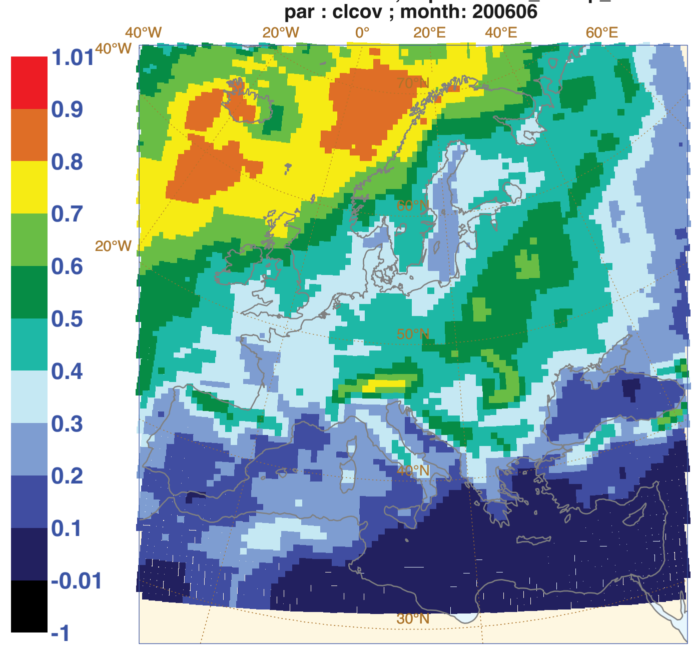


FIGURE 4: Radiative response of RACMO to aerosol field distributions generated by the LOTOS model relative to a result obtained with a "fixed" aerosol distribution. Left panel shows mean monthly cloud cover for June 2006, center panel shows the response in short wave radiation at the surface (LOTOS aerosol minus fixed aerosol), right panel shows response in daily mean 2-meter temperature.

model behavior within the range of related observations. Technically, because separate model codes to trace aerosols and to calculate atmospheric dynamics need to exchange relevant information at an agreed frequency, spatial domain and variable type. A fully coupled aerosol/RCM system is not yet operational at KNMI, but important progress is made here.

Conclusions

Global and regional climate models, such as the KNMI RACMO model, are continuously in development. The development is guided by an increasing availability of relevant observations, which are used to both detect areas where improvements are needed, and to provide high-level input to the changed modules. The improvements listed in this paper illustrate this continuous cycle of model improvements, and provide an outlook to future model versions that are increasingly capable of representing the important processes governing our climate system.

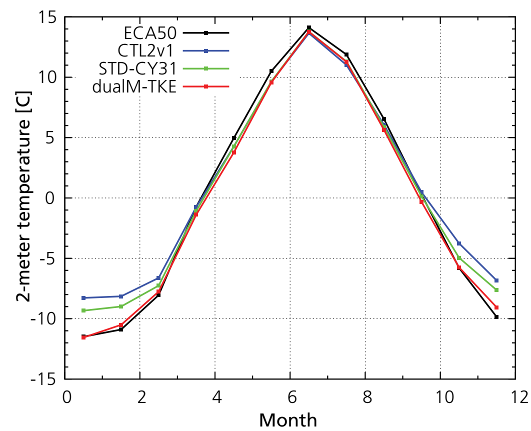
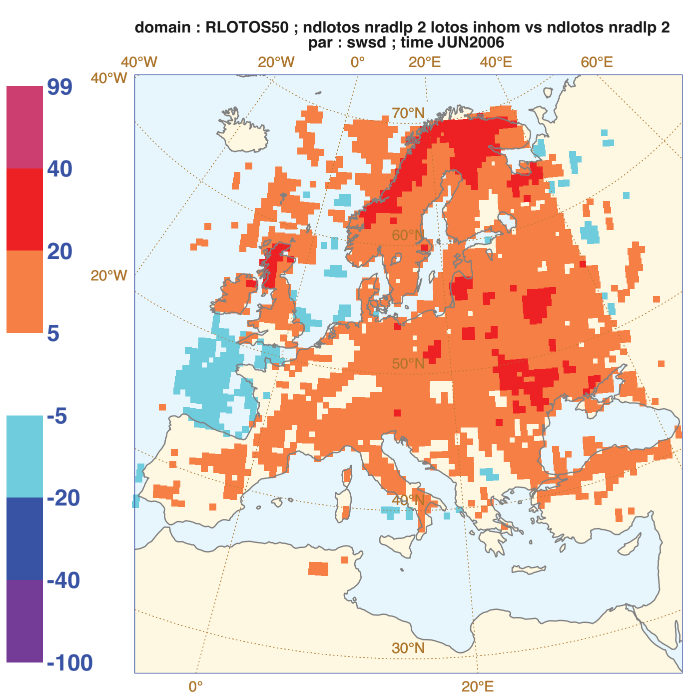
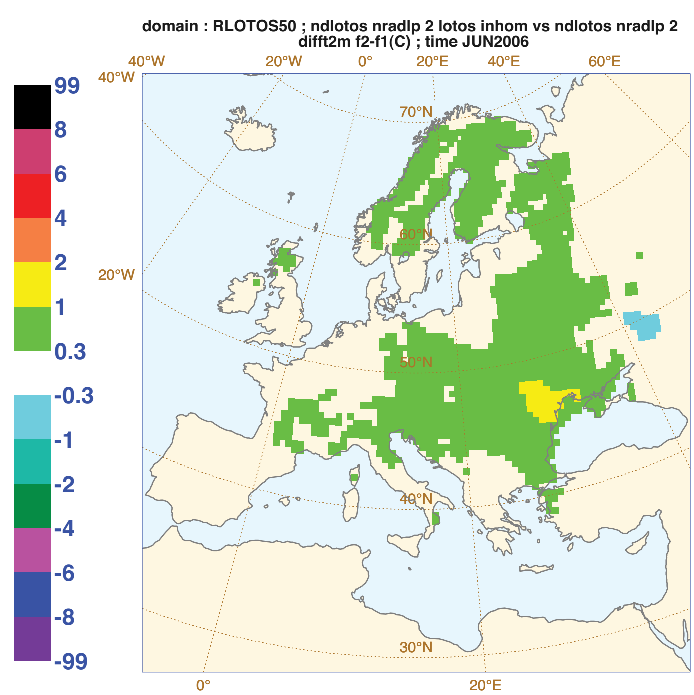


FIGURE 3: Mean annual cycle of 2m temperature in Northern Scandinavia during a 7 year period (2000 – 2006). Shown are observations (ECA50, in black), the current control version (blue), the new version without TKE mixing (green) and the version with the dualM-TKE mixing (red). During summertime the difference between the model versions and observations is very small. During wintertime, the systematic positive bias in the old and current RACMO versions is entirely removed by using the dualM-TKE formulation.





Despite continuous improvements of our climate models, there are fundamental limitations of the predictability of the climate system. Even with "perfect" models, natural variability and unknown evolution of the driving forces will inevitably lead to "imperfect" forecasts. The popular phrase "Model outcome should be used and interpreted with care" is not only a reflection of scientists modesty when their limited expert knowledge about the climate system is considered. It also refers to the need to interpret model results with a proper understanding of the fundamental limitations of predictability. Model results perfectly serve the need for credible and realistic outlooks towards how our future (regional) climate might look like, feeding our imagination that is necessary to take adequate measures. Better models will be better capable of providing these future snapshots. Thus, investing in model improvement remains a wise thing to do.

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Monitoring the North Atlantic Ocean

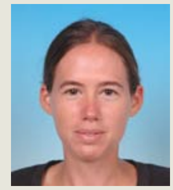
Monitoring the North Atlantic Ocean is important for gaining understanding of the processes involving deep water formation and for tracking changes which may occur therein as a result of a changing climate.

The North Atlantic Ocean is a key area for the thermohaline circulation. It is one of the few areas where the transformation of surface waters to deep waters takes place, thereby closing the link between the northward flow of warm surface waters and the southward flow of cold deep waters.

The monitoring of the North Atlantic is done by means of survey cruises and moored instruments. The survey cruises cross the northern part of the North Atlantic, from Labrador to Greenland and from Greenland to Ireland, nearly annually. These cruises, which started in 1990 as part of the World Ocean Circulation Experiment, offer insight into the interannual to decadal variability.

In September 2003, the NIOZ also deployed two moorings on the survey line east of Greenland. The instruments in the moorings monitor the currents and the vertical temperature and salinity structure of the water column on a daily basis. These daily measurements, which now form a 5 year long record, indicate that the variability at intra-annual time scales is of equal size as the interannual variability in this region. Information of both the interannual and daily time scales must be combined to fully understand the processes responsible for the variability of the North Atlantic, especially the variability in deep water formation.

With the Royal Netherlands Meteorological Institute (KNMI), a partner in the CS01 project, the observations from the monitoring project have been compared to simulation of the North Atlantic Ocean of Coupled Climate Models. This comparison shows that the deep water formation in the models could also be improved upon.



FEMKE DE JONG
Drs. Femke de Jong finished her study in Physical Oceanography and Meteorology at Utrecht University in 2004. She started her PhD study at the Royal NIOZ in which she investigates on the variability of the northern North Atlantic Ocean on a range of time scales. Special focus in this study lies on convective or deep mixing in the Irminger Sea.
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HENDRIK VAN AKEN
Dr. Hendrik M. van Aken obtained his Masters degree in Geophysics (Physical Oceanography and Meteorology) in 1981 at the University of Utrecht, where he also obtained his PhD. He is currently head of the Physical Oceanography department of the Royal NIOZ. His research focuses on the large scale ocean circulation and its role in climate, but also on climate variation in the Wadden Sea.

PROJECT: CS01 – North Atlantic Ocean modelling and monitoring

PARTNERS: Royal Netherlands Institute for Sea Research (Royal NIOZ) / Royal Dutch Meteorological Institute (KNMI) / Utrecht University / Institute for Marine en Atmospheric research Utrecht (IMAU)

The NIOZ research vessel Pelagia. The R/V Pelagia is used for the survey cruises and the deployment and recovery of the moorings.

PROJECTS
ME01 Integrated observations and modelling of: greenhouse gas budgets at the ecosystem level in the Netherlands
ME02 Greenhouse Gas budgets at the national level in the Netherlands
ME03 Soil carbon dynamics and variability at the landscape level

RONALD HUTJES
Wageningen UR

REIN DE WAAL
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EDDY MOORS
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Full carbon accounting: mission impossible?

Quantifying mitigation efforts against a large background variability is a demanding task, in which scientific complexity and manageable, transparent accounting systems have difficulty to meet. Can we bring these together?

To mitigate climate change, demanding greenhouse gas emission reduction targets are being negotiated. Meeting these targets requires putting to work a broad and integrated range of reduction options, including those related to land use. To merit the reduction achievements by motivated stakeholders in all sectors and to prevent leakage to less committed players requires a form of full carbon accounting.

Accountability

The above holds equally for emissions and reduction options associated with the use of fossil fuels in power generation, industry and transport, as well as for emissions associated with biomass production and consumption in managed and natural ecosystems. However, the first category basically comprises the uni-directional input of greenhouse gases (GHGs) to the atmosphere through heterogeneous, but largely man-controlled conversion processes of fossil carbon, extracted at a limited number of sites, i.e. coal mines, oil/gas wells. Biogenic emissions, on the contrary, are a small net result of large, spatially diffuse fluxes into and out of the atmosphere, only rudimentary controlled by humans and characterized by a strong temporal asymmetry ('slow in, fast out'). In this field therefore big challenges arise to the development of truly effective mitigation options, to the development of an appropriate accounting system that prevents, or at least shows leakage in space and time. It also increases the need for independent verification of reduction claims. To tackle some of these challenges, in 2005 we started an ambitious, integrated, combined modeling and monitoring programme. This should, then and now, serve as a basis for the development of *and* viable mitigation options *and* of fool-proof reporting systems *and* of ways to independently verify emission reduction claims, focusing on biogenic emissions.

The projects

To do so we developed a measurement programme that addresses the quantification of magnitude and variability of *fluxes* of carbon dioxide, methane and nitrous oxide in various ecosystems, as these provide more direct insight in drivers. Furthermore we work on quantification of carbon stocks, mostly the more permanent organic carbon in and on the soil, as these carbon stocks integrate long term processes and are closest to current accounting concepts based on changes in stocks.

Both C-stocks and GHG fluxes are being studied along gradients of land management or in manipulative experiments in order to study potential

> Over the past five year we have collected a great wealth of data on biogenic GHG emissions and made some significant progress in simulating these findings.

mitigation options. At the regional scale tall towers provide high precision GHG measurements that can be used to constrain regional to national scale fluxes using inverse methods, complemented by aircraft observed fluxes along transects covering representative Dutch Landscapes. Measurements at all these scales have been complemented by modeling efforts. In the following we will present some selected research highlights leading to the question whether full carbon accounting is possible.

Emissions from Dutch grasslands

A large biogenic source of GHGs in the Netherlands is found in the low-lying peat areas in western Netherlands. These are generally under grazing but increasingly frequent also under crops, made possible through tight controlled lowering of groundwater tables. This leads to the oxidation of organic soils. To better quantify this source, an extensive programme was setup jointly between several groups, using flux towers and chamber measurements to quantify fluxes of CO_2 and CH_4

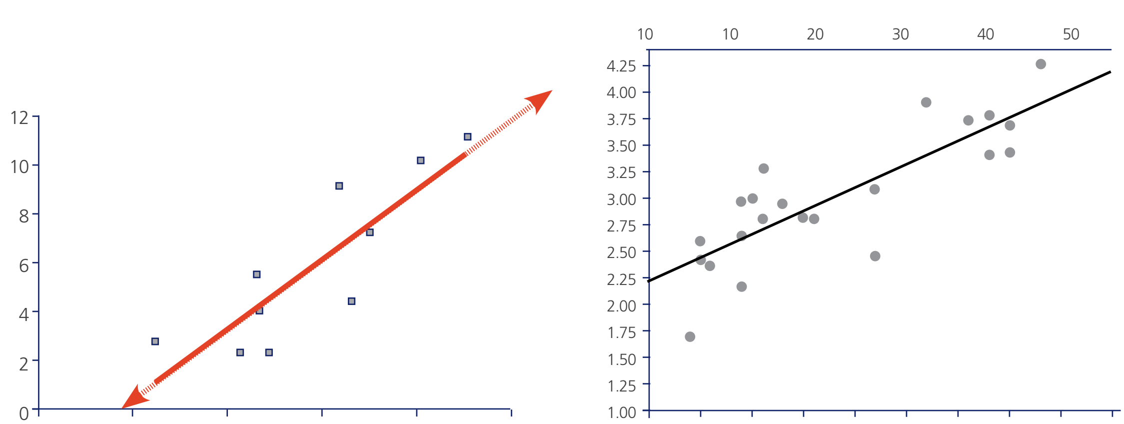

FIGURE 1. N_2O (left) and CO_2 (right) emissions as a function of ground water level in Dutch organic soils. Such simple relations are ideal to improve reporting methods.

and N_2O. Having completed a number of years of sometimes technically advanced measurements[1, 2, 3]. The data revealed a number of dependencies of emissions of all three GHGs on local water and land management conditions.

A comparative analysis of grassland fluxes in de Netherlands revealed a strong relation of the CO_2 exchange with general land management and underlying soil[4]. In general grasslands on mineral soils are a small sink of only 3.3 tonnes of CO_2 per hectare per year, but varying by almost the same amount from year to year.

On organic soils however, grasslands on average are a source of 8.1 tonnes of CO_2 per hectare per year with an interannual variability of about 40%, but systematically varying with land management: natural grasslands (restoration projects) are a small sink, drained grasslands under intensive grazing a highly significant source. The latter is mostly caused by strong oxidation of soil organic matter as a function of groundwater level (see figure 1, bottom), producing more than 27 tonnes CO_2 per hectare per year when groundwater is close to the surface to twice that number for groundwater levels half a meter below the surface[5].

For N_2O production a similar relation with groundwater has been found (figure 1, top): less than 2% of nitrogen applied as fertilizer is mineralized to N_2O on nearly inundated soils to more than five times that amount at groundwater levels half a meter below the surface[6].

Finally, also methane fluxes from these de-facto wetlands could be successfully quantified[7] showing emissions varying between roughly 2.5 tonnes CO_2-equivalents per hectare per year from intensively managed grasslands to almost threefold that number from extensively used fields (figure 2). Modeling work on all three GHG emissions from these peatlands is underway. Flux measurements have also been performed on croplands. A typical maize field on mineral soils in the Netherlands seems to be a net source of CO_2, even when accounting for the carbon input from manure application[8].

Carbon stocks of Dutch soils

Carbon stocks exhibit with various sources of variability and uncertainty. This variability is partly caused by spatial distribution of natural factors in the landscape, but is also strongly influenced by

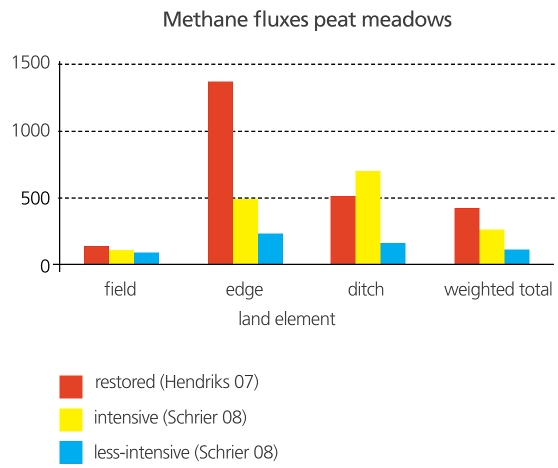

FIGURE 2.
Annual methane emissions as for various elements of the landscape in Dutch fen meadow areas[7,18].

past and present land use. Management in forestry and agriculture does not only provide us with an explanation of the observed variability and thus enables stratification in inventory based accounting methods, but enables us to make choices in respect to climate change mitigation. Above ground, living biomass stocks (forests) are generally well known, below ground stocks though estimated to be of similar size much less.

Insight in the determinants of the spatial distribution of soil organic matter (SOC) and forest floor carbon stock (FFC) can help us to improve estimation of the total carbon stocks. The influence of tree species, stand age and management on the SOC and FFC stocks has been investigated, on the base of two case studies on forest on representative poor sandy soil[9]. Tree species, age of the stand as well as management proved to be a an important source of variability on both the SOC as the FFC (Figure 3).

The influence of land use history on the carbon stock has also been studied[10]. The historical land use proved to explain a larger part of the variability than the present land use, r^2 =0.20 for 1850 land use and r^2= 0.14 still for 1780 land use as compared to against r^2= 0.02 for present day land use (the remaining variability explained by soil texture and groundwater). Including this land use history in a national-scale inventory of SOC and FFC stocks improved the SOC and FFC stocks by 5-10%. Increasing the sample density did not decrease the error of SOC in agricultural lands[11].

It is expected on the other hand that the FFC will benefit from collecting more additional data. For

A comparative analysis of grassland fluxes in de Netherlands revealed a strong relation of the CO_2 exchange with general land management and underlying soil.

de- and afforestation could be improved. Including historical land use could be beneficial to estimations in other countries with a comparable land use history.

Stocks and emissions at farm level.

Area and site based studies are important for processes and large scale accounting methods. Development of mitigation options, however, is better served with studies at appropriate management levels. An example in the current context is the farm level. Model based studies on the influence of dairy farm management on soil carbon stocks and integral GHG emissions have been made by Van Evert & Verhagen (in prep.)

Dairy farming in the Netherlands is a significant source of greenhouse gasses but it also has substantial mitigation potentials. Thus the question arises how a dairy farm can be managed in such a way that carbon storage is maximized and the emissions of nitrous oxide and methane are minimized. Since management options that lead to emission reduction may lead to a decrease in carbon sequestration, and vice versa, these processes are considered simultaneously using the FARMIN model[12].

Four trends in management have been simulated. Grassland productivity and application of manure significantly affect soil organic matter, the former because a large amount of dead roots is added to the soil, the latter because it adds organic material. Increased dairy cow productivity has an effect on (mostly methane) emissions because the relative fraction of feed used for body maintenance is reduced. Grazing time has hardly an effect on either stock or emissions.

Regional scale assessments using direct airborne flux measurements.

Using small aircraft it is possible to directly observe GHG fluxes over larger areas. During the full seasonal cycle of 2008 three transects covering the most relevant landscape types in the Netherlands were alternately flown on a weekly basis. This way a large dataset has been created that is currently under analysis. An example of CO_2 fluxes along one such transect is given in figure 5.

Regional scale assessments using inverse methods. Changes in atmospheric concentrations of GHG's in the well mixed planetary boundary layer integrate flux variability at much larger scales. These changes can be used to estimate average fluxes of large scales using so-called inverse methods.

Our project's new observational infrastructure includes high precision measurements of multiple GHG's at two tall towers and medium precision at two lower towers. We have build up datasets that are now increasingly used in national and interna-

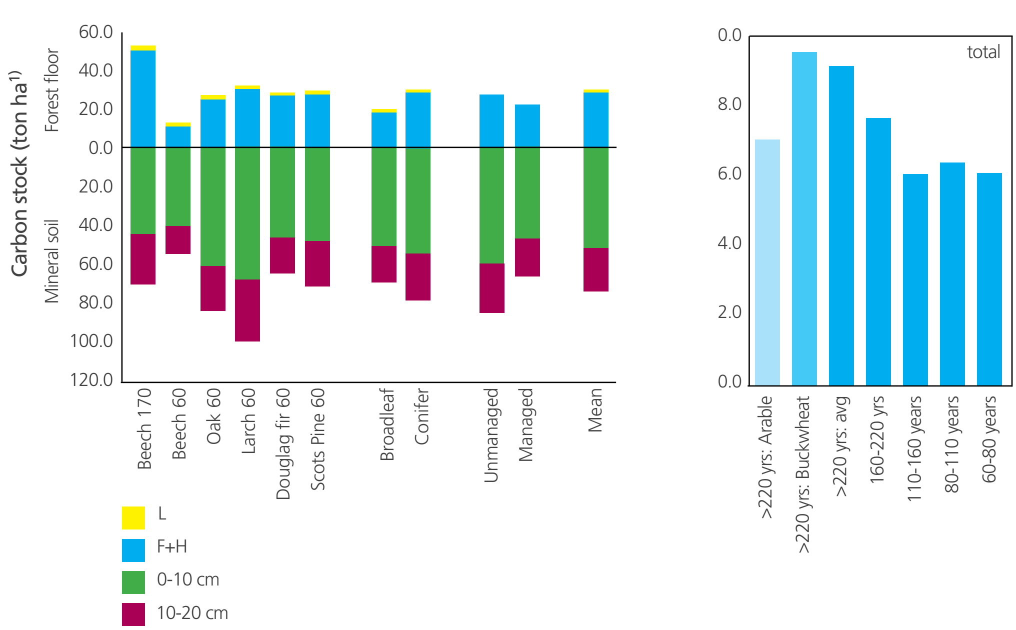

FIGURE 3. (top) Soil carbon and forest floor stocks (ton/ha) in forest stands as a function of management and tree species; (bottom) SOM contents (%) for different reclamation age groups averaged over soil types[9,10].

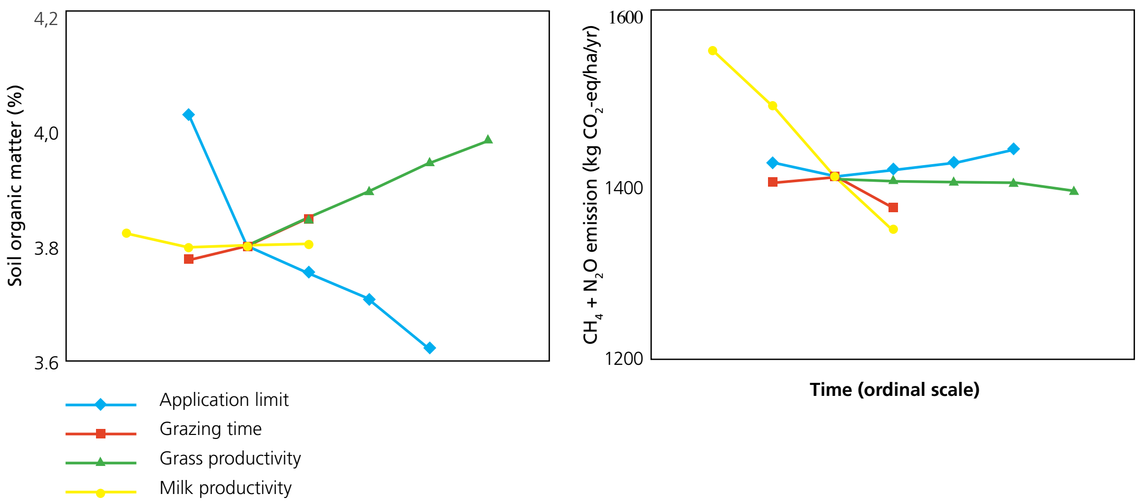

FIGURE 4. Effects of dairy farm management options on soil organic matter (left) and emissions of N_2O and CH_4, suggesting the potential for mitigation and for activity based reporting methods.

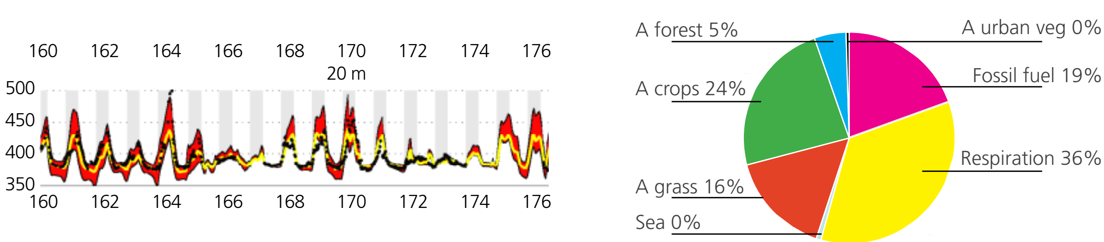

FIGURE 5. Effect of uncertainties in simulated biogenic fluxes on the concentrations observed at Cabauw (red band). These are considerably larger than transport errors and thus confirm the potential for inversion methods to better constrain these fluxes. The diagram at right shows the contribution of various emission sources/sinks to the Cabauw signal suggesting a potential of inversions to discriminate between the four main categories[17].

tional studies. The data can be used directly when concentration changes in the GHG of interest correlate with another tracer (here Radon) of which the flux is known. Based on the Lutjewad tower data, which with typical SW winds is downwind of the Netherlands, successful event-based data inversions have been made for CH_4 and N_2O[13]. Based on 2006-2007 data the Dutch annual emissions have been estimated at 631 +/-220 kton CH_4 and 37.4 +/- 12.5 kton N_2O. These estimates are close to the NIR reported emissions (2006–2008 averages) of respectively (760 ± 137) kton CH_4, and (54.0±24.9) kton for N_2O. In CO_2 equivalents for both together the 26.9 +/- 9.2Mt CO_2-equiv observed is lower but not significantly different from the 35.0 +/- 10.8 in the NIR. Attempts to apply the same method for CO_2 emissions are in preparation, but this appears to be more complicated.

Inversions for all three GHGs, based on different combinations of emission-, transport- and inversion-models are showing progress. Source aggregation methods using lagrangian transport models[14] provide first attempts at CH_4 estimates for the Netherlands. Contrary to the above mentioned data inversions, this model inversion estimates CH_4 emissions to be almost double the NIR estimates and do not show the downward trend reported in the latter. Resolving the discrepancy between the two estimates is subject to further work.

Pixel based CO_2 inversions for Europe are confirming inter-annual variations (e.g. the 2003 drought) and come steadily closer to bottom up estimates[15]. The resolution of forward models is greatly increased and the analysis shows that emission signals are significantly larger than transport and heat flux induced PBL errors, which is promising for inversions at this scale[16,17]. Work in progress using the same high resolution model, shows the added value of additional observations in constraining fluxes for areas the size of the Netherlands.

Conclusions

The examples presented here, are a few of the more integrative results bringing together measurements across multiple sites from various partners. Over the past five year we have collected

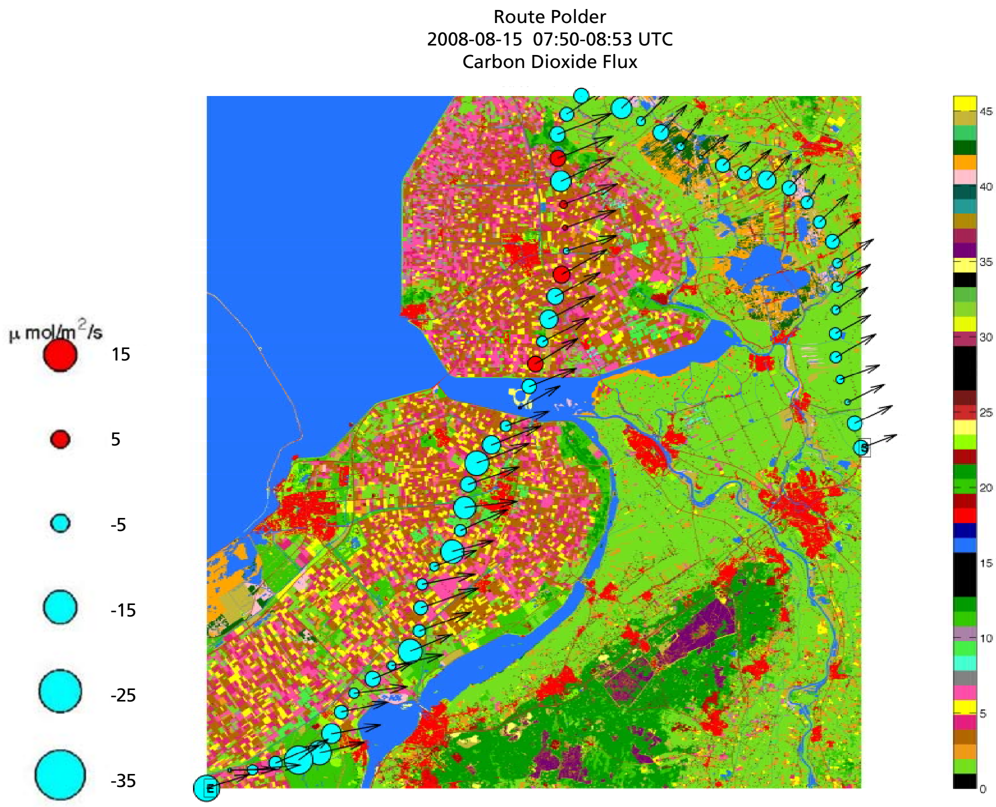

FIGURE 6. Example of aircraft observed CO_2 fluxes over the IJsselmeerpolders in mid- August. The big variation reflects the differences between harvested and still growing crops in this season.

a great wealth of data on biogenic GHG emissions and made some significant progress in simulating these findings.

The flux measurements on each of the three main GHGs have shown considerable variability within various land use types across our country, and could be explained in terms of physiographic and management features. This makes more country specific reporting on emissions possible.

The insights regarding forest soil carbon stock are being used to update the methodology of the National Inventory Reports for this category. Land use history could also be used as it is relatively well documented in the Netherlands (as in many parts of western Europe) through detailed topographical maps dating back to mid and early 19th century.

The opportunity to sequester carbon on Dutch dairy farms seems limited, given the limits on manure application for other reasons. The opportunity to reduce the emission of greenhouse gases by raising productivity seems limited in the Netherlands where productivity is high already, but may exist in other parts of Europe.

All in all this study reveals mitigation options at practical management levels and provides a basis for activity based reporting methods. Methods for verification of emissions by atmospheric methods is progressing fast, with resolutions quickly increasing to levels making them useful for small countries like the Netherlands. For the gases N_2O and CH_4 that exhibit diffuse sources only the downscaling goes faster than for CO_2 with both diffuse sinks and spatially more concentrated sources. Though absolute estimates exhibit large uncertainties, diverse models generally agree much better on trends and interannual variability. Application of inverse methods in legal procedures over emission reduction claims requires these uncertainties to come down and also a more rigorous benchmarking and eventually even certification of the tools used.

More integration steps remain to be taken in the last stages of the projects. Nevertheless we believe the results presented here are already useful in improving emissions estimates, by making them more country specific. They provide ways forward in activity based reporting for mitigation. Also, the verification of reported emissions through independent atmospheric approaches seems feasible in the foreseeable future. We are therefore positive about the scientific possibilities for full carbon accounting, and believe that negotiations on future emission reduction commitments should move in this direction.

This paper reflects the personal interpretations of the authors, not necessarily completely coinciding with those of the many research collaborators in the ME projects of Climate Changes Spatial Planning, who kindly provided the results and graphs used here.

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We are positive about the scientific possibilities for full carbon accounting.

Land use history explains soil carbon stocks

Through land use, people influence input and output of organic matter to the soil, which, after a long time, results in variability of soil organic carbon (SOC) stocks across the landscape.

Land use history is a dominant factor explaining the spatial distribution of the soil organic carbon stock. With data on land use history, insight in the spatial variability of SOC stocks was improved in several landscape-scale case studies and in the sand area of the Netherlands as a whole. These insights were used to improve understanding of the effects of future land use changes on SOC sequestration.

Case studies

Inventories of SOC stocks and assessments of SOC dynamics require better understanding of SOC variability to decrease uncertainties. In this study, SOC variability was investigated in landscape-scale case studies. In forests, SOC stocks significantly differed between different tree species and between unmanaged and managed locations[1]. In agricultural land, land use history explained much of the SOC variability, while the current land use had a small effect[2,3]. This is a result of the slow response of SOC to land use changes: it takes many decades before land use significantly alters the SOC stock, while effects of past land use on SOC stocks are preserved for a long time.

Applications

Knowledge from the landscape-scale studies was used for upscaling SOC stocks to the Dutch sand area. Using readily available data on long-term land use, the error of the SOC map decreased by around 20% in almost two-third of the area (FIGURE) compared to the state-of-the-art Dutch SOC map. The results can improve the Dutch greenhouse gas inventory and stress the importance of long-term land use for explaining SOC variability. The impact of land use change on SOC sequestration was applied in a European-scale study to model future SOC sequestration under different scenarios[4].

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PROJECT: ME03 - Soil carbon dynamics and variability at the landscape scale: its relation to aspects of spatial distribution in national emission databases.

PARTNERS: Wageningen UR / University and Research Centre / Netherlands Environmental Assessment Agency (PBL) / Biometris / Plant Research International

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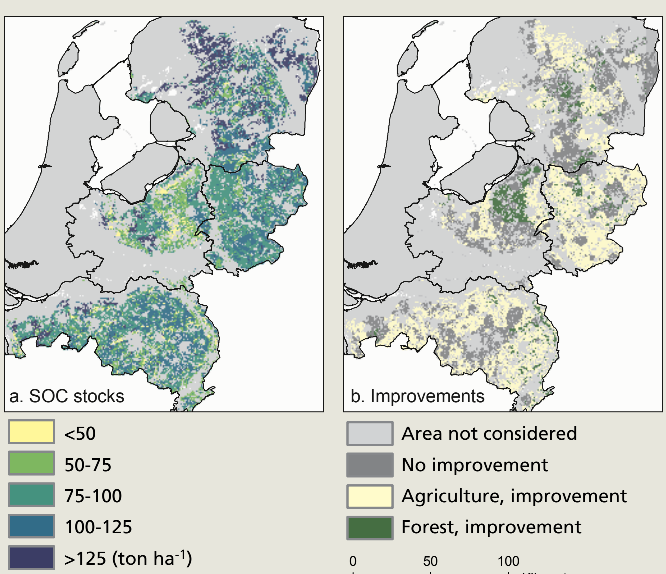

FIGURE
OC map of the Dutch sand area resulting from this study (a); areas where the state-of-the-art SOC map of the Dutch sand area can be improved (b).

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Hotspots: Where science meets practice

The hotspot method is a useful way to apply and integrate theoretical knowledge in the field. Which factors lead a hotspot to be a success and where can pitfalls be identified?

THE APPROACH WAS USED in Groningen and in the hotspot Zuidplaspolder, one of the deepest reclaimed areas in the Netherlands. Teams in both hotspots decided to work parallel to the mainstream planning processes, but with very different techniques.

There are at least two conventional definitions of a "hotspot". First, it is a location that offers internet access; it is a place for people to connect. Second, it can be a region of high activity within a larger area of low activity (Wikipedia. 2009). The research program Climate changes Spatial Planning (CcSP) combined the two meanings to create the concept of hotspots, that is, areas where science and practice connect and where trans-disciplinary research is carried out in 'melting pot' conditions: with many people and over a relatively short period.

In 2006 the Hotspot definition study was carried out to identify, describe and evaluate possible hotspots. A hotspot was defined as a pilot project in a region in which spatial planning and climate change play important roles and where conflicts of interest are found between these and other factors[1]. The research program was designed to start hotspots in order to apply and integrate knowledge in the field, that was produced in the CcSP program. Two workshops and several interviews were held with people from governmental organizations, the business community and nature conservation organizations. In total 65 hotspots were identified of which 13 were selected for closer study. Of these, six of were adopted as hotspots.

This article focuses on the Zuidplaspolder and Groningen Province. The methods used will be described, some of the results will be shown and finally a short analysis of the 'wicked by-pass' will be made.

Zuidplaspolder and Groningen

The Zuidplaspolder is located north of Rotterdam. The land is reclaimed from a lake. It contains the lowest point of the Netherlands: -6.76 m.

The Zuidplas-polder contains the lowest point of the Netherlands: -6.76m

Exactly this location has been designated for major housing developments in the southern part of the Randstad and for greenhouses to farmers. In total, 15.000 houses, 280 ha of greenhouses and 500 ha of nature are planned. The area is vulnerable to existing threats made riskier by climate change: flooding from the river, inundations by increased precipitation, deteriorating water quality, further land subsidence and drought. The hotspot research was intended to evaluate whether the plans, that were already prepared, were climate proof and if not, what could be done to improve them.

The Province of Groningen is situated in the north of the Netherlands, bordering the Wadden Sea. The province is vulnerable to different climate change effects: increased risk of flooding from the sea, heavier precipitation increasing the risk of winter floods, dry summers leading to long periods of drought and more extreme temperatures, all making nature more vulnerable. Groningen decided to prepare a new regional plan for its territory. Climate change was one of the pillars. The hotspot project set out to: identify adaptation options; analyze how climate change with its uncertainties can be fitted into spatial planning and decision making processes; reinforce the network of organizations involved in adaptation challenges.

Guarding creativity

The two hotspots applied different methods to achieve their objectives. But they had one thing in common: both teams decided to start parallel research processes and not to integrate these in the main planning process for the two areas. By so doing, the hotspot teams could follow their own creative paths and methods without being hindered by the procedures and logics of the main provincial planning practice. Rob Roggema, project leader of the hotspot Groningen, states:

Planning for climate change requires alternative methods because it deals with so-called wicked problems. These problems are complex and cannot be easily quantified, because they surface only after a longer period – often more than 30 years –

Oldehove in the north of Groningen province. Extended dry period causes erosion at the edge of a field.

The research program was designed to start hotspots in order to apply and integrate knowledge in the field, that was produced in the CcSP.

and they are uncertain due to the uncertainties of climate change. Yet, we know that we have to deal with them now to avoid higher costs in the future caused by possible climate disasters or by delayed investments[2].

The hotspot research Zuidplaspolder was conducted by the Xplorelab, a laboratory for renewed working and learning of the province of Zuid-Holland. It stimulates integral working through research and design by interdisciplinary and transdisciplinary cooperation between policy makers and scientists. In the first phase of the project, effects of climate change on flooding, inundation, drought, water quality and nature were analyzed in a rational analytical way according to the 'three layers approach': what is the situation now and how will this alter under the four climate scenario's designed by the Royal Netherlands Meteorological Institute KNMI for the underground layer, the network layer and the occupation layer. In the second phase many adaptation options were elaborated for the Zuidplas in creative workshop settings. These ideas were used to make five pilot designs for different parts of the polder. In the third phase the pilot designs were subjected to a cost-benefit analysis. A 'zero alternative' with measures already proposed in the existing plans was compared to the 'pilot design alternative'.

The hotspot Groningen applied a very different approach. It created a 'wicked by-pass'. By-passing the planning process of the regional plan allowed for the use of uncommon techniques such as back casting and back-tracking. With back-casting a desired future (climate-proof and sustainable) was designed and translated to strategies and measures to be taken as from today. With back-tracking a situation in the past was described in which a climate-proof situation and sustainable equilibrium existed. Elements of this past were also used to describe a possible future. New knowledge was developed in expert meetings and other special settings where creative and design oriented thinking were stimulated. Special attention was given to the composition of these groups; in expertise, gender and age they were made as diverse as possible. This enhanced unorthodox thinking.

Results of the studies

Conclusion of the hotspot Zuidplaspolder is that the existing plans are climate proof. Many of the measures proposed in the hotspot study were already used in the plans. However, for water shortage, water safety and inundation caused by precipitation the plans are insufficient under some of the climate scenarios. The five pilot designs offer supplemental solutions, often deviating from traditional approaches[3].

Hotspot Groningen concluded that the regional plan doesn't offer enough possibilities for a long-term and integrated climate proof perspective, while adaptation in the province is urgent. The coastal defence is inadequate, given future risks. Variations on the 'super-dike' and/or controlled inundations make it possible to combine various functions, like housing with safety against flooding. A climate proof ecological infrastructure needs more space, but this can be intelligently combined with space needed for water conservation for dry periods. Also other solutions for fresh water supply, local sustainable energy generation and agriculture are given (www.klimaatbestendiggroningen.nl).

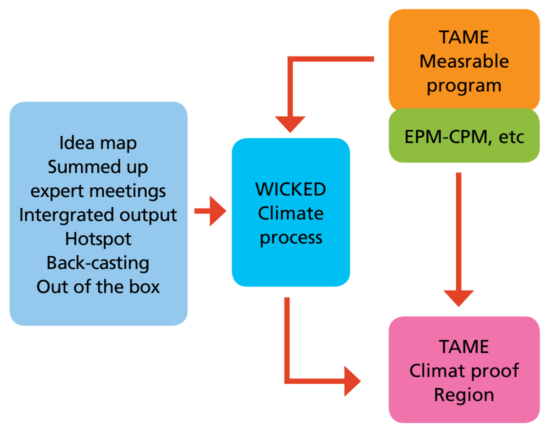
The wicked by-pass

Both hotspots decided to work parallel to the mainstream planning process. This had clear advantages, such as a positive environment to experiment and perform cross-boundary work. But the risk of not being able to influence the mainstream process was considerable. Having recognised this risk from the beginning, the Zuidplaspolder hotspot team set up a special structure: the project leader of the mainstream plan joined the hotspot research team, and one of the members of the steering committee of the mainstream plan was appointed rapporteur for the hotspot. This allowed the hotspot project to be taken seriously; some of the measures developed in the hotspots are included in the mainstream plan. The selected method of research probably helped as well. The steering committee recognized itself in the rational analytical research approach.

The hotspot Groningen was less successful in influencing the regional plan. The main reason was that it began to lag behind the regional planning process after the first phase. The hotspot research was complicated, techniques to tackle this 'wicked problem' were new and knowledge was more slowly produced than required for the regional plan. Results from the hotspot project came too late to be included in the plan. Climate adaptation was not sufficiently included in the plan also because the executive board of the province decided to reduce the plan's ambitions from one with new ideas and perspectives to one in which existing policies were confirmed.

The methods used, play a role as well. Civil servants and commissioners are not used to a creative and innovative approach. Moreover, since they were not fully involved in the conception of the hotspot, they didn't feel at ease with the outcome. A lesson learned is that within a planning organisation one has to accept that solving wicked problems needs a different planning approach.

Climate as a wicked problem integrated in an adjusted regular planning process



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Both teams decided to start parallel research processes and not to integrate these in the main planning process for the two areas.

PROJECT
A14 Hotspot
Zuidplaspolder

MARCO VAN STEEKELENBURG
Xplorelab

Zuidplaspolder: An example of an integrated approach

THE ZUIDPLASPOLDER IS LOCATED north of Rotterdam. It is one of the deepest polders of the Netherlands, and vulnerable to climate change. Because major housing developments are planned for it a hotspot research project was initiated to evaluate whether the plans could take full account of future risks. First an analysis was made of the area and the effects climate change would have on the area. Then based on the identified impacts of climate change, adaptation options were identified through workshops, consultation of stakeholders and design sessions. The options relate to water safety, inundation due to extreme rainfall, water shortage and heat stress caused by climate change. The workshops yielded over 50 adaptation options, for example:

- no construction in the lowest areas of the polder, but on the higher, more stable ground;
- aggregation of surfaces water management areas;
- expansion of peak rainwater storage space;
- seasonal storage of rain water for dry periods;
- placing of compartmental dikes;
- building waterproof houses;
- connecting and strengthening natural conservation areas;
- utilizing green areas and water as anti-"heatstress" measures.

The long-list of options was used to develop an adaptation strategy, being a coherent set of combined measures aimed to 'climate proof' the Zuidplaspolder. The strategy was developed in interactive sessions with stakeholders, in which the outcomes of the various impact studies were used. This led to the reduction of the list of 50 options to one integral adaptation strategy. This strategy consists of five concrete adaptation projects for climate proofing in specific areas of the Zuidplaspolder. Three of them are described below.

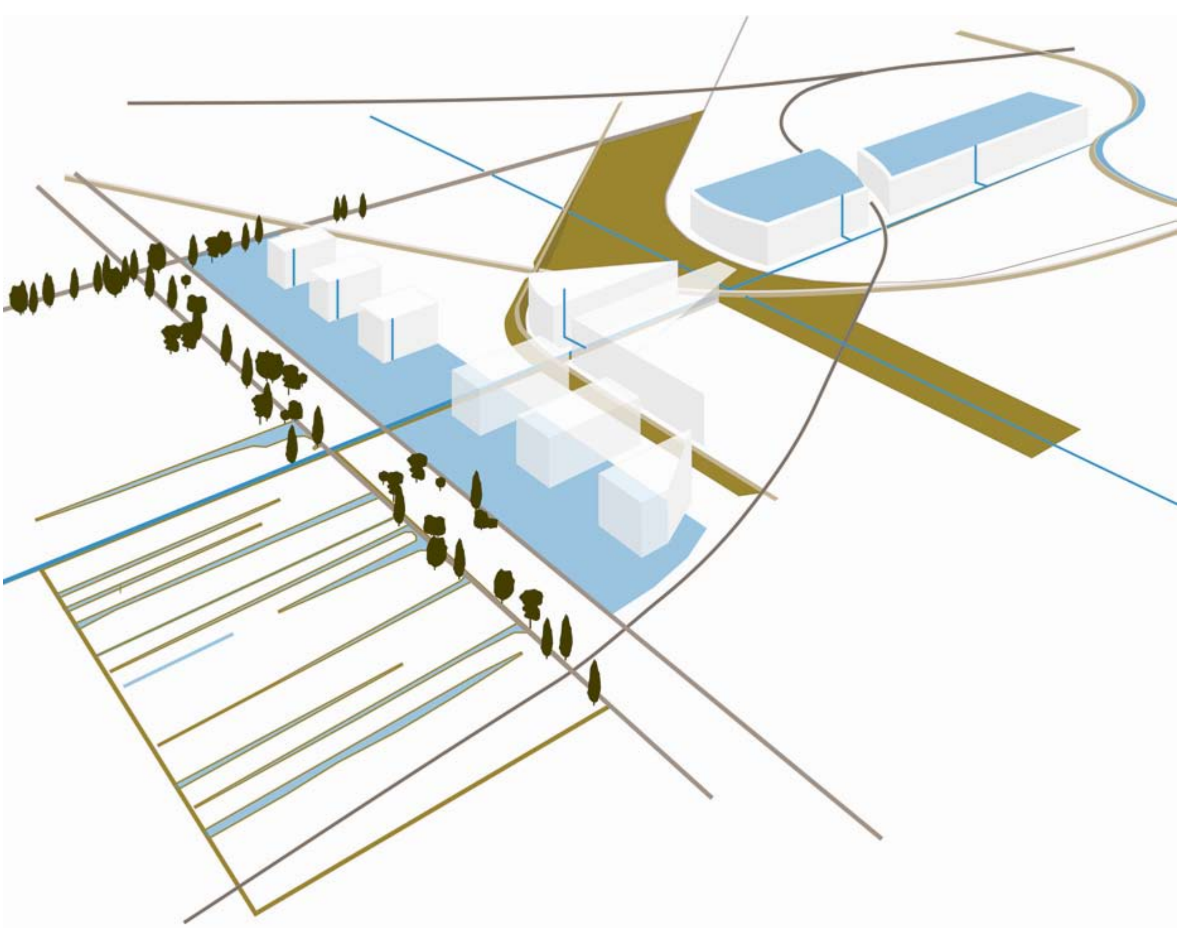
North Nieuwerkerk

Flooding and water safety: In total 1800 houses will be built, some close to the river the Hollandsche IJssel, some on weak peat soil. The new provincial road, the N219, on the eastern side of the housing development will be raised by 1.5 meters, creating an enclosed basin. The ground doesn't need to be raised within the basin. A unique residential environment can be created with a substantial amount of water which takes the natural peat landscape into account. This solution will stop subsidence of the peat soil. However, this construction method will involve more risks and investment in the initial phase, but savings are expected since there is no need for sand and maintenance will be cheaper.

Crystal clear water - dwellings

Flooding: This concept for a high quality residential environment caters for 1300 houses in the Rode Waterparel area (Red Water pearl), where water plays a prominent role. The water level will be raised by one meter, whereby the contours of the ridges of the original creek bed will become more visible. Rainfall can cause parts of the area to flood periodically. Three types of houses have been developed, each tailored to its typical geomorphologic structure and with additional technological features.

Overall picture of the concept masterplan according to the compartmentalization method at Nieuwerkerk Noord, incorporating the raised N219 to the east and maintaining the existing watercourse structure within the area.



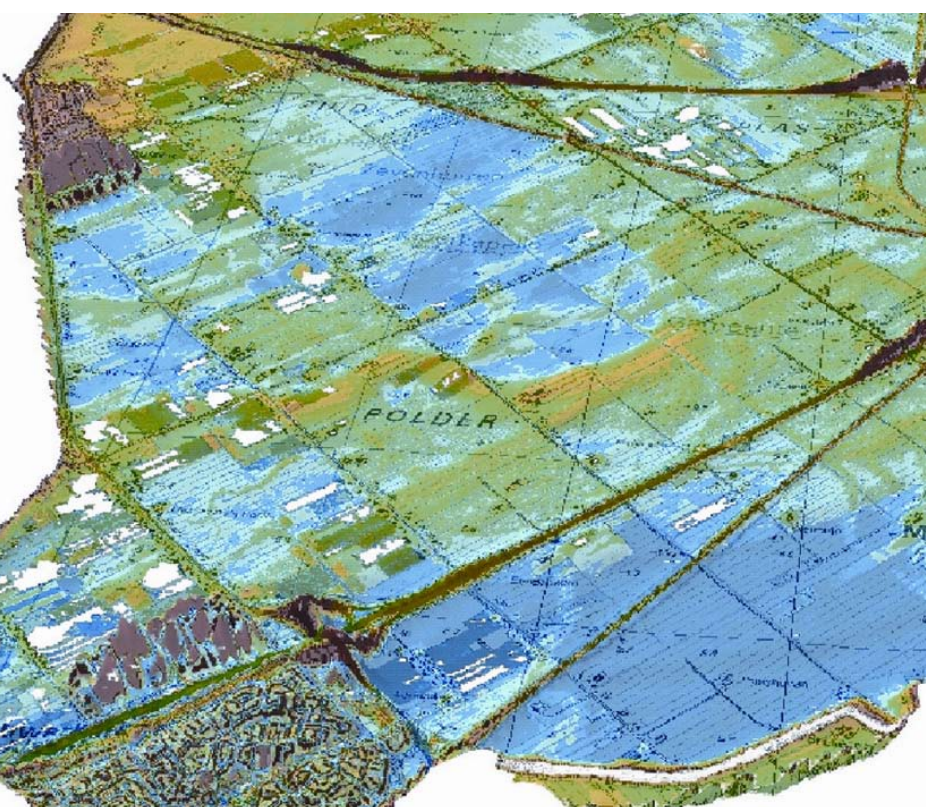
Birds eye view of the "Climate Engine Gouweknoop" with blue-green cross, water reservoir and water storage on rooftops.

Climate Engine Gouweknoop

Robust, climate proof natural reserves, water shortages and increase in temperature: The Gouweknoop is designated for intensive housing development. A park and a canal through the Gouweknoop are crucial in linking the various elements in the ecological structure within and outside the polder. Rainwater can be stored on a large scale in seasonal storage facilities and in "water towers" within buildings. When drought hits, this water can be used to keep natural reserves within the Waterparel wet and to provide cooling in the Gouweknoop itself.

Estimation of costs and benefits

The costs of these adaptation strategies include the direct investment cost, related to direct costs of flood protection measures (sand suppletions, creation of raised infrastructure) and the purchase of land to create additional water storage or nature areas. Avoided damages were estimated by taking the discounted sum of the expected annually avoided damage costs over a period of 100 years. A stated-preference valuation study was conducted to elicit values (of characteristics in the Zuidplaspolder) from residents living in or close to the Zuidplaspolder. When considering the total area of the Zuidplaspolder, the main factors in the cost-benefit analysis (CBA) proved to be the avoided damage costs and avoided costs of sand suppletion to elevate the area. Also the benefits from creating additional nature and water areas were considerable. Overall, the adaptation strategy had a positive net present value. Therefore the Hotspot project recommended the development of adaptation projects as one integrated adaptation strategy.



Zuidplaspolder after raising water level until the seepage pressure in all areas is lowered

Results

Despite this net positive result, implementation of these supplementary climate-related measures cannot be taken for granted on the lower scale. Merging long term interests into development plans demands close attention right up to the implementation stage. Using a "workshop" like Xplorelab is a tried and true method for achieving this. Climate resilience is not a standard, but a way of working. Involving the right partners at an early stage and a creative attitude is crucial. Recently the national government decided to support this way of working by granting 24 million euro for implementation of sustainable and climateproof pilots, including in the south western (Nieuwerkerk) and central part (Rode Waterparel) of the Zuidplas.

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PROJECT
A18 Hotspot
Groningen

ROB ROGGEMA
Province of
Groningen

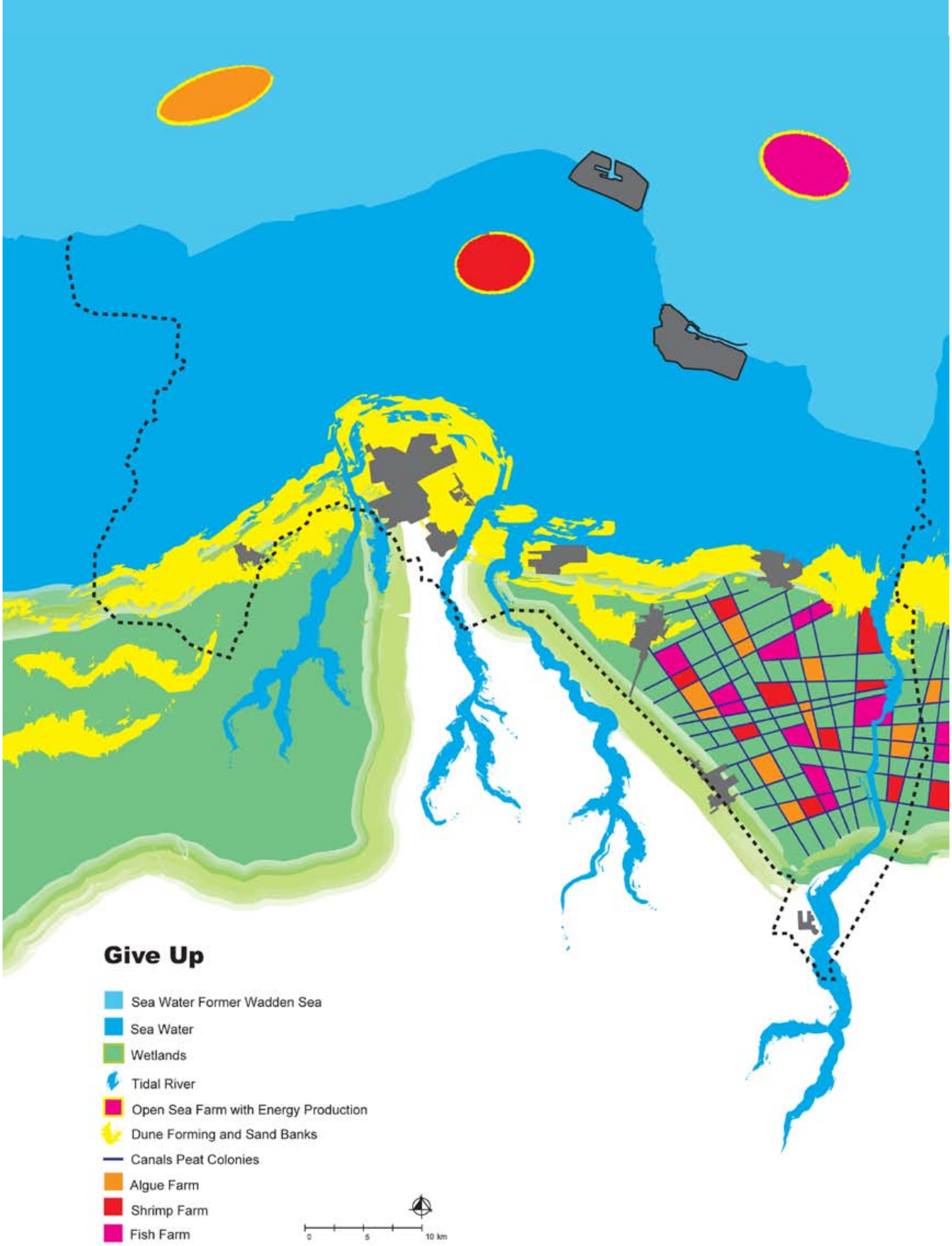
Climate-proof Groningen: A combinatory of mapping

The province of Groningen wants to get a sense of the direction of adaptation measures and strategies for the future. Therefore the hotspot approach has been applied. Several relevant themes (agriculture, nature and water, the coast, energy and fresh water supply) were put on maps separately. Every map showing the ultimate adapted future for that theme for the relatively short term (20-30 years). Combined these maps show an integrated adaptation map of the province of Groningen (see figure 1). To get a feeling of possible long term futures (100 year or more), three separate backtracking scenarios have been developed. They show the broad bandwidth of, sometimes unimaginable, futures. These scenarios are used as the background against which adaptation measures and strategies can be judged on robustness and usefulness in specific areas.

The combination of the integrated adaptation map and the long-term scenarios show the areas where adaptation measures and strategies are robust and other areas (so-called windows), where they form a dilemma, where further in-depth study is needed. In combination with the integrated adaptation map and the backtracking scenarios, the solutions for these windows can be used to develop long-term climate proof scenarios under extreme conditions. For the province of Groningen these scenarios are named 'Sustain' or 'Give-up' (see figure 2). These scenarios and the robust measures define a short-term adaptation agenda, because the measures and strategies, which are useful in even a every unlikely future, can be implemented at present.

The Content: Swarm planning

In a planning context with the objective to provide planning solutions for the longer term, the information developed in the hotspot is not flexible enough. The sum of thematic adaptation measures leads to a map on which every square metre is



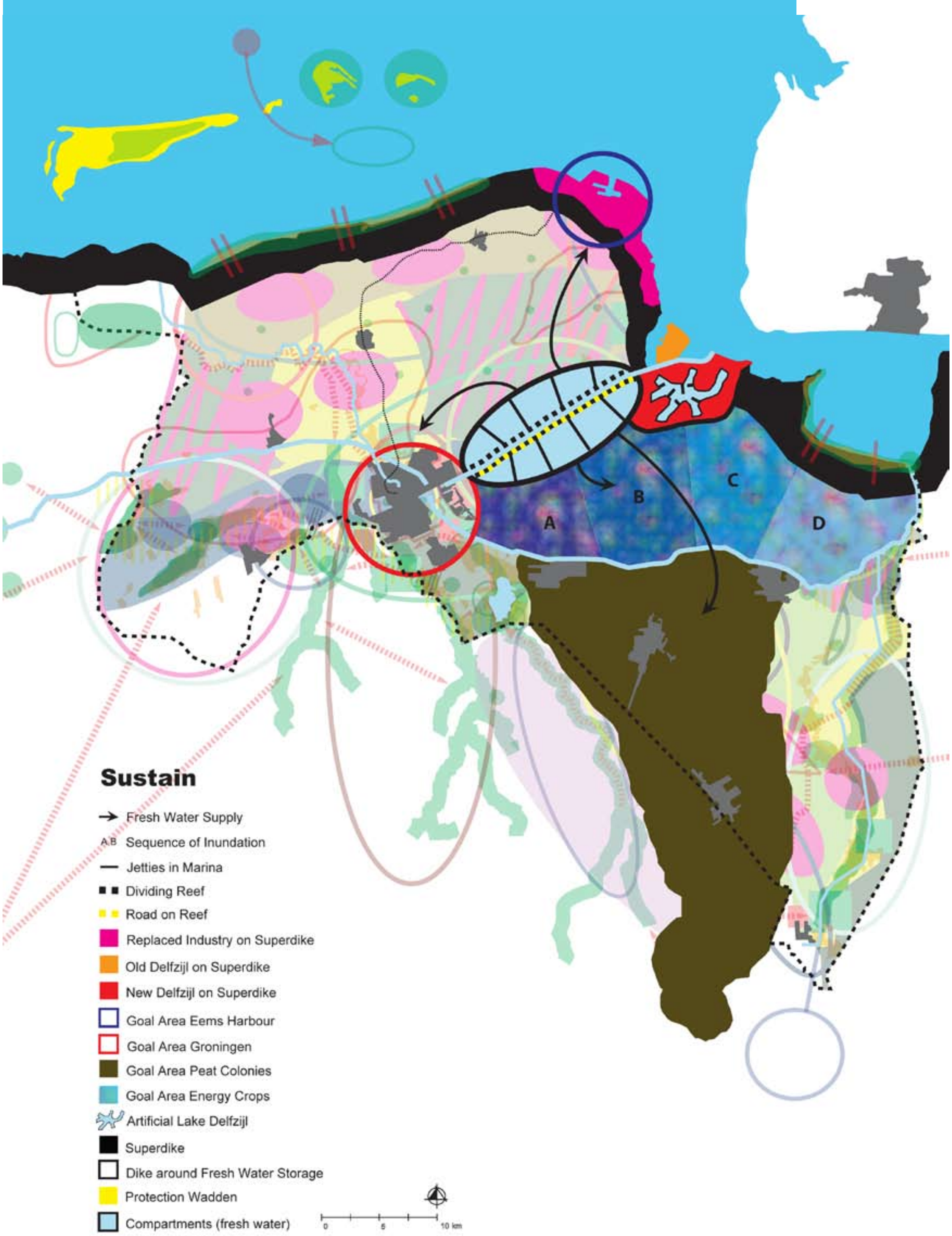
If sea level rises too much the only way to survive is to withdraw. People need to migrate to safe places and the coastline needs to move towards a safe position. In front of the new coastline new wetlands emerge naturally and the city of Groningen becomes a sea-side beach city.

exactly planned: a blueprint for the future. The only thing we know for certain, however is that the future is uncertain. Blueprint planning has proven more than once to be wrong.

Another type of planning is required if long-term and uncertain developments are to be integrated in spatial plans. This new type of planning identifies 'nodes' of special importance and gives direction through spatial incentives and impulses. It may be a certain spot in the dike-system or a crossing of several networks. Changes in these nodes influence the rest of the spatial system. Like giving an impulse to a swarm of birds will influence the pattern, shape and direction.
Swarm planning defines the nodes of special importance. It intervenes with a spatial impulses and then gives room for evolving developments, autonomously shaping the spatial future of the region. Strict regulations confine the 'natural will' of the system instead of increasing the resilience and the level of climate proofing.

A long way to discover

The method and the process used in the hotspot give a glimpse of new ways in spatial planning relat-



Sustain: if we want to continue living behind a coastal defense when sea level rises several meters, inland adaptation measures need to be taken to withstand the effects of climate change: water supply reservoirs, extension of nature reserves and space for sustainable energy supply.

ed to the phenomenon of climate change. But there is a long way full of discoveries to unfold. How to find the nodes of importance and how do we know what kind of impulse directs the process in the right - climate proof - direction? Questions we hope we can answer after finishing the hotspot climate proof Groningen. The first steps are taken!

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PROJECT
A09 Financial arrangements for disaster losses under climate change

JEROEN AERTS
VU University

Adaptation cost in the Netherlands: Climate Change and flood risk management

Climate change is expected to increase the frequency and severity of flooding in the Netherlands. The question is whether the Netherlands can adapt to increasing flood risk and whether the adaptation cost are acceptable.
The Netherlands is a densely populated country with approximately 16.5 million inhabitants. Approximately 9 million inhabitants live below sea level. This paper provides estimates of the adaptation cost of flood protection under various climate change scenario's.

Many low-lying parts of the Netherlands have been reclaimed from former lakes (usually referred to as 'polders') and are protected by so called 'dike rings' along the main rivers and coastal areas. The lower part of the Netherlands is divided in 53 of such dike rings (Figure 1). A dike ring is also a separate administrative unit under the Water Embankment Act of 1995. The latter aims to guarantee a certain level of protection against flood risks within each dike-ring area. For example, a dike ring with a safety norm of 1/10,000 has been designed in such a way that it can withstand a flood with a probability ('return period') of 1/10,000 years. Safety norms have been determined after a major storm surge in 1953 (van Dantzig, 1956)[1]. They reflect both the number of inhabitants and the economic value of assets within a dike ring; the more people and economic


Residential area and harbor in Delfzijl bordering the Eems river.

values to be protected by dike infrastructure, the higher the safety standard. The safety norms of dike rings vary in between 1/10,000 and 1,1250 throughout the country (Figure 1)[1]. [2,3]

Climate change is expected to increase the probability of flooding and hence dike reinforcements are needed to maintain the safety standards as required by law. Aerts et al. (2008) have calculated by how much flood probabilities may increase due to (combined) effects of sea level rise and increased river discharges. Depending on the location of the dike ring the flood probability may[4] increase with a factor 10 with each 50 to 80 cm sea level rise. For example, the largest dike ring around the cities of 0Rotterdam, The Hague and Amsterdam has the highest safety standard of 1/10,000 years. A sea level rise of 70 cm would increase the probability of flooding to 1/100 years.

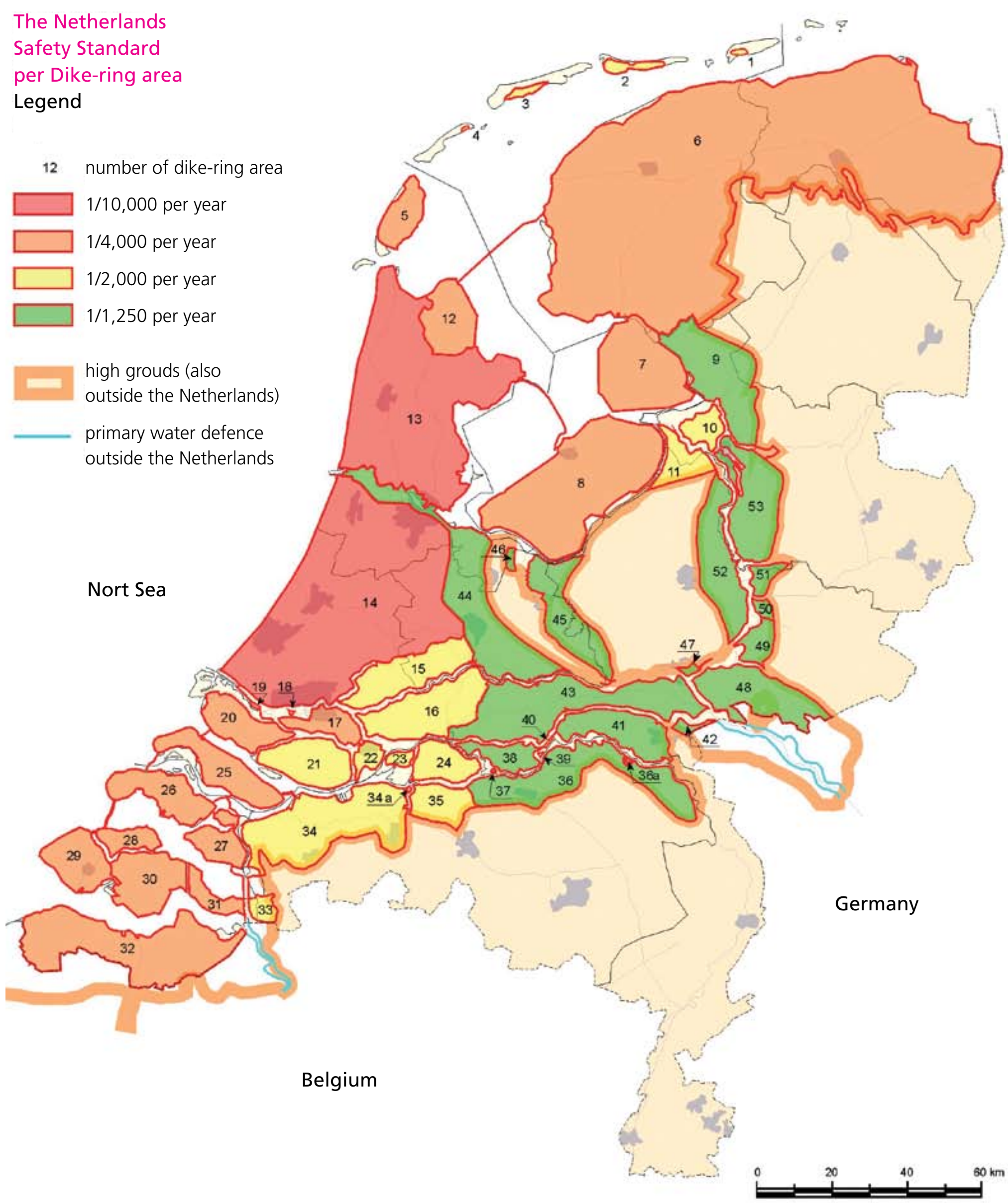

FIGURE 1:
a. Safety standards of dike ring areas in The Netherlands (left). b. Location of The Netherlands at the lower end of the rivers Meuse and Rhine(Right)

Uncertainties in flood damage assessments

In recent decades, a transition from protection to risk management can be observed in many European countries[1].

Within a flood risk management approach, flood risk assessments are of key importance to support decision making. However, flood risk assessments that try to quantify direct monetary damage due to flooding, are surrounded by considerable uncertainty[2]. On top of that, flood risk is not a static parameter, but varies through time because of, for instance, socio-economic developments and climate change, which are also uncertain. Quantifying and communicating such present and future uncertainties is imperative in order to make well informed decisions[3]. It also strongly influences the public confidence in such models[4].

In order to assess the uncertainty in flood damage assessments and attribute it to different sources, all possible sources of uncertainty need to be addressed. Up to now, mainly uncertainty in the hydrological component (i.e. river discharge, inundation depth) has been addressed[5], but the relation to flood damage has received considerable less attention.

This relation is usually represented by so-called stage-damage curves, which are curves that indicate the fraction of total damage that occurs at a given water depth. A study on the underlying empirical data (post-flood surveys) shows there's substantial variation and thus uncertainty in this relation[6]. Preliminary results of research done within the Climate Changes Spatial Planning programme shows that uncertainty in the stage damage curves (and associated maximum damages) is by far the largest contributor to uncertainty in flood damage estimates, outweighing hydrological factors.

In order to improve the quality of flood damage assessments research on the relation between hydrological factors and resulting damage deserves prioritization. The magnitude of future uncertainties due to climate change and socio economic developments on flood damage estimates and how it relates to present uncertainties remains to be investigated in the project. However, there are indications that they have a similar sized effect on flood damage estimates. When looking at the 20th century, socio economic developments were responsible for a tripling of potential flood damage and depending on the scenario for the 20th century it may have double again at end of the 21st century (see Figure).

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PROJECT: IC03 National adaptation strategies

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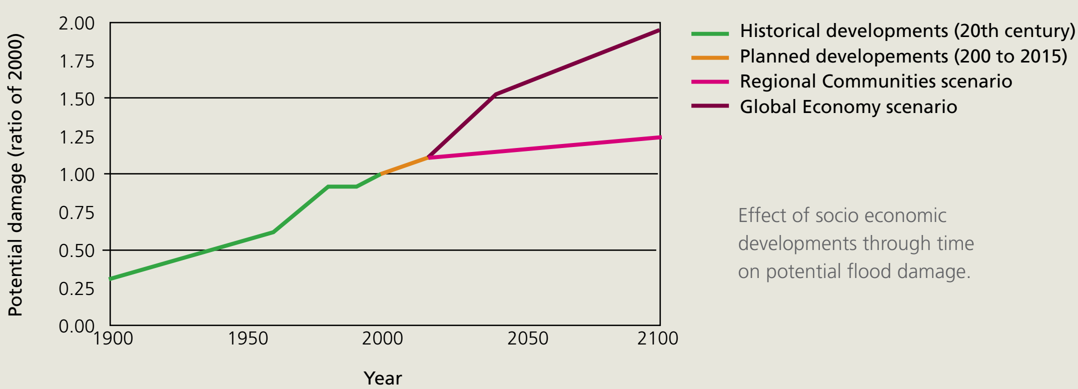

Effect of socio economic developments through time on potential flood damage.

The costs of natural disasters under climate change

Increasing frequencies of extreme weather events are expected to cause more losses from weather disasters. The interplay between hazards, and vulnerability and exposure, make reliable estimates of the actual risks difficult. Climate change will increase losses, but increasing exposure and value of capital are expected to be more important.

The project A09 "Financial arrangements for disaster losses under climate change" within the Climate changes Spatial Planning programme has identified impacts from climate change on disaster losses and the role of insurance arrangements in the Netherlands. The project investigates whether current financial arrangements for damage caused by extreme weather are sustainable and economically efficient. The project develops and evaluates alternative insurance arrangements in order to adapt to changing risks[1]. The role of insurance is discussed more in-depth in a separate article on page 41 (Botzen & Van den Bergh)

The analyses of future potential losses performed in this project, include historic data, loss modelling, and scenarios for climate and socio-economic change. Among these analyses are projections for hail storm losses, casualties due to flooding[2], and economic losses from flooding. Projections of future flood losses (Figure 1) in a case study area along the River Meuse in the Netherlands vary considerably, depending on the assumed climate scenario (KNMI '06 scenarios G and W+) and scenario for socioeconomic change (WLO scenarios Regional Communities; RC, or Global Economy, GE).

Taking into account only the increasing exposure and value increases of assets (socio-economic change) annual expected losses by the year 2040 are projected to increase by between 35% and 172%, compared to the baseline situation in the year 2000. Looking only at the effects of climate change, annual expected losses increase between 27% and 148%. A combination of climate and socio-economic change amplify each other, and may increase losses up to 71% and 575%.

In this case study, the effect of climate change is found to be of approximately equal magnitude as socio-economic change[3]. However, adaptation through reduction of flood probabilities is likely to severely reduce the contribution from climate change. Considerable uncertainties remain and more studies are required to quantify the precise role of exposure, vulnerability and climate change[4].

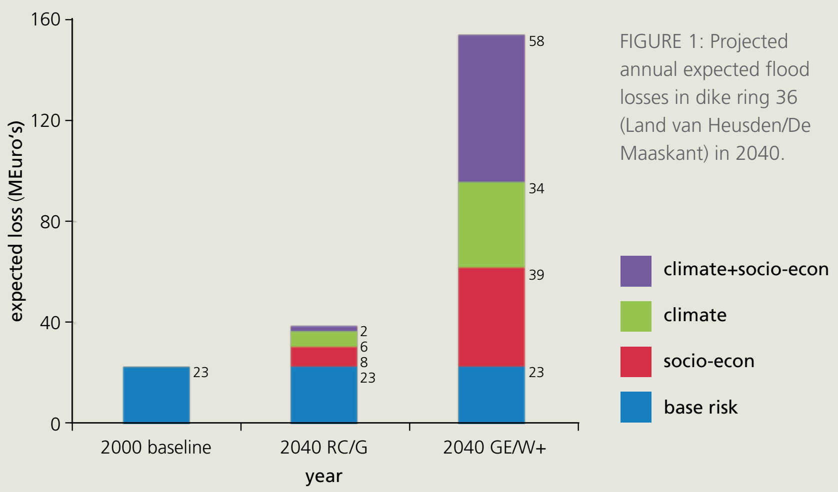

FIGURE 1: Projected annual expected flood losses in dike ring 36 (Land van Heusden/De Maaskant) in 2040.

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PARTNERS: VU University Amsterdam / Future Water / Rabobank / Interpolis

PROJECT: A09 "Financial arrangements for disaster losses under climate change"

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Apart from the effects of climate change, future projections show a gradual upward trend in house construction. In particular, by the year 2040 about 500,000 to 1,500,000 new houses will be constructed. Even if future flood risk defined as probability times damage are maintained at a constant level through heightening dikes, the potential damage of a flood is expected to increase. Therefore, it has been argued that an effective climate change adaptation policy should not only concern the reduction of flood probabilities with barriers but should also consider a wide range of adaptation options[5]. For example, measures could be implemented that reduce the vulnerability of buildings to flooding and thereby limit damage once a flood occurs[6]. Moreover, financial arrangements, such as insurance, could be promoted to compensate flood victims and heighten risk awareness[7].

An assessment of the development of the flood risk over time was made in Aerts et al.[4]. Flood risk is defined as probability multiplied with damage. Figure 5 shows the relative influence of climate change and urban development on flood risk. >

Potential flood damage may have double again at end of the 21st century.

Development of flood risk in the Netherlands

FIGURE 2.
The relative influence of sea level rise (60 cm and 150 cm in 100 years) on flood risk compared with the influence of urban development (according to the two scenarios, RC and GE)

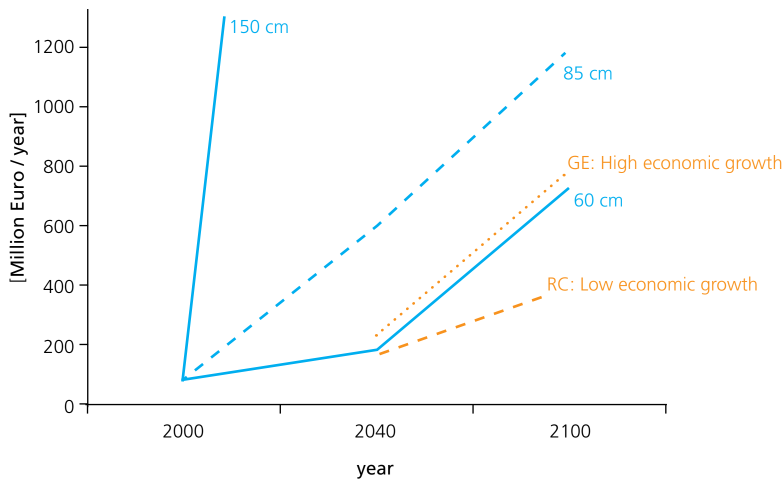

TABLE 1.
Costs of dams and storm surge barriers of the Deltaworks (Aerts et al., 2008)

Construction costs	Year in operation	Million Dutch Guilders	Net present value 2007 million €	Lifetime in years	Scenario Sea level rise in cm
Storm Surge barrier Hollandse IJssel	1954	33	98		
Haringvliet barrier	1961	586	1,464	150	20
Brouwersdam	1961	141	353	100	
Hellegatsplein and Volkerak sluices	1961	191	477		
Grevelingen dam	1961	66	165		
Storm Surge barrier Oosterschelde	1986	5,500	3,850	200	20
Compartmentworks	1984	1,069	1,604		
Canal through Zuid-Beveland	1984	610	915		
Maeslant storm surge barrier	1997	990	545	100	60
Europoort barrier and Hartel barrier	1997	460	253		
Total costs of the Deltaworks		**8,195**	**8,925**		

The influence of the sea level rise and high urban growth (GE scenario) is approximately the same, as long as the rate of sea level rise does not exceed 60 cm per century. For both trends, either a 60 cm per century sea level rise or the GE scenario, the risk in the year 2100 is about seven to eight times greater. A sea level rise of 85 cm causes a risk increase of a factor of one hundred to two hundred for the respective RC and GE scenarios, assuming that no preventative measures are taken.

Costs of climate change adaptation

An important aspect of the Dutch flood protection system is the Deltaworks. The catastrophic flood event of 1953, led to the implementation of the Deltaworks, which are a series of dams, sluices, dikes, and storm surge barriers constructed between 1958 and 1997 in the Southwest of the Netherlands. The aim of the Deltaworks was to improve flood protection by shortening the Dutch coastline, thus reducing the number of dikes that had to be raised. With over 10,250 miles of dikes (1,500 miles designated primary dikes and 8,750 miles as secondary dikes) and 300 structures, such as sluices and bridges, the project is one of the most extensive engineering projects in the

Insurance against climate change

Climate change may increase the frequency and severity of certain weather extremes. Insurers can promote adaptation to more natural disasters by spreading risks and providing incentives for risk reduction.

Climate change projections indicate that an increased frequency and severity of weather events may further augment already increasing natural disaster losses. This requires innovative adaptation policies for which the experience of the insurance sector with assessing, managing, and spreading risks may be useful[1].This project explored the role of insurance arrangements in the Netherlands in designing comprehensive climate change adaptation policies that comprise risk prevention and reduction, and efficient risk sharing strategies.

This study identifies the exposure of insurers to climate risk, which is large for extreme precipitation and possibly storms[2].Statistical models show that global warming may increase insured hailstorm losses in the Netherlands. Adaptation strategies for insurers are identified as well as new business opportunities. Flood insurance is not offered in the Netherlands, which is exceptional in Europe. At present, households rely on ad-hoc compensation of flood damage by the government.

The introduction of a public-private partnership (see Figure 1) to insure flood risks is proposed to enhance financial security and provide incentives to invest in risk reduction[3]. A survey shows that incentives provided by insurance, e.g. premium discounts, can be effective to encourage households to invest in 'flood proofing' houses[4].

Household demand for flood insurance has been examined by applying theories of decision-making under risk[5] and by a survey of approximately 1000 homeowners using contingent valuation and choice modelling. Results indicate that household willingness to pay for flood insurance may be sufficiently high for a (partly) private market. Also we find that, even though individual perceptions of flood risk are low[6], they significantly influence demand for insurance. The findings of this research highlight the useful role insurers can play in adaptation to higher flood risks.

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PROJECT: A09 Financial arrangements for disaster losses under climate change.

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Layer 3:	Extreme losses	Government
Layer 2:	Middle sized losses	Capital markets Reinsurance companies Primary insurance companies
Layer 1:	Small losses	Households and companies

FIGURE 1.
A multi-layered public-private partnership to insure flood risk

Future flood risk in the Rhine basin

Due to the impact of climate change, the probability of flooding in the Rhine basin in 2050 is expected to be two to five times as high as it is today[1]. That isa, in case no additional flood management measures are implemented. Population growth and increase in property values in flood prone areas further enhance future flood risk.

Many uncertainties exist in flood risk projections. For example, extreme value analysis on flood probabilities in 2050 are difficult to make and different methods are currently under debate. Furthermore, projections on the basin-wide potential damage are not available. The central aim of this research is to focus on extreme flood events, on their probability, and to simulate the effect of climate change on future flood peaks in the Rhine basin. Based on this information, cross-boundary flood management strategies can be developed and evaluated. Recent scientific literature describes the necessity to move away from traditional flood frequency analysis, since climate change undermines the basic assumption of stationarity[2]. Therefore, we adopted a process-based approach including different climate change projections, a rainfall generator, and hydrological models, to estimate changes in low-probability flood peaks and the impact of measures.

The embankments along the Lower Rhine and in the Netherlands have very high safety norms of 1/ 500 and 1/1250 years, respectively. Our results displayed that in the most extreme climate change scenario, associated design discharges increase by 17% (Figure 1). Due to variation in safety levels, however, upstream flooding in Germany might occur, which lowers peak discharges downstream in The Netherlands up to 15%. The only effective measure at the basin-wide scale to reduce flood probability is drastic dike heightening, while measures such as extra retention basins, reforestation and by-passes can be beneficial at the local scale[3]. However, in a risk-based approach, more could be gained by damage reduction than through flood defense measures to reduce flood risk. Calculations to estimate (future) potential damage in the Rhine basin are in progress.

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PROJECT A07 Adaptive Capacity to Extreme events in the Rhine basin (ACER).

PARTNERS: Alterra / Deltares / VU University Amsterdam / Future Water / Royal Dutch Meteorological Institute (KNMI) / Seecon GmbH / Delft University of Technology / Universität Osnabrück / Wageningen University and Research Centre / Water Service, Ministry of Transport, Public Works and Water Management

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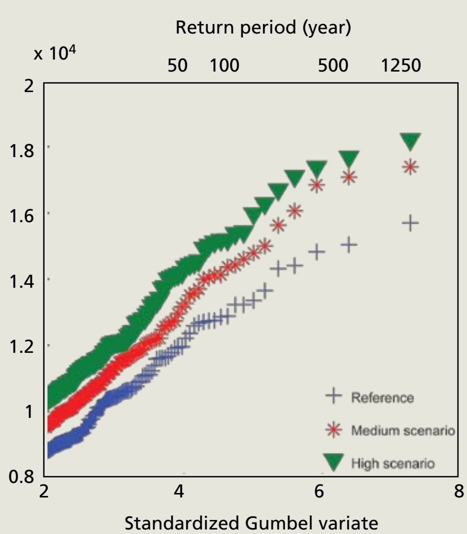

FIGURE 1.
Extreme value plots of yearly maximum discharges of the Rhine at the German Dutch border. As input for the rainfall-runoff model served 1000 years of daily meteorological input data that were obtained by a weather generator. Displayed are 1000 years of simulated yearly maximum discharges for the reference situation and two climate change scenarios for the year 2050.

TABLE 2.
Costs of flood management investments under different climate change scenarios [billion] excluding the costs of upgrading the current Dutch flood protection system

	Scenarios				
Year	**2040**	**2100**	**2100**	**2100**	**Far future**
Sea level rise (cm)	24 cm	60 cm	85 cm	150 cm	500 cm
Max discharge river Rhine [m^3/s]	16,700	18,000	18,000	18,000	18,000
Max discharge river Meuse [m^3/s]	4,200	4,600	4,600	4,600	4,600
River works	**Costs in billion €**				
River widening Rhine	2.7	5.5	5.5	5.5	5.5
River widening Meuse	1.3	4.2	4.2	4.2	4.2
Dike reinforcement	0.2	1.8	2.6	6.1	36
Coast	**Costs in billion €**				
Beach nourishment Holland	1.9	6.4	9.1	16.0	25
Beach nourishment Waddensea	1.1	3.8	5.4	9.6	Unknown
Beach nourishment Westerschelde	0.1	0.4	0.6	1.1	Unknown
Coastal dike reinforcement	1.9	2.3	2.6	3.4	8
Total	**9**	**24**	**30**	**46**	**>80**

world. The Deltaworks reduced the length of the dikes exposed to the sea by approximately 400 to 450 miles or 640 to 700 kilometres. In most cases, building a barrier or a dam was much faster and cheaper than reinforcing existing dikes. The total cost of the storm surge barriers of the Deltaworks are presented in Table 1.

Given the trends in increasing flood risk, different flood management strategies were explored by the government. In 2008, a special commission presented a new Delta Plan for the future addressing the issues of climate change. The strategy is following the current Dutch water management approach, which focuses on limiting the probability of flooding through the use of flood defences, such as dikes, beach nourishment, and storm surge barriers.

Table 2 shows the costs of additional flood protection measures under different climate change scenarios. These are costs for 3500 km of dikes, the nourishment of 450 km of beaches and widening of the main rivers. The Royal Dutch Meteorological Institute (KNMI) provided climate change projections for the years 2040 and 2100 for the Netherlands[8]. Each climate change scenario consists of a combination of projected sea level rise and maximum discharges of the rivers Rhine and Meuse. Table 2 provides the different combinations. For the year 2040, maximum discharges of the rivers Rhine and Meuse were set to 16,700 and 4,150 m3/s respectively. Maximum discharges for the year 2100 were projected as 18,000 and 4,600 m3/s. Note in this respect that in the current climate 16,000 m3/s is the discharge value of the river Rhine that has a probability of 1/1,250 years. In other words, dike rings with a current safety standard of 1/1,250 can withstand a flood peak of the river Rhine with a discharge of 16,000 m3/s. Different sea level rise scenarios (up to 500 cm) have been used to calculate the effects on flood probabilities. Note, however, that the maximum sea level rise scenarios provided by the KNMI project 85 cm in the year 2100.

The total costs for adaptation vary between 9 billion and over 80 billion euro. These are estimates

without upgrading the current Deltaworks storm surge barrier system. The costs expressed as a percentage of GDP are expected to be limited to 0.1% to 0.2% assuming a maximum sea level rise of 85 cm in 2100. The latter scenario is officially used by the government as the maximum sea level rise. Nevertheless, sea level rise will continue to increase after 2100 and large infrastructure investments should address the long-term sea level after 2100.

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Climate change modeling on Rhine discharge

Extremely low water levels in the Rhine, occurring more often, cause problems for water supply and navigation.

Climate scenarios suggest that Rhine river discharges in winter and spring may have increased by about 30% by the end of the century, whereas in summer and autumn they can decrease by about 30%. In addition, the snow melt season starts up to 2 months earlier in the year, and snow storage in the Alps is reduced dramatically.

To adapt water management in the Rhine basin to climate change, it is important to understand how the hydrological regime and river discharge will be affected. To investigate this, a hydrological model, the Variable Infiltration Capacity (VIC) model, is forced by three high-resolution (10km) climate scenarios, each corresponding to a different IPCC storyline describing societal and technological developments. The high model resolution enables a better representation of convective (small-scale) precipitation events and orographic features, especially in the Alps.

After correcting for structural errors in the global and regional climate models, the VIC-model, previously optimized for the Rhine basin[1], was forced by the climate scenarios and a reference model run for the 20th century. All three climate scenarios indicate a decrease in summer discharge and an increase in winter and spring discharge for the end of this century, as well as an increase in magnitude and frequency of streamflow droughts in summer and peak flows in spring[2].

It should be noted that only one global, regional and hydrological model was used. Seasonal changes in temperature and precipitation, are however, broadly consistent between models. Whereas increasing frequency and magnitude of peak flows has been acknowledged in previous studies, the increase in summer droughts may have consequences for many sectors and perhaps pose an even larger challenge for adaptive management in the Rhine basin.

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PROJECT
MSZD01 Fresh and salt water in the delta

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Fresh and salt water in the Delta

The South-western Delta consists of the estuaries of the rivers Rhine, Meuse and Scheldt. Interactions between sea, rivers and land are characteristic for the whole area.

The area is important as strategic freshwater reservoir for the rural area to the east, for river-discharge regulation (peak discharges of the Rhine-Meuse are diverted from the port of Rotterdam), for recreation (aquatic and cultural), aquaculture (shellfish, lobster, etc.), nature (especially relict intertidal areas), and as gateway to the port of Antwerp (Westerschelde). While the Deltawerken are still an international icon for Dutch water management, current land-use and water-management plans put emphasis on their environmental impacts (water quality), as well as prospected climate change. Currently water management strategies and land-use plans are reconsidered in order to minimize flood risks, optimize freshwater availability, reduce salinisation, and improve water quality and biodiversity, as most recently described in the National Water Plan (2008). Two main fresh water basins, constructed as part of the Delta Works, are the Haringvliet and the Volkerak-Zoom lake. The unlimited fresh water availability created opportunities for the development of agriculture and drinking water supply, thereby boosting economic development.

It has recently been decided to manage the Haringvliet sluices in such a way that a small fresh-saline gradient is established ('Kier besluit'), in order to reduce the current water-quality problems. In the Krammer-Volkerak Zoommeer lake (especially algal blooms) it is an objective to restore estuarine dynamics (i.e. a saline gradient) in the year 2015 (the decision making process is on-going).

Re-introduction of a saline-freshwater gradient in the Krammer-Volkerak Zoommeer may reduce the occurrence of algae blooms, but it reduces freshwater availability for agriculture, drinking-water supplies and greenhouse horticulture in the region. Possible solutions are increase of fresh water supply and distribution, inclusive alternative internal

Krammer Locks in the Philips Dam. The locks enable navigation between Rhine and Scheldt and are constructed to keep the sweet water of the Volkerak (above) separated from the salt water of the Eastern Scheldt.

A huge volume of fresh water is used to keep the system fresh, while only a small percentage is used for irrigation or potable water.

or external freshwater sources, (b) land-use and local water-management transitions geared at more efficient freshwater use and/or the introduction of other forms of agriculture (salt-water agriculture or aquaculture).

The project

The major challenge is to develop the southwest part of the Netherlands in a sustainable manner, including the restoration of the estuarine dynamics under a changing climate, thereby safeguarding the freshwater supply for agricultural and other uses. A number of possible approaches have been identified:

- supply follows demand, i.e. guarantee fresh water supply artificially by separation from the natural environment (external supply)
- demand follows supply; i.e. adaptation to the natural environment
- a combination of 1 and 2 including the applications of innovative technology

Specifically the project focussed on the following aspects:

- To investigate whether new approaches to the supply of fresh water and/or the current land use are desirable or required in the context of a changing environment
- To list the knowledge caps that need to be resolved before a substantiated decision can be taken towards possible changes to the water supply system and/or land use.

Approach

The investigation has been carried out for eight different areas in the southwest delta, that are directly affected by the planned interventions and climate change. For each of these study areas, data and scientific insights have been collected on the current water demand for the different sectors and on water supply. Based on different climate scenarios [1] and the proposed interventions to the system, the bandwidth of expected changes to the available fresh water has been determined.

In order to select the most important factors affecting the water demand and availability, besides the scenarios, the water- and salt balances of the different regions have also been looked at. The factors include the intensity of up-welling of brackish groundwater, the actual volume of freshwater being used for different uses, the chloride concentration in the drainage system and the salt sensitivity of different crops and natural ecosystems.

Given the possible approaches the study suggest different viable options for land use, water-management, and water-technology for the long-term future. Also for the near future the study suggests no regret measures in order to adapt or resist to the expected changes.

Results

The preliminary water balances clearly show a low conveyance efficiency [2] of a number of areas with respect to the fresh water use. It has been shown that only a small percentage of the total fresh water intake is used for irrigation or drinking water. The largest part of the intake is used for flushing out the salt from the system and for sustaining the water levels. In other words, a huge volume of fresh water is used to keep the system fresh, while only a small percentage is used for irrigation or potable water.

Resisting strategy

Given the small demand with respect to the total intake, it seems logical to look at measures that limit the volume of water required for washing out and sustaining the water levels. The dependency on external supply will decrease while the self-

In summer algal bloom is a major problem in sweet water bodies in the Netherlands.

sufficiency will increase. The measures to be taken would include structural changes to the whole water management system.

Adaptation strategy

For this strategy the salt water intrusion is no longer controlled. The system is no longer maintained fresh implying that that the intake of fresh water is no longer required. It does imply that the fresh water supply is separated from the natural system. This could involve a change in cropping patterns or to innovations in water-technology, such as desalinisation.

Outlook

The challenge is to select the most viable strategy. The preference mainly depends on the characteristics of the area, and the inefficiency in particular. The characteristics would include the sensitivity to salinisation but also the type of agricultural practices. The study has clearly shown that in order to develop strategies to cope with climate change in areas sensitive to salinisation it is essential to understand the water balance both in terms of quality and quantity. It has been illustrated that in some areas the inefficient fresh water use is the major challenge while other areas can be climate proof with only limited interventions.

Knowledge caps

The study has identified a large number of technical knowledge caps that need to be answered to make a selection of measures that eventually leads to a climate proof freshwater supply. In addition to technical knowledge, a number of policy considerations have been proposed to focus the research for the coming years:

- Before selecting and implementing measures, make a well considered choice of a policy strategy
- Consider whether a top down policy approach is required or whether there are opportunities for local initiatives
- What are the opportunities, challenges and benefits of a participative approach when formulating regional options in policy strategies
- Fresh water supply should be considered in relation to other water issues, such as safety, saltwater intrusion, and storage.

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PROJECT
IC 10
Communicating climate change: Methods for revealing risks and opportunities

JOOP DE BOER
VU University

Frames and tools for public participation

People's understanding of climate change is shaped by underlying organizing principles or "frames". Frames enable a person to develop a culturally accepted opinion about an issue without having to consider all the details. Hence, well-founded frames are prerequisites for public participation in climate-related planning.

Given that climate change cannot be observed directly, the public's opinions on this issue are partly dependent on knowledge institutes and their tools, such as model tools, cost-benefit-analysis, and dialogue tools, each with its own built-in frames. Because different framings of an issue might significantly affect public participation, this paper aims to clarify the role of frames in this context.

Frames

Frames are underlying structures of perception, knowledge, and behavior, which are studied by researchers in such varied fields as anthropology, linguistics, cognitive psychology, social and organizational psychology, management science, sociology, communication and media studies, social movements research, policy science, and science studies. One of the reasons why it is often difficult to reveal their role is their "hidden" or "taken-for-granted" character. Moreover, when people plan an event, such as learning more about climate change, they often begin by partially activating a frame for the event being planned[1]. That is, a frame of an abstract issue, such as a concept, an event or a plan, is never experienced directly in its entirety.

Depending on the circumstances, subsets of frame information become active to highlight specific aspects of the issue at hand. For example, climate change is often seen as a science-based issue and an important aspect of such an issue is the link with knowledge institutes as potential sources of relevant information.

Although there is no standard methodology to measure frames, they can be better understood by analyzing the interactions of knowledge institutes and community stakeholders. In the Netherlands, these interactions happen in the context of regional "hotspots", where climate change and land use planning may have large impacts on the quality of life.

Some core aspects of the interactions are schematized in Figure 1. Figure 1 demonstrates that climate change can be framed in an event-like structure that combines aspects related to "causal attributions", "identifiable places", "time horizon", and additional "uncertainties". Particular combinations of these aspects enable understanding and prediction of specific patterns of observations, such as "changes in snow" (short time horizon) and "sea level rise" (long time horizon). Without going into all the details, it should be noted that the figure's key point in the present discussion involves the articulation of uncertainty. A knowledge institute can frame climate change in ways that may or may not highlight uncertainties in science. Less obvious is what will happen with uncertainties in politics (shown dashed in Figure 1).

Strategic questions

Highlighting uncertainty is a matter of strategy. Thinking about climate-related planning, for instance, may require that several conditions of uncertainty have to be accepted. Instead of just focusing on the question "How can we reduce uncertainty in our estimates of future climatic

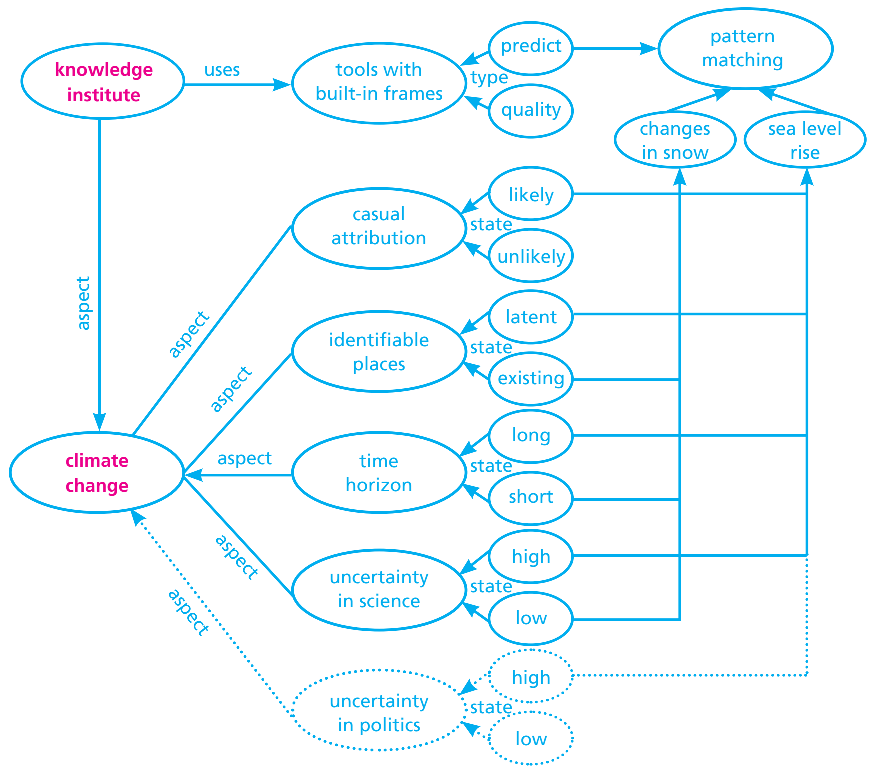

FIGURE 1.
Main characteristics of the climate change manifestations "changes in snow" and "sea level rise", represented by an event-like frame (inside the box) that combines various aspects of the climate change concept.

conditions?", it may be important to give more attention to the question "Given that there is considerable uncertainty about our future, how can we best manage this coastal area to reduce risk and increase system resilience?"

Following Thompson's seminal approach to decision-making[2], the basic question is whether there is (1) a need for more scientific knowledge about the cause/effect relations that are instrumental for what the decision might actually accomplish or (2) a need for more deliberation on preferences regarding the possible outcomes of the decision. Figure 2 displays the main uncertainties that should be considered in developing a decision strategy and characterizes four strategy types that focus on (1) computation, (2) compromise, (3) judgment, or (4) inspiration. In addition, each strategy is accompanied by methods and tools with built-in frames that fit the strategy.

If the planners believe that there is enough certainty regarding both cause/effect relations and outcome preferences (upper left cell of Figure 2), decision-making is relatively straightforward. It may require a computational strategy to process voluminous data, relying on conventional forms of decision support, such as multi-criteria analysis tools (MCA) and cost-benefit analysis (CBA). The built-in frame of these methods sees the decision situation as a problem for which an optimal solution might exist, provided that trade-offs will be accepted.

In contrast, if outcome preferences are uncertain or disputed, although cause/effect relations are considered certain, the planners need a compromise strategy to identify an acceptable preference (upper right cell of Figure 2). This means that the decision situation is framed as a problem which solution should satisfy a wide set of constraints instead of a single optimum criterion. To find a course of action that is acceptable to all kinds of stakeholders, participatory tools can be applied, such as some form of open, goal-directed conversation or "dialogue" between decision-makers, experts and other stakeholders, which may create favorable conditions for the exchange of diverging arguments.

If outcome preferences are clearly known and shared but cause/effect relations are uncertain or disputed, the planners must rely on a judgmental strategy to find a solution (lower left cell of Figure

Beliefs about cause/effect ↓ / Preferences regarding possible outcomes →	Certain	Uncertain
Certain	**Computational strategy** • Cost-benefit analysis tools • Multi-criteria analysis tools • Accounting tools and physical analysis tools	**Compromise strategy** • Participative tools, e.g. stakeholder analysis and focus groups • Argumentation support tools • Negotiation tools
Uncertain	**Judgmental strategy** • Scenario analysis tools, expert panels, simulation gaming • Model tools (biophysical, socio¬economic, or integrated) • Checklists for judging model quality and uncertainties	**Inspirational strategy** • Cognitive aids, e.g. checklists for prompting new ideas, "rich picture" drawing • Development of learning-scenarios

FIGURE 2
The horizontal and vertical dimensions of decision call for different decision strategies, which require their own methods and tools.

2). Whether cause/effect relations are uncertain may depend on several conditions, such as the planners' belief that the existing knowledge is incomplete, that there is inherent uncertainty or uncertainty due to competition with opponents (e.g. rivals in the market). The nature and the relevance of scientific uncertainty (e.g. focusing on means or on variability) can lead to difficult discussions between decision-makers and experts, as well as between experts among themselves. There are several tools that can support this strategy, but a potential drawback is that discussions among experts might reduce feelings of problem ownership among planners and the public at large.

Finally, both causation and outcome preferences can be uncertain or disputed (lower right cell of Figure 2). When dealing with climate adaptation problems, for example, this may happen if there are external constraints that make planners at the regional level dependent on governmental institutions that can exercise veto power over some possible solutions. In many of these cases, the most likely action for the planners is to avoid any decision on the issue, unless an inspirational strategy can be introduced to create a new vision or belief. An inspirational strategy may include tools to stimulate creativity, such as the development of learning-scenarios.
Interestingly, there are two diverging frames of creativity[3]. Some persons tend to emphasize the value of spontaneous insight and the magical "Aha!" moment that occurs when a long-sought idea suddenly appears at the conscious level. Other persons emphasize systematic approaches to exploring problems and potential solutions. Generally, the occurrence of insight is associated with restructuring or reframing a problem space, for example, from a broader perspective.

Divergence and overlap

Taken together these insights show that there is a close relationship between frames, tools and public participation. This may give rise to a new generation of participatory tools that take the role of frames more explicitly into account, for example, by introducing a contrasting frame to open-up the process of decision-making. These notions have been elaborated in a short toolkit. A key point in this context is how contrasting frames will be appreciated. Political science has identified "divergent frames" as a potential source of intractable conflicts[4]. In a more neutral problem solving setting, however, "multiple frames" or "perspec-

Frames are underlying structures of perception, knowledge, and behavior.

People with diverging arguments can only communicate meaningfully if their frames overlap to a certain degree.

tives" are often seen as fruitful complements to each other[5]. Appreciating divergence is partly a matter of accepting diversity in preferences as an unavoidable social reality. Diversity can also be seen as an essential source of creativity, provided that there is at least a certain degree of commitment to support the planning process. It should be added, however, that people with diverging arguments can only communicate meaningfully if their frames overlap to a certain degree. Hence, a careful consideration of frames in their role of organizing principles may significantly facilitate the interaction between knowledge institutes, decision makers and stakeholders.

To read more on frame based information tools you can download the Toolkit: http://www.chem.uu.nl/nws/www/research/risk/NWS-E-20093.pdf

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Constructive Conflict Methodology for stake-holder dialogues

Constructive Conflict Methodology is an over-arching approach to the design of stakeholder dialogues on complex societal issues.

Stakeholder participation is generally seen as a necessary means to integrate divergent problem perceptions and various sources of knowledge in policy processes on environmental and ecological issues. But how to design a stakeholder dialogue in such a way that divergent problem perceptions are included meaningfully?
Constructive Conflict Methodology aims to facilitate learning in stakeholder dialogues[1]. Constructive Conflict Methodology's learning effect was evaluated in a stakeholder dialogue on energy from biomass in the Netherlands.
Constructive Conflict Methodology (CCM) starts from the notion that most environmental problems, such as strategies for climate adaptation or sustainable energy, are unstructured or wicked[2]. Unstructured problems are characterized by (scientific) uncertainties, and a diversity of (conflicting) values at stake. Stakeholder dialogue is a means to structure the problem, i.e. to improve the understanding of how different stakeholders perceive and define the problem and its potential solutions.
The focus on constructive conflict rather than consensus seeking is underlined by empirical research that shows the value of diversity and conflict for group problem solving and learning[3,4]. CCM consists of four steps and relies on the use of specific social science methods to support each of the steps within the methodology (see Figure). Q methodology[5,6] was for instance used to select stakeholders on the basis of their perspective rather than their affiliation.
CCM was applied in the Biomass Dialogue, a stakeholder dialogue on energy from biomass in the Netherlands. A quasi-experimental evaluation approach showed that, as a result of taking part in the Biomass Dialogue, participants better understand and acknowledge the diversity of perspectives on biomass.

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PROJECT IC08 PRObing a method to Facilitate the Interactive Linking of Expert knowledge to Stakeholder assessment (PROFILES)
ME04 An integrated framework to assess spatial and related implications of increased implementation of biomass delivery chains.

PARTNERS:
VU University Amsterdam / Wageningen University and Research Centre / Alterra / Utrecht University / Energy Research Centre of the Netherlands (ECN) / KEMA

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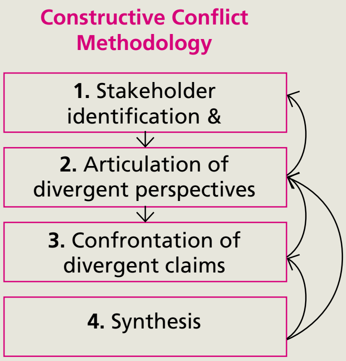

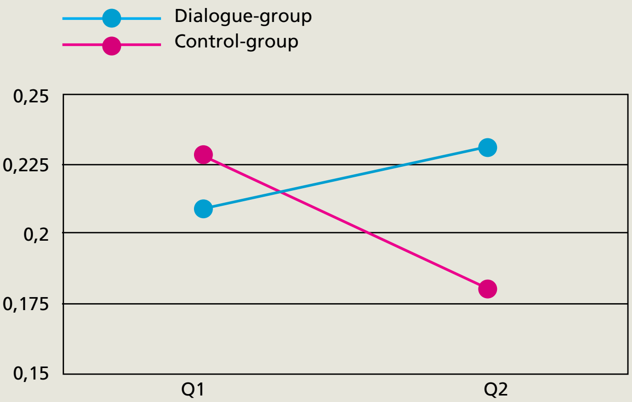

FIGUUR 1 (left): Constructive Conflict Methodology aims to facilitate learning in stakeholder dialogues on complex societal issues
FIGUUR 2 (right): The application of Constructive Conflict Methodology in the Biomass Dialogue resulted in a significant learning effect

PROJECT
CS07 Tailoring climate information for impact assessment
COM21 Climate change sketchbooks
COM27 Climate Impact Atlas

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Climate Impact Atlas promotes the use of climate information in policy making

The Climate Impact Atlas is an effort to disclose spatial information on climate change impacts. It contains information about projected impacts of regionalized climate change scenarios, including flooding, ecosystem shifts and agricultural production.

CLIMATE CHANGE increases the vulnerability of the Netherlands. Not surprisingly, adaptation of spatial planning is high on the political agenda. Integration of knowledge on climate change into spatial planning is difficult due to the gap between science and policy and because the issues involved are uncertain, long term and multisectoral of nature. Dutch provinces all share the intention to develop 'climate proof' policies. In this article, we describe experiences during the development of the "climate impact maps".

Objectives

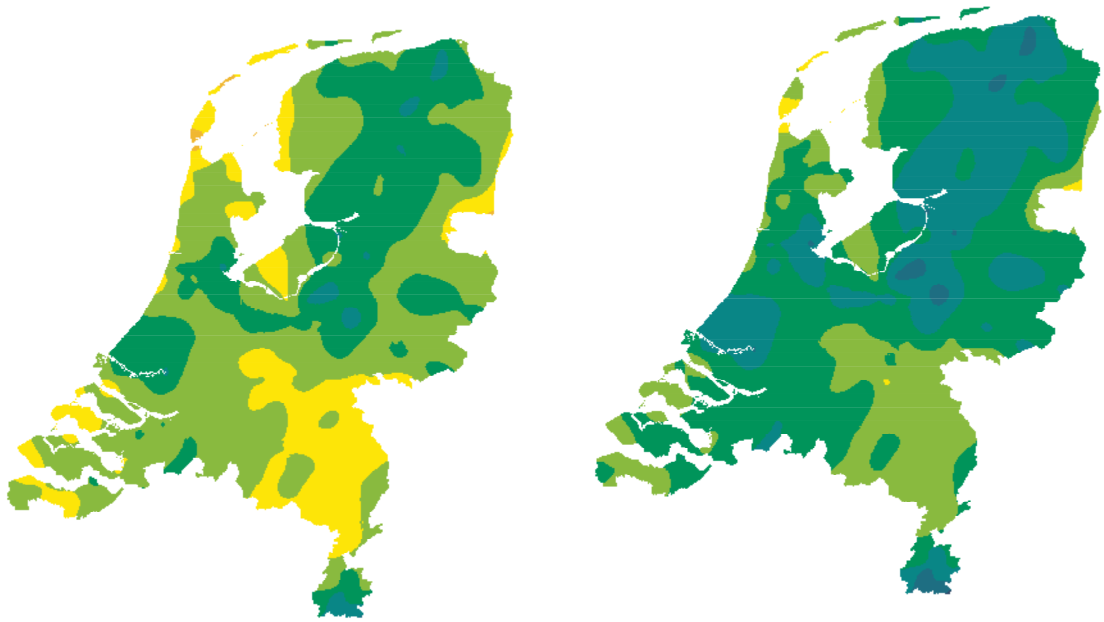
The aim of the Climate Impact Atlas (CIA) is to promote the use of scientific information on climate change in spatial planning and decision making. Provinces are required to include climate change into their "revisions of spatial plans" in the Netherlands. In connection with this, the development of the atlas was initiated by four Dutch provinces, within the framework of the Dutch 'Climate Changes Spatial Planning' and 'Knowledge for Climate' research programs. Since the impacts do not stop at Provincial borders and there is considerable uncertainty about the impacts, there was a need for a consistent way of generating and presenting state of the art information on climate change impacts.

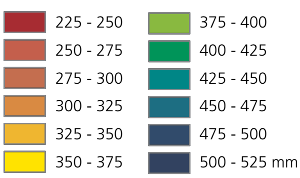
The Climate Impact Atlas

The impacts of climate change affect a wide range of sectors, therefore an interdisciplinary team of researchers was involved in the development of a first generation CIA. The climate impact atlas consists of a large number of maps disclosed via an online Geoportal. The maps in the atlas are divided into three categories:

1) *Primary effects*: meteorological variables such as average summer- and winter precipitation are included, but more importantly data was included on extremes such as the number of days per year with > 15mm rain, number of tropical days, summer days, frost days, etc. All variables are presented for the current situation (1976-2005), and for the future (2020, 2050 and 2100) for the four climate change scenarios for the Netherlands, developed by KNMI[1]. Data for the future are

FIGURE 1. Average summer precipitation (April-September) in the current climate (1976-2005) and in 2050 for the W and W+ scenarios, based on transformation of time series to the scenario's and automatic interpolation of meteorological stations without additional climatological knowledge. Regional differences in the future are associated with regional differences in the current climate.





There was a need for a consistent way of generating and presenting state of the art information on climate change impacts

based on transformations of historical data from meteorological stations (see: http://climexp.knmi.nl/Scenarios_monthly/) and spatially interpolated (figure 1).

2) *Secundary effects*: a set of maps representing the impacts of the meteorological changes (primary effects) on hydrological variables such as soil moisture content (drought), salinity, water depth (floods and peak rainfall), see figure 2.

3) *Tertiary effects*: maps that indicate potential impacts on agriculture, nature conservation, flood damage etc. These maps are often generated through a combination of (secondary) impact maps and vulnerability maps of land use functions. This category of maps requires subjective choices about the severity of impacts, (e.g.) dealing with uncertainties and weight factors that are required when combining impact maps with vulnerability maps. The tertiary impact maps can be used to identify areas where proposed investment policies may face future damage or opportunities due to climate change (figure 3).

To indicate potential impacts of droughts on agriculture and nature, the map of figure 2 is combined with maps indicating the possibilities for irrigation, water quality requirements, crop drought sensitivity and sensitivity of nature types to droughts. Figure 3 presents the results of such a combination of maps, which is referred to as 'tertiary impact map'.

So-called tertiary impact maps such as the one in figure 3 are used by Dutch provinces to perform climate impact scans, highlighting areas where adaptation is more urgent. An increasing number of provinces and regions are performing such scans, leading to an increased political support for action. Communication on, and dissemination of impact maps and robustness maps was occasionally difficult. The maps often contained political sensitivities and in some cases the quality of the CIA maps was not good enough to be used at the local level.

Lessons learned from the design process of the maps

Setting up the CIA required close cooperation between the research community and policy makers (end users). The translation of climate information into practice requires 3 essential components[2]: salience (the perceived relevance of the information), credibility (the perceived technical quality of the information) and legitimacy (the perceived objectivity of the process by which the information is shared).
Below we discuss the relevance of these components for the CIA.

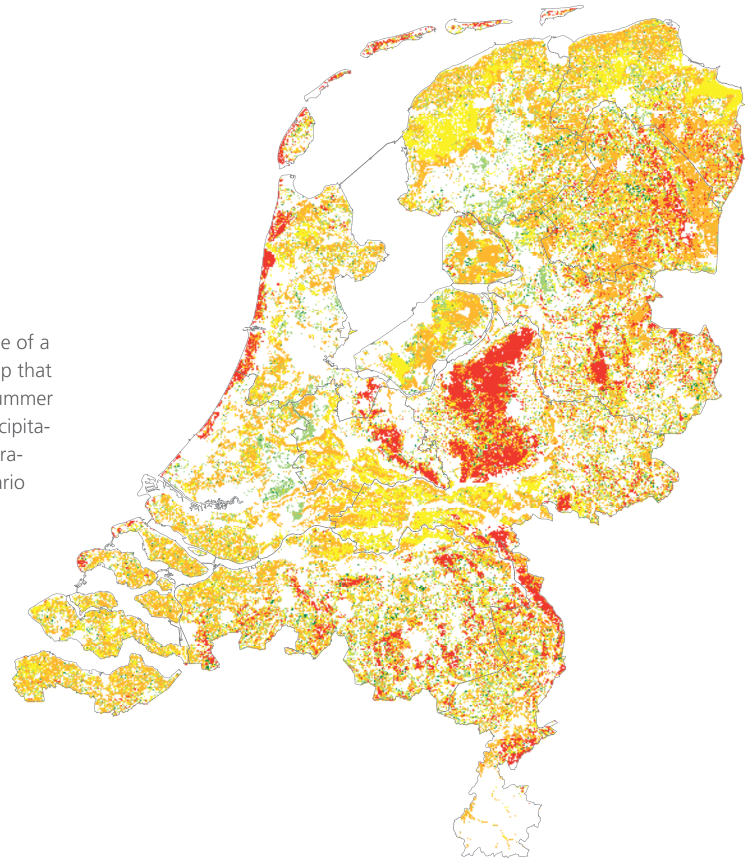


FIGURE 2: An example of a secondary impact map that shows the average summer soil water deficit (precipitation minus the evaporation) in the W+ scenario in 2050.

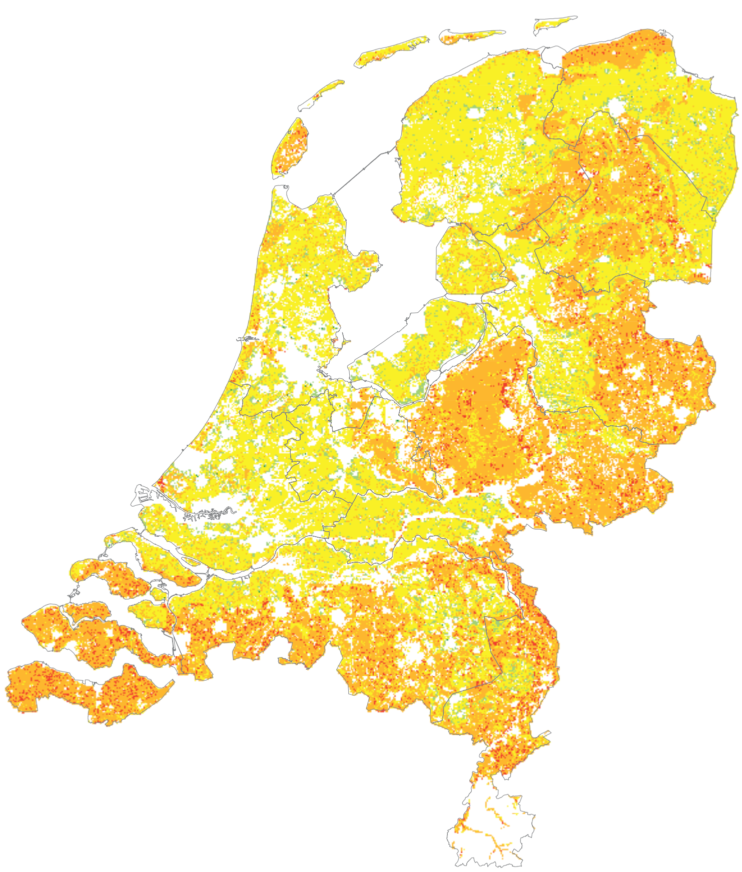


FIGURE 3: Example of a map in the Climate Impact Atlas, indicating the robustness for drought in 2050 under the W+ scenario. In this example, robustness is determined by the sensitivity of agriculture and nature to drought, the impacts of climate change on average water deficits and the possibilities for irrigation.

To increase the salience or relevance of the information, and to avoid a 'data dump', a series of interviews was held at the very start of the project to clarify the information requirement. It became clear that specification of the information requirement is not straightforward. For instance, the end users were interested in a drought map. Hydrologists however, need to know which parameters they need to visualize: water availability in the root zone, ground water levels, in what period of the year, for a standard year or in cases of severe drought periods etc. The first round of interviews resulted in a long list of wishes of climate change issues to be addressed by the atlas but it took more elaborate discussions about relevant issues and indicators to narrow down to a realistic number of issues and indicators. Rather than just offering maps and information, we applied a framework to better understand the potential use of information in different decision making and planning situations. For this purpose an additional series of workshops was organized on the available information and maps and to discuss the first generation impact maps for the 3 main issues: spatial planning, ecosystems, and agriculture.

The use of scientific information and the best way to present it depends on the decision making setting and the type of problem at hand[3]. Hisschemöller (1993) identifies four typical problems along two dimensions (Table 1). One dimension refers to the (lack of) certainty concerning the knowledge about the subject and possible solutions. The other dimension refers to the (lack of) consensus on relevant values that are at stake. Each of the four types of problems requires a different approach. In case of well-structured problems, a high degree of stakeholder participation is not recommended. Yet if the problems and knowledge are unstructured, a high degree of participation is required. For example, if there is a clear problem (need for a new road) and there is a clear overview of the consequences of all alternative ways to build the road, then the main activity is to take a (formal) decision on building the best possible alternative. When it is not clear that building a road is necessary, or maybe other alternatives such as a railroad are suggested, such a formal decision is more difficult to make. The process of making the CIA appeared to have many characteristics of semistructured or unstructured problems.

The scientific credibility of the information is another important aspect. Climate impact maps were constructed in consultation with a multidisciplinary group of professionals and scientists

TABLE 1.
The problem typology, relating the degree of structuredness of problems to the level of certainty and agreement on knowledge and to the level of agreement on values and objectives (after Hisschemöller, 1993).

	Agreement on values and objectives	Disagreement on values and objectives
Certainty and agreement on knowledge	Structured problem	Semi structured
Uncertainty and disagreement on knowledge	Semi-structured	Unstructured problem

from the research networks of the Dutch Climate Changes Spatial Planning and Knowledge for Climate programs. The team of researchers provided information on changes in meteorological variables and secondary effects (i.e. damage to agricultural production, ground water levels, river discharge) for a wide range of sectors. The main aim of these maps is to support the many political and economical discussions regarding the adaptation to climate change.

Legitimacy reflects the perception that the production of information and technology has been respectful of stakeholders' divergent values and beliefs, unbiased in its conduct, and fair in its treatment of opposing views and interests[4]. The maps and the proposed methods were applied and tested in a number (6) of workshops with stakeholders, end-users and researchers. A web based 'Geoportal' (www.klimaateffectatlas.wur.nl) is developed to disclose all information to the end users and also to the general public.

The development of climate impact atlases became a useful process for creating awareness and a uniform sense of urgency among policy makers and their staff. About half of the project budget was allocated for interaction between scientists and policy makers/end users during a substantial number of meetings and workshops. This was necessary to further specify information needs, to gain understanding of the complexity of adaptation issues. Both the developers and end users learned that defining the right set of impacts, indicators and scenarios needs to be done together. Stakeholders alone can't specify the exact knowledge needs, and scientist alone can't provide the appropriate answers. Researchers of different backgrounds learned to cooperate in transdisciplinary teams which, for most of them, has been a useful and pleasant experience which has led to enhanced creativity and scientific quality of their results.

Conclusions and recommendations

The CIA offers easy access to regionalized state-of-the-art knowledge on the impacts of climate change. The CIA is work in progress and still a number of impacts have not been addressed properly. We have learned that setting up a nationwide atlas requires 4 crucial elements:

Close collaboration between science and policy. Before jumping into the science, it is vital to understand the type of problems at hand to produce salient information. Where structured problems can be solved through science (optimization), un-

It took more elaborate discussions about relevant issues and indicators to narrow down to a realistic number of issues and indicators.

	Agreement on values and objectives	Disagreement on values and objectives
Certainty and agreement on knowledge	**Structured problems:** • flood risk prevention • peak rainfall damage prevention Main activities: gathering data, analysis, empirics and ratio. Maps as decision tools	**Semi-structured problems:** • Fresh water supply and its distribution over functions • Changing relations between agriculture and nature Main activities: consensus building, using maps as a discussion tool
Uncertainty and disagreement on knowledge	**Semi-structured problems:** • how to include climate change in spatial policy plans? • How robust are Natura 2000 targets? • What are the impacts of extreme events on agriculture? • How robust are ecological networks? Main activities: investigating uncertainties and sensitivities. The CIA serves as a support tool to advocate knowledge	**Unstructured problems:** • Urban heat island effect • Opportunities for tourism Main activities: investigating scenarios and alternatives, identification of preferences and goals. Maps as discussion tools to help identify and clarify objectives and preferences

TABLE 2.
The issues mentioned by the provinces characterized in terms of structuredness of problems. For each category the main activities and the potential roles of the CIA were discussed.

structured and semistructured problems require more interaction.

A multidisciplinary approach. Although trivial, cooperation between disciplines (hydrology, ecology, meteorology, spatial information sciences, decision and policy sciences) is essential. Tailoring of information is important which depends on objectives, requirements and the context in which the information is to be used. Integration of information on impacts is often difficult, due to different ways of handling climate change and uncertainties (use of climate and spatial scenarios), differences in spatial resolution and so on.

Visualization. Translating science and data to maps improves communication and use of science and data. By now a lot of information about climate change and impacts available, yet it is often difficult to express the information in a spatial way. Spatial presentation is important since spatial planners are used to working with information that is presented in maps.

Leave the 'predict then act' principle. Be prepared to accept uncertainties. There is always the urge to produce more accurate data and better predictions. However, dealing with climate change and adaptation will always leave some level of uncertainty.

Adaptation issues are not to be solved through more science and data alone. Incomplete data and uncertain maps can indeed be helpful in investigating robust adaptation strategies.

ACKNOWLEDGEMENTS

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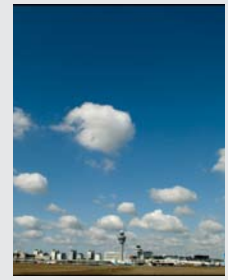
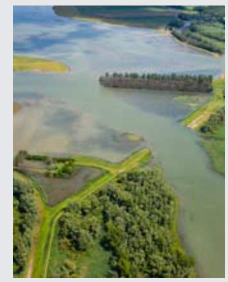
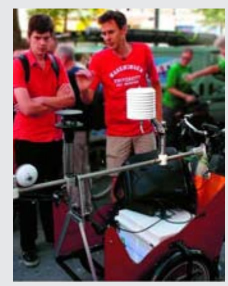
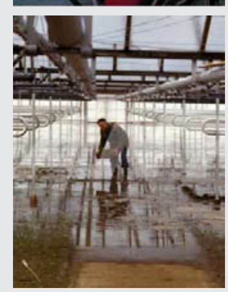
Ongoing research in the Knowledge for Climate programme

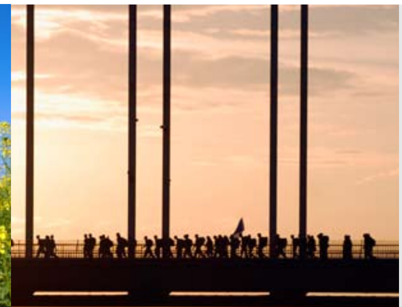
In the research programme Knowledge for Climate, knowledge institutes work closely with the Dutch authorities and the business community. The better the cooperation between these parties, the better the chance of successful and feasible adaptation strategies. Demand is a significant driver for knowledge development. Knowledge about climate, water, the natural environment, urban areas and physical space serves as the basis for further developing and shaping ideas and plans for climate-proofing the Netherlands. This encompasses both scientific and technical knowledge as well as knowledge from the social sciences. Since the official kick-off of the programme in November 2008 in Rotterdam, the first group of projects are approved and are underway. Here we present a selection of these projects. For a full overview and more information on their progress and preliminary results, please visit: www.climateresearchnetherlands.nl.















Model platform – Coupling (KKF01b)

The process of designing adaptation strategies requires a supply of consistent climate, hydrological, ecological and socio-economical scenario's. The inherent interdisciplinary character of climate change and the need to develop adaptation strategies at local to regional scales requires that climate and climate impact data and models need to be coupled to determine regional implications of global climate change. For developing spatial planning strategies, this requires coupling between climate scenario's and sectoral climate impact models (water, nature, agriculture and socio-economic models). The end product of this project will be a data and modelling platform that facilitates the supply of consistent scenarios for physical boundary conditions as well as for other boundary conditions. Initially this platform will be limited to data exchange; later fully coupled models may be constructed. Such a platform allows for regularly updating and guarantees that the scenarios will be based on up-to-date science and technology.

Model platform – Tailoring (KKF01c)

Results from research on climate change, possible impacts and adaptation options are often not available in a format that can be used directly by people that need to develop climate adaptation strategies. Therefore pre-processing and post-processing of data, and generation of additional data/information is needed. This process is called "tailoring". This project pays special attention on how to tailor information on climate change, its impacts and adaptation options for various users (ranging from researchers to policy makers). In this project tailoring is not limited to climate data, but also includes tailoring of data on hydrology, nature/ecology, agriculture and land use scenarios.

Adaptation to Meuse flood risk **(HSGR06)**

Given the expected increases in flood probability and risk, research is needed to provide adaptation measures that can maintain future safety. The effectiveness of flood defence measures has traditionally only been assessed in terms of their contribution to reducing flood probabilities. The damages associated with low probability flood events are high, and hence adaptation should also aim to reduce potential damage. The proposed research aims to assess the sensitivity of Meuse flood risk to changes in climate, land use, and socioeconomic development. The project will contribute to the emerging scientific discourse in this field, whilst also providing concrete risk estimates for the Meuse. Moreover, it will develop new spatial planning based adaptation strategies, in a multi-stakeholder workshop setting.

Relationship between perceived flood risks, problem ownership and adaptation choices **(HSRR07/HSGR08)**

There is a strong need for a better understanding of what risk perception is and what policy-makers can do to converge their policy with the perceptions of residents and business owners, without creating unwanted side-effects such as lower property values. Currently, policy-makers are reluctant to communicate clearly and fully about risks and problem ownership. One of the sensitive issues is liability. Hence, it is important to understand that the perception of climate-related risks and their geographical variation is crucial for developing adaptation policy and for communication about collective and individual choices that affect risks. This project will enhance our understanding of how policy-makers and professionals can foster shared ownership of flood safety problems among residents and business owners by communicating about risk, without creating unwanted side-effects in a spatial planning context.

The impact of climate change on the critical weather conditions at Schiphol airport

(HSMS03) Schiphol airport operations is very sensitive to critical weather conditions such as fog and low clouds, intense precipitation, heavy winds, and severe lightning. Flight safety and efficiency requires reliable weather information on local scales. This project aims to quantify and better understand how climate change affects the weather conditions at the airport, and will use this knowledge to improve the quality of their weather forecast. They will use the newly developed high-resolution (1-2 km) weather analysis and forecast model Harmonie, to determine the effect of global climate change on the weather parameters and the scales that are relevant for Schiphol operation. Results will contribute to determine which adaptation strategies are most effective to make the airport "Climate Proof".

Managing climate effects in peat meadows and shallow lakes

(HSOV1c) Peat meadows and associated shallow waters encompass a major part of the Netherlands. There are major challenges to regional and local governments to come up with adaptive management strategies to cope with the major stresses posed by climate change on basic environmental requirements for agriculture, drinking water production, nature and residential areas. In the development of adaptation strategies for peat meadows and shallow lakes a difficulty is that the interdisciplinary scientific information available is complex and does not match the requirements of the decision process. This project aims to develop knowledge that is necessary to be able to assess investments to be made in spatial planning and infrastructure over the coming twenty years in terms of their resistance to climate change, and for making changes where necessary.

Heat stress in the city of Rotterdam (HSRR05)

In this project the Urban Heat Island effect over Rotterdam will be predicted, measured and analysed to determine the magnitude, the causes and the mechanisms and frequency of occurrence in the present and in the future. An estimation will be made of the implication of heat on energy consumption, thermal comfort and public health targeting the most risky areas in the city and vulnerable groups such as elderly, children and patients. Various options to reduce the Urban Heat Island effect, heat stress and its consequences will be regarded: 1) behavioural measures (life style adaptation), 2) solutions at building level (for example energy efficient design of building by means of building orientation, materials and construction), 3) solutions at city level (urban planning strategies: building densities, parks, ponds, canals and city green). The most relevant (no regret) options or strategies for the city of Rotterdam will be pointed out, including a recommendation concerning the implementation of the strategies in practice.

Using scientific knowledge by policy-makers in the Deltaregion (HSZD01)

Decisions about (infrastructural) investments related to water management and land use are a regular issue within the Dutch Southwest Delta region since decades. Predicted changes in the global climate require that the policy makers in this region currently reconsider their water management strategies and land use zoning plans in order to minimize flood risks and optimize freshwater availability. The first goal of this research project is to map the patterns of certainties and uncertainties regarding the freshwater availability for land use both qualitatively, through analysis of cultural concepts, and quantitatively, with statistical analysis. The second goal is to translate theory and empirical findings towards practical guidelines for a science policy interface in the Southwest delta.

climate changes spatial planning

Knowledge for Climate