Climate change risks for severe storms in developing countries in the context of poverty and inequality in Cambodia

Least developed countries are generally regarded as particularly sensitive to climate change due to among other vulnerable locations and low adaptation capabilities. In the present study, we address climate change hazards in least developed countries by presenting a methodological framework, which is suitable for the estimation damage costs as a function of risk aversion, equality, income distribution and climate scenario using state-of-the-art climate model projections. As a case study, the methodology is applied to study severe storms in Cambodia based on two future climate scenarios and data on historical damages from storm events, which are used as a proxy in performing a sensitivity analysis on all input parameters. For the assumptions and parameter ranges used here, the study shows a high sensitivity to the income distribution (reflected by discount rates) and risk aversion and smaller effects from equality measures and extreme wind climate scenario. We emphasize that the assumptions on risk aversion reflecting consumption smoothing possibilities of low-income households clearly depicts that climate risks can be particularly high as a consequence of poverty and therefore recommend that context-specific vulnerabilities and equity concerns in climate risk studies should be included when making assessments for least developed countries.

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Decomposing the cascade of uncertainty in risk assessments for urban flooding reflecting critical decision-making issues

Climate change risk assessments traditionally follow an analytical structure in which climate information is linked to impact models, and subsequently to damage models and decision-making tools. This structure generates a wide cascade of uncertainties that accumulate with each analytical step, consequently resulting in a wide range of risk estimates. This cascade of uncertainties can suggest that climate change risk assessments are not very useful in the context of decision-making regarding climate adaptation. However, many of the uncertainties revealed in traditionally structured climate risk assessments are not equally relevant to specific decisions, and presenting wide cascades of uncertainties can mask key decision-making parameters. In this paper, we show how the cascade of uncertainty relevant to decision-making can be reduced by applying an uncertainty decomposition approach, which, in study design, initially identifies the uncertainty cascade elements of particular relevance to the focal decision-making context. We compare the full cascade of uncertainties that emerge in a traditional risk assessment based on linked climate scenarios, impact modeling, and damage cost assessment with the uncertainty cascade generated by a detailed assessment of urban flooding risks where the focus is on key uncertainties in decision-making on climate change adaptation. A case study on flooding from extreme precipitation in the Danish city of Odense is used to decompose major sources of uncertainties in the climate modeling, the hydrological modeling, and the damage cost assessment. The decomposition approach reduces the focal range of damage cost estimates by 7% to 9 M EUR, which corresponds to a 20% to 24% reduction in the full uncertainty range without the application of the decomposition approach. Assuming that damage cost assessments can provide an indication of how much society should be willing to spend on climate adaptation, a decomposition approach as presented here could assist decision-makers in increasing the economic effectiveness when investing in protective measures.

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Simulation of flood hazard and risk in the Danube basin with the Future Danube Model

Major river and flash flood events have accumulated in Central and Eastern Europe over the last decade reminding the public as well as the insurance sector that climate related risks are likely to become even more damaging and prevalent as climate patterns change. However, information about current and future hydro-climatic extremes is often not available. The Future Danube Model (FDM) is an end-user driven multi-hazard and risk model suite for the Danube region that has been developed to provide climate services related to perils such as heavy precipitation, heat waves, floods, and droughts under recent and scenario conditions. As a result, it provides spatially consistent information on extreme events and natural resources throughout the entire Danube catchment. It can be used to quantify climate risks, to support the implementation of the EU framework directives, for climate informed urban and land use planning, water resources management, and for climate proofing of large scale infrastructural planning including cost benefit analysis. The model suite consists of five individual and exchangeable modules: a weather and climate module, a hydrological module, a risk module, an adaptation module, and a web-based visualization module. They are linked in such a way that output from one module can either be used standalone or fed into subsequent modules. The utility of the tool has been tested by experts and stakeholders. The results show that more and more intense hydrological extremes are likely to occur under climate scenario conditions, e.g. higher order floods may occur more frequently.

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Organisations: Department of Technology, Management and Economics, Climate Risks and Economics, Sustainability, Potsdam Institute for Climate Impact Research, Imperial College London, Genillard & Co, Helmholtz Centre Potsdam - German Research Centre for Geosciences, Pannon Pro Innovations Ldt, OASIS LMF, Budapest Sewage Works Pte. Ltd
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Comparison of the impacts of urban development and climate change on exposing European cities to pluvial flooding

The economic and human consequences of extreme precipitation and the related flooding of urban areas have increased rapidly over the past decades. Some of the key factors that affect the risks to urban areas include climate change, the densification of assets within cities and the general expansion of urban areas. In this paper, we examine and compare quantitatively the impact of climate change and recent urban development patterns on the exposure of four European cities to pluvial flooding. In particular, we investigate the degree to which pluvial floods of varying severity and in different geographical locations are influenced to the same extent by changes in urban land cover and climate change. We have selected the European cities of Odense, Vienna, Strasbourg and Nice for analyses to represent different climatic conditions, trends in urban development and topographical characteristics. We develop and apply a combined remote-sensing and flood-modelling approach to simulate the extent of pluvial flooding for a range of extreme precipitation events for historical (1984) and present-day (2014) urban land cover and for two climate-change scenarios (i.e. representative concentration pathways, RCP 4.5 and RCP 8.5). Changes in urban land cover are estimated using Landsat satellite imagery for the period 1984-2014. We combine the remote-sensing analyses with regionally downscaled estimates of precipitation extremes of current and expected future climate to enable 2-D overland flow simulations and flood-hazard assessments. The individual and combined impacts of urban development and climate change are quantified by examining the variations in flooding between the different simulations along with the corresponding uncertainties. In addition, two different assumptions are examined with regards to the development of the capacity of the urban drainage system in response to urban development and climate change. In the "stationary" approach, the capacity resembles present-day design, while it is updated in the "evolutionary" approach to correspond to changes in imperviousness and precipitation intensities due to urban development and climate change respectively. For all four cities, we find an increase in flood exposure corresponding to an observed absolute growth in impervious surfaces of 7-12% during the past 30 years of urban development. Similarly, we find that climate change increases exposure to pluvial flooding under both the RCP 4.5 and RCP 8.5 scenarios. The relative importance of urban development and climate change on flood exposure varies considerably between the cities. For Odense, the impact of urban development is comparable to that of climate change under an RCP 8.5 scenario (2081-2100), while for Vienna and Strasbourg it is comparable to the impacts of an RCP 4.5 scenario. For Nice, climate change dominates urban development as the primary driver of changes in exposure to flooding. The variation between geographical locations is caused by differences in soil infiltration properties, historical trends in urban development and the projected regional impacts of climate change on extreme precipitation. Developing the capacity of the urban drainage system in relation to urban development is found to be an effective adaptation measure as it fully compensates for the increase in runoff caused by additional sealed surfaces. On the other hand, updating the drainage system according to changes in precipitation intensities caused by climate change only marginally reduces flooding for the most extreme events.

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Electronic versions:
Integrated climate change risk assessment: A practical application for urban flooding during extreme precipitation

Risk assessments of flooding in urban areas during extreme precipitation for use in, for example, decision-making regarding climate adaptation, are surrounded by great uncertainties stemming from climate model projections, methods of downscaling and the assumptions of socioeconomic impact models. The multidisciplinary character of such risk assessments also requires that research groups and experts from different scientific disciplines combine knowledge and share model outputs. This paper describes an integrated framework and tool, the Danish Integrated Assessment System (DIAS), which has been designed to address the complex linkages between the different kinds of data required in assessing climate adaptation. It emphasizes that the availability of spatially explicit data can reduce the overall uncertainty of the risk assessment and assist in identifying key vulnerable assets. The usefulness of such a framework is demonstrated by means of a risk assessment of flooding from extreme precipitation for the city of Odense, Denmark. A sensitivity analysis shows how the presence of particularly important assets, such as cultural and historical heritage, may be addressed in assessing such risks. The output of the risk assessment for Odense indicates that highly detailed geographical data reduce the overall uncertainty and assist climate adaptation decision-makers in focusing on protecting those assets that are considered to be relevant in the given context. Also, using an integrated framework such as DIAS enables the relative importance of the different factors (i.e. degree of climate change, assets value, discount rate etc.) to be determined, thus influencing the overall output of the assessment.

Sea level adaptation decisions under uncertainty

Sea level rise has serious consequences for harbor infrastructure, storm drains and sewer systems, and many other issues. Adapting to sea level rise requires comparing different possible adaptation strategies, comparing the cost of different actions (including no action), and assessing where and at what point in time the chosen strategy should be implemented. All these decisions must be made under considerable uncertainty—in the amount of sea level rise, in the cost and prioritization of adaptation actions, and in the implications of no action. Here we develop two illustrative examples: for Bergen on Norway’s west coast and for Esbjerg on the west coast of Denmark, to highlight how technical efforts to understand and quantify uncertainties in hydrologic projections can be coupled with concrete decision-problems framed by the needs of the end-users using statistical formulations. Different components of uncertainty are visualized. We demonstrate the value of uncertainties and show for example that failing to take uncertainty into account can result in the median-projected damage costs being an order of magnitude smaller.
Climate Change Risks – Methodological Framework and Case Study of Damages from Extreme Events in Cambodia

Climate change imposes some special risks on Least Developed Countries, and the chapter presents a methodological framework, which can be used to assess the impacts of key assumptions related to damage costs, risks and equity implications on current and future generations. The methodological framework is applied to a case study of severe storms in Cambodia based on statistical information on past storm events including information about buildings damaged and victims. Despite there is limited data available on the probability of severe storm events under climate change as well on the actual damage costs associated with the events in the case of Cambodia, we are using the past storm events as proxy data in a sensitivity analysis. It is here demonstrated how key assumptions on future climate change, income levels of victims, and income distribution over time, reflected in discount rates, affect damage estimates and thereby the economic recommendations for climate change adaptation decision making. The conclusion is that taken vulnerabilities and equity concerns into consideration in adaptation planning for Least Developed Countries really makes a strong case for allocating economic resources to the protection of these countries.
Cost-benefit analysis of adaptation Investments for Flood Risk Management for Industrial Estates in Mumbai

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Impacts of urban development and climate change in exposing cities to pluvial flooding
Urban areas are characterized by very high concentrations of people and economic activities and are thus particularly vulnerable to flooding during extreme precipitation. Urban development and climate change are among the key drivers of changes in the exposure of cities to the occurrence and impacts of pluvial flooding. Cities are often dominated by large areas of impervious surfaces, that is, man-made sealed surfaces which water cannot penetrate, and increases in these – for example, as a consequence of urban development – can cause elevated run-off volumes and flood levels during precipitation. Climate change is expected to affect the intensity and frequency of extreme precipitation, with increases projected for many regions, including most parts of Europe.

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Influence of urban land cover changes and climate change for the exposure of cities to flooding during high-intensity precipitation
Urban areas are characterized by very high concentrations of people and economic activities and are thus particularly vulnerable to flooding during extreme precipitation. Urban development and climate change are among the key drivers of changes in the exposure of cities to the occurrence and impacts of pluvial flooding. Cities are often dominated by large areas of impervious surfaces, that is, man-made sealed surfaces which water cannot penetrate, and increases in these – for example, as a consequence of urban development – can cause elevated run-off volumes and flood levels during precipitation. Climate change is expected to affect the intensity and frequency of extreme precipitation, with increases projected for many regions, including most parts of Europe.

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Influence of urban land cover changes and climate change for the exposure of European cities to flooding during extreme precipitation

In this paper we present a methodology suitable for investigating the relative and combined influence of urban land cover changes and climate change for the exposure of cities to pluvial flooding. A combined hydrological-hydrodynamic modelling and remote sensing approach enables the quantification of the flood risk relative to changes in imperviousness and climate change. The methodology is evaluated for the Danish city of Odense, but is easily applicable for the majority of cities within Europe, as it relies on open source data for the European continent. Results from Odense show that urban development during the past 30 years caused an increase in flood exposure that is comparable to what is expected in the RCP4.5 (+2°C) climate scenario.

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Influence of urban land cover changes and climate change for the exposure of European cities to flooding during extreme precipitation

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Influence of urban land cover changes and climate change for the exposure of European cities to flooding during high-intensity precipitation

The extent and location of impervious surfaces within urban areas due to past and present city development strongly affects the amount and velocity of run-off during high-intensity rainfall and consequently influences the exposure of cities towards flooding. The frequency and intensity of extreme rainfall are expected to increase in many places due to climate change and thus further exacerbate the risk of pluvial flooding. This paper presents a combined hydrological-hydrodynamic modelling and remote sensing approach suitable for examining the susceptibility of European cities to pluvial flooding owing to recent changes in urban land cover, under present and future climatic conditions. Estimated
changes in impervious urban surfaces based on Landsat satellite imagery covering the period 1984–2014 are combined with regionally downscaled estimates of current and expected future rainfall extremes to enable 2-D overland flow simulations and flood hazard assessments. The methodology is evaluated for the Danish city of Odense. Results suggest that the past 30 years of urban development alone has increased the city’s exposure to pluvial flooding by 6% for 10-year rainfall up to 26% for 100-year rainfall. Corresponding estimates for RCP4.5 and RCP8.5 climate change scenarios (2071–2100) are in the order of 40 and 100 %, indicating that land cover changes within cities can play a central role for the cities’ exposure to flooding and conversely also for their adaptation to a changed climate.

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Influence of urban land cover changes for the exposure of European cities to flooding during high-intensity rainfall events

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Key drivers and economic consequences of high-end climate scenarios: uncertainties and risks
The consequences of high-end climate scenarios and the risks of extreme events involve a number of critical assumptions and methodological challenges related to key uncertainties in climate scenarios and modelling, impact analysis, and economics. A methodological framework for integrated analysis of extreme events and damage costs is developed and applied to a case study of urban flooding for the medium sized Danish city of Odense. Moving from our current climate to higher atmospheric greenhouse gas (GHG) concentrations including a 2°, 4°, and a high-end 6°C scenario implies that the frequency of extreme events increase beyond scaling, and in combination with economic assumptions we find a very wide range of risk estimates for urban precipitation events. A sensitivity analysis addresses 32 combinations of climate scenarios, damage cost curve approaches, and economic assumptions, including risk aversion and equity represented by discount rates. Major impacts of alternative assumptions are investigated. As a result, this study demonstrates that in terms of decision making the actual expectations concerning future climate scenarios and the economic assumptions applied are very important in determining the risks of extreme climate events and, thereby, of the level of cost-effective adaptation seen from the society’s point of view.

General information
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Using Landsat Vegetation Indices to Estimate Impervious Surface Fractions for European Cities

Impervious surfaces (IS) are a key indicator of environmental quality, and mapping of urban IS is important for a wide range of applications including hydrological modelling, water management, urban and environmental planning and urban climate studies. This paper addresses the accuracy and applicability of vegetation indices (VI), from Landsat imagery, to estimate IS fractions for European cities. The accuracy of three different measures of vegetation cover is examined for eight urban areas at different locations in Europe. The Normalized Difference Vegetation Index (NDVI) and Soil Adjusted Vegetation Index (SAVI) are converted to IS fractions using a regression modelling approach. Also, NDVI is used to estimate fractional vegetation cover (FR), and consequently IS fractions. All three indices provide fairly accurate estimates (MAEs ≈ 10%, MBE’s < 2%) of sub-pixel imperviousness, and are found to be applicable for cities with dissimilar climatic and vegetative conditions. The VI/IS relationship across cities is examined by quantifying the MAEs and MBEs between all combinations of models and urban areas. Also, regional regression models are developed by compiling data from multiple cities to examine the potential for developing and applying a single regression model to estimate IS fractions for numerous urban areas without reducing the accuracy considerably. Our findings indicate that the models can be applied broadly for multiple urban areas, and that the accuracy is reduced only marginally by applying the regional models. SAVI is identified as a superior index for the development of regional quantification models. The findings of this study highlight that IS fractions, and spatiotemporal changes herein, can be mapped by use of simple regression models based on VIs from remote sensors, and that the method presented enables simple, accurate and resource efficient quantification of IS.
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Vurdering af omkostninger ved klimaændringer – principper og et eksempel fra Odense

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CEESA 100% Renewable Energy Transport Scenarios Towards 2050: Technical Background Report Part 2
This report presents the results regarding 100% renewable energy transport scenarios in the strategic research project “Coherent Energy and Environmental System Analysis” (CEESA) which was conducted in 2007-2011 and funded by the Danish Strategic Research Council together with the participating parties. Transport is one of the key challenges in society and has had special attention in the 100% renewable energy scenarios also developed in CEESA. This report also presents the TransportPLAN scenario tool developed in the CEESA project for analysing renewable energy in transport. The CEESA project was interdisciplinary and involved more than 20 researchers from 7 different universities or research institutions in Denmark. Moreover, the project was supported by an international advisory panel. The results include further development and integration of existing tools and methodologies into coherent energy and environmental analysis tools as well as analyses of the design and implementation of future renewable energy systems.

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Organisations: Aalborg University, University of Southern Denmark, University of Copenhagen
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Remote sensing estimates of impervious surfaces for hydrological modelling of changes in flood risk during high-intensity rainfall events

This paper addresses the accuracy and applicability of medium resolution (MR) remote sensing estimates of impervious surfaces (IS) for urban land cover change analysis. Landsat-based vegetation indices (VI) are found to provide fairly accurate measurements of sub-pixel imperviousness for urban areas at different geographical locations within Europe, and to be applicable for cities with diverse morphologies and dissimilar climatic and vegetative conditions. Detailed data on urban land cover changes can be used to examine the diverse environmental impacts of past and present urbanisation, including the importance of such changes for the exposure of cities towards the occurrence and impacts of climate extremes like high-intensity rainfall events.

Remote sensing estimates of impervious surfaces for pluvial flood modelling

This paper investigates the accuracy of medium resolution (MR) satellite imagery in estimating impervious surfaces for European cities at the detail required for pluvial flood modelling. Using remote sensing techniques enables precise and systematic quantification of the influence of the past 30-40 years of urban development towards the impacts of high-intensity rainfall.
Satellite estimates of urban development for hydrological modelling

We investigate the applicability of medium resolution Landsat satellite imagery for mapping temporal changes in urban land cover in European cities for direct use in urban flood models. The overarching aim is to provide accurate and cost-efficient quantification of temporal changes in risk towards the impacts of pluvial flooding. The results show that satellite imagery may have considerable potential in this respect, and that Landsat imagery can be used to provide accurate information on recent urban development patterns.

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Assessing Land Degradation/Recovery in the African Sahel from Long-Term Earth Observation Based Primary Productivity and Precipitation Relationships

The 'rain use efficiency' (RUE) may be defined as the ratio of above-ground net primary productivity (ANPP) to annual precipitation, and it is claimed to be a conservative property of the vegetation cover in drylands, if the vegetation cover is not subject to non-precipitation related land degradation. Consequently, RUE may be regarded as means of normalizing ANPP for the impact of annual precipitation, and as an indicator of non-precipitation related land degradation. Large scale and long term identification and monitoring of land degradation in drylands, such as the Sahel, can only be achieved by use of Earth Observation (EO) data. This paper demonstrates that the use of the standard EO-based proxy for ANPP, summed normalized difference vegetation index (NDVI) (National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) Global Inventory Modeling and Mapping Studies 3rd generation (GIMMS3g)) over the year (ΣNDVI), and the blended EO/rain gauge based data-set for annual precipitation (Climate Prediction Center Merged Analysis of Precipitation, CMAP) results in RUE-estimates which are highly correlated with precipitation, rendering RUE useless as a means of normalizing for the impact of annual precipitation on ANPP. By replacing ΣNDVI by a 'small NDVI integral', covering only the rainy season and counting only the increase of NDVI relative to some reference level, this problem is solved. Using this approach, RUE is calculated for the period 1982–2010. The result is that positive RUE-trends dominate in most of the Sahel, indicating that non-precipitation related land degradation is not a widespread phenomenon. Furthermore, it is argued that two preconditions need to be fulfilled in order to obtain meaningful results from the RUE temporal trend analysis: First, there must be a significant positive linear correlation between annual precipitation and the ANPP proxy applied. Second, there must be a near-zero correlation between RUE and annual precipitation. Thirty-seven percent of the pixels in Sahel satisfy these requirements and the paper points to a range of different reasons why this may be the case.

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© 2013 by the authors; licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution license (http://creativecommons.org/licenses/by/3.0/).
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Economic assessment of climate change adaptation options incorporating Bayesian networks: An integrated framework
Using satellite imagery to assess the influence of recent urban development on the impacts of extreme rainfall

We investigate the applicability of medium resolution Landsat satellite imagery for mapping temporal changes in urban land cover for direct use in urban flood models. The overarching aim is to provide accurate and cost- and resource-efficient quantification of temporal changes in risk towards the impacts of pluvial flooding. Initial results show that satellite imagery may have considerable potential in this respect.

Using satellite imagery to assess the influence of urban development on the impacts of extreme rainfall

We investigate the applicability of medium resolution Landsat satellite imagery for mapping temporal changes in urban land cover for direct use in urban flood models. The overarching aim is to provide accurate and cost- and resource-efficient quantification of temporal changes in risk towards the impacts of pluvial flooding. Initial results show that satellite imagery may have considerable potential in this respect.

Biomasse til transportsektoren

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Dansk transport uden kul og olie - hvordan? Et oplæg til debat om hvordan dansk transport bliver uafhængig af fossile brændsler inden 2050

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Impact Assessment and Decision Support Matrices for Climate Change Adaptation Planning

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Impact Assessment, Costs, and Decision Making for Climate Change and Adaptation

Methodological framework, analytical tool and database for the assessment of climate change impacts, adaptation and vulnerability in Denmark

This report was prepared at the request of and funded by the Coordination Unit for Research in Climate Change Adaptation (KFT). The report is a milestone of the project titled "Udvikling af metodisk ramme for dansk analytisk værktøj og database over klimasårbarhed og klimatilpasning", funded by KFT. The project is one of seven initiatives proposed by KFT for 2012. The methodology report includes definitions of major concepts, an outline of an analytical structure, a presentation of models and their applicability, and the results of case studies. The work presented in this report draws on intensive research collaboration with several Danish universities and Centres of Excellence, including DMI, GEUS, DHI, Aarhus University, Copenhagen University, and DTU. Work carried out by our research partners has been co-funded by a number of different sponsors, including KFT and the Danish Strategic Research Council. The flood hazard maps presented in this report constitute the first preliminary results of on-going methodological and analysis development in mapping potential impacts in relation to flooding from extreme precipitation in the city of Aarhus. For all purposes the Aarhus flood maps presented in this report should be considered work-in-progress. The analysis was conducted by DHI as part of the DSF project Centre for Regional Change of the Earth System (CRES).

A Spatiotemporal Analysis of Climatic Drivers for Observed Changes in Sahelian Vegetation Productivity (1982-2007)

Linear trend analysis and seasonal trend analysis are performed on gridded data of vegetation, rainfall, solar radiation flux, and air temperature, in order to examine the influence of the past three decades of climate variability and change on the Sahelian vegetation dynamics. Per-pixel correlation analyses are conducted on annual and monthly data, and analyses of change in the potential climatic constraints to the natural vegetation development from 1982-2007 are performed. The results reveal two distinct periods: (a) 1982-1994 marked by large increases in vegetation productivity and rainfall and little change in average air temperatures and solar radiation and (b) 1995-2007 characterized by no distinct trends in vegetation productivity and rainfall and increase in average air temperatures and decrease in solar radiation flux. Correlations between vegetation productivity and climatic constraints were found to be statistically significant only for rainfall explaining only a moderate degree of observed NDVI variation, indicating that nonclimatic factors are also
important for the Sahelian vegetation dynamics.
The Future of European long-distance - Scenario Report

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The Future of European long-distance - Synthesis Report, Interview meetings on long distance transport and global warming

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