Impact of a Climate Change Scenario on the Weser Estuary Region: scientific results and experiences with the interdisciplinary research process

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Introduction

Detailed research on the potential impacts and adaptation measures to climate change on a regional level has been identified as necessary (Sterr *et al.* 2000; Parry 2000). In an interdisciplinary project the possible consequences of a Climate Change scenario for the natural and the socio-economic system of the Weser Estuary region have been analysed. The case study to be reported here, "Climate Change and the Weser Estuary Region" (KLIMU), was funded by the German Ministry for Education and Research and the State of Bremen, the research period was 1997 to 2000.

KLIMU aimed at a high resolution on a small scale (ca. 1500 km^2) and a high degree of interdisciplinarity by combining oceanography, hydrology, coastal engineering, biology and economics. Moreover, we applied a whole set of climate parameters and a sea-level rise scenario for the impact assessment (Schirmer & Schuchardt 2001).

The analysis of the regional sensitivity to climate change included the natural system and the socioeconomic system, the consideration and analysis of the interdependencies between these systems, consideration of the adaptive capacity, and aspects of the future situation (year 2050) and developments. Finally we developed potential action/reaction scenarios and tested their feasibility, thereby initiating public information, awareness and discussion.

The Climate Change Scenario used in KLIMU for the year 2050

The climate change scenario, based on IPCC assumptions (www.ipcc.ch), was formulated as a methodological standard tool for the impact and sensitivity assessment to be performed by the subprojects (for more details see Schirmer & Schuchardt 2001):

- Rise of mean sea level: **+55 cm** (15 cm eustatic; 40 cm man made)
- Increase of tidal range: **+30 cm** (mthw + 15 cm; mtlw –15 cm)
- Rise of air temperature: **+2.7° C**
- Precipitation: **+9.8 %** (March-May + 22.1 %; June-August –6.0 %)
- Wind speed: **+3.8 %** (Sept.-Nov. +6.8 %; June-August –4.3 %)
- CO_2: **+100 %**

The study area

The Weser estuary is located in Northern Germany. The study area covers about 1,500 km^2 and includes the inner estuary, the accompanying lowlands, mostly used as agricultural land, and several cities and villages along the shores (Schirmer & Schuchardt 1999). Geological history and a millennium of anthropogenic shaping and use of this landscape has resulted in such features as a deep penetration of the sea inland (more than 80 km for the tidal impulse), amplification of storm surges within the funnel like shape of the estuary, low lying fluvial and coastal marshes often protected by dikes, an extensive water management system, endemic brackish habitats, economically important deep-sea shipping and port activities, and some urban centres.

The Project KLIMU and its Research Groups

Considering the complexity of the climate system, its impact mechanisms and the natural and societal structures to be assessed, an interdisciplinary set of sciences and working groups has been put together using a top-down approach that had to be coordinated and integrated during the research process (Table 1).

Table 1. Participating groups (subprojects) in the KLIMU project.

Task key words	Methods	Leader of the working group	Institution
modelling of estuarine water levels and quality	Numerical modelling	A. Müller I. Grabemann	GKSS Research Centre Geesthacht grabemann@gkss.de
modelling of inland water levels, river discharge, water exchange estuary / inland waters	Numerical modelling GIS	U. Maniak	Technical University of Braunschweig u.maniak@tu-bs.de
modelling of groundwater levels and salinity, soil moisture	Numerical modelling	B. Hoffmann	University of Hannover
coastal protection, probability of wave-overtopping, measures, costs	numerical modelling risk analysis	C. Zimmermann N. von Lieberman	Franzius Institute, University of Hannover nicole@fi.uni-hannover.de
ecological aspects types of habitats, species composition, land use	GIS	M. Schirmer	Department of Biology University of Bremen schi@uni-bremen.de
spatial demands, regional planning, agriculture, tourism	interviews	G. Bahrenberg	Department of Geography University of Bremen gbah@uni-bremen.de
regional economic structure and consequences, social dynamics	interviews econometric modelling	W. Elsner	Department of Economics University of Bremen welsner@uni-bremen.de
integrative analysis, coordination, interdependencies evaluation of impact	GIS	M. Schirmer B. Schuchardt	University of Bremen schi@uni-bremen.de BioConsult schuchardt@bioconsult.de

After an analysis of the status quo situation we have assessed the impact of the climate change scenario on the present situation of nature and society without any specific adaptation measures. In the next step we took countermeasures into account. Three alternative solutions for coastal protection have been developed and analysed with respect to efficiency, costs, environmental problems and social conflicts. Another important aspect is that the full impact of climate change will unfold not on the natural and socio-economic systems of today, but rather on a yet unknown future status - a problem that is too often neglected in climate impact studies (Arnell 1998). For selected aspects like coastal protection, agriculture and the degree of excavation of the Lower Weser Channel we have thus formulated assumptions on their future states and performed a second assessment of the climate change impact.

In order to handle the complexity of the system under consideration has 3 subsystems, each including aspects of the natural and the social systems, have been identified (for a more detailed description of the methodological approach see Schirmer & Schuchardt 2001):

- Subsystem "Lower Weser Estuary", characterised by the river, shipping channel, banks, tidal flats, forelands, hydrography, water quality, uses, economics etc.;
- Subsystem "Coastal Protection", characterised by the structures and functions of dikes, sea-walls, sluices, water-levels, waves, the organisation of coastal protection etc.;
- Subsystem "Agriculture", as characterised by the farming intensity, local site conditions, biotope types, economics, cultivation techniques, water management etc.

Results

The impact of the KLIMU-scenario on nature and society in their present situation will be as follows (see also Grabemann *et al.* 2001; Osterkamp *et al.* 2001; Knogge in press; Schuchardt & Schirmer in press):

Subsystem Lower Weser Estuary

- Nearly the same changes of water levels up to the tidal limit
- Increase of river discharge during winter/spring (March-May +28%); very slight decrease in late summer
- Upstream displacement of low salinity region and turbidity cloud (1-2 km)
- Increase of residence time (> 30% in summer)
- Increase of water temperature: +2.7°C
- Increase of oxygen deficits (1-2 mg/l)
- Increase of tidal reeds: + 58% (esp. below mthw)
- Shifts in the species spectrum due to changes in habitats and due to increasing temperature
- Increase of the production of the tidal reeds by about 10-25%
- Losses of tidal pasture land: – 34%
- All tidal foreland no longer useable as pasture land
- Energy production in power plants slightly hindered in summer
- Shipping/harbour activities: only small impact

Subsystem Coastal Protection

- Probability of wave-overtopping will increase: recurrence interval on the left bank from ca. 1000 y to 200 y and on the right bank from ca. 3000 y to 800 y (strong local heterogeneity)
- A rise of the design water level and thus coastal protection measures will be necessary

Subsystem Agriculture (behind the dikes, maintaining present water-levels)

- The water volume which has to be drained by pumping or via free flow will increase by up to 15 %. The share which has to be pumped will increase significantly
- The soil humidity will remain more or less stable or decrease by 1 standard unit
- Only small changes within the habitat-types, however, some changes in the species composition
- Overall increase of agricultural productivity
- Demands will change only little and can probably be mastered using the present (infra)structure

Adaptation Measures

The climate change scenario will require further adaptation of the coastal protection systems (von Lieberman & Zimmermann 2001). Three response strategies have been outlined, all already under consideration as possible coastal protection concepts. The three different alternative solutions, showing very different acceptabilities in the region, have been tested for their efficiency, their approximate costs and the impact on the environment.

Option 1: Reinforcement of the existing dikes and their infrastructure

- A rise of 0.2 – 2.3 m is necessary
- Costs: about 50 mill ECU for maintaining the actual recurrence interval
- Problems: stability of soils, construction time, availability of space, ecological consequences

Option 2: Construction of storm surge relief polders

- Construction of 3 polders (total area 5,570 ha)
- Relocation of main dike at Luneplate (ca. 1,000 ha)
- Leads to a lowering of storm surge water level by 0.35 cm in the outer part and 0.70 cm in the inner part
- Costs (dike construction only): about 300 mill ECU
- Problems: chains of high tides; availability of space; size of construction measures, ecological consequences

Option 3: Construction of a storm surge barrier near Bremerhaven

- Costs: about 250-370 mill ECU
- Problems: Availability of space; hydrodynamic and ecological consequences; maintenance costs

Future Developments and Climate Change

The full climate change impact will not hit the region and the society as they are today. Looking ahead to the year 2050, the specific evolution of the future social and economic conditions is yet unknown. To take this uncertainty into account, the scenario approach has been used again in formulating different future developments, assuming that reality will (hopefully) be somewhere in between. However, the scenarios are supposed to represent the amplitude of possible futures and serve as a methodological tool for analysing future sensitivity to climate change. Four future developments have been examined:

- Further deepening of the Weser Estuary
- Re-shallowing of the Weser Estuary
- Intensification of land-use
- Extensification of land-use

The results have shown, that possible future developments of nature and society can alter the sensitivity of the region to climate change.

Conclusions

- Overall impact of the Climate Change scenario is relatively weak and controllable;
- Several consequences are within the present amplitude of the natural and economic dynamics;
- Adaptation capacity of the region is high (coastal protection, water management);
- Stronger impact will occur in the foreland areas (restrictions for agricultural use; increase of natural habitats);
- Need for action especially for coastal protection;
- Possible future developments of nature and society can alter the sensitivity for climate change;
- Future planning should include an assessment of the consequences for climate change sensitivity.

The interdisciplinary research process

Considering the interdisciplinary research process, the following conclusions can be drawn:

- it yields more results than the sum of the single disciplines
- it should not be planned as a self-organizing process
- it is only partly controllable
- it requires a top-down approach already in the planning phase and must be well structured
- it requires clear definition of the interfaces between the subprojects
- it needs “open-minded” people
- needs a theory or at least some terms, which are appropriate for the different disciplines

- it might be stimulated, if a common “attractor” (a theory; a tool) is available

Future research

A new interdisciplinary project, funded by the German Climate Research Program DEKLIM (Focal point C: Climate impact research), has been started. The research period is 2001-2004. The project is titled “Climate Change and Preventive Risk and Coastal Protection Management on the German North Sea Coast (KRIM)”. Development of a Decision Support System is used as integrative tool (“attractor”, see above). For further information: www.krim.uni-bremen.de.

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