Tools

Title: **Tools for modelling the impacts of climate change and the consequences on the economy**

Keywords:
Regional climate scenarios; water-balance modelling; hydraulic modelling; vulnerability analysis; cost-benefit analysis; communication

Audience:
Technical tools: water management professionals
Communication tools: decision makers, stakeholders, general public

Level of expertise required to use the tool:
The tools themselves can only be used by experts, for instance consultants. However, non-experts on the project management level are enabled to use the holistic approach described in the guidance in their field of work.

Messages in the ESPACE strategy where the tool can be applied:							
	1.	2.	3. X	4.	5.X	6.	7.X
	8. X	9.	10.X	11. X	12.	13.	14. X

Sentences linking the tool to relevant strategy messages:

3. The 3A's and the 4th A – Action and Reflection - were integrated in the Communication Tool developed by LfU especially via stakeholder dialogues. Knowledge of regional climate change factors are a key element of successful risk management and the choice of effective measures.

5. The technical tool developed by LfU provides instruments for the integration of climate change related issues into new plans, policies etc.

7. The technical tools developed by LfU allow the assessment of vulnerabilities whereas the communication tool facilitates dialogue with politicians and communities.

8. The knowledge gained from the use of tools developed by LfU helps achieve a balance between different necessary measures for the implementation of spatial planning.

10. The communication tool developed by LfU helps communicate flood related climate risks to stakeholders and decision makers by quantifying possible impacts of climate change.

11. Using the tools developed by LfU, the calculation of climate change factors enables the development of sustainable long term solutions.

14. The tools developed by LfU show how advanced knowledge on climate change can easily be integrated into flood protection planning by deriving adjusted climate change factors and enables revisions of existing flood protection plans.

Photo/diagram/map:	Overview: The tools described below are the pieces of the jigsaw puzzle, which combine to form the Bavarian Environment Agency (LfU) guidance on the estimation of the flood-related impacts of climate change in a river catchment and determination of sustainable adaptation measures. The correct interaction of these tools, as described in the guidance, enables the estimation of the impact of climate change in a catchment area and subsequently the finding of the most efficient measures for the flood protection taking climate change into account. In detail, the tools mentioned below enable the estimation of quantitative information on climate change and the consequences for regional water budgets. Based on this, the flood increase and the resulting physical and economic impacts as well as the ecological and socio-cultural impacts can be assessed following the principles of sustainability. The main result using these tools is the calculation of “climate change factors” as the basis for an analysis of effectiveness for the different planning options. Another important more general tool is the communication tool, in which the specific tools mentioned above should be embedded.

Description:

The development of flood risk management plans uses a broad range of tools. To be able to take climate change into account new additional tools were necessary, which had to be developed and tested in ESPACE.

The **first** one is related to applied natural and economic sciences. It concerns the quantitative estimation of the impacts of climate change on river catchments, including the following components:

1. regional climate models
2. water balance models both without and with climate change
3. hydrological statistics (extreme values)
4. hydrodynamic modelling (water levels, discharge)
5. vulnerability analyses: calculation of damage potentials with and without climate change

In detail:

1. **Regional Climate Models**
   Regional climate models deliver and quantify information and are a prerequisite for all climate change impacts studies.
   In order to make statements about possible climate changes in the River Main Catchment for the coming decades, regional climate scenarios had to be developed. As an optimum

method has not yet been devised for this purpose, different institutions were given the task of establishing regional climate scenarios based on a global circulation model (ECHAM4/OPYC3). They were required to develop three different methods, namely:

- a statistical downscaling method using cluster analysis (Potsdam Institut für Klimafolgenforschung/PIK),
- a statistical dynamic downscaling using classification of weather conditions (Fa. Meteo-Research /MR) and
- a regional dynamic climate model (REMO) (Max-Planck-Institut für Meteorologie /MPI).

These scenarios have to be validated on a control run (in our case study we chose the period 1971-2000). To apply the scenarios, they have to be adapted to the scale relevant for river basin management.

Results: Detailed data on expected climate change under IPCC B2 emission conditions for a 30 year future period (2021-2050) on river basin level (spatial and temporal distributed results including changes in temperature, precipitation, humidity, sunshine duration and wind speed) for the River Main catchment. These data sets serve as input for the water balance modelling under climate change.

2. **Modelling the hydrological impacts of climate change**
   Modelling of the characteristic response in the case study area (e.g. discharge and water storage in the upper Main Catchment). Input data for the water budget model (precipitation, temperature, snow etc) and GIS (**Geographic Information System**) based data (land-use, topographic data etc) had to be prepared and GIS layers have to be combined and transformed into a specific data base format. In the case study the water budget model ASGi was used.
   Following these preparatory tasks the modelling of the current state and derived water relevant parameters for simulation of climate change scenarios is possible. Based on this, the changes in the water-resource conditions under climate change with the climate change scenarios and the calibrated water-budget-model ASGi can be calculated.

   Results: The model system ASGi with its water balance model WASIM-ETH shows a sufficient process description and can be used to model the impacts of climate change scenarios on the water balance in the case study area. In the first step, the water balance models for the Main catchment have been established, calibrated and validated at a daily temporal scale (period 1961-2000) and a 1000m spatial scale.

3. **Hydrological Statistics**
   Characteristic flood events with and without climate change impacts have been calculated for the Main catchment along with its sub-catchments. Climate change factors for floods with different probabilities of occurrence (1 to 100 years) were derived.

4. **Hydrodynamic Modelling (water levels, discharge etc)**
   The results from the hydrological statistics are the input for hydrodynamic modelling of water levels, discharge and flow velocity. These results are then combined with digital topographic models of the catchment to simulate the physical impact of the calculated floods with different probabilities of occurrence (with and without climate change impact).

5. **Vulnerability Analyses: Calculation of damage potentials with and without climate change**
   A comparison of the physical impacts calculated with the hydrodynamic model with land

use, infrastructure and property values gives insight into the level of vulnerability for a particular area. This allows the determination of damage potentials with and without taking climate change into account.

The **second** innovation in flood protection planning is the communication tool which takes climate change into account. Communication with all the parties involved has to accompany all phases of the planning process to ensure decision-making and implementation of an optimal mix of measures concerning mitigation and adaptation to climate change.
The focus of the communication strategy is the communication process with stakeholders. Key elements of the communication tool are websites offering (detailed spatial) flood protection information and possible precautionary measures, meetings with the stakeholders and the distribution of information material (Leaflets etc.).

Author:	Further information:
Belau, Morscheid, Schmidtke Bavarian Environment Agency (LfU)	• „Modellierung des Wasserhaushalts des Mittleren und Unteren Mains mit Focus Fränkische Saale“ (water budget model for the river basin lower Main with focus on the Fränkische Saale) Consultant Willems and LfU, October 2005 • „Darstellung und Vergleich regionaler Klimaszenarien (ENKE) des Maingebiets in Bayern“ (Graphical and statistical analysis of regional climate change scenarios) Consultant Bronstert and LfU, 2005 • “Einfluss des Klimawandels auf Wasserbilanzen und Abflüsse für Einzugsgebiete des bayerischen Mains mittels Klimaszenarien“ (Influence of climate change on the water budget and discharge in the catchment of the River Main using climate change scenarios) Consultant Willems and LfU, February 2006 • „NA-Simulation der Fränkischen Saale unter Berücksichtigung von klimaänderungsbedingten Variationen des KOSTRA-Bemessungsniederschlags“

	(Precipitation-discharge simulation of the Fränkische Saale taking into account climate change related variations of the KOSTRA-design-precipitation) Consultant Hydrotec and LfU, December 2005 • "Ergänzung Schadenspotentialermittlung Fränkische Saale" (Supplementary document on the determination of damage potential in for the river "Fränkische Saale") Consultant Hydrotec and LfU, March 2007 • "ESPACE Decision Making Framework and Tools" Halcrow-Report and EA, February 2006