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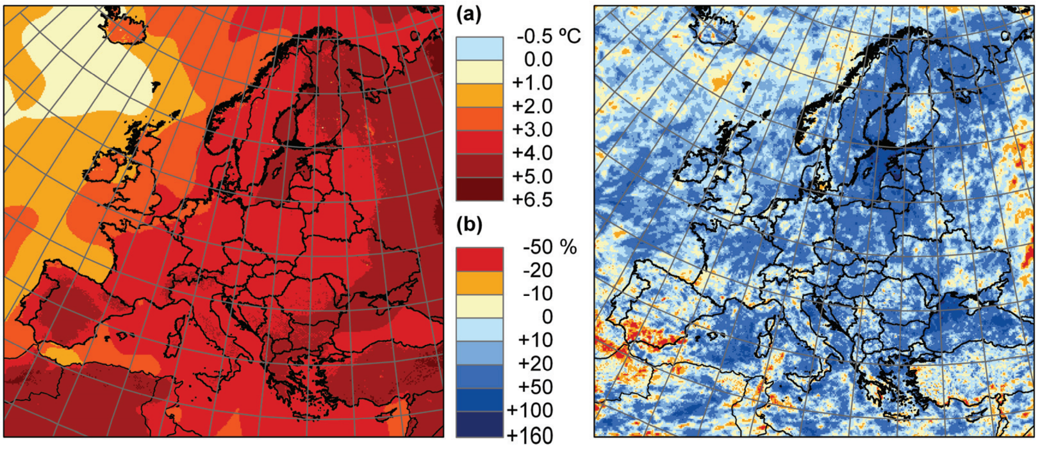
Institute for Environment and Sustainability

PESETA

Projections of economic impacts of climate change in sectors of Europe based on bottom-up analysis

Flood risk in Europe in a changing climate



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Abstract

The aim of the PESETA project is to assess the impacts of climate change in Europe in view of the costs and benefits of EU policies on climate change. PESETA seeks to provide climate impact and adaptation cost estimates on a policy-relevant time horizon (2020, 2030) using consistent methods (climate scenarios) for six sectors (agriculture, river floods, coastal floods, energy demand, health and tourism) across Europe. The task of the Weather Driven Natural Hazards Action (LMNH Unit, IES) of the JRC is to carry out the study on flood risk in Europe for the predefined projections of climate change.

This document outlines an integrated methodology for the assessment of current and future flood risk at the European scale. Changes in flood hazard obtained by combining high-resolution regional climate scenarios with a hydrological model are transformed into direct monetary damage assessments using water depth-damage functions and land-use information.

Results of the methodology are presented for the Upper Danube and Meuse catchments. For the Upper Danube the estimated total damage of a 100-year flood is projected to rise by ~40% of the current damage estimate (corresponds to an increase of €18.5 billion) for the high emission scenario (A2) and ~19% for the low emission scenario (B2). The number of people affected in the Upper Danube is projected to increase by 242,000 (~11%) for the A2, and 135,000 (~6%) for the B2 scenario. For the Meuse catchment, the total damage of a 100-year flood is projected to increase by ~14% for the A2 scenario and ~11% for the B2 scenario. For both scenarios, the estimated increase in number of people affected is approximately 4%. These results serve as an initial, interim assessment until better information becomes available and some parts of the methods are elaborated in more detail. Several assumptions underlie the calculating of these costs, and should be kept in mind when interpreting the results.

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1. Introduction

The aim of the PESETA project is to assess the impacts of climate change in Europe in view of the costs and benefits of EU policies on climate change. PESETA seeks to provide climate impact and adaptation cost estimates on a policy-relevant time horizon (2020, 2030) using consistent methods (climate scenarios) for six sectors (agriculture, river floods, coastal floods, energy demand, health and tourism) across Europe. The task of the Weather Driven Natural Hazards Action (LMNH Unit, IES) of the JRC is to carry out the study on flood risk in Europe for the predefined projections of climate change.

Floods have been the most reported natural disaster in Europe, and have affected more people than all other natural disasters (WDR, 2003, 2004). Berz (2001) showed that the number of great flood disasters (those requiring international and inter-regional assistance) in the nine years 1990-1998 was higher than in earlier three-and-a-half decades, 1950-1985, together. Consequently, the costs of flood disasters have increased considerably (Munich Re, 2005). Part of the observed upward trend in flood damages and costs can be attributed to socio-economic factors, such as an increase in population and wealth, and land-use changes. For the coming decades, it is projected that the magnitude and frequency of extreme weather events will increase due to climate change and that floods will likely be more frequent and severe in many areas across Europe.

In the last years, many climate change impact studies have appeared in the literature. The majority of impact studies have focused on water resources and average flow conditions (e.g., Arnell et al., 2004; Wilby et al., 2006), in part because long-term average values are generally considered the more reliable outputs of climate and large-scale hydrological models. Other studies analysed seasonal changes in runoff (e.g., Andreasson et al., 2004; Zierl et al., 2005). Relatively few studies focused on the impacts of climate change on extreme flows (e.g., Prudhomme et al., 2003; Lehner et al., 2005).

Regional assessments of climate change impacts on flood hazard have been rare. Most studies have adopted a basin-scale approach (e.g., Booij, 2005; Kay et al., 2006), because floods are often determined by small to meso-scale processes. The application of different climate scenarios, hydrological models and the basin-specific characteristics make it difficult to compare the results of the different studies and to draw an overall picture of the effects of climate change on flood hazards at the European scale. To date, only the study of Lehner et al. (2006) considered an integrated European assessment of changes in flood risk due to climate change. They used climate data from the ECHAM4 and HadCM3 climate models (General Circulation Model, GCM), based on a scenario that is largely consistent with the no-policy IPCC-IS92a scenario, in combination with the global integrated water model WaterGAP to define large critical regions of increases in flood and drought hazards. The monthly averaged GCM output was disaggregated in space and time to the temporal scale (daily) and (coarse) spatial scale

(0.5 degrees) of WaterGAP. In the climate signal, only long-term trends and changes in seasonal climate were taken into account, while changes in short-range variability were neglected. These assumptions do not allow a proper evaluation of changes in climatic extremes, which may show a very different pattern compared to the average changes in climate, and constrain the reliability of the results with respect to changes in flood hazard.

Monetary assessments of the impacts of climate change in Europe have been poorly covered to date. Hall et al. (2005) presented a national-scale assessment of current and future coastal and river flood risk in England and Wales. Their analysis uses information on flood defences (including probability of failure), land use, impact (depth-damage and population data) together with datasets on floodplain extent and topography. Results indicated an up to 20-fold increase in real terms economic risk by the 2080s for the scenario with the highest economic growth. No studies have yet appeared in the literature with a European coverage.

The WDNH Action of the JRC is developing an integrated methodology for the assessment of current and future flood risk at the European scale. For the physical impact assessment, high-resolution regional climate scenarios are combined with a well-calibrated hydrological model implemented at a spatial and temporal scale appropriate for simulating floods. Water depth-damage functions and land-use information are used to transform the calculated inundation water depths into direct monetary damage assessments. The methodology is data and computation intensive. Due to time and data constraints, it was not feasible to make a European-scale assessments within the timeframe of the PESETA project. In this document, we show preliminary results of two pilot catchments.

2. Methodology - data

2.1. Integrated framework

To assess the impacts of climate change on flood hazards at the European scale an integrated framework is developed. The core of the framework is the hydrological model LISFLOOD, which transfers the climate forcing data into river runoff estimates. LISFLOOD (de Roo et al., 2000) is a spatially distributed, mixed conceptual-physically based hydrological model developed for flood forecasting and impact assessment studies at the European scale. The model simulates the spatial and temporal patterns of catchment responses in large river basins as a function of spatial information on topography, soils and land cover. Owing to its general nature, LISFLOOD is optimally suited for simulating the different hydrological regimes across Europe.

The framework is depicted through a flowchart in Figure 1. LISFLOOD is one-way coupled with the regional climate model (RCM), i.e., there is no feedback from the hydrological model back to the climate model. If necessary, correction factors that make use of meteorological observations are applied to avoid adverse effects from systematic RCM biases. Hydrological simulations on the basin scale using LISFLOOD typically run with a grid spacing of 1-5 km. This implies that there is still a scale-discrepancy between the forcing climate data and the hydrological simulation scale. Further downscaling of the regional climate data using statistical methods may be required to bridge the remaining scale gap. After bias corrections and downscaling, the regional climate data serve as input to the LISFLOOD model.

For both time slices, the hydrological model calculates daily discharges at each grid within the area of interest. Changes in runoff statistics are determined employing extreme value analyses. The calculated changes in flood frequency and water level statistics yield an assessment of the expected changes in flood hazard, resulting from the emission scenario and climate model used. This can be expressed as a change in the discharge of a flood with a certain (e.g., 100 years) return period (change in intensity), or a change in the return period of a certain event (change in recurrence) under a changed climate. With a high-resolution digital elevation model, stream water levels are readily transferred into flooded areas and inundation water depths, and changes in flooded areas and water depths are determined for each return period. Using water depth-damage functions and land-use classifications, direct damage estimates are made per land use class for each flood event under present and future climate. Losses are then accumulated over the frequency distributions to get an overall estimate of the changes in losses

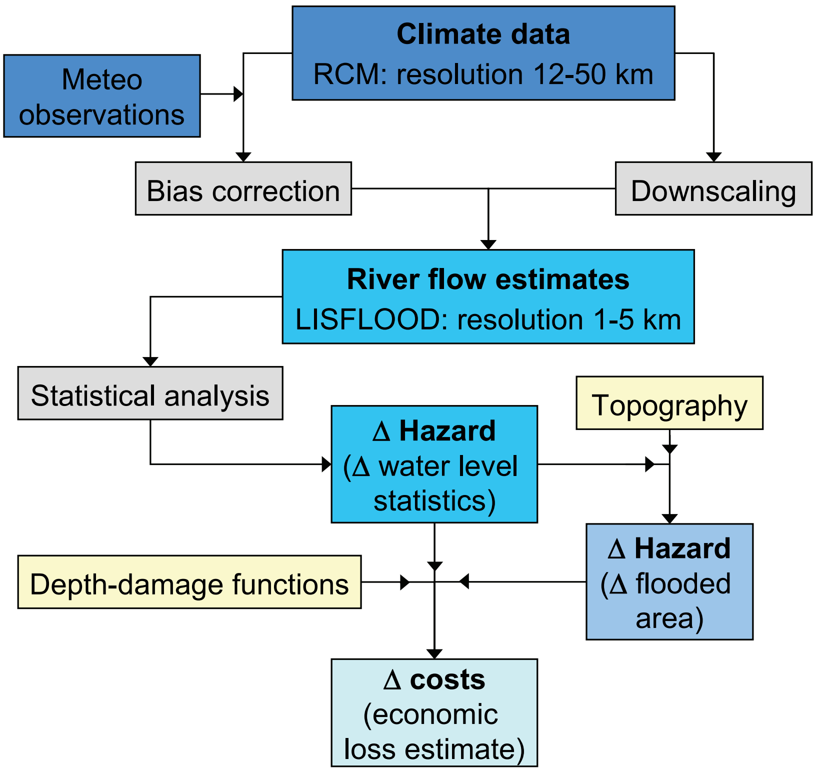

Figure 1. Flowchart of the integrated framework developed to estimate the economic impacts of changes in flood risk due to projected climate change.

2.2. Data

2.2.1. Climate data

In recent years, under the umbrella of several EU funded projects (e.g., PRUDENCE, STARDEX (FP5) and ENSEMBLES (FP6)), a series of regional climate change scenarios have been developed for Europe. The spatial resolution of these regional climate model projections ranges from 12 to 50 km. For the assessment of flood risk costs within the framework of PESETA, output from two RCMs are used (see Table 1).

Table 1. Climate change scenarios used for flood risk estimation in PESETA

RCM	GCM	SRES	control period	future period	resolution
HIRHAM (DMI)	HadCM3	A2	1961-1990	2071-2100	12 km
HIRHAM (DMI)	HadCM3	B2	1961-1990	2071-2100	50 km

The socio-economic scenarios considered are based on the IPCC SRES A2 (high emission scenario) and B2 (low emission scenario) storylines. Climate simulations were done with the regional climate model HIRHAM of the Danish Meteorological Institute (Christensen et al., 1996), using boundary conditions from the global coupled atmosphere-ocean HadCM3 model (Gordon et al., 2000; Pope et al., 2000). The RCM run for the A2 scenario has a spatial resolution of 12 km, which is currently the highest resolution available (with European coverage); the run for the B2 scenario has a much coarser resolution of 50 km (the implications of this will be discussed further on).

To evaluate if the RCM climate data exhibit any systematic bias, output for the control run is compared with two observation-based estimates of the climatological conditions: the MARS meteorological database of gridded daily observations at synoptic weather stations (available from the JRC Crop and Yield Monitoring Activity), and/or a high-resolution set of meteorological observations, depending on the availability within the area of interest.

2.2.2. Hydrological data

Input parameters and variables of the LISFLOOD model are derived from European databases as much as possible. For example, soil physical properties are derived from the European Soil Geographical Database (King et al., 1994). The HYPRES database (Wösten et al., 1999) is used to estimate porosity, saturated hydraulic conductivity and moisture retention properties for each texture class. Vegetation and land use information are obtained from the CORINE Land Cover database (EEA, 2000). Digital elevation data are obtained from the Catchment Information System, which has a spatial resolution of 1 km (Hiederer and de Roo, 2003). Certain parameters that lack physical basis and cannot be determined from existing spatial datasets are determined by calibrating the model against historical records of river flow measurements (Feyen et al., 2006). In the hydrological model, the area of the basins is subdivided in 1 by 1 km grid blocks.

2.2.3. Topographic data

The Digital Elevation Model (DEM) with a resolution of the 100 m was derived from the SRTM (Shuttle Radar Topography Mission) data. The raw SRTM data were pre-processed (e.g., filling voids and missing values, projection, re-sampling) to obtain a more reliable representation of topography (Voigt et al., 2003).

2.2.4. Damage assessment data

No comprehensive collection of flood damage functions currently exists for Europe. In this work, we used the damage functions and economic values produced for the Netherlands by Van der Sande (2001, 2003). This represents a coarse assumption, because the values may vary considerably between countries and regions. Nevertheless, the estimated losses produced in this study are useful for comparison purposes, e.g., between the control and scenario runs for A2 and B2 scenarios, and to produce reference values of the potential damage.

We used an approach based on direct estimated financial damage caused by water depths on land use typologies. Other factors that might contribute to the increase of losses are not included in this study: flood velocity, building characteristics, content of sediment in water, and estimated of indirect economic losses.

2.3. General limitations

When applying the framework outlined above in the PESETA project, it was necessary to adopt the following assumptions due to time and/or data constraints:

- The climate scenarios used only capture a part of the uncertainty range attributable to emissions (A2 and B2 out of six SRES storylines) and a part of the uncertainty due to inter-GCM (1 out of approximately 10 used worldwide) and inter-RCM (1 out of 10 used within PRUDENCE). Hence, the current analysis does not allow a comprehensive assessment of the range of uncertainty due to climate input.
- There is a discrepancy in scale between the RCM climate runs for A2 (12 km) and B2 (50 km), which makes it difficult to separate the effects of scale and storyline used when comparing the results of the two scenarios.
- No downscaling was applied to the climate data, which for the coarse resolution run (B2, 50 km) may locally lead to underestimation of flood frequencies due to the inability of the coarse RCM to explicitly represent fine-scale climatic structures.
- No bias correction was applied to the climate data, in part because no strong biases were observed for the two test catchments.
- Hydrological uncertainty is not accounted for. Several studies (e.g., Wilby, 2005) showed that this layer of uncertainty is generally much lower than the uncertainty of the climate input to the hydrological model.
- Changes in land use and land cover are not incorporated in the climate runs or economic impact evaluation due to the absence of reasonable macro-scale land use change scenarios

for the SRES storylines (e.g., 100 x 100 m). This may result in a serious underestimation of the flood risk for future periods.

- Changes in population are not incorporated in the impact evaluation due to the absence of reasonable scale scenarios (e.g., 100 x 100 m) for the SRES storylines. This may result in under- or overestimation of the affected people for future periods.
- In the calculation of river water levels, river cross sections had to be approximated due to a lack of data.
- In the calculation of the flood extent and floodplain water depth, water spreads out over the floodplain and no protection structures are taken into account. This may result in an overestimation of the flood extent and water depth.
- The SRTM DEM contains inaccuracies and, more important, the SRTM data represent surface elevation (roofs of houses, vegetation canopy) and not ground elevation. This leads to a potential underestimation of water levels and damage.
- Estimates of the changes in economic loss are based on water depth-damage functions derived for the Meuse (based on 1995 flood event) due to the lack of a pan-European dataset.
- Cost estimates are based on 100-year flood events. Ideally, cost estimates should be integrated over the frequency distribution to get a more accurate estimate of the expected change in total costs.

The accurate estimation of the monetary impacts of climate change impacts on floods is difficult and inherently uncertain, irrespective of the method used. The results presented in the remainder of this document serve as an initial, interim assessment until better information becomes available and some parts of the methods are elaborated in more detail. The above assumptions should be kept in mind when interpreting the results.

3. Physical impact assessment results

Changes in river flow due to climate change depend primarily on changes in the volume, intensity, and timing of precipitation, and on changes in temperature, which affects evapotranspiration and determines whether precipitation falls as rain or snow. Figure 2 shows the absolute change in mean temperature and the relative change in annual maximum precipitation over Europe as simulated by the regional climate model HIRHAM using scenario A2 and a spatial resolution of 12 km. Temperature is expected to increase throughout Europe. Annual maximum precipitation is projected to increase in most parts in Europe, except for southern Spain and localized regions in several other European countries. As will be shown for the pilot studies, the predicted changes in temperature and precipitation will alter the hydrological regime in European catchments, and change flood risk.

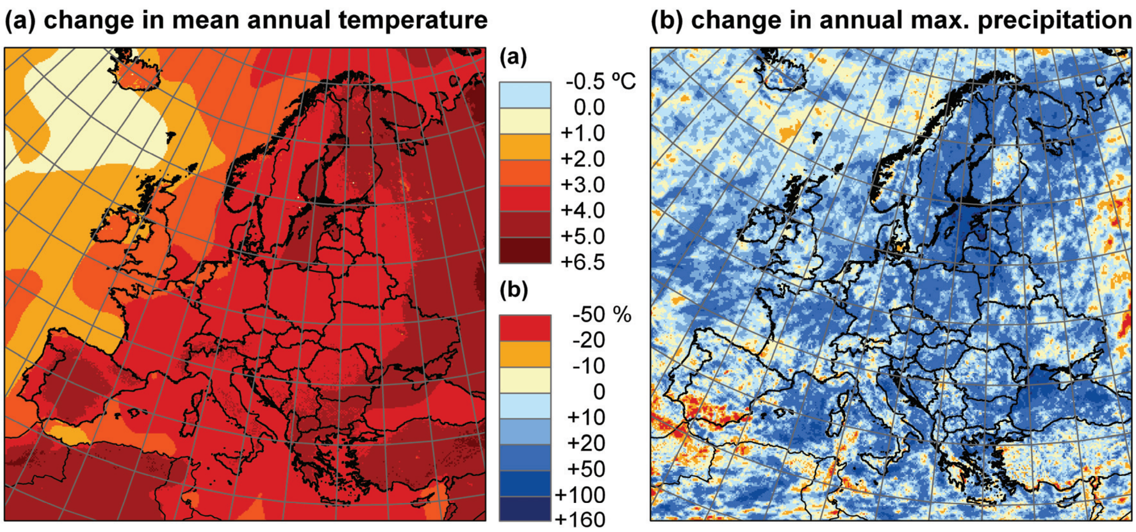

Figure 2. Absolute change in mean temperature (a) and relative change (scenario divided by control) in annual maximum precipitation (b) over Europe as simulated by the regional climate model HIRHAM (scenario A2, resolution 12 km).

In the remainder of the document, we present results of two pilot catchments, namely the Danube catchment upstream of Bratislava (~130,000 km^2 situated in Austria, Germany, Switzerland, Slovak Republic and Czech Republic) and the Meuse catchment upstream of Borgharen (~22,000 km^2 situated in France, Luxembourg, Belgium and the Netherlands). For both catchments, comparison of the RCM output for the control run with observations from synoptic stations showed that the high-resolution RCM represents precipitation and temperature characteristics in a realistic manner.

Figure 3 shows the relative change in the average annual maximum 5-daily precipitation amount for the Upper Danube. The changes in average annual maximum 5-daily precipitation amount vary spatially, with a considerable increase in some areas of the catchment. Other areas show a negative change, however less pronounced. Differences in the observed patterns can be attributed to the different underlying emission scenario and different spatial resolution of the RCM. Results show that the coarse RCM is unable to represent fine scale detail in the predicted climate variables.

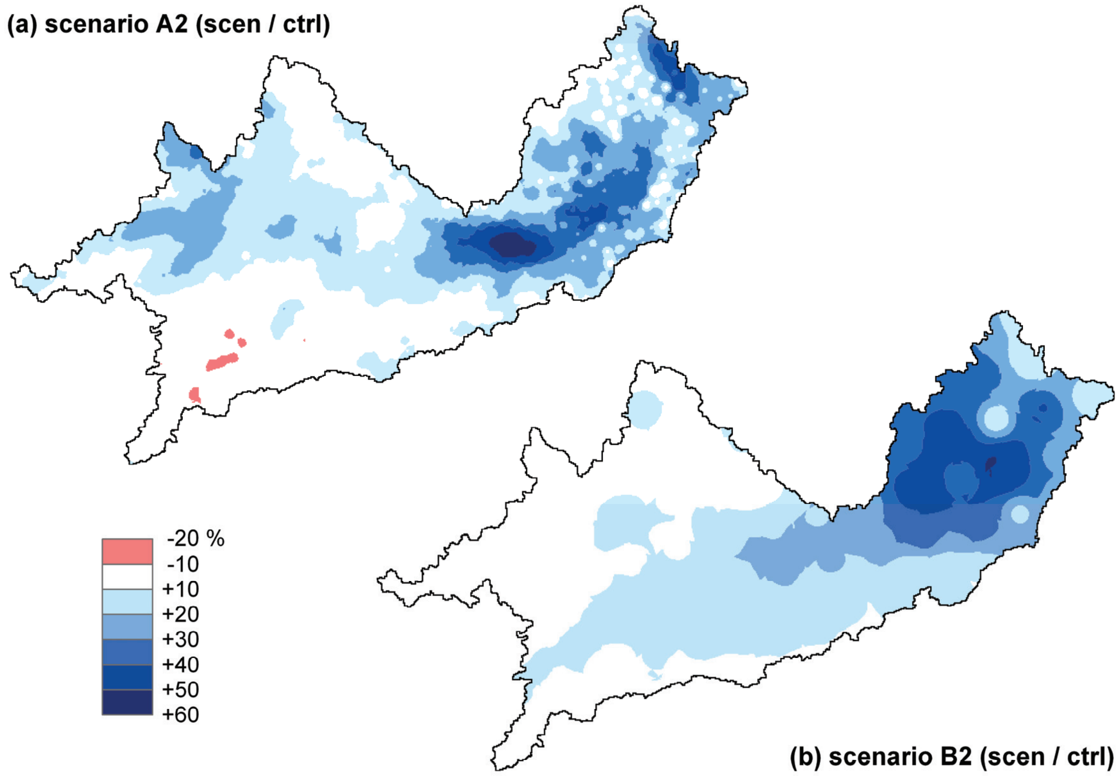

Figure 3. Relative change in the average annual maximum 5-daily precipitation amount for the Upper Danube: (a) emission scenario A2, HadCM3, HIRHAM 12 km resolution; (b) emission scenario B2, HadCM3, HIRHAM 50 km resolution.

Relative changes in the 100-year flood river water levels, derived from the hydrological simulations with the LISFLOOD model and estimated river channel geometries, are presented in Figure 4 for the Upper Danube. Overall, the pattern observed for both climate scenarios is similar. Some regions show a marked increase in river water levels, whereas other regions show a decrease in water level of the 100-year flood. The latter may be attributed to a decrease in the extreme precipitation levels over some areas (cf. Figure 3) in combination with dryer conditions in the catchment due to the higher temperatures in the scenario run.

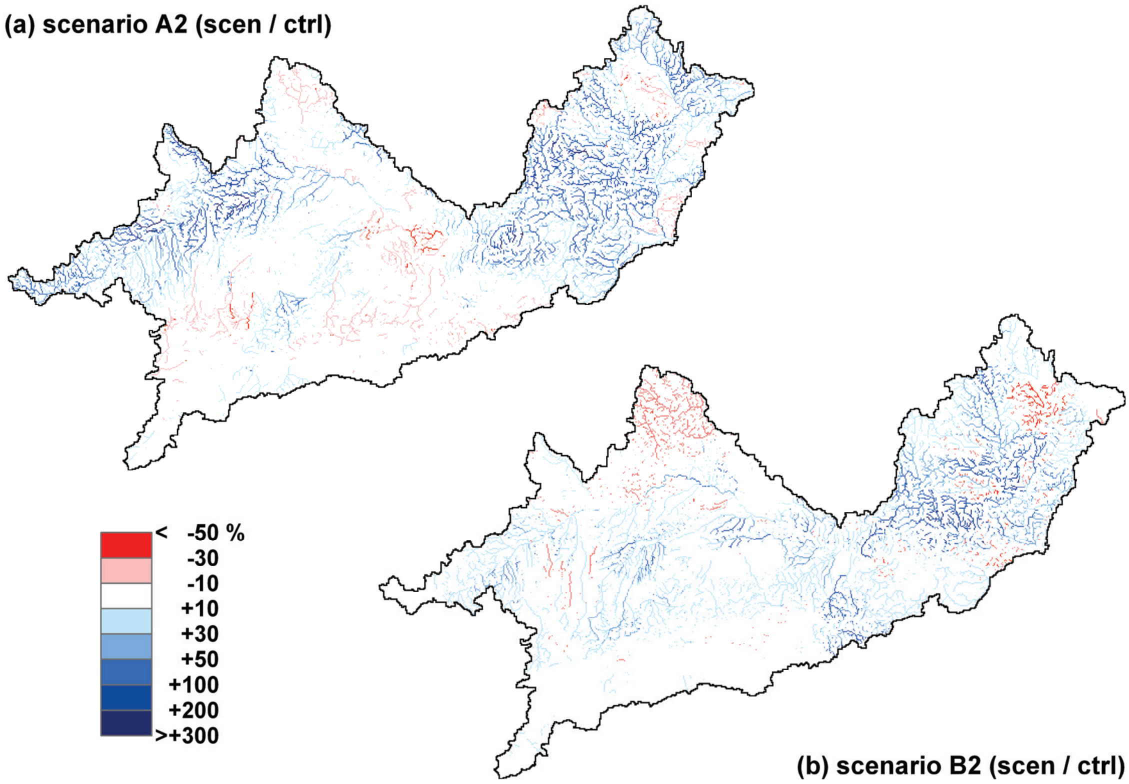

Figure 4. Relative change in 100-year flood river water levels for the Upper Danube: (a) emission scenario A2, HadCM3, HIRHAM 12 km resolution; (b) emission scenario B2, HadCM3, HIRHAM 50 km resolution.

The river water levels for the 100-year flood have been translated into flood extent and water depths in the flooded area using the high-resolution SRTM DEM. Figure 5 presents the calculated changes in water depth in the Upper Danube for both climate scenarios. The changes in water depth vary spatially and change in sign depending on the location. The spatial differences are more pronounced for the A2 HIRHAM 12 km climate scenario, which can be attributed to the higher spatial resolution of this scenario.

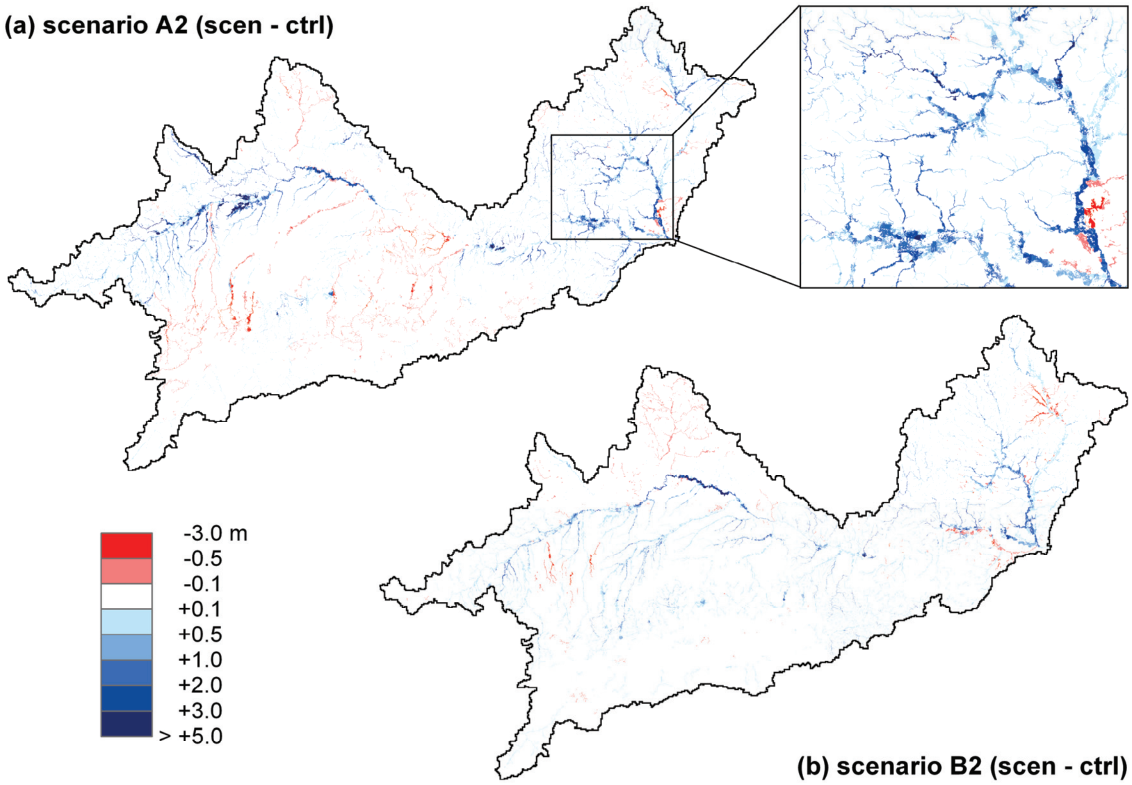

Figure 5. Change in 100-year flood water depth for the Upper Danube: (a) emission scenario A2, HadCM3, HIRHAM 12 km resolution; (b) emission scenario B2, HadCM3, HIRHAM 50 km resolution. The inset shows the flood zones in more detail.

Relative changes in the 100-year flood river water levels for the Meuse catchment are presented in Figure 6. The pattern observed for both climate scenarios is similar, with some regions showing a marked increase in river water levels, and others a decrease in water level of the 100-year flood. Increases in river water levels are more pronounced for the A2 HIRHAM 12 km scenario, due to the higher emission scenario, and possibly also due to the higher resolution used in the RCM, but are mainly restricted to smaller tributary rivers.

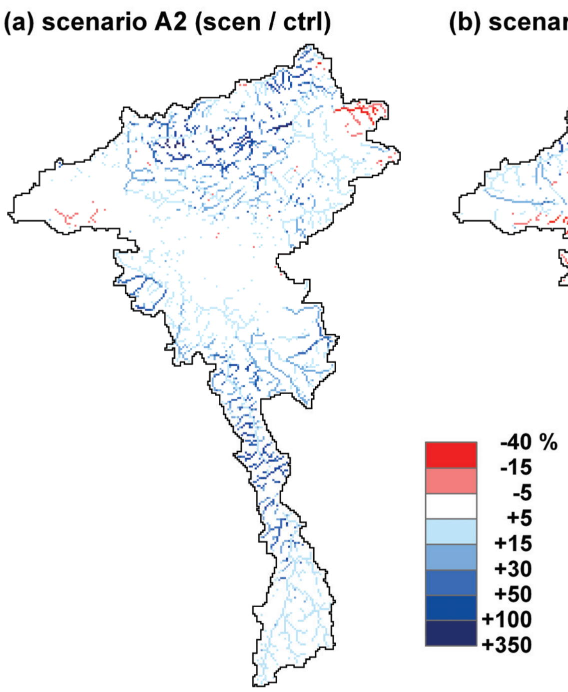

Figure 6. Change in 100-year flood river water levels for the Meuse: (a) emission scenario A2, HadCM3, HIRHAM 12 km resolution; (b) emission scenario B2, HadCM3, HIRHAM 50 km resolution.

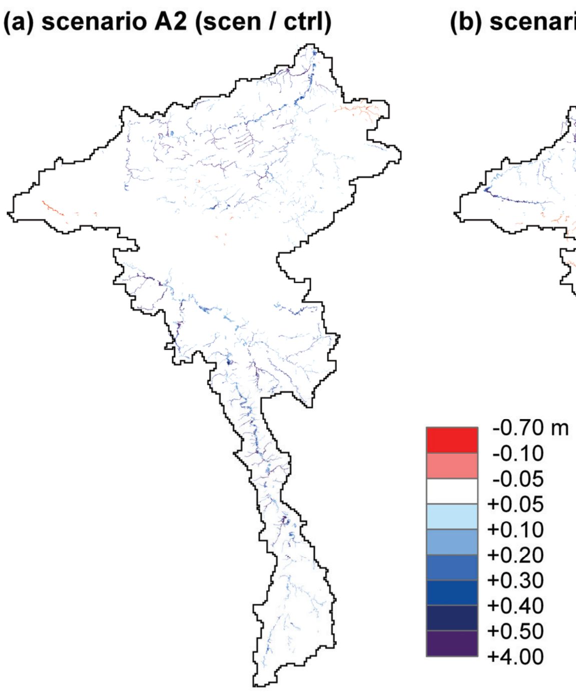

Figure 7. Change in 100-year flood water depth for the Meuse: (a) emission scenario A2, HadCM3, HIRHAM 12 km resolution; (b) emission scenario B2, HadCM3, HIRHAM 50 km resolution.

Figure 7 presents the calculated changes in water depth in the Meuse catchment for both climate scenarios. The changes in water depth vary spatially and change in sign depending on the location. Changes in flood extent and water depths are less pronounced compared to those estimated for the Upper Danube, and the flooded areas are more confined to the river valleys, and therefore less visible in the figure.

4. Economic impact assessment results

Damages due to flood inundation depend on the water depth and the type of land use. Based on water depth-damage functions derived for the Meuse 1995 flood event (Van der Sande et al., 2001; 2003) and land-use classifications from CORINE Land Cover 2000 (EEA, 2000), damages resulting from the 100-year flood were estimated for the control and scenario run for both climate scenarios.

Table 2. Damages per land use type and water depth (m) class for the A2 HIRHAM 12 km climate scenario (top: control run; bottom: scenario run) for the Upper Danube. All damage numbers are in €.

A2 control run					
Land use type	Depth >0 to 1	Depth 1 to 2	Depth 2 to 3	Depth 3 to 4	Depth > 4
Continuous urban fabric	251,450,063	298,866,360	335,266,750	118,684,430	0
Discontinuous urban fabric	18,462,071,670	15,149,288,325	6,329,378,869	3,198,957,285	1,993,712,625
Industrial or commercial units	54,365,819	104,352,082	63,989,484	47,477,799	81,091,210
Road and rail networks	2,712,112	7,210,272	5,763,120	2,010,720	0
Construction sites	596,352	851,931	0	0	0
Green urban areas	11,152,260	21,417,300	22,454,775	18,855,810	15,502,500
Sport and leisure facilities	301,113,512	298,914,600	174,968,115	19,257,659	73,869,700
Non-irrigated arable land	36,081,750	34,499,850	11,314,940	4,741,500	2,874,000
Total per water depth class	19,119,543,537	15,915,400,720	6,943,136,053	3,409,985,203	2,167,050,035
Total damage	**47,555,115,547**				

A2 scenario run					
Land use type	Depth >0 to 1	Depth 1 to 2	Depth 2 to 3	Depth 3 to 4	Depth > 4
Continuous urban fabric	240,050,993	313,234,935	402,320,100	387,137,306	249,055,300
Discontinuous urban fabric	17,205,008,048	16,320,338,325	11,113,557,263	7,054,288,095	10,864,416,375
Industrial or commercial units	50,390,141	114,423,799	106,333,610	83,312,541	212,667,220
Road and rail networks	2,638,480	6,098,240	8,047,600	4,959,776	5,475,200
Construction sites	773,049	504,848	938,702	0	0
Green urban areas	10,918,530	17,505,900	23,206,050	21,388,680	46,984,500
Sport and leisure facilities	266,480,648	312,314,220	241,708,530	126,695,125	202,712,200
Non-irrigated arable land	32,318,500	36,551,550	21,829,990	10,913,500	14,504,000
Total per water depth class	17,808,578,388	17,120,971,817	11,917,941,844	7,688,695,023	11,595,814,795
Total damage	**66,132,001,867**				

Table 2 shows damages per land use type and water depth class for the A2 HIRHAM 12 km climate scenario for the Upper Danube. The top part of the table represents the control run, the lower part of the table the scenario run. Total damages of a 100-year flood under current climate conditions are estimated to be €47.5 billion for the Upper Danube. Under the considered projected climate scenario, total damages are estimated to be as high as €66 billion, or an increase of 40% of the current climate cost estimate. Calculations for the B2 HIRHAM 50 km climate scenario resulted in cost estimates of €44.5 billion under current conditions, and €53 billion for the climate scenario run, or an increase of approximately 19% of the current damage estimate. The difference in numbers can be attributed to the difference in emission scenario (A2 higher emissions than B2), and to the coarse spatial resolution of the B2 HIRHAM 50 km climate scenario, which may potentially underestimate flood frequencies (the difference in cost estimate of €3 billion between the 2 control runs is solely attributable to the resolution effect). It is important to note that these numbers are a theoretical maximum, as it is unlikely that a 100-year flood will occur in the entire basin at the same time. Also, flood protection structures will typically not all fail under such conditions, but will likely only partially fail.

In addition to damage assessments, changes in the number of people affected by floods were also calculated. This was done by overlaying a Population Density Grid with a resolution of 100 m (Gallego and Peedell, 2001) with the flood extent maps. Table 3 tabulates the number of people affected per water depth class in the Upper Danube for both climate scenarios. For the A2 HIRHAM 12 km scenario it is projected that 242,000 more people will be affected, which corresponds to an increase of approximately 11%. The projected increase for the B2 HIRHAM 12 km scenario is 135,000, or approximately 6%.

Table 3. Number of people affected per water depth (m) class in the Upper Danube for the A2 HIRHAM 12 km climate scenario (top: control run; bottom: scenario run).

People affected	Depth >0 to 1	Depth 1 to 2	Depth 2 to 3	Depth 3 to 4	Depth > 4	Total
A2 control run	1,129,200	738,085	215,003	65,824	29,511	**2,177,623**
A2 scenario run	1,064,033	765,380	324,936	132,042	133,018	**2,419,409**
B2 control run	1,163,602	729,953	155,441	62,415	25,013	**2,136,424**
B2 scenario run	1,090,227	776,672	263,568	81,418	59,212	**2,271,097**

For the Meuse catchment upstream of Borgharen, the total damage under current climate conditions amounted to €6.6 billion for the A2 HIRHAM 12 km resolution, and €6.5 billion for the B2 HIRHAM 50 km resolution. Under the corresponding climate scenarios, projected damages summed up to €7.5 billion and €7.2 billion, respectively. This corresponds to an increase of ~14% for the A2 HIRHAM 12 km scenario and of ~11% for the B2 HIRHAM 50 km scenario. For both scenarios, the increase in number of people affected was approximately 4%.

5. Conclusions

This document outlined an integrated methodology to assess flood risk under current and future climate. Results were presented for two pilot catchments, namely the Danube catchment upstream of Bratislava and the Meuse catchment upstream of Borgharen. For the Upper Danube (~130,000 km^2) the estimated total damage of a 100-year flood is projected to rise from

€47.5 to €66 billion under the A2 HIRHAM 12 km climate scenario, which corresponds to an increase of ~40% of the current damage estimate. For the lower emission scenario B2 (HIRHAM, 50 km), the projected increase is ~19%. The number of people affected in the Upper Danube is projected to increase by 242,000 (~11%) for the A2, and 135,000 (~6%) for the B2 scenario. For the Meuse cathment (~22,000 km^2), the total damage of a 100-year flood is projected to increase by ~14% for the A2 scenario and ~11% for the B2 scenario. For both scenarios, the estimated increase in number of people affected is ~4%. It is important to note that in the current damage assessment, socio-economic factors, such as an increase in population and wealth, and land-use changes, were not considered. It is to be expected that including such factors will considerably inflate the cost estimates of future floods.

The results presented herein serve as an initial, interim assessment until better information becomes available and some parts of the methods are elaborated in more detail. The assumptions adopted should be kept in mind when interpreting the results. Results for the Upper Danube and Meuse catchment cannot be extrapolated to other areas in Europe, but may be indicative of expected changes in costs and people affected in regions with similar projected changes in climate, hydrological and socio-economic conditions. The projected changes in extreme precipitation and in temperature indicate that other areas in Europe will likely also see changes in flood risk.

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