GOCE 036822

SCENES

Water Scenarios for Europe and for Neighbouring States

Instrument: Integrated Project

Thematic priority: Global change and ecosystems

D4.6
Socio-economic and ecological impacts of future changes in Europe's freshwater resources

Volume D: Water for People

Due date of deliverable: 31.03.2011
Actual submission date: 29.04.2011

Start date of project: 1.11.2006 Duration: 54 months

Lead contractor: Deltares Revision version 1

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

This report is a result of contributions by the following persons (in alphabetical order by last name):

Name	Institute
Karen Meijer	Deltares, The Netherlands
Sibren Loos	Deltares, The Netherlands
Kathryn Roscoe	Deltares, The Netherlands
Lineke Woelders	Deltares, The Netherlands

Woelders, L., Roscoe, K., Loos, S., Meijer, K.S., 2011. Socio-economic and ecological impacts of future changes in Europe's freshwater resources. SCENES project. D4.6: Volume D: Water for People. Deltares, Delft, The Netherlands.

Preface

SCENES is a four year European research project developing scenarios for the changes in the quantity and quality of fresh water resources in pan-Europe due to climate change, land use change and socio-economic development. The water scenarios are developed based on the SAS-approach that combines storylines with simulations. The storylines are developed by a Pan-European Panel (PEP). This report describes impacts of future changes in Europe's freshwater resources in terms of indicators for 'Water for People'.

This report is deliverable D4.6 of the FP6 Project SCENES (EU contract GOCE 036822).

Contents

1 Introduction

SCENES impact indicators

This report is an appendix to deliverable D4.6 of the SCENES Project. Deliverable D4.6 is reporting the results of an analysis of the socio-economic and ecological impacts of future changes in Europe's freshwater resources. In the SCENES project water scenarios have been developed describing possible future climate and socio-economic developments and the impacts of these scenarios. The impacts are expressed through a set of indicators covering a wide range of topics.

Within SCENES, we distinguish two types of impact indicators:

- Generic hydrological impact indicators: indicators that are addressing the hydrological changes in freshwater availability and quality in terms of too much (flood events) or too little (drought events, water stress).
- Impact indicators for water system services: indicators that are addressing the environmental, ecological and socio-economical consequences of changes in the state of fresh water resources on water system services: Water for Food, Water for Nature, Water for People and Water for Industry and Energy.

The total set of impact indicators is listed in Table 1.1. The indicator ID's refer to water system services. The generic hydrological indicators have "Water" as ID.

Table 1.1 Overview of SCENES impact indicators

ID	Name
Water 1	Water Consumption Index
Water 2	Water Stress Index
Water 3	Water Scarcity Index
Water 4	Change in frequency of flood events
Water 5	Change in flood hazards
Water 6	Change in frequency of river low flow
Water 7	Change in magnitude of river low flow
Water 8	Change in mean annual river flow
Food 1	Agricultural crop production
Food 2	Irrigation water withdrawals
Food 3	Water stress in irrigation
Nature 1	Environmental flows
Nature 2	Floodplain wetlands
Nature 3	Ecosystem services of wetlands
Nature 4	Change in water supply to wetlands
Nature 5	Aquatic macrophyte diversity in lakes
Nature 6	Habitat suitability for river water temperature for fish
People 1	Domestic water stress
People 2	Flood risk
People 3	Risk for harmful algal blooms in shallow lakes and reservoirs
People 4	Domestic water availability
Industry 1	Extra demand for cooling water
Industry 2	Navigability of large rivers
Industry 3	Cooling water stress

SCENES scenarios and indicator quantification

For quantification of future scenarios, four socio-economic scenarios are combined with two climate change scenarios. The socio-economic scenarios are based on UNEP's GEO4 scenarios and adjusted in a participatory exercise with key European scientists. Four scenarios resulted which are called: Economy First (EcF), Fortress Europe (FoE), Policy Rules (PoR), and Sustainability Eventually (SuE). Two climate scenarios are used which were generated by two different global circulation models (GCM's): MIMR and IPCM4, following the SRES A2 emission pathway. The reference period (2000s) is represented by the climate normal period (1961-1990) for river discharges and considers the water uses of the year 2005 (except for irrigation for which demand is influenced by the variation in evaporation and precipitation).

These eight scenarios have been used as input for the global water model WaterGAP (Water – Global Assessment and Prognosis; Alcamo et al. 2003, Döll et al. 2003). The resulting output for a baseline (2000s) and eight future (2050s) situations has formed the basis for the quantification of the indicators.

This report

The indicators are discussed in detail in five Appendices:

- Volume A: Generic indicators
- Volume B: Water for Food
- Volume C: Water for Nature
- Volume D: Water for People (this volume)
- Volume E: Water for Industry & Energy

This report, Volume D, discusses the Water for People indicators. Each indicator chapter starts with an introduction to the indicator, followed by the method that was used to calculate the indicator. Next, the results are described. Each chapter ends with a synthesis and the most important key messages that could be derived from the analysis.

The indicator chapters are preceded by a chapter providing an overview of the results for main input data used for the computation of the indicators, consisting of either input for or output from WaterGAP. Chapter 7 discusses the key findings that can be drawn from the analysis of the generic indicators.

The method applied to analyse the regional variations in impacts as well as to assess whether climate change or socio-economic development is the more dominant driving force for changes in the indicator, used in chapter 7 is discussed in chapter 2 of Volume A.

References

Alcamo, J., Döll, P., Henrichs, T., Kaspar, F., Lehner, B., Rösch, T. & Siebert, S., 2003. Development and Testing of the WaterGAP 2 Global Model of Water Use and Availability, *Hydrological Sciences Journal,* 48 (3): 317–337.

Döll, P., Kaspar, F. & Lehner, B., 2003. "A Global Hydrological Model for Deriving Water Availability Indicators: Model Tuning and Validation", *J. Hydrol.*, 270, pp. 105-134.

2 Main input data for the impact indicators

Chapter 3 in Volume A presented the main input data for the generic indicators:

- Mean annual river flow
- Low flows
- Consumptive use
- Withdrawals

The results for the change in flood hazard frequency is presented in Volume A as Water 4. This chapter describes in addition the four scenarios for GDP and population growth.

2.1 GDP

The Gross Domestic Product (GDP) is an indicator for economic growth. It is used in the assessment of flood risk as an indication of how much damage may occur. Figures 2.1 until 2.4 present the change in GDP as compared to the baseline situation. The regional changes are indicated in Table 2.1.

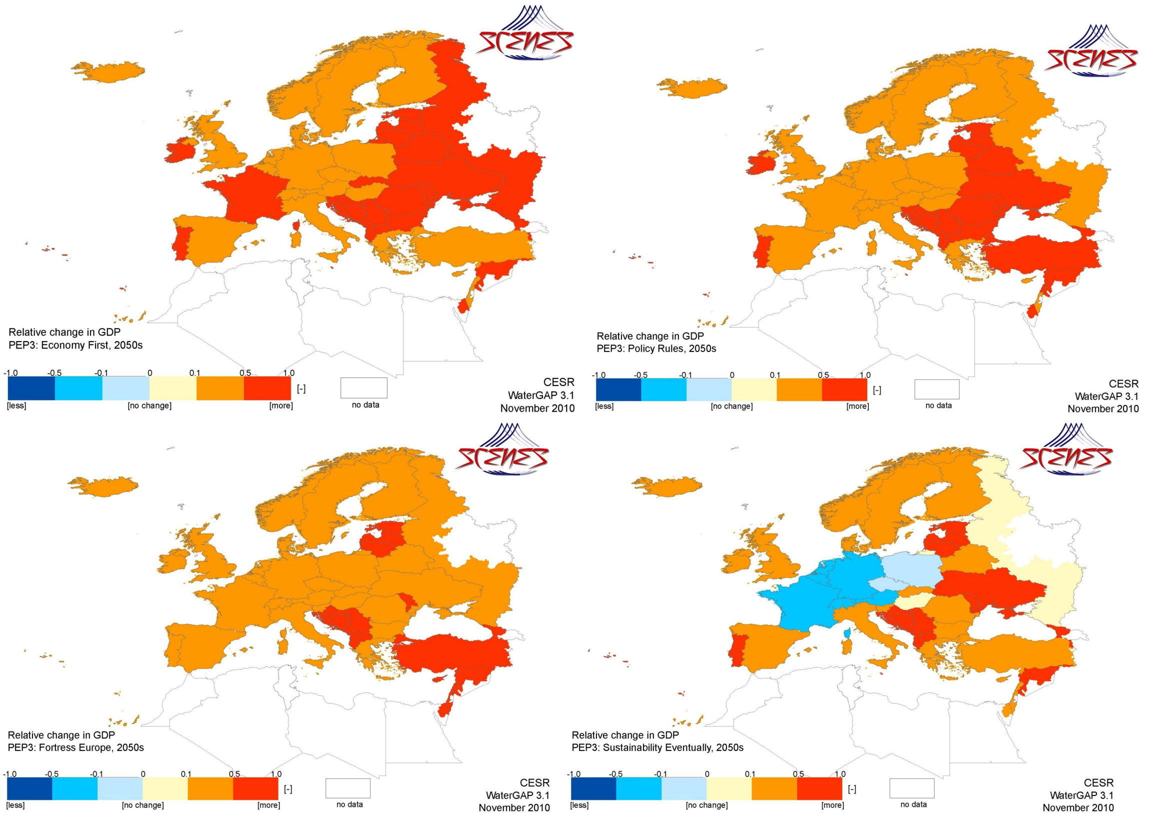

Figure 2.1 until 2.4 (left to right). Relative change in GDP for Economy First (2.1), Policy Rules (2.2), Fortress Europe (2.3) and Sustainability Eventually (2.4).

Table2.1 Regional impacts as deviation from the baseline scenario – GDP

	Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
EcF	NA	++	++	++	++	++	++
FoE	NA	++	++	++	++	++	++
PoR	NA	++	++	++	++	++	++
SuE	NA	--	++	++	+/-	+/-	++

Generally, GDP increases in the whole of Europe. Only the Sustainability Eventually scenario shows a GDP decrease in western Europe. The strongest increases can be seen in Eastern Europe.

2.2 Population growth

Figures 2.5 until 2.8 show the relative change in population for the four socio-economic scenarios. Table 2.2 presents the regional results. In this table decreases in population are marked as a positive change and increases in population as a negative change.

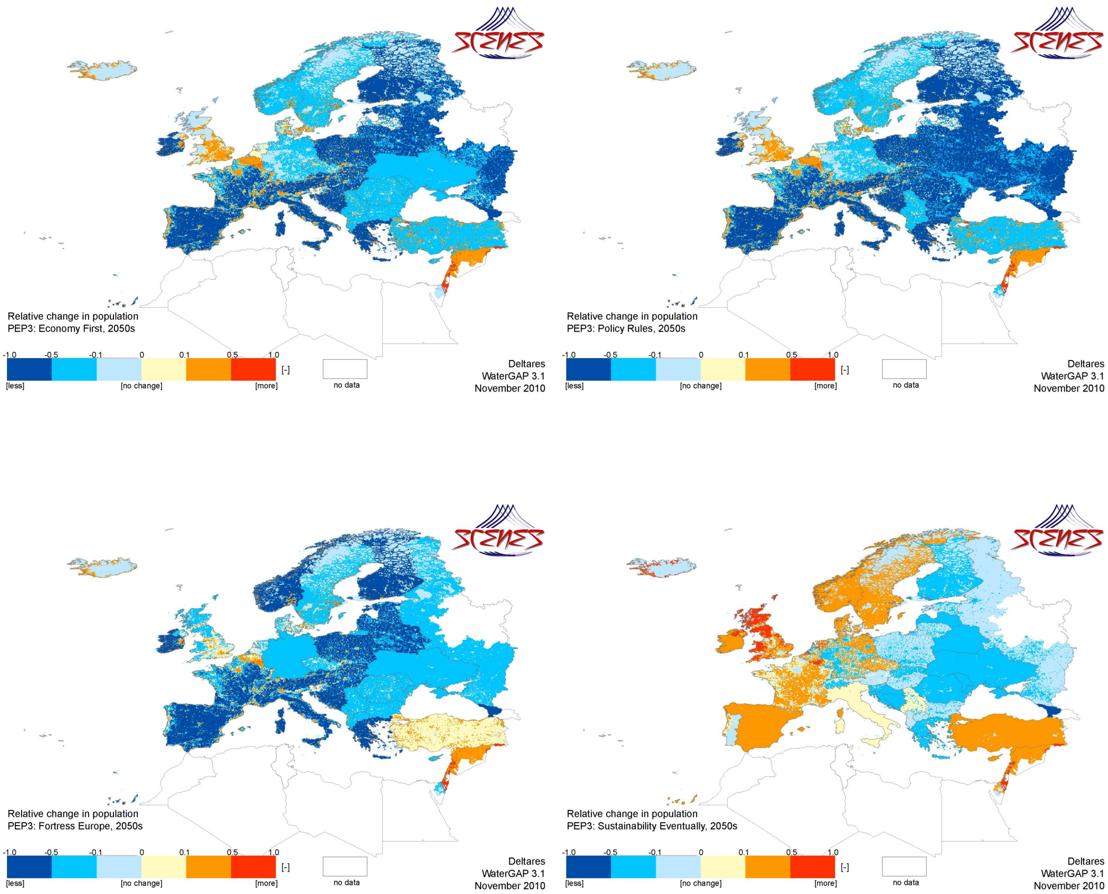

Figure 2.5 until 2.8 (left to right). Relative change in population for Economy First (2.5), Policy Rules (2.6), Fortress Europe (2.7) and Sustainability Eventually (2.8).

Table 2.2 Regional impacts as deviation from the baseline scenario – population

	Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
EcF	NA	+/-	++	++	++	++	++
FoE	NA	+/-	++	++	++	++	--
PoR	NA	+/-	++	++	++	++	++
SuE	NA	-	-	+/-	++	++	--

The population development under the Sustainability Eventually scenario is different from the population development seen under the other scenarios. The other scenarios show a general population decrease in most of Europe, except for the area around London and the Benelux. Also in Turkey some increase in population is observed. Under the Sustainability Eventually scenario, however, far more increases are observed. Spain, western Europe, the UK, Scandinavia and Turkey all are expected to encounter population increases. Also, the decreases in the other regions are not as strong as observed for the other scenarios.

3 Water for People 1 - Domestic Water Stress

3.1 Introduction to indicator

Domestic water refers to all types of water use by households, for drinking and cooking, but also for cleaning, showering, flushing of toilets, washing of cars and watering of lawns. In most countries, domestic water has a higher priority than other (economic) water users. Moreover, since domestic water generally concerns a relatively small amount of water, shortages are not likely to occur on an annual basis at the river basin level. Shortages may occur however during dry periods of the year, and especially when upstream withdrawals take place for other uses despite of allocation hierarchies.

The domestic water stress indicator compares withdrawals for domestic use with the amount of water available after economic sectors have taken the water they need. This means that this indicator is defined as a 'worst case scenario': with a priority lower than the economic water use sectors.

3.2 Method

Calculation approach

Domestic water stress is defined as the ratio between withdrawals for domestic use and the availability after other sectors (manufacturing, electricity, irrigation and livestock) have consumed water. The calculation can be expressed as:

$$\frac{\text{withdrawals for domestic use (mm/year)}}{\text{total availability - consumptive use by agriculture and industry (mm/year)}}$$

Input data

The following WaterGAP output is used to calculate the indicator:

- Total availability
- Total consumptive use for electricity, manufacturing, irrigation and livestock
- Withdrawals for domestic use

Spatial and temporal scales

The indicator is calculated on a basin scale for average annual situation.

Thresholds/classes

The resulting water stress is presented with the same classes as the other 'stress' indicators. The thresholds used to define the level of water stress are:

<0.2 = low water stress
0.2-0.4 = medium water stress
>0.4 = sever water stress

Uncertainties
The largest uncertainties are due to the fact that regulation and infrastructure are not included in the model. Moreover, the basin level calculation gives a rough assessment. The fact that use by other economic sectors is subtracted from the availability gives a worst-case scenario.

Modeling rainfall-runoff and water use at the large scale to cover entire Europe will have uncertainties as a result of scale itself and gaps in data. Projecting water use and availability for future scenarios is uncertain by its very nature. Alcamo *et al.* (2000) provides more information on the uncertainties involved and their order of magnitude.

Validation
The WaterGAP results are validated as part of the modelling process. No further validation is carried out as part of the indicator calculations.

3.3 Results

3.3.1 Baseline

For Domestic Water Stress under the baseline scenario, see Figure 3.1. In the current situation, domestic water use is only stressed in isolated regions. Considering that the indicator represents a worst case scenario and that the delivering of water to users through infrastructure is not taken into account, it can be concluded that domestic water stress does not present a major problem in the pan-European area.

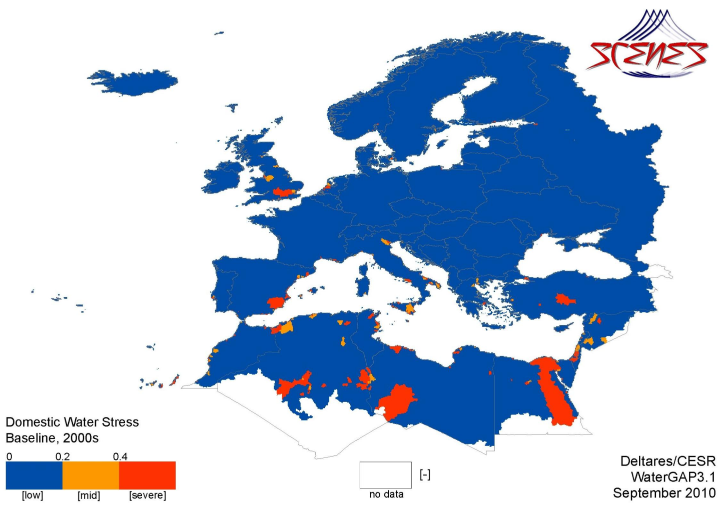

Figure 3.1. Domestic Water Stress calculated for the baseline scenario.

3.3.2 Future Scenarios

General pattern
See Figure 3.2 until 3.9.

In general, all scenarios show a similar patter of isolated areas with domestic water stress in Northern Africa (especially the Nile Basin), Western Asia, eastern Spain, and around London and Amsterdam. The difference between the scenario results are small. To better understand what causes the differences the three main input factors (water availability, withdrawals for domestic use and consumptive use for all other sectors) are discussed.

Water availability
Water availability is highest in Northern Europe. Northern Africa, the Iberian Peninsula, Greece, Turkey and Israel have generally a low water availability. Also in Eastern Europe water availability tends to be low. Both climate scenarios predict a decrease in water availability in the southern Mediterranean (Southern Spain, the Northern coast of Africa, Israel, Greece and Turkey. Under the IPCM climate scenario generally the changes in water availability from the baseline are more negative than from the MIMR scenario, especially in central and western Europe and the area around the Mediterranean Sea. However, the decreases in water availability in Northern Africa are higher for the MIMR scenario. Also the water availability in the Nile basin decreases in the IPCM scenario, but increases in the MIMR scenario.

Consumptive use for agriculture and industry
For industry, the future water consumption shows a similar pattern for all socio-economic scenarios. Most water will be used in the Nile Delta, the Benelux, England (around London), Germany and northern Italy. The least water will be used in Northern Africa, Scandinavia, eastern Europe and the Iberian Peninsula. This general pattern is most extreme for the Economy First and Fortress Europe scenarios. The least consumptive use can generally be found in the Policy Rules and Sustainability Eventually scenarios.

For agriculture, the future water consumption does not show such a clear pattern. It can be seen however that for all scenarios, the Nile Basin, Greece, Israel, northern Italy, parts of the North African coast and parts of Turkey have a high water consumption for agriculture. The least water consumption can be seen in northern Africa, Scandinavia and eastern Europe. This general pattern can be seen for the Policy Rules and Sustainability Eventually scenarios. For the Economy First scenario, also the Iberian Peninsula, parts of France, the Benelux and the area around London have a high water consumption. For the Fortress Europe, parts of France and Northern Germany will have a high water consumption for agriculture in addition to the general pattern.

Withdrawals for domestic use
The future projections for domestic water withdrawals show large differences between the scenarios. For Economy First, the largest increases in water withdrawals for domestic use can be observed. Especially in the Nile Basin, Turkey and Israel, but also in the North African coast (Morocco, Libya, Tunisia), the Danube basin and parts of western Europe (France, Germany, England). Decreases in water withdrawals are seen in southern Italy, Greece and Scandinavia. For the Fortress Europe scenario, this picture is generally the same, but less severe. The Iberian Peninsula, Italy and Greece experience large decreases in water withdrawals. For the Policy Rules scenario, large increases are only observed in Israel, the North African coast and the Nile Basin. Decreases are observed in the remainder of Europe, but the largest decreases can be found in Eastern Europe, southern Italy, Greece and Norway. For the Sustainability Eventually scenario, this picture is generally the same as the Policy Rules scenario, but this scenario experiences almost no increase in domestic water withdrawals anywhere in Europe.

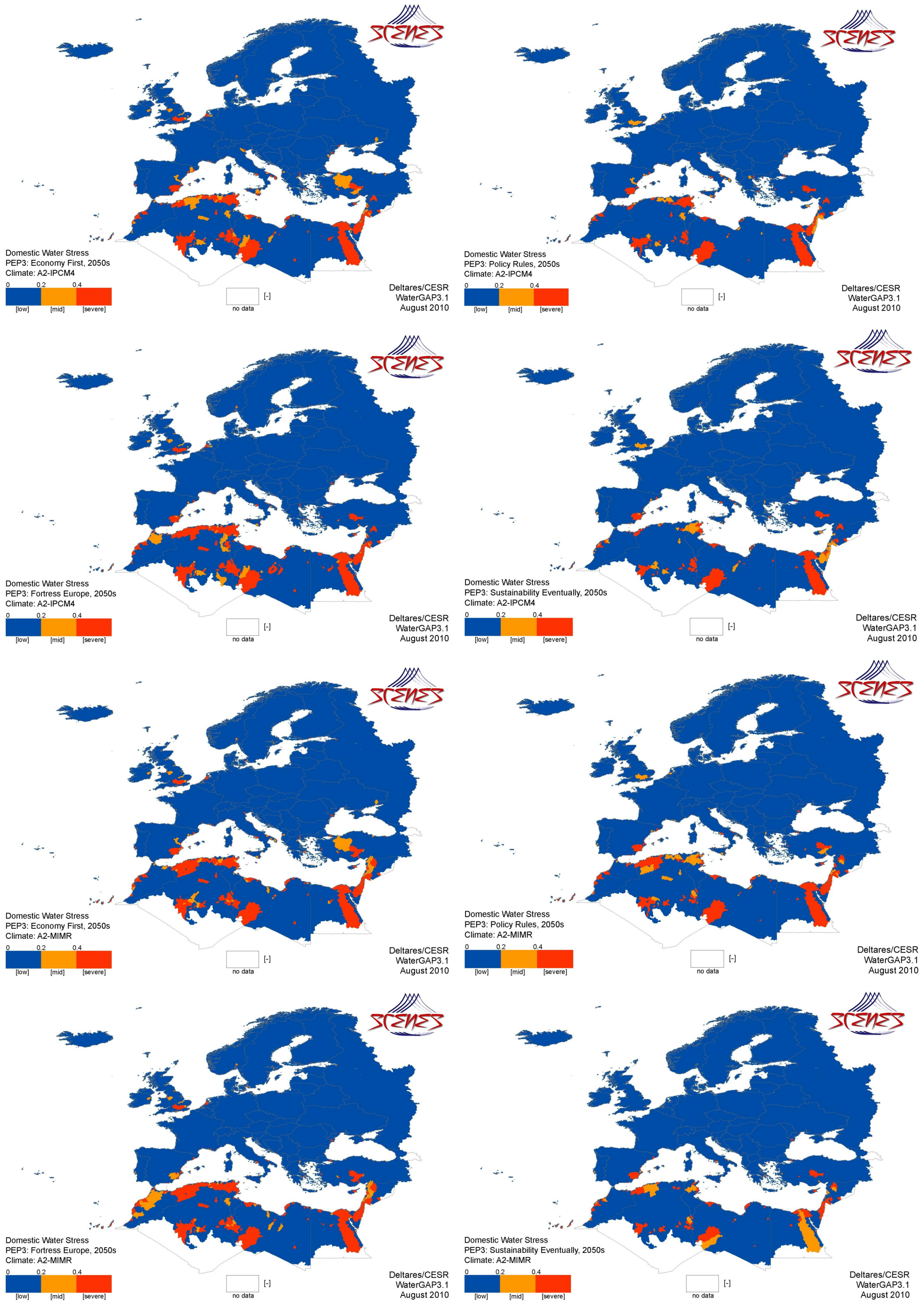

Figure 3.2 until 3.9 (left to right). Domestic Water Stress under different climate scenarios (Figure 3.2 until 3.3 under IPCM, 3.4 until 3.7 under MIMR) and socio economic scenarios (Figure 3.2 and 3.6: Economy First. Figure 3.3 and 3.7: Policy Rules. Figure 3.4 and 3.8: Fortress Europe. Figure 3.5 and 3.9: Sustainability Eventually).

3.4 Synthesis

Regional observations

Generally, domestic water stress will not be experienced in large areas in Europe in 2050. However, some areas will experience severe or high domestic water stress for all scenarios. This is the case in Northern Africa (especially the Nile Basin), Western Asia, eastern Spain, and around London and Amsterdam. Under Economy First and Fortress Europe domestic water stress will be experienced the most, and under the other two scenarios the least. However, the differences are not large, also not under different climate conditions. A summary of the expected changes under all scenarios for all regions in Europe can be found in Table 3.1.

Table 3.1 Regional impacts as deviation from the baseline scenario – domestic water stress

		Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
IPCM	EcF	-	o	o	o	o	o	-
	FoE	-	o	o	o	o	o	o
	PoR	o	o	o	o	o	o	o
	SuE	o	o	o	o	o	o	o
MIMR	EcF	-	o	o	o	o	o	-
	FoE	-	o	o	o	o	o	o
	PoR	o	o	o	o	o	o	o
	SuE	o	o	o	o	o	o	o

Climate change and socio-economic changes

The driver influencing the pattern of water scarcity indices the most is not easy to derive, since all drivers show problems in generally the same areas. Socio-economic scenarios however tend to influence this driver slightly more.

Future projections

The projected changes show no changes for most scenarios. It is useful to note that the computation of the domestic water stress index represents a worst-case scenario: domestic water has the lowest priority. With respect to the baseline scenario, this means that it is likely that in the future, domestic water stress will be similar and thus as low as it is today. In some areas also negative changes are expected. These projections are however not unanimous and the changes are relatively small compared to the baseline scenario. Therefore, the overall image obtained from the future projections are that changes in domestic water stress will be small.

3.5 References

Alcamo, J., Henrichs, T. & Rösch, T., 2000. World water in 2025 – Global modeling and scenario analysis for the World Commission on Water for the 21st century. Report A0002, Center for Environmental Systems Research, University of Kassel, Kurt Wolters Strasse 3, 34109 Kassel, Germany.

4 Water for People 2 - Flood Risk

4.1 Introduction to indicator

The flood risk indicator serves as a measure of the change in flood risk that follows as a consequence of both climate and policy changes. Flood risk is of importance to policy decisions in that increased flood risk translates to increased risk to human lives, society, infrastructure, and the economy.

Flood risk is a function of the probability of a flood hazard, and the consequence that such a hazard would produce. Typically, flood risk is estimated by the change in the flood hazard, or the change in frequency of a given flood hazard, which is relatively straight-forward to quantify. An example of a flood hazard is the discharge associated with an exceedance frequency of 1/100 years. Change in flood hazard does not take into account the effect that the economy and demographics have on flood risk, because these factors affect the consequences of the hazard, not the hazard itself. The consequence is itself a function of exposure and vulnerability. Exposure refers the recipients of the hazard which can be damaged (both in terms of human casualties and economic damage), whereas vulnerability refers to how well the exposed people/properties/industry are protected from the hazard. In general, an increase in population will increase flood risk because it increases the exposure. For example, a hazard may be very large, but if there are no inhabitants or buildings to experience it, there is also no risk. An increase in gross domestic product (GDP) also increases the exposure because there is more economic production that can be damaged by a flood, leading to larger losses. Flood risk also depends on vulnerability, where the vulnerability of a location refers to how well the exposed people/properties/industry are protected from the hazard. For example, there may be a large hazard, and many inhabitants and industry, thus high exposure, but if there are strong dikes and efficient evacuation plans in the event of a flood, there is also less risk.

It is useful to describe flood risk in formulaic terms. Let $H_{1/100} = Hazard(p \mid p = 0.01)$ denote the hazard associated with a probability (p) of exceedance of 1/100 (note that at such small values of probability, the probability of exceedance and frequency of exceedance are indistinguishable), and let C(H,E,V) denote the consequences as a function of the magnitude of the hazard (H), the exposure (E), and the vulnerability (V). Then the 1/100-year flood risk is given as

$$FR_{1/100} = f_{Q100} \times C(H_{1/100}, E, V) \quad , \qquad (1)$$

where fQ100 is the frequency associated with the current 1/100-year discharge Q100 (under current conditions this of course equal to 1/100). Because we are interested in changes in flood risk, this equation becomes

$$\Delta FR_{1/100} = \Delta(f_{Q100} \times C) \quad , \qquad (2)$$

where Δ represents "change in". The future frequency of the current Q100 has been calculated by Kerstin Verzano (Kassel) for each grid cell in the WaterGAP model. The methodology here thus focuses on the consequences C.

4.2 Method

As mentioned in the Introduction, the focus of the method is on the combination of the frequency of the 1/100-year discharge, Q100, with the consequences of such an event. On a regional scale this would ideally be done with hydraulic routing models that include flood defenses and elevation maps, which would calculate the extent and depth of flooding that such a discharge event would cause. Economic damage functions which relate economic damage to flooding depths would then be applied as well as casualty functions that relate the number of casualties to features of the flooding event such as the rate of rise of flood waters, the depth of flood waters, and the velocity. All of this information is unavailable at the pan-European scale. ISPRA is currently compiling a pan-European database of damage functions, but this is not yet available. Even if it were, the damage functions require coupling with digital elevation maps, knowledge of local defenses, and routing models to estimate the depths that a given discharge event would cause.

This lack of information is not considered a severe limitation since the current study aims to calculate indicators of flood risk; specifically to focus on the direction and relative magnitude of the change in flood risk. This does not require such detailed information. The relevant information that was available from the PEP2 storylines was population and GDP. As described in the introduction, an increase in both population and GDP will increase flood risk because it increases the exposure to the flood hazard (the entities which can be harmed by the flood).

It was not considered advantageous to combine GDP and population. Each of these is related to a different sort of risk: GDP is related to economic risk, whereas population is related to social risk. For example, in a region where the economy grows but the population decreases, the net effect, taking both GDP and population into account is that flood risk does not increase or decrease. This obscures the information; it would be better to separate these drivers and present the increase in economic risk and the decrease in social risk separately. This is more useful for managers to know which types of risks they are confronted with and therefore which types of measures would be most practical for risk mitigation. For instance, focusing on evacuation plans and early warning systems would reap little reward in the case where there is low social risk and high economic risk.

Calculation approach

Two indicators were therefore calculated: a social risk indicator and an economic risk indicator. The social risk indicator is the change in flood risk associated with population growth and is given in equation (3) below.

$$\Delta FR_{social} = \left(f_{Q_{100},2050} \times Pop_{2050} \right) - \left(f_{Q_{100},2000} \times Pop_{2000} \right), \tag{3}$$

The relative increase or decrease in flood risk is much more meaningful, since a large change in a region where the flood risk is already large is not equivalent to a large increase where the flood risk was small. Therefore, the social risk indicator is defined as the relative change in flood risk, as described in equation (4) below.

$$\Delta FR_{social,rel} = \frac{\Delta FR_{social}}{\max\left(FR_{2000}, FR_{2050} \right)}, \tag{4}$$

The equations for the economic flood risk indicator are presented in equations (5) and (6) below.

$$\Delta FR_{economic} = \left(f_{Q_{100},2050} \times GDP_{2050} \right) - \left(f_{Q_{100},2000} \times GDP_{2000} \right) \qquad (5)$$

$$\Delta FR_{economic,rel} = \frac{\Delta FR_{economic}}{\max\left(FR_{2000}, FR_{2050} \right)} \qquad (6)$$

To avoid misleading results, a couple of adjustments were made to the data, specifically related to small values of GDP and small population. For example, if the frequency of the baseline 100-year discharge changes only by a small amount, then the difference in the flood risk will be purely based on GDP or population. If the population of a cell was 6 people in 2000 and 0 people in 2050, then for the exact same frequency of discharge (thus no change in the hazard), then the formulas for the indicators would result in a 100% decrease in flood risk. This is misleading, because in fact the change in flood risk has barely changed. To avoid such misleading results, all cells in which the population was less than 10 people were set to population equal to zero, and similarly, any cell with GDP less than 1000 euros was set to a GDP of zero euros.

Important limitation of the current method
The future frequency of the current (baseline) 100-year discharge was only calculated by WaterGAP for cells in which the 100-year discharge increased; that is, in cells where the hazard increased. This was because that research used the flood hazard as an indicator of flood risk, and the study was only interested in areas where the flood risk increased. As described earlier in this section, flood risk can increase even in cases where the hazard decreases – for example if the population increases enough, the risk will still increase because of the increased exposure. It is considered very important that the future frequencies of the current 100-year discharge are calculated for all cells to be able to produce a complete analysis in which the flood risk is calculated at all cells.

Input data
- Frequency of baseline 100-year discharge in the year 2050 (WaterGAP)
- Population 2000 and Population projections 2050 (EcF, FoE, PoR, SuE)
- GDP 2000 and GDP projections 2050 (EcF, FoE, PoR, SuE)

Spatial and temporal scales
The frequency of the baseline 100-year discharge was based on annual maxima discharge modeled with WaterGAP. The values are not considered reliable per grid cell but are rather to be viewed as a basin-scale indicator for change in flood risk; that is, to detect large scale patterns in flood risk change due to climate and policy changes.

Thresholds/classes
The only thresholds that play a role in the current analysis are concerned with the avoidance of misleading results described in the Methods section – specifically, that GDP values per cell less than 1000 euros are insignificant and that population less than 10 people in a cell are considered insignificant (see Methods section).

Uncertainties
Sources of uncertainty in the input are
- Flood frequencies, which are in turn due to uncertainties in
  - Climate model output
  - WaterGAP modeled discharges

    - Choice of statistical distribution for the extrapolation (used in the determination of the return periods (i.e. frequencies) longer than the length of the time series of discharges)
    - Statistical extrapolation
- Population projections for 2050
- GDP projections for 2050

Validation

Validation has not yet been carried out. Validation will consist of comparing the direction and relative magnitude of flood risk change with regional results at locations where research has been carried out (e.g. The Netherlands). Validation of the flood frequencies will be done by comparing the results from WaterGAP with a secondary method using a statistical model based on measurements at stations across Europe.

4.3 Results

4.3.1 General

The drivers of flood risk are the change in frequency of the current 100 year discharge and the change in population, for the population-based indicator, and the change in GDP, for the economic-based indicator. The change in GDP and population is computed per cell. GDP changes per cell are estimated by assuming the country change is distributed according to population. See Figure 3.1 and 3.2 for the change in frequency of Q100 discharges under the different climate scenarios, the figures for the change in GDP and in population were presented in Chapter 2. In section 4.3.3 and 4.3.4, the flood risk maps are displayed for GDP based and population based flood risk, respectively.

4.3.2 Change in frequency of Q100 discharges

Two climate models were used for calculating changes in the flood hazard: IPCM4 and MIMR, using the climate scenario A2. A very important note, mentioned above as a limitation to the current method, is that only changes in frequency were computed where the flood hazard *increased*. This is because the project that computed the change in frequency was only interested in flood hazard increases. Cells where the frequency decreased are left blank in the maps.

Since the maps only show the increases in frequency, it is easy to see which model results in larger areas with increases. Under MIMR, there are more and stronger increases around the Balkan states and western Turkey, also in the UK and Ireland relative to IPCM4. Under IPCM4, there are more increases in Spain (strong increases), Portugal, Germany, and northern Scandinavia (weak increases) relative to MIMR.

.

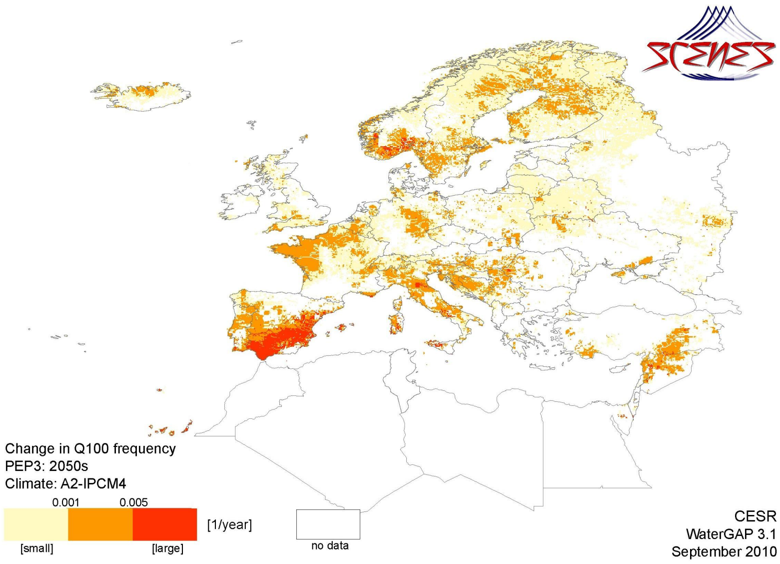

Figure 4.1 Change in Q100 frequency under the IPCM scenario

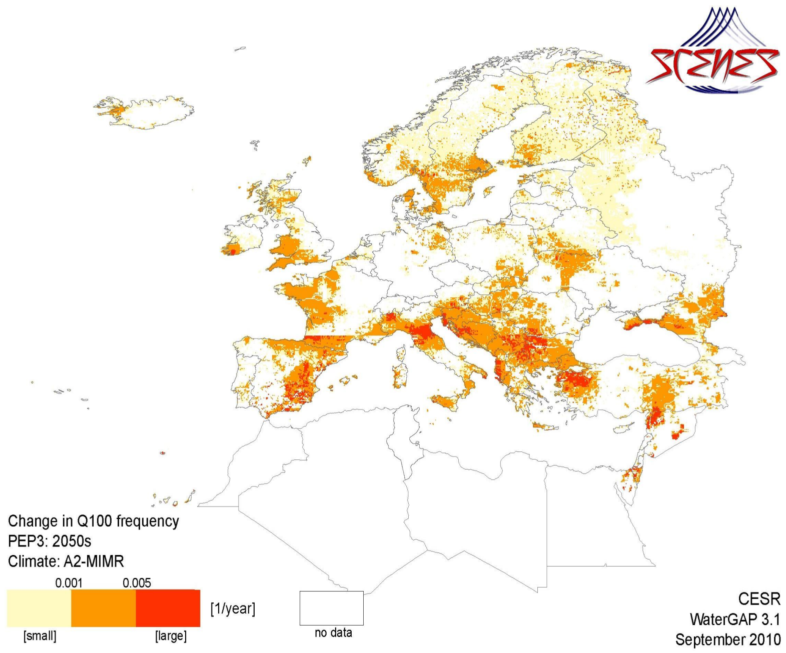

Figure 4.2 Change in Q100 frequency under the MIMR scenario.

4.3.3 GDP-based indicator

The GDP drivers were included in Chapter 2; shown are the relative changes in GDP for the four socio-economic scenarios (Figure 2.1 until 2.4). Under EcF, PoR, and FoE, the GDP increases for entire Europe. Under EcF, the strongest increases over the largest area are seen – particularly in eastern Europe, Portugal, Spain and Ireland. Under PoR the areas with very strong increases are less compared with EcF, restricted mostly to limited parts of eastern Europe, Turkey, Ireland and Portugal. Under FoE, the strong increases are even further limited, to Turkey, some Baltic states, Lithuania, Latvia, and Estonia. Under SuE, decreases are seen in certain areas, with medium decreases in France, Benelux, Germany, Austria, and Switzerland, and only mild increases in Russia; strong relative increases are still observed in the same areas as under FoE.

The change in GDP is a substantial driver for the GDP-based flood risk indicator. See Figure 4.3 until Figure 4.10 for the GDP-based flood risk indicator. In particular, because of the limitation that only frequencies which *increased* were computed, the flood risk maps will appear overwhelmingly 'orange' and 'red'; that is, when the GDP driver is positive, the flood risk indicator for computed cells will also be positive, since all computed cells have a positive increase in frequency (the second driver). The areas that are blank are areas in which the frequency decreased – for blank areas which experience an increase in GDP, it is not clear in these areas if the flood risk would have been dominated by the increase in GDP or the decrease in frequency; thus, the direction of change of flood risk is in these areas unknown. For the SuE scenario in which GDP decreased, the effect on flood risk is dependent on which driver (increasing frequency or decreasing GDP) dominates. As is seen in the results below, GDP largely dominates. Note that for blank cells (i.e. a decreased frequency) in which GDP also decreased, the direction of flood risk is known (decrease), even if the magnitude is not.

Between the two climate models, you see the effect of the area for which frequencies increased (described in section 4.3.1); that is, under IPCM4 you see much more area with increases in Scandinavia, Spain, Portugal, and Germany, while under MIMR, you see much more increase in the Baltic states, and western Turkey.

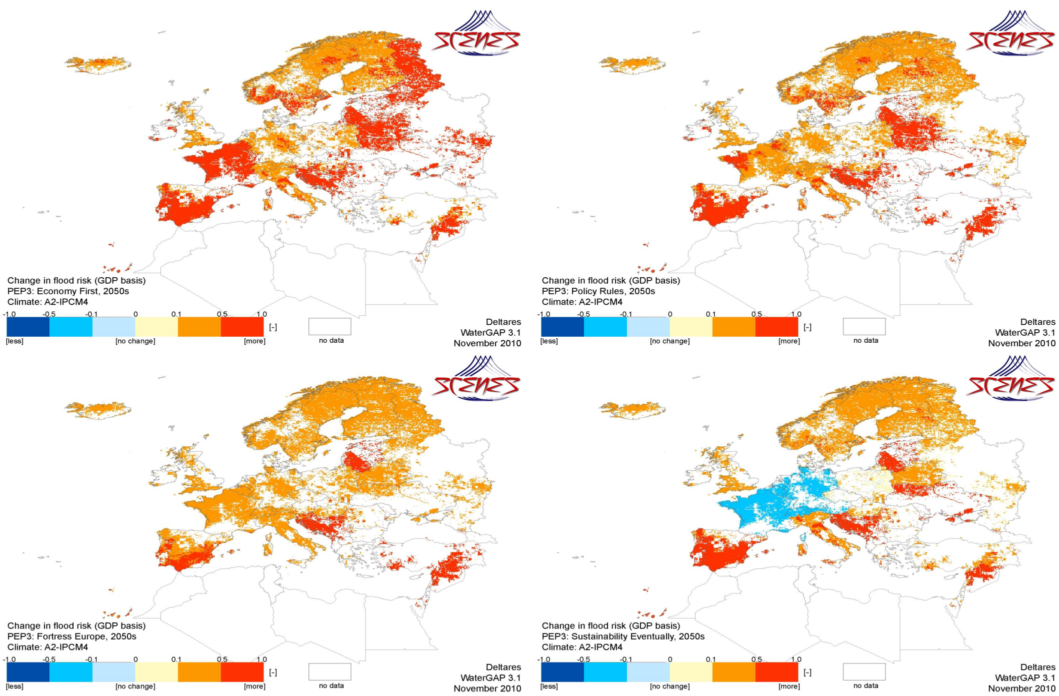

Figure 4.3 until 4.6 (left to right). Change in GDP based flood risk under the IPCM scenario. Economy First: Figure 4.3. Policy Rules: Figure 4.4. Fortress Europe: Figure 4.5. Sustainability Eventually: Figure 4.6.

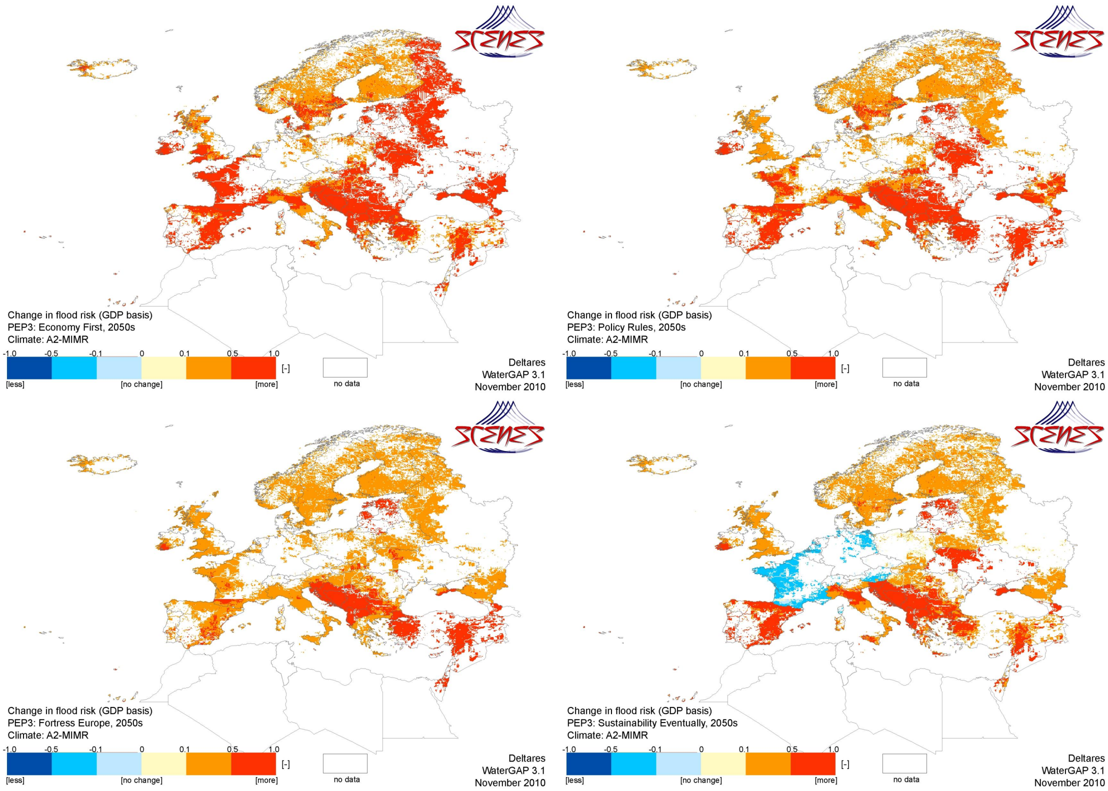

Figure 4.7 until 4.10 (left to right). Change in GDP based flood risk under the MIMR scenario. Economy First: Figure 4.7. Policy Rules: Figure 4.8. Fortress Europe: Figure 4.9. Sustainability Eventually: Figure 4.10.

4.3.4 Population-based indicator

The population drivers were included in Chapter 2 (Figure 2.5 until Figure 2.8); shown are the relative changes in population for the four socio-economic scenarios. Under EcF, PoR, and FoE, the population decreases for almost entire Europe. Exceptions are eastern UK and areas in Benelux, with EcF and PoR showing stronger increases in those areas than under FoE. Under FoE a small increase in population is also seen in Turkey. Under SuE, there are many regions with small and medium increases in population. Sweden, Norway, Spain, Ireland, France, Turkey, speckled areas in Germany and just to the east all experience medium increases in population under SuE. The UK experiences large population increases, and Italy experiences mild increases.

The change in population is a substantial driver for the population-based flood risk indicator. See Figure 4.11 until 4.18 for the population-based flood risk indicator. It largely dominates over the frequency driver, as is evident for the first three socio-economic scenarios. The increase in frequency serves predominantly as a tempering effect. That is, it reduces the decrease, but does not tend to change the direction of the indicator. An exception is some of the Balkan states under climate model MIMR, which experienced a quite strong increase in frequency for that area. For the scenario SuE, the change in population dominates the direction of flood risk change; the effect of the frequency is again a tempering effect for decreased flood risk, and serves to intensify the increases for areas where population increased.

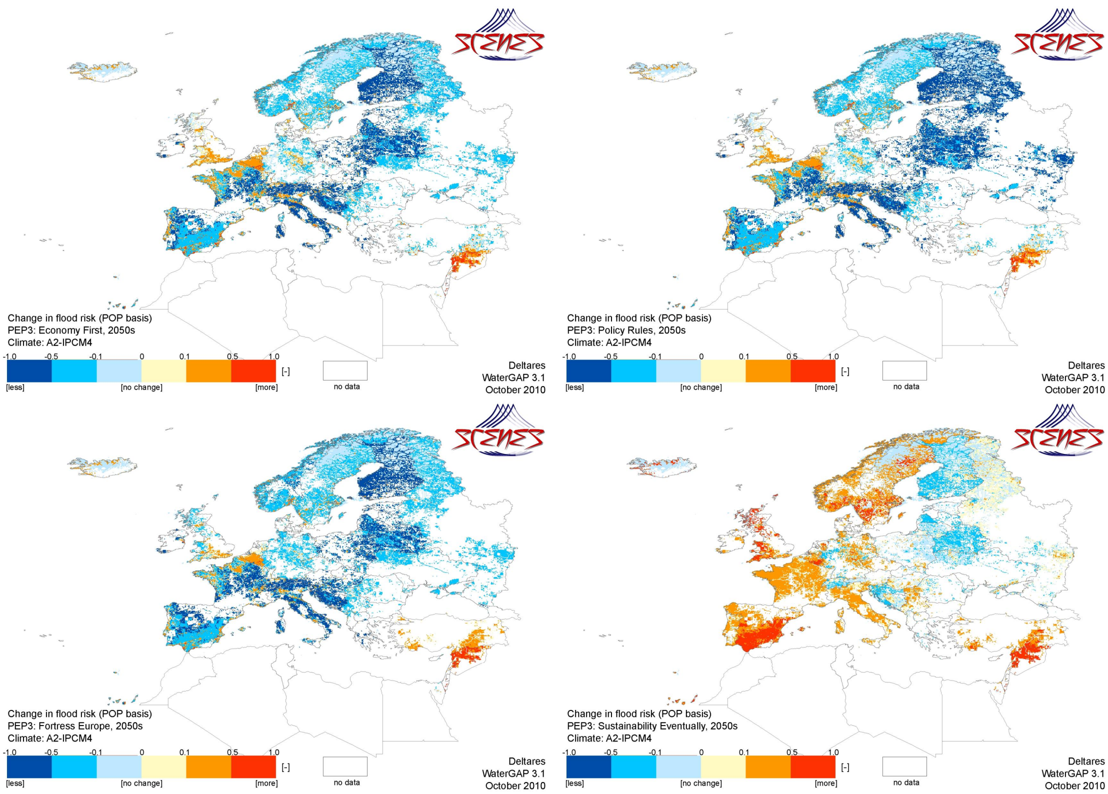

Figure 4.11 until 4.14 (left to right). Change in population based flood risk under the IPCM scenario. Economy First: Figure 4.11. Policy Rules: Figure 4.12. Fortress Europe: Figure 4.13. Sustainability Eventually: Figure 4.14.

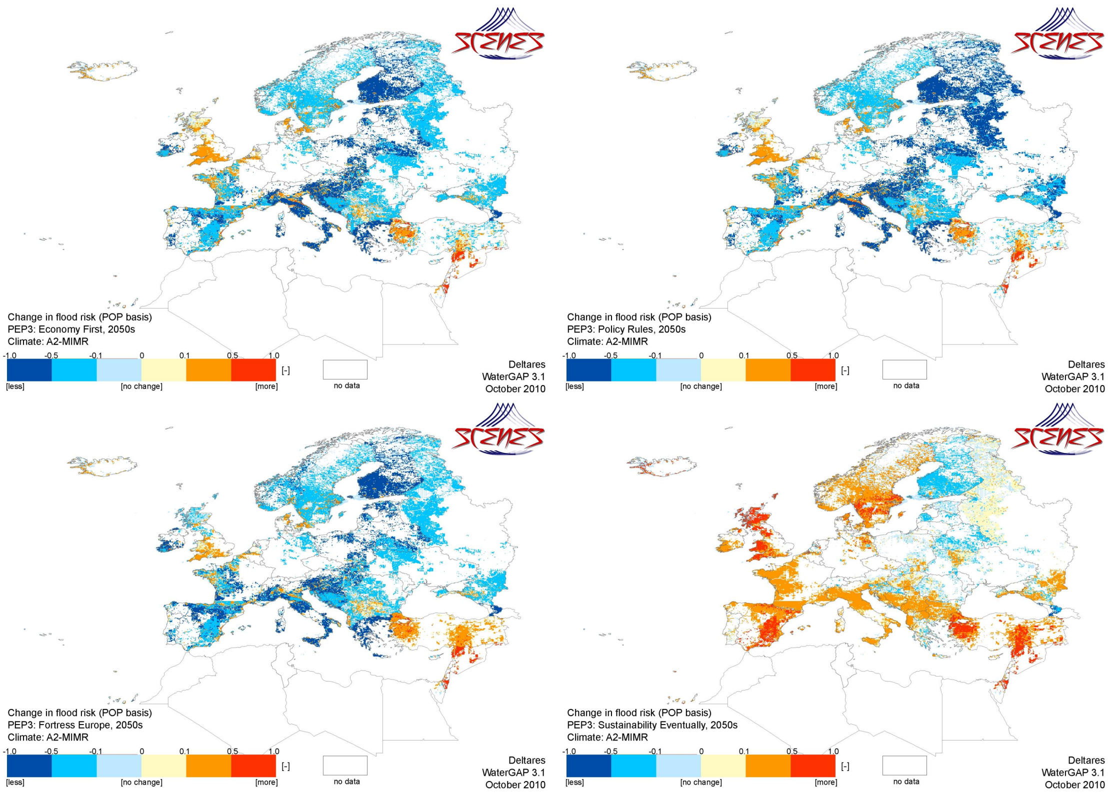

Figure 4.15 until 4.18 (left to right). Change in population based flood risk under the MIMR scenario. Economy First: Figure 4.15. Policy Rules: Figure 4.16. Fortress Europe: Figure 4.17. Sustainability Eventually: Figure 4.18.

4.4 Synthesis

Regional observations

Certain areas showed increases in flood risk under all socio-economic scenarios, such as parts of the Balkan states and western Turkey under the MIMR model, and parts of the UK under both models. The direction of change of the flood risk indicators is opposing for population-based and GDP-based indicators (decrease in population went together with an increase in GDP, or vice versa). Thus, which type of measures are necessary for protection of people versus assets is an important discussion when assessing the different socio-economic scenarios. In Table 4.1 and Table 4.2, a summary of population-based and GDP-based flood risk changes per region can be found, respectively.

Table 4.1 Regional impacts as deviation from the baseline scenario –Population-based flood risk

		Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
IPCM	EcF	NA	-	++	+/-	++	NA	NA
	FoE	NA	-	++	+/-	++	NA	NA
	PoR	NA	-	++	+/-	++	NA	NA
	SuE	NA	--	+/-	-	+	NA	NA
MIMR	EcF	NA	-	++	+/-	++	NA	NA
	FoE	NA	-	++	+/-	++	NA	NA
	PoR	NA	-	++	+/-	++	NA	NA
	SuE	NA	--	+/-	-	+	NA	NA

Table 4.2 Regional impacts as deviation from the baseline scenario –GDP-based flood risk

		Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
IPCM	EcF	NA	--	--	--	-	NA	NA
	FoE	NA	--	--	--	-	NA	NA
	PoR	NA	--	--	--	-	NA	NA
	SuE	NA	++	--	--	-	NA	NA
MIMR	EcF	NA	-	--	--	-	NA	NA
	FoE	NA	-	--	--	-	NA	NA
	PoR	NA	-	--	--	-	NA	NA
	SuE	NA	+	--	--	-	NA	NA

Climate change and socio-economic changes

Both the GDP-based and population-based flood risk indicators are predominantly driven by changes in GDP and population, and less by changes in frequency of the baseline 1/100-year discharge. The frequency largely had a tempering effect – that is, in cases where the two drivers were in opposing directions, it reduced the effect of the GDP or population driver, and in cases where they were the same direction, it heightened the effect. Thus, the driver maps for GDP change and population change serve themselves as good indicators of the change in flood risk.

Future projections

Although there are quite some missing values for this indicator which makes the interpretation for some regions hard, it appears that the observed changes in the different regions are supported by most scenarios. Only the Sustainability Eventually scenario shows different projections in some regions. It can therefore be stated that the future developments of flood risk are relatively certain for most regions, but in some regions, there is some uncertainty.

4.5 References

Verzano, K., 2009. Climate Change Impacts on Flood Related Hydrological Processes: Further Development and Application of a Global Scale Hydrological Model, PhD thesis, International Max Planck Research School on Earth System Modelling.

5 Water for People 3 - Risk for harmful algal blooms in shallow lakes and reservoirs

5.1 Introduction

In addition to impacts on ecosystems, the effects of nutrients and eutrophication also cause problems for surface water and bathing water quality as well as water for livestock (EEA, 1999). Harmful algal (cyanobacterial) blooms (HAB's) can arise, especially when an excess of nutrients is combined with high temperatures. Public health concern regarding cyanobacteria centres on the ability of these organisms to produce cyanotoxins (WHO, 1999). Cyanotoxins can cause adverse health effects, the main culprit being microcystines and nodularins, which affect the liver. These are produced by species such as *Microcystis*, *Anabaena* and *Oscillatoria (Planktothrix)*.

For the assessment of the impact indicator "Risk for harmful algal blooms in shallow lakes and reservoirs" the model BLOOM was used. BLOOM uses linear programming to find the maximum total net production, or optionally the total biomass, of selected algae species in a certain time period consistent with the environmental conditions and the existing biomass levels (Los, 2009). TN and temperature were varied to produce several response curves showing the chlorophyll-concentration in relation to these parameters.

5.2 Method

Calculation approach and input data

The total nitrogen concentration and water temperature in rivers were derived from the HABITAT TN (Malotaux, 2010) and HABITAT water temperature models. For the calculation approach of these models see the indicator chapters Nature 5 and Industry 1, respectively. For each scenario the model has been run using the IPCM4-A2 and MIMR-A2 models.

The relationships between the relevant environmental factors and the phytoplankton biomass were assessed by running a box model version of the phytoplankton model BLOOM. The modeling of algae is focused primarily on calculation of its growth and mortality, as well as on its interaction with the nutrient species and its affect on oxygen concentrations. The total net production or the total biomass of the system is maximized given the availability of nutrients, light and temperature.

The model was run for a set of conditions, in which temperature and total N concentrations were varied, in a scenario wise fashion in order to determine the most relevant function relationships in the form of response curves. The result of these runs is shown in Figure 5.1.

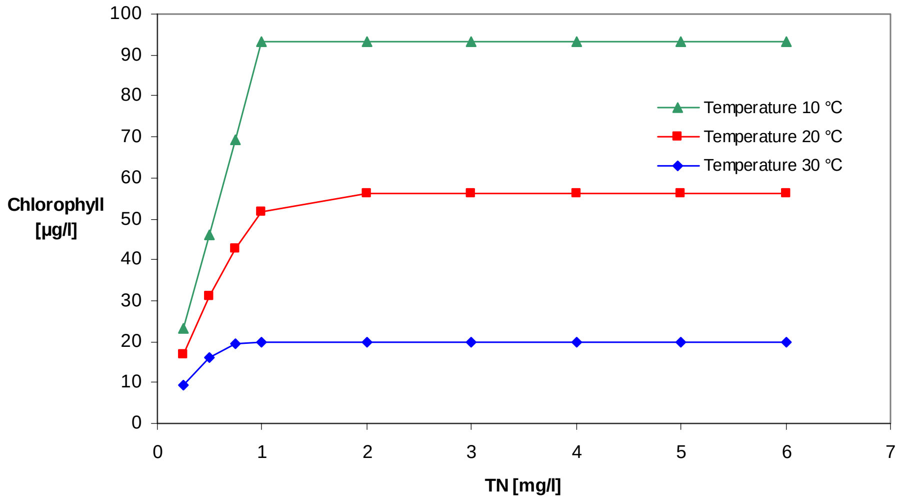

Figure 5.1 Response curves derived from the phytoplankton model BLOOM, showing the relation between total N and chlorophyll concentrations for different temperatures.

In the model only the availability of nitrogen and temperature has been varied. Other factors that can limit phytoplankton growth such as phosphorus, depth, turbidity, weather conditions, were kept constant. Phosphorus was assumed not to be limiting the growth rate. Chlorophyll concentrations resulting from various model runs were used as an indicator for the risk of algal blooms.

The relation between nitrogen and temperature for specific chlorophyll levels as presented in Figure 5.2 is derived from Figure 5.1. It can be seen that chlorophyll concentrations increase with higher TN concentrations. Also lower chlorophyll concentrations are predicted with higher temperatures for equal TN concentration. This can be explained by the fact that, although the growth rate increases with higher temperatures, the mortality rate increases relative to the growth rate, resulting in a lower total living biomass. As mentioned before many factors including weather conditions, limitation of other nutrients, have not been taken into account. Since many variables have been assumed constant the model results do not support the whole range of conditions that affect the future risk of algal blooms. The impact indicator results should therefore be interpreted in this context.

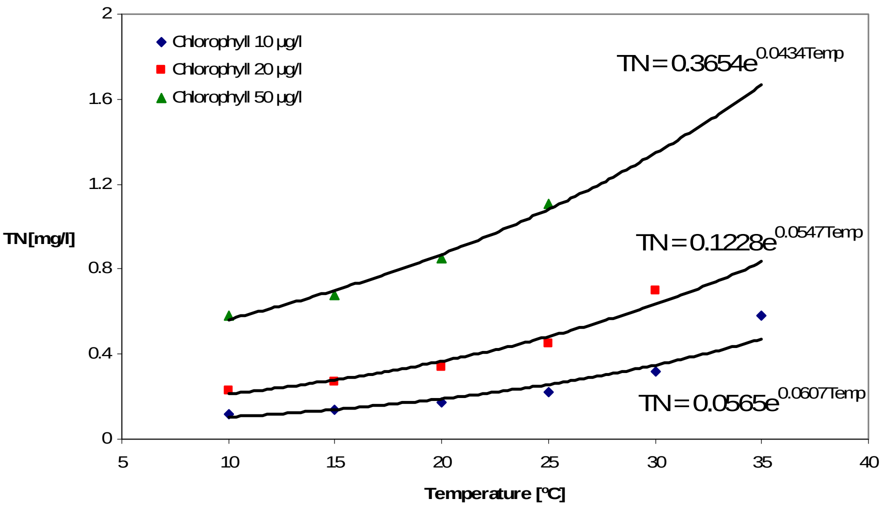

Figure 5.2 Response curves derived from the phytoplankton model BLOOM, showing the relation between total N and temperatures for three Chlorophyll concentrations (10, 20, and 50 µg/l) that were used to represent the class boundaries.

Chlorophyll thresholds and critical values

Thresholds for bathing water quality have earlier been defined by several institutes and authors, for example by the World Health Organization (WHO, 1999), the Netherlands Organization for Scientific Research (NOW, 2010) and in the scope of the Dutch WFD-index (Van der Molen and Pot, 2007). Thresholds by WHO have been taken as guiding. Table 5.1 shows the defined thresholds.

Table 5.1. Thresholds for Chlorophyll concentration, a measure for the risk for harmful algae blooms.

Class	Description	Chlorophyll (µg l^{-1})	Reference
I	No risk	< 10	WHO (1999)
II	Low Risk	< 20	Van der Molen and Pot (2007)
III	Medium Risk	< 50	WHO (1999)
IV	High Risk	≥ 50	WHO (1999)

Validation

The threshold at a Chlorophyll concentration of < 10 µg l^{-1} is identified by WHO (1999) as being relatively mild and/or with low probabilities of adverse health effects. At < 50 µg l^{-1} the risk is defined as moderate probability of adverse health effects. At ≥ 50 µg l^{-1} there is a very high probability of adverse health effects. In order to differentiate between the relatively large gap between 10 and 50 µg l^{-1}, the Dutch WFD-index on chlorophyll concentrations (Van der Molen and Pot 2007) puts the threshold for good status for most freshwater lakes close to 20 µg l^{-1}. Thus, a threshold has also been set at 20 µg l^{-1}.

The model was validated in a similar fashion as in impact indicator Water for Nature 5. TN concentrations were compared to measured N concentrations at river outlets.

Uncertainty and sensitivity

Uncertainties for this indicator can be high, since the impact indicator results have been calculated with output from four different models, each with their own uncertainties. The four models are WaterGAP3.1, HABITAT TN model, HABITAT water temperature model and

BLOOM model. The uncertainties associated with the TN and water temperature models are described in the impact indicator chapters Water for Nature 5 and Water for Industry 1, respectively.

Uncertainties associated to the BLOOM model are the limited representation of real conditions in shallow lakes and reservoirs. Important factors, including lake depth, turbulence, weather conditions, phosphorus limitation, and light penetration into the water have all not been taken into account, but were assumed constant. Therefore the results represent a maximum level for biomass growth and may overestimate the risk for harmful algal blooms.

5.3 Results

The chlorophyll thresholds have been applied to all regions. Maps have been created for the socio-economic scenarios in combination with the two climate models depicting the share of grid cells falling in a risk class (Figure 5.3 until 5.11).

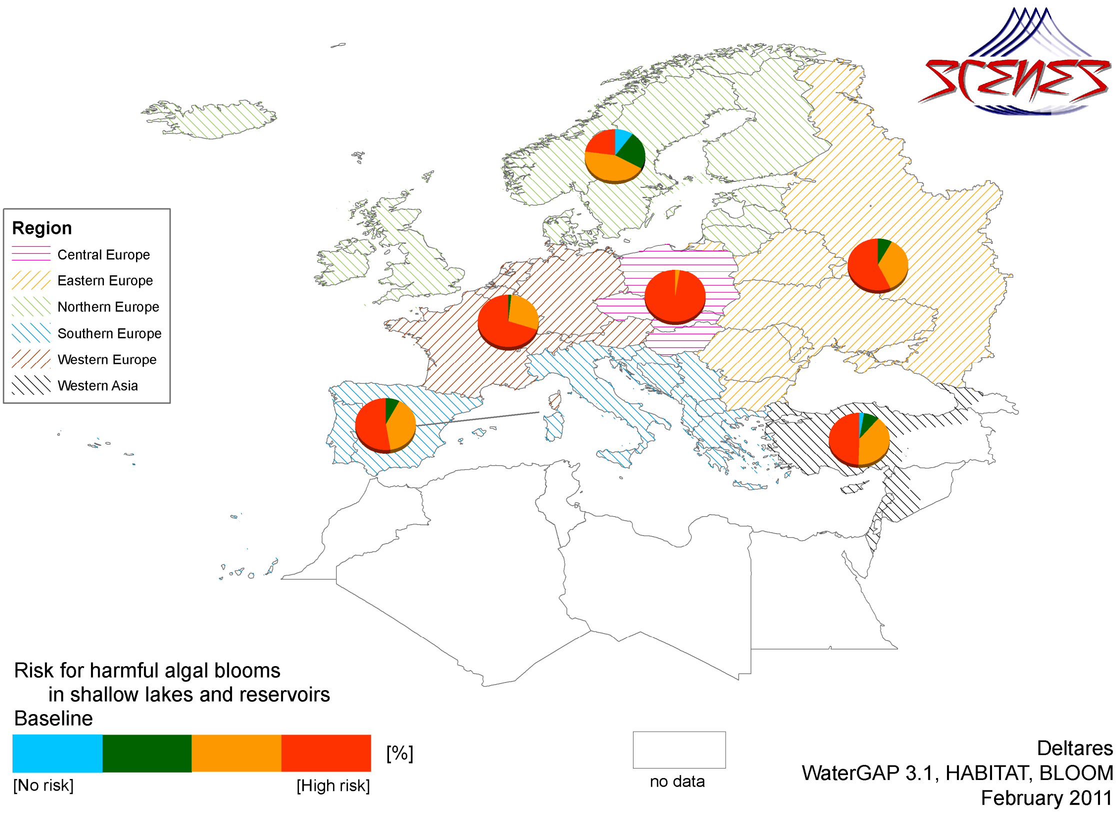

Figure 5.3 Risk for harmful algal blooms in shallow lakes and reservoirs for Baseline scenario

5.3.1 Baseline scenario

Most areas fall in the medium to high risk class for harmful algal blooms (HABs), and according to the model results all water bodies in Central Europe fall into the high risk class (Figure 5.3). Exceptions are Northern and Western Asia, where around 10% to 30% of the water bodies show low to no risk for HABs. Except for Northern Europe (25%) all regions have over 50% of water where there is a high risk for HABs.

5.3.2 Future scenarios

Except for Western Asia all regions show some improvement for nearly all scenarios (Figures 5.4 until 5.11). Only for the combined scenario IPCM4-A2 with both Economy First and Fortress Europe no significant change is seen for Central, Western and Southern Europe. For all regions MIMR show slightly lower risk for HABs than IPCM4. The best results are obtained for the Nordic region, in which slightly less than 25% is not at risk of harmful algal blooms for all scenarios and climate models. For Eastern Europe the category ‘no risk’ (20%) is observed for Sustainability Eventually/MIMR-A2. Other regions show a vast majority of the area being at high to moderate risk. Central Europe is almost entirely at high risk. For this region some improvement is seen for Sustainability Eventually compared to the baseline scenario. Nevertheless, 85% of the waters remain at high risk for HABs. The Sustainability Eventually scenario and MIMR-A2 scenario give the most positive results. For Fortress Europe the risk is highest in all regions. Western Europe only shows areas that are at some to high risk and Southern Europe contain < 10% of area at no risk. For region with the highest variability between the different scenarios, Western Asia, Fortress Europe shows the highest risk for HABs.

5.4 Synthesis

Except for Western Asia, there are no remarkable changes between the various scenarios, most likely because of the high share of waters that falls in the ‘high’ risk category. The MIMR-A2 gives the most positive results, as the climate model predicts a wetter climate that allows for the dilution of nutrients and a smaller temperature rise resulting in lower water temperatures. The results seem to reflect the current situation, as EEA (2007) reports that the majority of area in Western Continental Europe has been affected by (the effects of) eutrophication. For a summary of the observed changes in all regions, see Table 5.2.

Table 5.2 Regional impacts as deviation from the baseline scenario – harmful algal blooms

		Northern Africa	Westerm Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
IPCM	EcF	*no data*	o	+	+	o	+	-
	FoE	*no data*	o	+	o	o	+	-
	PoR	*no data*	+	+	+	+	+	+
	SuE	*no data*	+	+	+	+	+	-
MIMR	EcF	*no data*	+	+	+	+	+	-
	FoE	*no data*	+	+	+	o	+	-
	PoR	*no data*	+	+	+	+	+	+
	SuE	*no data*	+	+	+	+	++	o

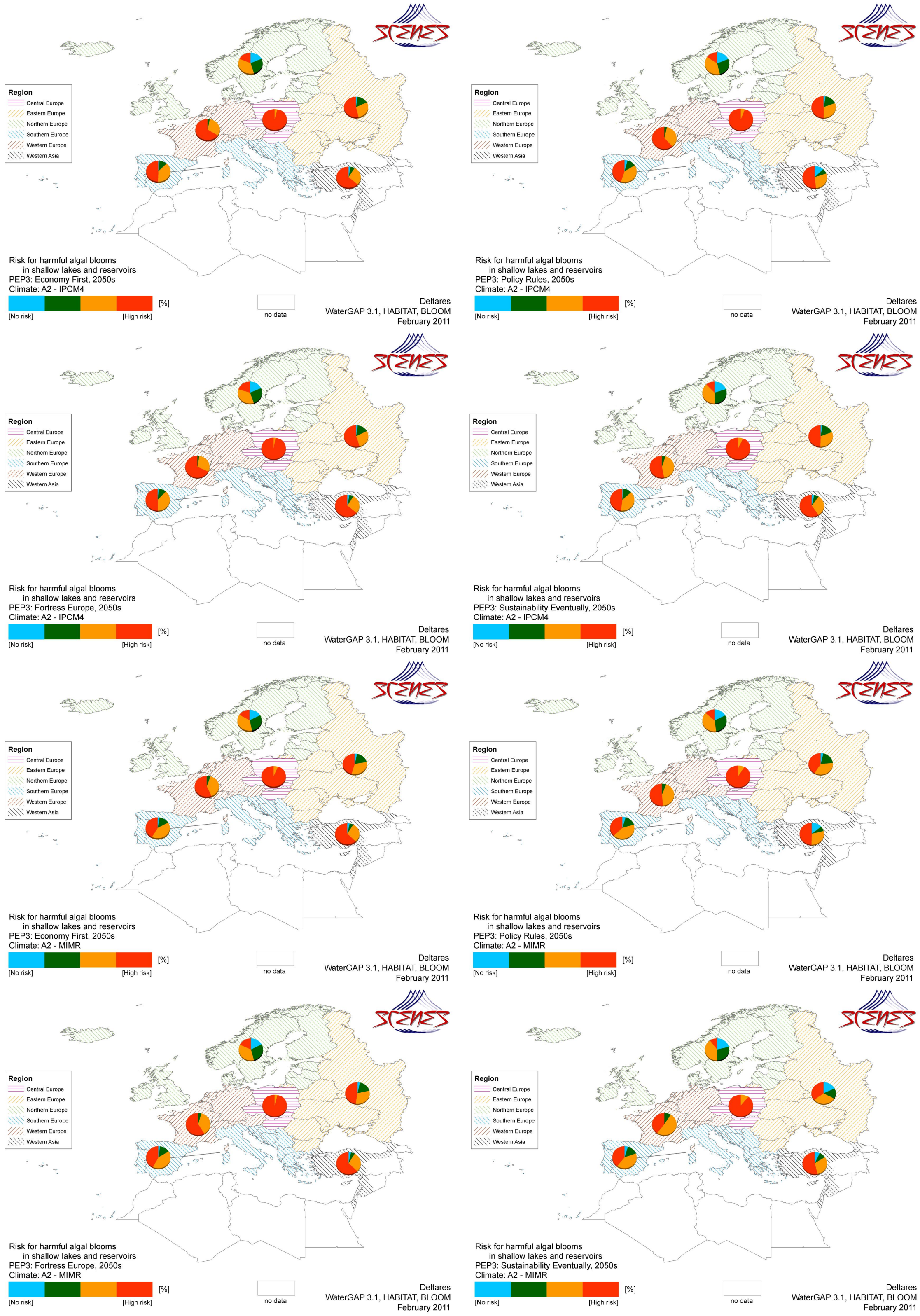

Figure 5.4 until 5.11 Risk for harmful algal blooms in shallow lakes and reservoirs for future scenarios (Figure 5.4 until 5.7 under IPCM, 5.8 until 5.11 under MIMR) and socio economic scenarios (Figure 5.4 and 5.8: Economy First. Figure 5.5 and 5.9: Policy Rules. Figure 5.6 and 5.10: Fortress Europe. Figure 5.7 and 5.11: Sustainability Eventually).

5.5 References

EEA, 1999. *Nutrients in European ecosystems.* Environmental assessment report No. 4. European Environmental Agency, Copenhagen, Denmark, 156 pp.

Los, H., 2009. *Eco-hydrodynamic modelling of primary production in coastal waters and lakes using BLOOM*. PhD Thesis Wageningen University, ISBN 978-90-8585-329-9.

Malotaux, J.M., 2010. *Total nitrogen concentration modeling for European river basins. Master thesis sustainable development*. Department of Innovation and Environmental Sciences, Utrecht University

WHO, 1999. *Toxic Cyanobacteria in Water: A guide to their public health consequences, monitoring and management*. I. Chorus & J. Bartram (eds.). World Health Organization, 400 pp.

NWO, 2010. *Blauwalgenprotocol* 2010, 7 pp

Van der Molen, D. & Pot, R., 2007. *Referenties en maatlatten voor natuurlijke watertypen voor de Kaderrichtlijn Water*. STOWA, Utrecht, 362 pp.

EEA, 2007. *Europe's environment – The fourth assessment*. European Environment Agency, Copenhagen, Denmark, 453 pp.

6 Water for People 4 - Domestic water availability

6.1 Introduction to indicator

Domestic water refers to all types of water use by households, for drinking and cooking, but also for cleaning, showering, flushing of toilets, washing of cars and watering of lawns. In most countries, domestic water has a higher priority than other (economic) water users. Moreover, since domestic water generally concerns a relatively small amount of water, shortages are not likely to occur on an annual basis at the river basin level. Shortages may occur however during dry periods of the year, and especially when upstream withdrawals take place for other uses despite of allocation hierarchies.

The domestic water availability indicator is a measure for the long-term availability of domestic water per capita within a river basin. The indicator is defined as a 'worst case scenario': with for domestic water use a priority lower than the economic water use sectors.

6.2 Method

Calculation approach

The availability is calculated by subtracting industrial (electricity generation and manufacturing) and agricultural consumption (irrigation and livestock) from the climate driven availability, leaving the potential availability for domestic use. The available water per basin is then divided by the number of people living in the basin. The calculation can be expressed as:

$$\frac{\text{availability - consumptive use economic sectors (m}^3\text{/year)}}{\text{population (inhabitants)}}$$

The indicator is expressed in liters per person per day (l/cap/day).

Input data

The following WaterGAP output is used to calculate the indicator:

- Total availability
- Total consumptive use for electricity, manufacturing, irrigation and livestock
- Population numbers

Spatial and temporal scales

The indicator is calculated on a basin scale.

Thresholds/classes

In Europe, average water use per capita is between 100 and 200 liters per day. The results are presented with much larger classes, to better show the variation in values over Europe. Less than 1000 l/cap/day is orange, less than 500 l/cap/day is red.

Uncertainties

Modeling rainfall-runoff and water use at the large scale to cover entire Europe will have uncertainties as a result of scale itself and gaps in data. Projecting water use and availability for future scenarios is uncertain by its very nature. Alcamo *et al.* (2000) provides more information on the uncertainties involved and their order of magnitude.

Validation
We make direct use of WaterGAP output, which has already been validated.

6.3 Results

6.3.1 Baseline scenario

See Figure 6.1. The areas with very low per capita domestic water availability are confined to isolated areas in northern Africa, Spain, Egypt, Western Asia and around London and Amsterdam. Largely European river basins have high amount of domestic water per capita.

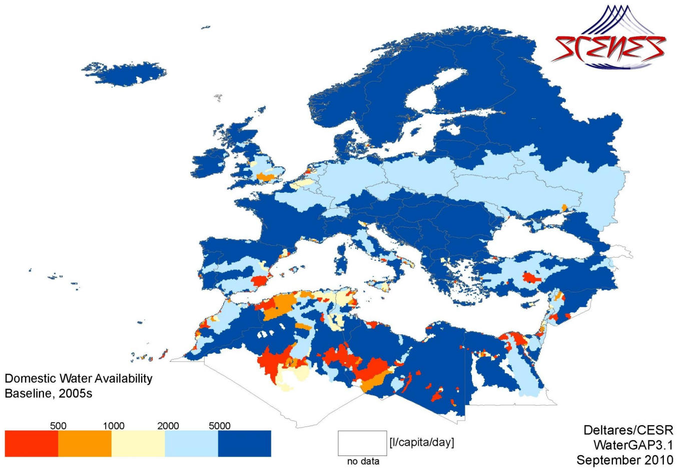

Figure 6.1. Domestic Water Availability under the baseline scenario.

6.3.2 Future scenarios

General pattern
See Figure 6.2 until 6.9. The general pattern for domestic water availability in Europe under the different socio-economic scenarios and the different climate scenarios is very comparable. The least water is available for domestic use in parts of the North African coast (Morocco, Tunisia, Libya), the Nile Delta, eastern Spain, Israel and central Turkey. In north and central Europe, generally, the highest amounts of water are available for domestic use. The most striking difference between the scenarios is the domestic water availability in the Nile Basin. Under the MIMR climate scenario water availabilities in this basin are higher than under the IPCM scenarios, for all scenarios but Fortress Europe. The availability in the North African coast is generally slightly higher under the IPCM scenario.

The variations in main driving forces for all scenarios is discussed below.

Water availability
Water availability is highest in Northern Europe. Northern Africa, the Iberian Peninsula, Greece, Turkey and Israel have generally a low water availability. Also in Eastern Europe water availability tends to be low. Both climate scenarios predict a decrease in water availability in the southern Mediterranean (Southern Spain, the Northern coast of Africa, Israel, Greece and Turkey. Under the IPCM climate scenario generally the changes in water availability from the baseline are more negative than from the MIMR scenario, especially in central and western Europe and the area around the Mediterranean Sea. However, the decreases in water availability in Northern Africa are higher for the MIMR scenario. Also the

water availability in the Nile basin decreases in the IPCM scenario, but increases in the MIMR scenario.

Consumptive use for agriculture and industry (economic sectors)
For industry, the future water consumption shows a similar pattern for all socio-economic scenarios. Most water will be used in the Nile Delta, the Benelux, England (around London), Germany and northern Italy. The least water will be used in Northern Africa, Scandinavia, eastern Europe and the Iberian Peninsula. This general pattern is most extreme for the Economy First and Fortress Europe scenarios. The least consumptive use can generally be found in the Policy Rules and Sustainability Eventually scenarios.

For agriculture, the future water consumption does not show such a clear pattern. It can be seen however that for all scenarios, the Nile Basin, Greece, Israel, northern Italy, parts of the North African coast and parts of Turkey have a high water consumption for agriculture. The least water consumption can be seen in northern Africa, Scandinavia and eastern Europe. This general pattern can be seen for the Policy Rules and Sustainability Eventually scenarios. For the Economy First scenario, also the Iberian Peninsula, parts of France, the Benelux and the area around London have a high water consumption. For the Fortress Europe, parts of France and Northern Germany will have a high water consumption for agriculture in addition to the general pattern.

Population
For all socio-economic scenarios, the general pattern of the distribution of the population in Europe is very much the same. The North-African coast (Morocco, Libya, Tunisia), the Nile basin and delta, Israel, western Europe (Northern France, Germany, the Benelux, England, northern Italy) and Portugal are very densely populated. Northern Africa, Scandinavia and eastern Europe are very sparsely populated. The differences between the socio-economic scenarios are small. Only under the Sustainability Eventually scenario the population in the more densely populated areas is lower than under the other scenarios.

Economy First
The least water is available for domestic use in parts of the North African coast (Morocco, Tunisia, Libya), the Nile Delta, Israel and central Turkey. In north and central Europe, generally, the most water is available for domestic use. The most striking difference between the climate scenarios is the domestic water availability in the Nile Basin. Under the MIMR climate scenario, the water availability is relatively high in this basin, and under the IPCM scenario the water availability is very low.

Fortress Europe
The least water is available for domestic use in parts of the North African coast (Morocco, Tunisia, Libya), the Nile Delta, Israel and central Turkey. In north and central Europe, generally, the most water is available for domestic use. The availability in the North African coast is slightly higher under the IPCM scenario.

Policy Rules
The least water is available for domestic use in parts of the North African coast (Morocco, Tunisia, Libya), the Nile Delta, Israel and central Turkey. In north and central Europe, generally, the most water is available for domestic use. The most striking difference between the scenarios is the domestic water availability in the Nile Basin. Under the MIMR climate scenario, the water availability is relatively high in this basin, and under the IPCM scenario the water availability is very low.

Sustainability Eventually

The least water is available for domestic use in parts of the North African coast (Morocco, Tunisia, Libya), the Nile Delta, Israel and central Turkey. In north and central Europe, generally, the most water is available for domestic use. The most striking difference between the scenarios is the domestic water availability in the Nile Basin. Under the MIMR climate scenario, the water availability is relatively high in this basin, and under the IPCM scenario the water availability is low. The availability in the North African coast is slightly higher under the IPCM scenario.

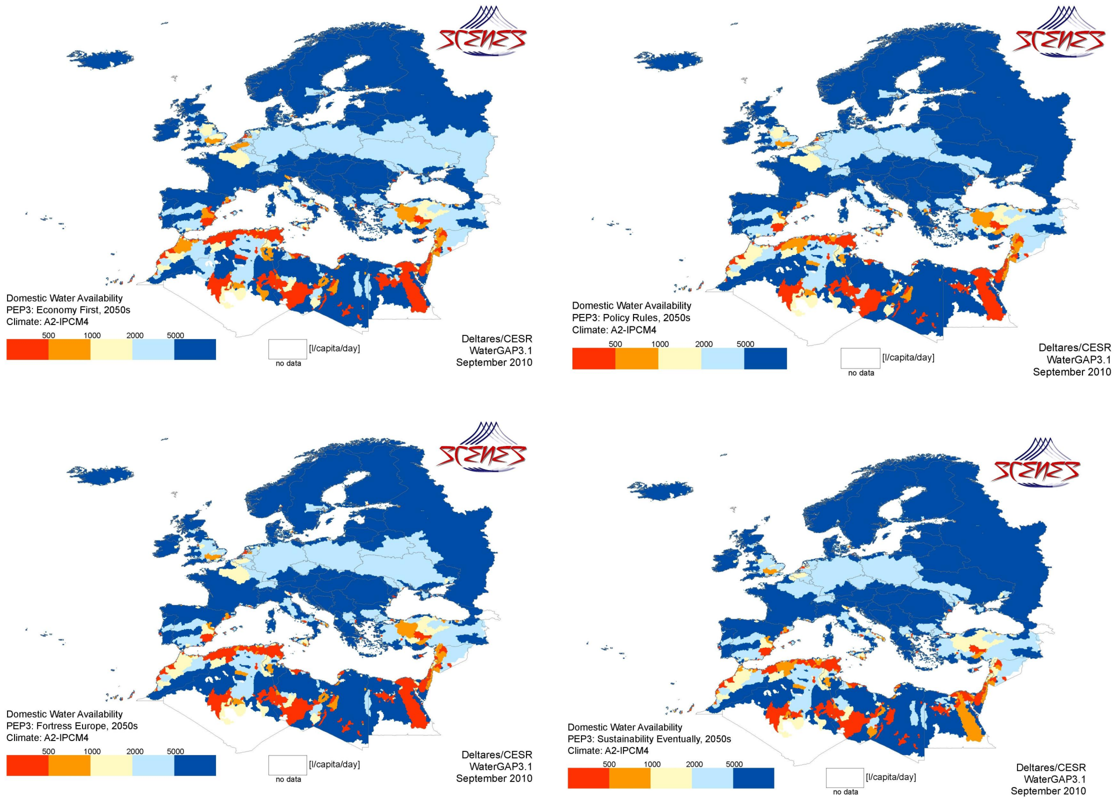

Figure 6.2 until 6.5 (from left to right). Domestic Water Availability under the IPCM scenario combined with the Economy First scenario (Figure 6.2), the Policy Rules scenario (Figure 6.3), the Fortress Europe scenario (Figure 6.4), and the Sustainability Eventually scenario (Figure 6.5).

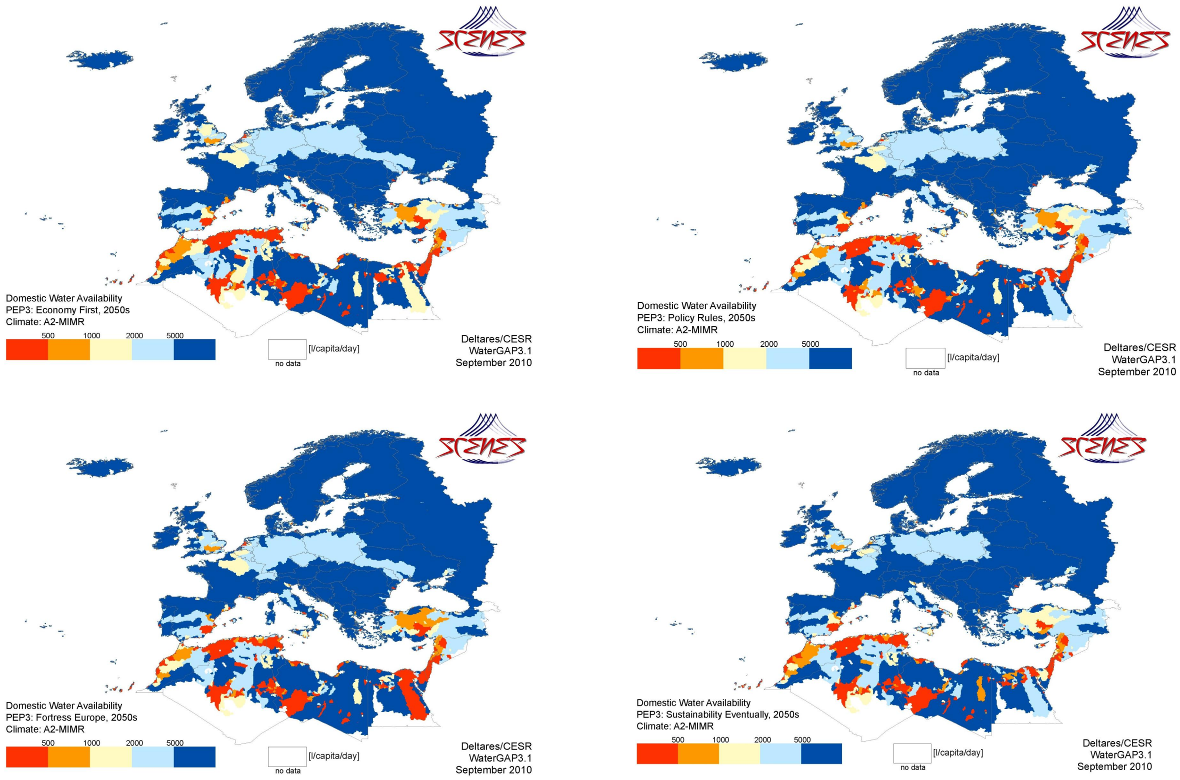

Figure 6.6 until 6.9 (from left to right). Domestic Water Availability under the MIMR scenario combined with the Economy First scenario (Figure 6.6), the Policy Rules scenario (Figure 6.7), the Fortress Europe scenario (Figure 6.8), and the Sustainability Eventually scenario (Figure 6.9).

6.4 Synthesis

Regional observations

Generally, domestic water availability shows the same pattern under all socio-economic and climate scenarios for 2050. Domestic water availability is high in north and central Europe, and low in the Nile delta, the North African coast, eastern Spain and Israel. The most striking differences are seen in the expectations for the Nile basin, and slight differences are seen in the expectations for the North African coast. For a summary of the observed changes in all regions, see Table 6.1.

Table 6.1. Regional impacts as deviation from the baseline scenario – domestic water availability

		Northern Africa	Western Europe	Northern Europe	Southern Europe	Central/Eastern Europe	Eastern Europe	Western Asia
IPCM	EcF	--	-	o	-	o	o	--
	FoE	--	-	o	-	o	+	--
	PoR	--	-	o	-	o	+	--
	SuE	--	o	o	-	o	+	--
MIMR	EcF	--	-	o	o	o	+	--
	FoE	--	-	o	o	o	+	--
	PoR	-	-	o	o	o	+	--
	SuE	-	o	o	o	o	+	--

Climate change and socio-economic changes

The driver influencing the pattern of water scarcity indices the most is not easy to derive, as all drivers show problems in generally the same areas. Therefore, it is not clear if this indicator is influenced more by climate change or by socio-economic changes.

Future projections

The projected changes show largely the same general pattern for all socio economic scenarios. It can therefore be concluded that it is likely that in Europe, in the future, domestic water availability is likely to be distributed over Europe the way it is expected. However, in southern and western Europe it is more unclear what is going to happen, as the socio-economic scenarios and climate scenarios expect other developments in these regions.

6.5 References

Alcamo, J., Henrichs, T., Rösch, T., 2000. Wordl water in 2025 – Global modeling and scenario analysis for the World Commission on Wate rfor th e21st century. Report A0002, Center for Environmental Systems Research, University of Kassel, Kurt Wolters Strasse 3, 34109 Kassel, Germany.

7 Key messages

Based on the findings for the generic indicators, this Chapter provides an answer to three general questions:

- What is the overall image per region?
- Are there big differences between regions?
- Can socio-economic changes (SE) or climate changes (CC) be identified as dominant driving forces of these changes?

To answer these questions the analysis for all scenarios is aggregated into an indication per indicator and per region of where the focus lies (positive, negative, no change, or a combination) and what the uncertainty is with respect to future changes (do the different scenarios point in the same direction or not) as presented in Table 7.1.

In Table 7.1, the indicators are grouped slightly differently and the main input data are included as well:

- Climate-driven input:
  - Mean annual runoff
  - Flood hazard
- Socio-economic driven input:
  - Population
  - GDP
- Indicators in which climate change and socio-economic change have been combined:
  - Domestic water stress
  - Domestic water availability
  - Risk for harmful algal blooms
  - Flood risk – population-based
  - Flood risk – GDP based

What is the overall image per region?

Northern Africa
Overall result: strongest indication of degradation, but as for this region for one driver and 3 indicators values are missing, it is not possible to draw further conclusions from this result. It is therefore also not possible to determine whether for the total result CC or S-E is dominant.

Western Europe
Overall result: In Western Europe results for different scenarios range from negative impacts for the entire region to positive impacts for the entire region. The emphasis is however slightly on negative impacts.

Northern Europe
Overall result: The results for northern Europe show that this area becomes wetter: mean annual river flow increases. Even though population and GDP increase, domestic water stress and domestic water availability decrease. GDP based flood risk increases, but the population based flood risk is expected to decrease.

Region	Climate				Socio-economic				Impacts									
	Mean annual river flow		Flood Hazard		Pop.		GDP		Dom. Water Stress		Dom. Water Avail.		Risk for HABs		FR-GDP		FR-pop	
	Focus	Uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty	Focus	uncertainty
N. Africa	-/+	M							o/-	M	--	L						
W. Europe	-	M	-	L	+/-	M	++	M	o	L	-	L	+	L	-	M	-	L
N. Europe	++	L	-	L	++	M	++	L	o	L	o	L	+	L	--	L	+	M
S. Europe	-	M	-	L	++	M	++	L	o	L	o/-	M	+	L	--	L	-/+	H
C/E. Europe	-/+	H	0	L	++	L	++	M	o	L	o	L	o or +	M	-	M	+	L
E. Europe	-/+	M	0	M	++	L	++	M	o	L	+	L	+	L				
W. Asia	--	L	-/+	M	++/--	H	++	L	o	L	--	L	- or +	M				

Southern Europe

Overall result: Water availability in this region in the future is likely to decrease. However, even although population and GDP increase, the domestic water stress and domestic water availability are not expected to change much. Overall, flood risk is mainly expected to decrease.

Central/Eastern Europe

Overall result: The development of water availability in this region is highly uncertain. But even though population and GDP increase, the domestic water stress and domestic water availability are not expected to change much. GDP-based flood risk is expected to increase, whereas population based flood risk is expected to decrease.

Eastern Europe
Overall result: Water availability in this region is likely to increase, as well as domestic water availability, even though population is expected to grow. Domestic water stress is not expected to change much.

Western Asia
Overall result: Mean annual water availability is likely to decrease throughout this region, resulting in a decreasing domestic water availability. Domestic water stress is expected to remain largely unchanged. If population is growing or declining in this region is uncertain.

Are there big differences between regions?
Table 7.1 shows that for some indicators, such as domestic water stress, most regions experiences hardly any change. For domestic water availability the changes, and also the differences between regions are more pronounced. Selected location in western and southern Europe, the Middle East and Northern Africa may experience shortage for domestic water use. In reality the situation is likely to be less severe, because domestic water use is not expected to have the lowest priority. This also means that for those regions where no domestic water shortage problem is indicated for this worst-case scenario, there is indeed very little chance that such a problem may occur in the future.

When based on GDP, the flood risk situation degrades for most regions, However, when based on population numbers, the opposite is the result: a decrease in flood risk for all regions, except western Europe.

The water quality situation degrades for all regions except northern Europe and is rather constant across scenarios.

Can socio-economic changes or climate changes be identified as dominant driving force of these changes?
Table 7.2 summarises whether climate change (CC) or socio-economic change (SE) seems dominant.

Table 7.2 Dominant driving force per indicator

Indicator/driver	**CC or SE?**
Domestic Water Stress	SE
Domestic Water Availability	SE/CC
Risk harmful algae blooms	SE/CC
Flood Risk – GDP based	SE
Flood Risk – population based	SE