5 EUROPE'S WATER STRESS TODAY AND IN THE FUTURE

Thomas Henrichs*, Joseph Alcamo
Center for Environmental Systems Research, University of Kassel, Germany
*henrichs@usf.uni-kassel.de

5.1 Introduction

A recent assessment of Europe's environment by the European Environment Agency warns that high levels of water stress, i.e. pressure on both quantity and/or quality of water resources, exists in many places throughout Europe and identifies several significant continuing pressures on water resources on the European scale (Stanners and Bourdeau, 1995). Growing demand for water in the domestic, industrial, and agricultural sectors has led to increased withdrawals, and may lead to even higher withdrawals in the future. At the same time climate change may reduce water availability at some locations.

In this chapter, we examine more closely the water stress situation in European river basins applying the global integrated WaterGAP model. First, the current situation (Section 5.2) of water availability and water withdrawals is compared, and resulting stress on water resources is characterized. In this study, to compare the level of water stress in different river basins we make use of the widely applied *withdrawals-to-availability (w.t.a.)* ratio. A river basin's w.t.a. ratio is defined by dividing annual water withdrawals (i.e. withdrawals within the basin including withdrawals in all upstream subbasins) by annual water availability. In principle, the higher this ratio is, the more intensively water in a river basin is used, and hence the more stress is placed on water resources due to water extraction. We employ commonly used thresholds (e.g. Raskin, 1997; Cosgrove and Rjisberman, 2000) to identify river basins under *low* (w.t.a. ≤ 0.2), *medium* ($0.2 <$ w.t.a. ≤ 0.4) and *severe* (w.t.a. > 0.4) water stress. Based on this description of the present-day state, the implications of the Baseline-A scenario (as introduced in Chapter 4) related to the future water stress situation are discussed (Section 5.3).

For the studies presented within this chapter, the global integrated water model WaterGAP is applied in its version 2.1. A detailed model description is provided in Chapter 2 of this report.

5.2 Europe's water stress today

5.2.1 Water availability

There is a large spatial variability in water availability (here: the annual long-term average renewable water resources, derived from natural discharge without subtraction of consumptive water use) of river basins in Europe. Figure 5.1.a shows that annual water availability ranges between well above 1000 mm/yr (Western Norway, Britain's West Coast, Southern Iceland) to below 100 mm/yr (parts of Spain, Sicily, large parts of the Ukraine, Southern Russia, large parts of Turkey). In most parts of Europe this reflects current patterns of precipitation – while in other parts discharge is carried through streams into more arid regions (Hungary, for example, receives most of its water from outside the country borders through the Danube river). This is accounted for in the WaterGAP model via its lateral routing scheme.

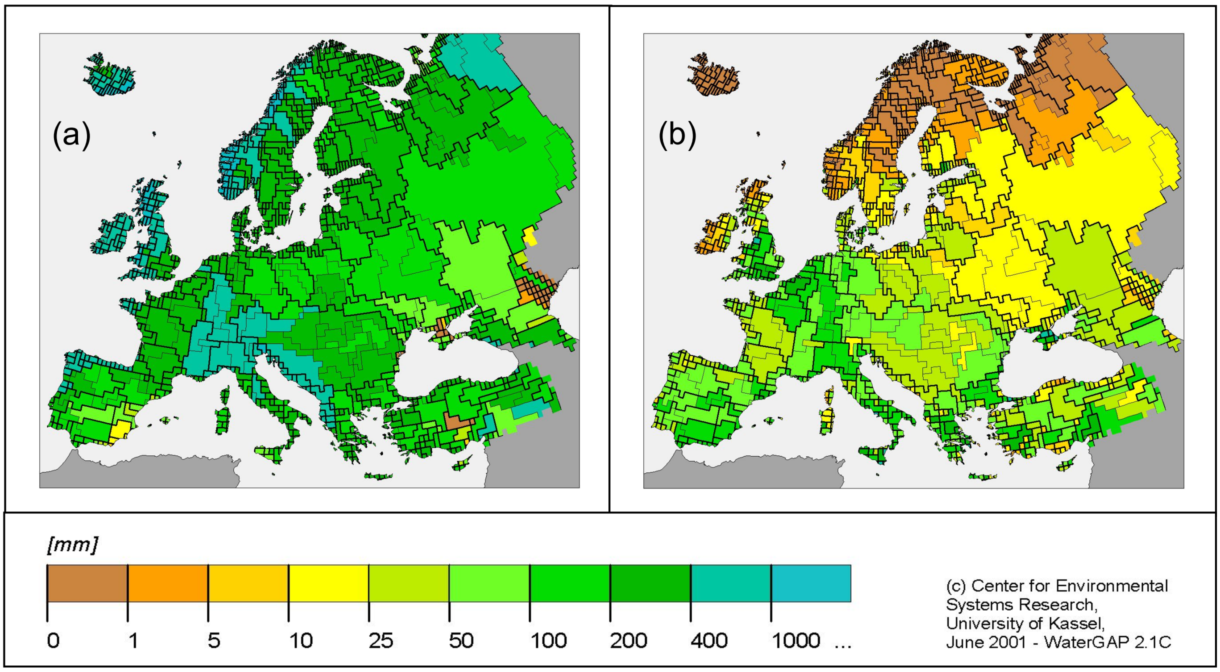

Figure 5.1: WaterGAP 2.1 computations for: (a) Average annual water availability in European river basins based on the 30-year climate time series 1961-90. (b) Average annual water withdrawals from European river basins in 1995. Both availability and withdrawals are aggregated for a subbasin (thin lines) by accumulation over its respective total upstream area within the larger basin (bold lines).

5.2.2 Water withdrawals

During the last decades, total water withdrawals in Europe have, in general, increased. By 1995, a total of about 476 km^3 water was withdrawn annually – 45% of this water is used for industry, 41% for agriculture, and 14% for domestic needs (Shiklomanov, 1997). There is a huge difference between countries in how much water is withdrawn and for what purposes. The needs of industry dominate water withdrawals in most of Europe, while the share of irrigation is highest in Southern and South-Eastern European countries with low precipitation. Total withdrawals per river basin (Figure 5.1.b) range from nearly zero (in the thinly populated areas of sub-polar Scandinavia and Russia) to well above 400 mm/yr (in the most densely populated urban regions).

5.2.3 Water stress

Here, the level of water stress is characterized by the withdrawals-to-availability (w.t.a.) ratio. Figure 5.2 provides an overview of the current situation utilizing this common water stress indicator for European river basins, calculated from the results of the WaterGAP model as presented in Figure 5.1. River basins identified to be experiencing severe water stress are - among others - the Don, the Seine, the Meuse, the Thames, as well as most river basins in Southern Italy, Spain, Greece, and Turkey. All in all, about one fifth of European river basin areas are classified as being under severe water stress.

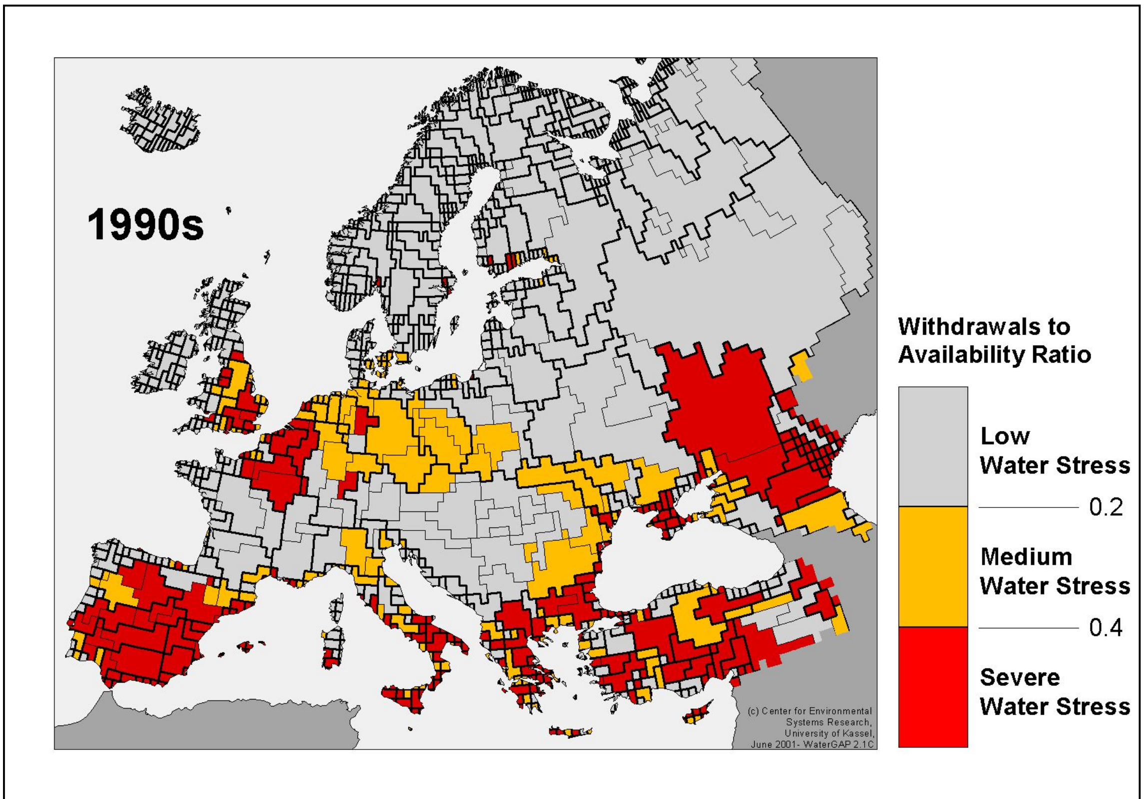

Figure 5.2: Water stress in Europe for today’s situation. Water stress is defined by the withdrawals-to-availability ratio.

However, river basins may be in the severe water stress category for very different reasons. In Southern Spain, for example, there are considerable amounts of river water extracted for irrigation purposes in rather dry regions with low water availability. In low flow periods these relatively high levels of water consumption involve a threat of absolute water shortages. Conversely, very high demand of water for industrial use and in households may put a high pressure on both water quality and quantity in otherwise water rich river basins. Recent meteorological drought years in the Thames basin, for example, have prompted supply to fall below unrestricted demand, and thus led to water shortages. Although the w.t.a. indicator cannot distinguish these different aspects of water stress, it still gives a clear signal of severe water stress in both cases mentioned above. Thus, the w.t.a. indicator gives a good first impression of where water resource systems are under notable pressure.

5.3 Europe's water stress in the future

5.3.1 Water availability

In its most recent assessment the IPCC warns that "projected climate change could further decrease streamflow and groundwater recharge in many water-stressed countries" (IPCC 2001). Furthermore, the IPCC highlights that the effect of climate change on water availability will vary regionally and among scenarios, largely following projected changes in precipitation. As noted in Chapter 4, there are significant variations in the projected changes between different climate models. In order to give an impression of the induced uncertainties, we present the implications of two different General Circulation Models (GCMs) (ECHAM4 and HadCM3, for further details see Chapter 4) on water availability as computed by the WaterGAP model.

Figure 5.3 shows WaterGAP projections of mid-term (2020s) and long-term (2070s) changes in water availability. Relatively small changes in water availability are computed for most of Europe's river basins until the 2020s. Here, using climate output from different GCMs leads to contradictory results in some parts of Europe, with the most significant contrast in Southern Spain: Climate data from ECHAM4 suggests a decrease in water availability, whereas climate data from HadCM3 results in an increase. Notably, the trend for Southern Spain under HadCM3 climate projections reverses in time, and by 2070 also leads to a decrease in water availability. In general, long-term changes in annual renewable water resources are found to be more pronounced – in some regions being as high as 50% and more (both increases and decreases). Especially the Mediterranean is subjected to high decreases. Conversely, nearly all of Northern Scandinavia and Northern Russia (including the Volga basin) display an increased average annual water availability under both GCM realizations. Despite their differences, WaterGAP results based on both GCM projections agree that climate change will increase water availability in Northern and North-Eastern Europe and decrease it in large parts of Southern and South-Eastern Europe. In this overall tendency the results presented here agree with the recent findings of the ACACIA study (Parry, 2000).

Projected changes in water availability can differ considerably from projections of changes in rainfall (compare Figures 4.1 and 5.3). In most of Europe the effect of decreasing or increasing precipitation is amplified significantly. For example, decreasing precipitation in Southern Europe is accompanied by increasing temperature, and thus increasing evapotranspiration – combining these trends results in even stronger decreases in availability than would be expected from considering precipitation changes only. Other non-linear processes are responsible for the situation in Northern Europe (e.g. increased precipitation on saturated soils leads to more than a linear rise in discharge). These effects indicate that in assessing future water availability it does not suffice to analyze changes in rainfall only, but that other factors are bound to be just as influential.

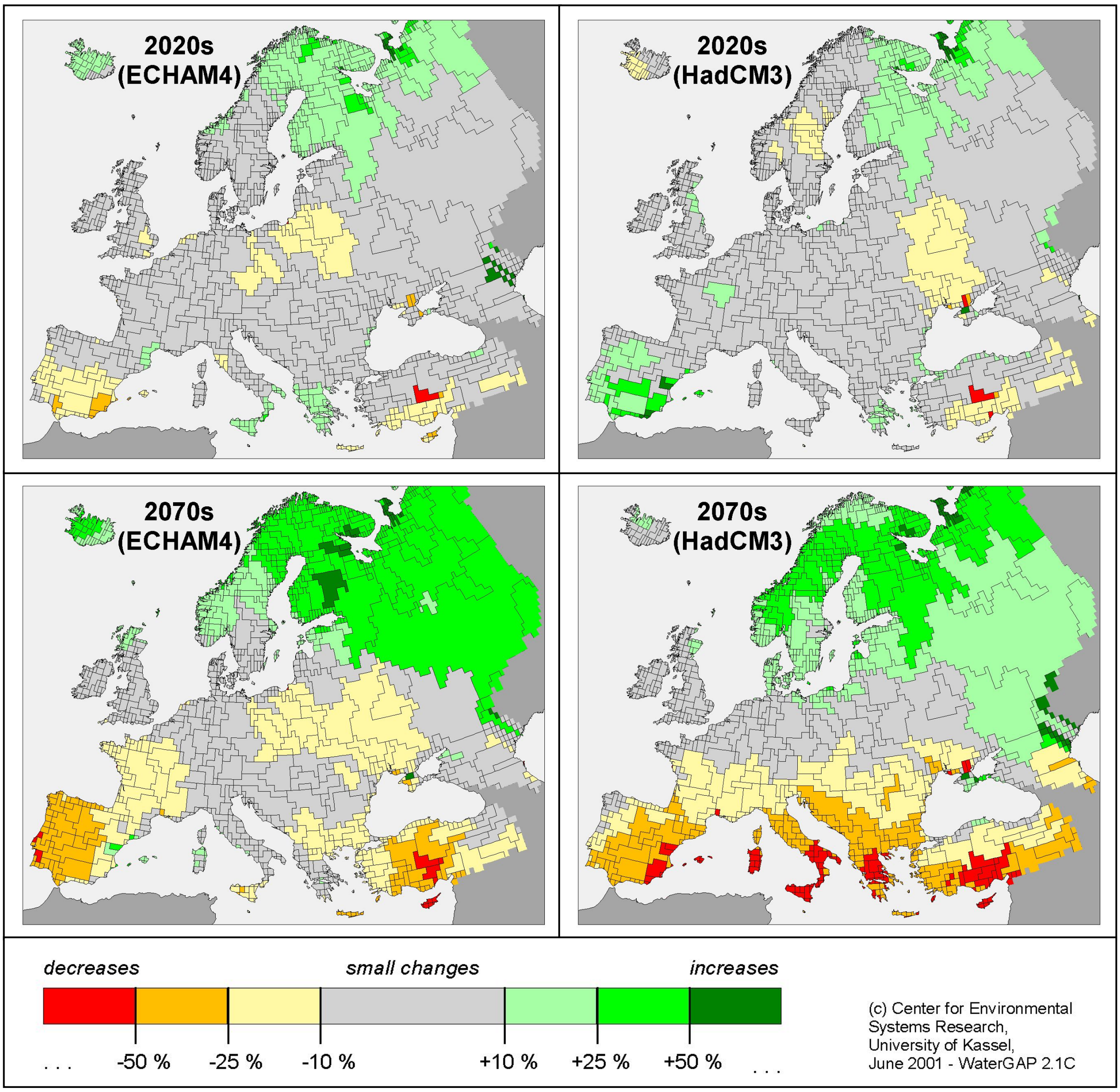

Figure 5.3: Percentage change in average annual water availability (natural discharge without subtraction of consumptive water use) for European river basins as compared to today's levels, realized with two different GCMs (ECHAM4 and HadCM3) for the 2020s and the 2070s.

5.3.2 Water withdrawals

The Baseline-A scenario leads to a marked difference in the development of water withdrawals between Western and Eastern Europe; Figure 5.4 and Table 5.1 highlight this development. For most of Western Europe the scenario leads to decreases in total withdrawals in the first half of the 21st century. Still, until the 2020s, small increases are seen in Ireland, France, and the United Kingdom. These increases result from assumed increases in population in these countries which lead to increased demands in the domestic sector. In the long-term (i.e. until the 2070s) these increases in the domestic sector are outweighed by decreases in industrial water abstractions, due to projected decreases in water use intensity for this sector.

For the rest of Western Europe, reductions in total water withdrawals are computed nearly everywhere. These reductions stem mainly from technological changes which increase efficiency of water use in the industrial sector. Additionally, water abstractions for domestic needs decrease slightly in many Western European countries under the analyzed scenario.

In Eastern Europe, on the other hand, the Baseline-A scenario leads to large increases in water withdrawals, as a consequence of high increases in demand for water in both the domestic and the industrial sector. Especially abstractions for industrial purposes are assumed to rise sharply as a result of the large increases assumed in electricity production (which is assumed to grow by more than a factor of six in total, see Chapter 4). In total, water withdrawals in Europe (excluding Turkey) are projected to rise from today's 415 km^3 to about 660 km^3 per year until the 2070s in the Baseline-A scenario. While annual total withdrawals in Western Europe decrease from 236 km^3 to 191 km^3, they rise considerably in Eastern Europe and the European CIS from 180 km^3 to 469 km^3.

The reader should be reminded that these projections are based on one feasible set of assumptions only. As this particular set of assumption presumes high increases in thermal electricity production in Eastern Europe compared to today's level, increases in water withdrawals are computed to be very high. While this set of assumptions is as legitimate as any other projection of the development of socio-economic driving forces, we note that other equally feasible projections are possible, some of which may lead to somewhat lower water withdrawals in Eastern Europe. Still, even if the magnitude of changes may be contested, generally strong growth in water demand is likely to accompany economic and industrial development.

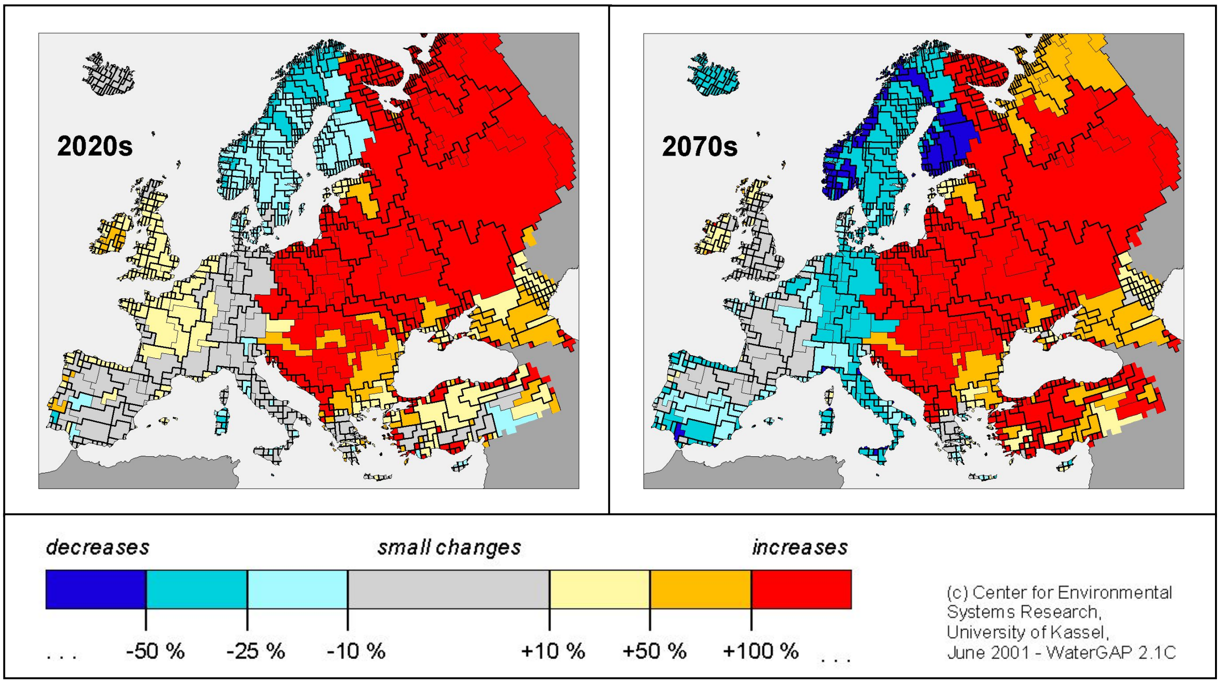

Figure 5.4: Percentage change in annual total water withdrawals for European river basins under the Baseline-A scenario assumptions compared to today's levels, realized for the 2020s and 2070s. (Note that water withdrawals for agriculture are based on climate data of HadCM3 for the respective period.)

Table 5.1: Water withdrawals [km^3/yr] in Europe by sector today (1995) and in the 2070s under the Baseline-A scenario.

World-region (*)	Withdrawals today (1995)				Withdrawals in the 2070s (Baseline-A)			
	Domestic	Industrial	Irrigation	***Total***	Domestic	Industrial	Irrigation	***Total***
Western Europe	41	118	76	***235***	48	69	74	***191***
Eastern Europe	10	32	33	***75***	27	164	36	***227***
European CIS	15	57	33	***105***	80	126	36	***242***
Europe	**66**	**207**	**142**	***415***	**155**	**359**	**146**	***660***

(*) World-regions are here defined as follows:
Western Europe: Belgium, Denmark, France, Finland, Germany, Greece, Iceland, Ireland, Italy, Malta, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom.
Eastern Europe: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia, Slovenia, Yugoslavia.
European CIS: Belarus, Estonia, Latvia, Lithuania, Moldova, Ukraine, European part of Russian Federation.
Note that **Turkey** is not included in this table; this is due to lack of consistent historical and scenario driving force data making the estimates for Turkey less meaningful.

5.3.3 Water stress

In discussing future levels of water stress, the effects of changing water availability due to climate change and changing water withdrawals have to be brought together, as they are bound to be complementary in some parts of Europe and contrary in others. Figure 5.5 shows the combined implications of the Baseline-A scenario with HadCM3 climate projections. Results indicate decreasing pressure on water resources in large parts of the Scandinavian countries, due to combined effects of decreasing withdrawals and increasing availability. Also, most of the Benelux countries and Germany see decreasing water stress mainly due to reduced water withdrawals, as water availability is only slightly changed. Conversely, water stress increases in most of Spain and large parts of Southern France, often despite smaller water withdrawals. In these river basins the effects of decreasing water availability due to climate change dominate the overall trend. This may be particularly important, as many river basins on the Iberian peninsula are already regarded to be under severe water stress. Also, most of Eastern Europe faces increases in the level of water stress, primarily because of projected growths in water withdrawals. In South-Eastern Europe this growth in water demand is complemented by reductions in water availability due to climate changes, which enhances the increases in water stress.

In total, European river basin area in the severe water stress category increases from 19% today to 34-36% by the 2070s (depending on the climate scenario). Figure 5.6 shows that most of the river basins regarded today to be experiencing high levels of water stress remain in the highest stress category under the scenario projections. Additionally, many Eastern European river basins are lifted into the highest water stress category. As noted above, it should be kept in mind, that these increases in water stress are rather sensitive to the assumption of a very high increase in the extraction of cooling water for thermal power generation throughout Eastern Europe. But although these results are based on one set of scenario assumptions only, they show that socio-economic development and industrial growth can have the same magnitude of impact on water stress as climate change.

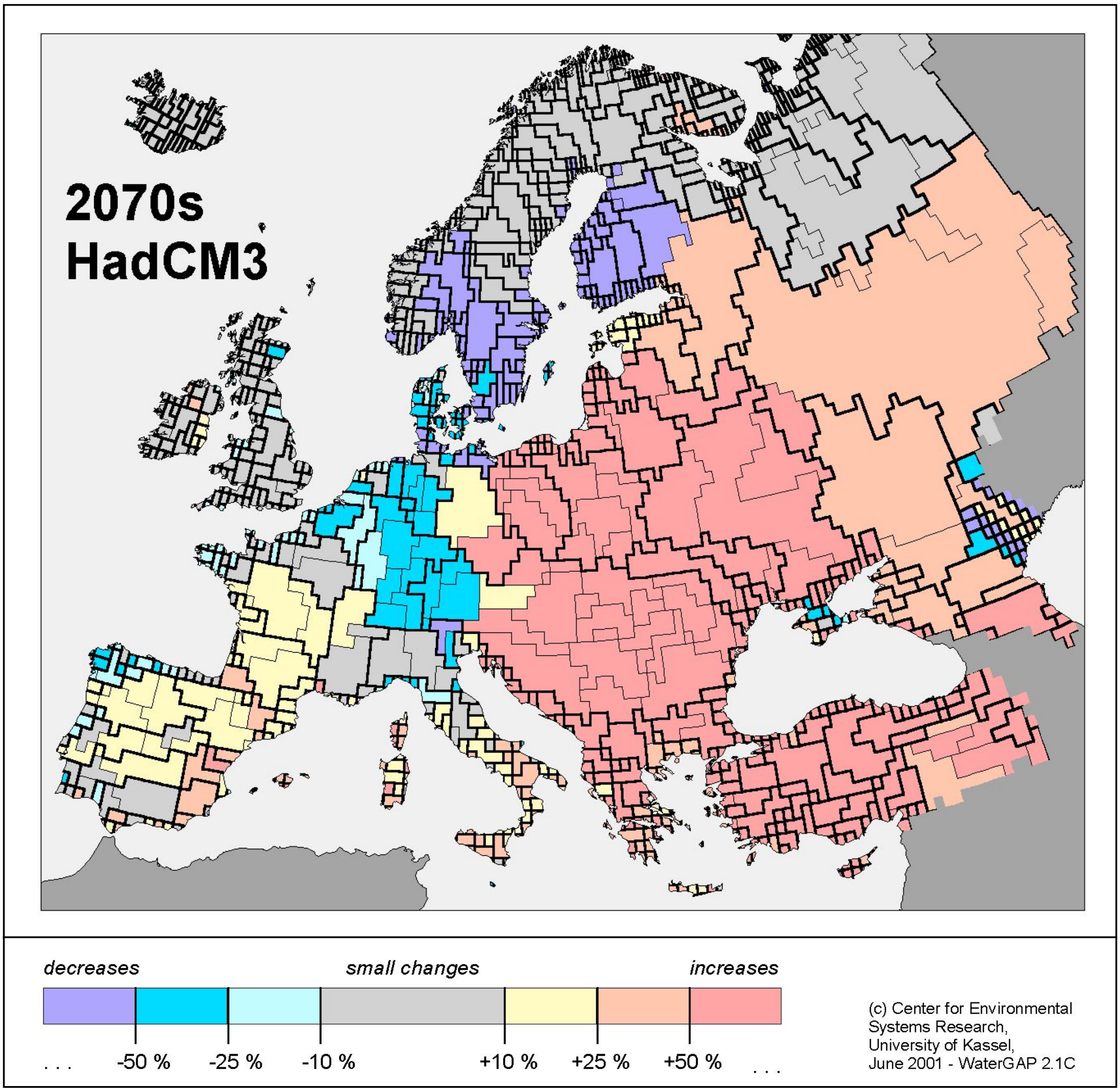

Figure 5.5: Long-term projection of changes in water stress in Europe under the Baseline-A scenario (with climate data of HadCM3) scenario between today and the 2070s. Combined changes in water availability and water withdrawals are aggregated for a subbasin (thin lines) by accumulation over its respective total upstream area within the larger basin (bold lines).

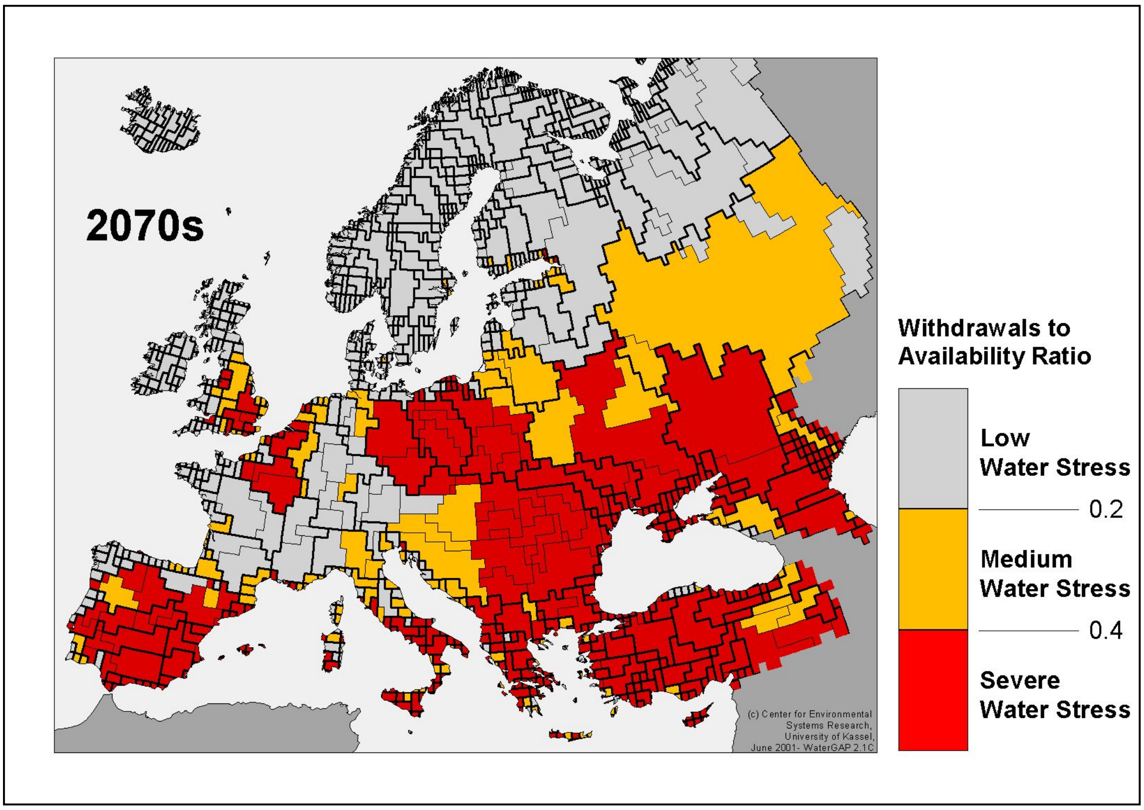

Figure 5.6: Water stress in Europe in the 2070s under the Baseline-A scenario (with climate data of HadCM3). Water stress is defined by the withdrawals-to-availability ratio.

5.4 Conclusions

We presented an integrated analysis of global change impacts on European river basins, that brings together projected changes in both water withdrawals and water availability in a consistent manner. While preliminary, this study indicates several important trends that will influence future changes in water stress in Europe:

- Despite their differences, two different state-of-the-art climate models indicate that annual water availability generally increases in Northern and North-Eastern Europe and decreases in Southern and South-Eastern Europe. This overall trend agrees with the general findings in other recent studies (e.g. Parry, 2000; IPCC, 2001)
- Projected changes in water withdrawals strongly depend on the assumptions regarding economic and industrial growth. Following a common set of assumptions we result in very different trends in water withdrawals for Western and Eastern Europe. Withdrawals tend to decrease in the long-term in Western Europe, mainly resulting from gains in the efficiency of water use. In Eastern Europe withdrawals are projected to increase strongly, particularly due to growing demand for cooling water in thermal electricity production.

- When trends in water availability and water withdrawals are combined, pressure on water resources increases sharply in most of Eastern Europe. This increase lifts many Eastern European river basins into the high water stress category. Additionally, those river basins in Western Europe under high water stress today remain in this category despite reductions in water withdrawals. In Europe as a whole, this leads to a significant increase in river basin area under high water stress, from one-fifth under present-day conditions to about one-third for the 2070s.

It has to be noted, however, that the presented scenario results are very sensitive to the socio-economic driving forces assumed. Therefore, using a different set of scenario driving forces for the domestic, industrial, or irrigation sectors may lead to very different results for water use. For a more complete picture it is worthwhile to repeat this analysis with a wider range of scenario assumptions.

Overall, the assessment presented here confirms that the impacts of societal, economic, and industrial development on water resource systems may be of the same order of magnitude as changes in water availability due to climate change. Therefore, the analyses of future global change impacts upon the water sector should take into account not only changes in climate but also changes in socio-economic driving forces.

5.5 References

Cosgrove, W. J., Rjisberman, F. R. (2000): World Water Vision - Making Water Everybody's Business, Earthscan Publications Ltd., London, U.K.

EEA (European Environment Agency) (1999): Environment in the European Union at the turn of the century - Environmental Assessment Report No.2, European Environment Agency, Copenhagen, Denmark.

IPCC (Intergovernmental Panel on Climate Change) (2001): Climate Change 2001: Impacts, Adaptation, and Vulnerability - A Report of Working Group II of the IPCC. Cambridge University Press, Cambridge, U.K.

Parry, M. (ed.) (2000): The Europe ACACIA project: Assessment of Potential Effects and Adaptations for Climate Change in Europe, Jackson Environment Institute, Norwich, U.K.

Raskin, P., Gleick, P., Kirshen, P., Pontius, G., Strzepek, K. (1997): Water Futures: Assessment of Long-Range Patterns and Problems. Stockholm Environment Institute, Box 2142, S-103 14 Stockholm, Sweden, Stockholm, Sweden.

Rjisberman, F. R. (2000): World Water Scenarios: Analyses, Earthscan Publications Ltd., London, U.K.

Shiklomanov, I. (1997): Assessment of Water Resources and Water Availability of the World, Stockholm Environment Institute, Box 2142, S-103 14 Stockholm, Sweden, Stockholm, Sweden.

Stanners, D., Bourdeau, P. (1995) : Europe's Environment - The Dobris Assessment , Earthscan Publications, London, U.K.