# 1 INTRODUCTION

Water is a vital need of society, but it is not an easy need to satisfy. In particular, the fluctuation of precipitation from season-to-season and year-to-year means that there is often either too little water for its needs or too much to contain within the banks of a river. But over the scale of several decades both society and aquatic ecosystems are usually adapted fairly well to expected fluctuations, in that towns are usually built above the elevation of frequent floods and the sources of water supply do not frequently run dry. Of course society also uses many other strategies to cope with "normal" climate fluctuations such as by storing water in reservoirs, or constructing dikes to protect cities from periodic floods.

But climate change related to greenhouse gas emissions has changed the situation. Now it is conceivable, if not likely, that the build-up of greenhouse gases in the atmosphere will lead to major shifts in the spatial and temporal patterns of precipitation and temperature in Europe and elsewhere in the world over the next several decades. Figure 4.1 in this report shows, as an example, the changes in annual average precipitation in the 2020s and 2070s according to two different credible scenarios compared to the "climate normal" period (1961-90). Here annual average precipitation changes from about –25% to +25% depending on location. Climate modeling results also show that it is likely that climate change will alter the fluctuation of rainfall and other climate variables, that is, a change in the frequency or intensity of dry and wet periods (IPCC, 2001).

In the light of these climate changes, Europe needs to re-examine its current strategies for dealing with the fluctuations of climate. Important questions are: In which regions will average changes in water withdrawals and water availability significantly increase water stress? And in which "critical regions" of Europe might changes in the frequency and intensity of droughts and floods require new adaptive measures? These questions are addressed by the "EuroWasser" project whose findings are given in this report. EuroWasser was carried out by the Center for Environmental Systems Research at the University of Kassel, Germany and was financially supported by the Ministry of Education and Research of the Federal Republic of Germany.

Compared to other studies, the EuroWasser project has several unique features:

- Previous climate impact studies have focused either on the impacts of changes in the occurrence and intensity of extreme climate events such as droughts and floods over small areas, or the impact of average changes over large areas (as in the case of the ACACIA study; Parry, 2000). In this study we examine the impacts of changes in extreme climate events over a large area, namely continental Europe with about 10.5 million km$^2$.
- Studies up to now have usually focused on the impact of too little water (drought) or too much (floods), whereas in this study we examine changes in frequency and intensity of both. This study presents the first continental estimates of changes in intensity and

frequency of droughts and floods under climate change and under changes in water withdrawals.

- Most studies have focused either on the impacts of climate change on water availability or the impact of changes in society on water use. Here we examine the impacts of both on Europe's water resources.

This study takes an "integrated assessment approach", meaning that information from various disciplines is drawn together and linked in a unified analysis. Furthermore, integrated assessment implies a link between science and policy, and we make this link by pointing out the regions in Europe where new adaptive policies may be needed to contend with climate-related changes in water resources. Scenario analysis is also used to evaluate "if – then" propositions – If climate changes according to a particular climate scenario, then how might the occurrence of droughts and floods change?

Another key aspect of our approach is that we use a global water assessment model called "WaterGAP" for obtaining a synoptic, long-term view of changes in Europe's water resources. The WaterGAP model provides quantitative estimates of water withdrawals and water availability (defined as the sum of annual average river discharge and groundwater recharge) for Europe with a spatial resolution of 0.5° latitude by 0.5° longitude (in Europe approx. 30 km by 50 km), and over a long time horizon (1901 to 2100). The model consists of two main components – a Global Water Use Model and a Global Hydrology Model – which are applied to compute water use and availability on the river basin level.

In Chapter 2 a detailed description of WaterGAP's model version 2.1, which is applied for all EuroWasser calculations, is provided. Thereafter, the following main questions are targeted:

- What is the performance of the WaterGAP model as compared to higher resolution hydrological models? (Chapter 3)
- What is a credible scenario for future climate and global change in Europe? (Chapter 4)
- What is the current situation of water stress in Europe's rivers and how will water stress change in the future? (Chapter 5)
- Will floods become more frequent? (Chapter 6)
- Will droughts occur more often? (Chapter 7)
- Will the potential to generate hydroelectricity be affected by climate change? (Chapter 8)

As some of these questions, to the authors' knowledge, have not been addressed in previous research, new approaches are considered and new concepts developed. Here the main goal of the EuroWasser project is to provide a comprehensive view over for the whole of Europe rather than to investigate single basins.

Finally, Chapter 9 reviews the results of the EuroWasser study, points out some inherent uncertainties, gives an outlook on future work and draws some final conclusions and recommendations.