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Modelling scenarios as a link between research and policy making

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Abstract: The aim of the ClimWatAdapt project was to support EU policy development regarding adaptation strategies. This paper presents some of the results related to water scarcity and highlights the importance of scenario applications in this context. Within this study, an impact assessment for the summer season (June, July, August) was conducted by using different indicators based on existing hydrological and water use scenarios. To cover a range of uncertainty, an economic-oriented (Economy First) and sustainability-targeted (Sustainability Eventually) scenario was selected together with an ensemble of climate input. Based on the water scarcity results, the potential of water savings were analyzed. Overall, Europe’s future vulnerability to water scarcity is more dependent on socio-economic developments than on climate change impacts. Southern and South-Eastern Europe is still likely to suffer from water scarcity during summer, primarily caused by agricultural water use as indicated by both scenarios. Even a substantial decrease in water withdrawals as simulated for the Sustainability Eventually scenario will not prevent water scarcity in some regions. In the Economy First scenario, additional water stress appears mainly due to the rise in thermal electricity production and a decrease in Q90 in western parts of Eastern Europe. In order to reduce water stress, adaptation measures and policies are required in Europe, in particular Southern and Western Europe. Most water saving obligations are related to irrigation and thermoelectric power production. However, in approximately half of the vulnerable river basins an integrated multi-sectoral approach is needed. Therefore, adaptation should not be discussed in isolation and the focus of any policy intervention should be on socio-economic drivers, such as land use and production patterns. Technical measures that mainly aim at maintaining the current state or are trying to reduce the impacts are not sufficient to save water and to reduce vulnerability to water scarcity in the future.

Keywords: adaptation; climate change; EU policy; scenario analysis; water scarcity

1 INTRODUCTION

Floods, droughts, and water scarcity have already affected large parts of the European Union and have an important impact on socio-economic developments [EEA 2010]. In the future, climate change is likely to alter water availability and will probably increase both the frequency and magnitude of hydrological extremes [Ludwig et al. 2009]. Simultaneously, water use is expected to change due to a combination of changing environmental and socio-economic drivers as well as policy and technology responses. Furthermore, annual river flows are projected to
decrease in many parts of Southern and South-Eastern Europe [Arnell et al. 2011, Feyen and Dankers 2009] and increase in Northern and North-Eastern Europe [Dankers and Feyen 2008]. Overall, strong changes in seasonal run-off are projected with lower flows in the summer (except in North-Eastern and Western Europe) and higher flows in the winter. Consequently, droughts and water stress will increase in particular in the summer season. Here, the most drought prone areas are Southern and South-Eastern Europe.

Hence, water scarcity can be both a natural and human-made phenomenon and defined as the point where there are insufficient water resources to satisfy long-term average requirements. In other words, it refers to long-term water imbalances, combining low water availability with a level of water demand exceeding the supply capacity of the natural system [EC 2011].

The future management of Europe’s freshwater resources needs to take into account these changes in water availability and water use. Even if research and development activities on climate change adaptation have rapidly expanded over the last decade, still many policy makers struggle with climate change adaptation. Especially the large uncertainty about the impact of climate change remains a major concern. The EU’s White Paper “Adapting to climate change: Towards a European framework for action” calls for adaptation actions to deal with unavoidable impacts. In order to develop adequate adaptation measures, regions and sectors impacted by climate, socio-economic, political, and environmental changes must be identified. In this respect, scenario development and analysis helps to explore what might happen over the next half century and it therefore is an important method for flexible mid- and long-term planning [VanWynsberghe et al. 2003, Alcamo 2008].

Within the ClimWatAdapt project (Climate Adaptation – modelling water scenarios and sectoral impacts) [Flörke et al. 2011], scenarios were used to assess the vulnerability to climate change impacts and the effectiveness of adaptation measures. The aim of this project was to support EU policy development regarding adaptation strategies; impact indicators were applied for identifying hot spots and vulnerable sectors.

In this paper, we present some main findings focussing on water scarcity. First, we compare the results of the impact assessment in the 2050s for two scenarios. The above mentioned indicators are based on model simulations of freshwater availability and water use. We focus on the summer season (June, July, August) where water scarcity is most pronounced and increasing competition between the different water-related sectors is likely. In a second step, we assess the potentials of water savings on a river basin level. Here, we aim at the provision of EU-level, long-term information on efforts needed to reduce or limit future water scarcity. Third, this paper provides recommendations whether EU-relevant measures or support actions should be either promoted or prevented.

2 METHODS

Hydrological scenarios were calculated with the LISFLOOD model for the time period 2041-2070 representing the 2050s. LISFLOOD is a combination of a grid-based water balance model and a 1-dimensional hydrodynamic channel flow routing model that has been developed to simulate the hydrological behaviour in European catchments [van der Knijff et al. 2010]. In ClimWatAdapt, we made use of the bias-corrected climate datasets developed in the ENSEMBLES project [van der Linden and Mitchell 2009]. Dosio and Paruolo [2011] applied a statistical bias correction technique developed by Piani et al [2010 a,b] to correct the Regional Climate Model (RCM) runs driven by the IPCC SRES A1B emissions.

To address uncertainty related to climate change projections, transient time series of future precipitation and temperature simulated by an ensemble of 11 GCM-RCM model combinations were used to drive the model. All hydrological parameters are represented by the ensemble median.

In order to build quantitative scenarios of future water use, it is necessary to use a suitable tool for quantifying current and future water use. The tool used in this study is the WaterGAP model [Flörke and Alcamo 2004, aus der Beek 2010,
Flörke et al. 2012]. The water use model of WaterGAP consists of various submodels to determine both the water withdrawals and water consumption in the domestic, tourism, electricity, manufacturing, irrigation, and livestock sector. Water use scenarios were taken from the SCENES project [Kämäri et al. 2008, Kok et al. 2011] which aimed at developing and analyzing a set of comprehensive water-related scenarios for Europe through a participatory process. Here, four comprehensive scenarios were developed: Economy First (EcF), Fortress Europe (FoE), Policy Rules (PoR), and Sustainability Eventually (SuE). The scenarios include consistent projections of the main drivers such as total population, GDP, thermal electricity production, agricultural production as well as information on technological changes.

Here, we address uncertainty by taking into account two different scenarios, i.e., EcF and SuE, which show the largest range of the projections for water scarcity. The EcF scenario is characterized by a globalised and liberalised economy pushing the use of all available energy sources accompanied by an intensified agricultural intensification. The adoption of new technologies and water-saving consciousness is low resulting in an increasing water demand of all water-related sectors. Only water ecosystems providing ecological goods and services for economies are preserved and improved. On the contrary, the SuE scenario sketches the transition from a globalising, market-oriented Europe to environmental sustainability. This fundamental change in human behaviour, governance structures, and level of decision making is projected to come about through a phase of strong top-down policies ("quick change measures"), accompanied with a set of "slow-change" measures that bear fruit on the long run.

A set of impact indicators was derived from hydrological parameters and water use parameters, which were aggregated for river basins that are, at least partly, located within the territory of EU27, Norway and Switzerland.

The water exploitation index (WEI) is defined as the total water withdrawals-to-availability ratio within a river basin. Generally speaking, the larger the volume of water withdrawn the higher the water stress. Increasing water stress results in stronger competition between society’s users and between society and ecosystem requirements. A river basin is assumed to be under low water stress if \( \text{WEI} \leq 0.2 \); under medium water stress if \( 0.2 < \text{WEI} \leq 0.4 \), and under severe water stress if \( \text{WEI} > 0.4 \) (Vörösmarty et al. 2000, Alcamo et al. 2007).

Next to WEI, we address water stress related to water consumption, i.e., the share of water withdrawals that is not returned to the surface waters, with the consumption-to-availability ratio \( \text{CTA} \). It seems reasonable to suppose that a river basin is under severe water stress if \( \text{CTA} > 0.3 \) (EEA 2003). Because evapotranspiration amounts up to about 80% of the withdrawals for irrigation, this impact indicator predominates in regions where agriculture is a major water user. Both indicators, WEI and CTA, are computed on a monthly basis and added up to the summer season (June, July, August).

Thermal electricity production is vulnerable when river discharge does not provide enough cooling water during low flow periods. In these situations, a lack of cooling water often coincides with high water temperatures. This leads to insufficient cooling capacity and forces operators of power plants to reduce or even shut down electricity production. To take into account the global change impacts on the power sector, we use the ratio of cooling water withdrawals to low flow river discharge (\( \text{WTQ90el} \)) as a third impact indicator. Low flows are derived from monthly river discharges representing the flow with a 90 percent probability of being equalled or exceeded (Q90). The power sector in river basin faces severe water stress if \( \text{WTQ90el} > 0.5 \) (derived from Alcamo et al. [2007]).

Finally, we merge the results of WEI, CTA, and \( \text{WTQ90el} \) into one map showing which of these indicators exceeds its critical threshold, i.e., indicates severe water stress in individual European river basins. This overlay allows for the identification of hot spots, where adverse impacts of climate change and socio-economic change manifest themselves in multiple ways.

Based on a large literature review and two stakeholder meetings with representatives of EU-27 we identified a set of adaptation measures which reduce the risks and impacts of droughts and water scarcity situations. These adaptation measures were assessed along the following main attributes: i) social
environmental and economic impacts, ii) time frame of application, and iii) political and social implementability. The information was compiled in fact sheets which are currently translated into an online database allowing access to water managers at all levels. The range of measures identified varies widely and ranges from technical measures (e.g. increasing storage) to soft measures like awareness campaigns. For some of these measures the data was sufficient to assess their potential to reduce water scarcity across Europe.

In order to do so, we define as a target to reach a \( \text{WEI} \leq 0.4 \) in 2050. Subsequently, we calculate water savings and additional water supply that are needed to meet this target during summer in 2050. For demand-side measures, e.g. increasing water use efficiency, we focus on the question whether the targeted water savings can mainly be attributed to a single sector. For this purpose, we define the sectoral water savings (SWS) as the percentage share of the targeted (total) water savings in the sector-specific water withdrawals. If, in a given river basin, the SWS-value for the sector with the highest SWS is less than 50%, we assume that the targeted water savings could be achieved by improvements mainly in this individual sector. Otherwise, an integrated multi-sector approach is needed to meet the target WEI. The threshold of SWS=50% is based on the assumption that a sector could save a maximum of 50% of its water abstractions.

3 RESULTS

Baseline (Figure 1):

Today, hot spots where all three indicators show severe stress are located in Spain, Italy, Greece, Bulgaria, and UK. The agricultural sector leads to severe water stress in Southern Europe as indicated by WEI and CTA exceeding the thresholds. This is in line with the observation that around the year 2000 (2000-2003), the majority of the real irrigated areas is located in the Mediterranean region, and here the countries France, Greece, Italy, and Spain account for 80% of the area actually irrigated in EU-27 [aus der Beek et al. 2010]. In Central Europe some river basins (Rhine, Weser, Meuse) face water stress because of cooling water abstractions in the energy sector illustrated by WEI and WTQ90el above the threshold values. In south-eastern Europe, severe water stress occurs due to generally high demands but agriculture and power sector are not the main cause (only \( \text{WEI} > 0.4 \)). On the contrary, none of the indicators shows severe water stress in Eastern and Northern Europe and major parts of France.

The actual situation could be less severe due to the use of groundwater or water stored in reservoirs and dams which are not considered in the model simulations. However, sustainable management of the surface and even groundwater bodies seems elusive and competition with other water use sectors is likely.

Figure 1 Overlay of the impact indicators WEI, CTA, and WTQ90el for the summer season under current conditions.
Overlay of the impact indicators WEI, CTA, and WTQ90el for the summer season in 2050 for the Ecf (left map) and SuE (right map) scenarios.

**Economy First scenario, EcF (Figure 2, left map):**
In 2050 under EcF scenario conditions, a strong increase in the number of basins is likely where WEI, CTA and WTQ90el concurrently indicate severe stress. The basins entering this class are mainly located in Spain, France, Italy, the Benelux Countries, UK, and Black Sea region.

In Southern Europe agriculture is still the main cause of water stress, where the values of WEI and CTA increase due to both increasing irrigation water demand and decreasing water availability. Some small river basins show water stress at low flows (Q90) related to the energy sector. In Western Europe and in some river basins in Eastern Europe, additional water stress is mainly due to the rise in thermal electricity production and a decrease in Q90.

The most severe impact manifests in France, which is almost completely covered by river basins with severe water stress according to at least two indicators under EcF in 2050. Here, severe water stress is a result of socio-economic changes and less influenced by climate change (although water availability decreases, too).

**Sustainability Eventually scenario, SuE (Figure 2, right map):**
Overall, the area under severe water stress is expected to decrease under SuE scenario conditions in 2050 compared to the baseline (Figure 1). The main reasons for this decline are decreasing water withdrawals because of technological, structural, and behavioural changes. Main parts of Southern Europe still face severe water stress caused by irrigation requirements as indicated by the WEI and CTA indicators. WEI increases in western France compared to the baseline because of reduced water availability. In this region, reduced water use cannot compensate for the adverse climate impact. However, severe water stress diminishes in the remaining parts of the EU as a result of expected technological improvements that save water in the thermoelectric sector, i.e., a shift in cooling systems, and a decline in thermal electricity production (in Western Europe).

The results of the impact assessment show that adaptation measures and policies are required in Europe, in particular Southern and Western Europe, to reduce water stress. From the water demand perspective it is necessary to know how much water must be saved to reach a target below the limit of WEI < 0.4 in summer. However, from a policy perspective, it is even more interesting to know which sector(s) must be addressed predominantly by water saving measures. Figure 3 shows the key sectors that need to be involved in water saving efforts in order to reach the target (WEI ≤ 0.4) under the EcF and SuE scenarios in 2050. Here, we assume that the main sector is able to reduce water withdrawals by a
maximum of 50% (section 2.4). Accordingly, in some river basins the water savings required can be achieved by water savings in a single sector under EcF conditions (Figure 3, left map). Most water saving obligations are related to irrigation (e.g. in France, Greece, Italy, and Spain) and thermoelectric power production (e.g. Germany and France). However, in approximately half of the vulnerable river basins an integrated multi-sectoral approach is needed. In the SuE scenario (Figure 3, right map) the reduction of water withdrawals can especially be achieved by savings in the irrigation sector (Mediterranean rim countries), in smaller river basins also by the manufacturing sector (Italy).

Figure 3 Water saving efforts needed to achieve the target (summer WEI < 0.4) in the EcF (left map) and SuE scenarios (right map) in 2050. Maximum saving per sector is assumed to be 50%.

4 conclusions and recommendations

In this study, model results from LISFLOOD and WaterGAP were used to assess current and future water stress during the summer season. The indicator-based analysis shows that the European water sector will be affected by changes resulting from socio-economic developments as well as climate change. Here the majority of the EU regions need to prepare for water scarcity which is in particular a problem in Southern and South-Eastern Europe. Therefore, climate change adaptation will be necessary throughout the entire EU and can in many circumstances significantly reduce vulnerability.

Currently, large areas of Europe, particularly in Southern and South-Eastern Europe, are vulnerable to water scarcity and drought events and this area is likely to increase in size in the future. Water scarcity and droughts have severe consequences for people living in water scarce areas, for economic activities, and for aquatic ecosystems. These consequences are likely to become more severe in the future, resulting in social, economic, and environmental losses.

Water stress is expected to increase in Europe under EcF scenario conditions, however, the agricultural and thermoelectric water sectors are the most vulnerable ones. On the contrary, water stress can be reduced in SuE due to water savings and structural changes. Here, the agriculture sector remains to be vulnerable to water scarcity. The storage of water in dams and reservoirs will help to ease the situation; however, according to our findings further drastic cuts or the replacement of freshwater by wastewater will be necessary to achieve a sustainable use of freshwater resources and for compliance of the WFD.

By comparing different scenarios, it can be concluded that socio-economic scenarios dominate the dynamics of water scarcity. Even a substantial decrease in water withdrawals does not prevent some regions from water scarcity. This is apparent during the summer season. Therefore, adaptation should not be discussed in isolation and the focus of any policy intervention should be on the socio-economic drivers, such as land use and production patterns. Technical measures that mainly aim to maintain the current state or are trying to reduce the
impacts are not sufficient to save water and to reduce vulnerability to water scarcity in the future. From a sector perspective, agriculture mostly contributes to water scarcity, but at the same time the sector is most vulnerable in many regions. Therefore, EU agricultural policy (the Common Agricultural Policy, CAP) should remove any incentive to farmers to grow water intensive crops in already water scarce areas and any investments related to irrigation have to ensure water savings. While the latter is already part of the new CAP proposal there is still a payment for cotton in water scarce regions foreseen. Nevertheless, even if agriculture is the dominating water consuming sector in many regions in Europe, other sectors can also contribute to the achievement of reducing vulnerability to water scarcity. This however requires that EU water policies are more mainstreamed into other sectoral policies such as industry (in particular water saving in the energy sector), urban development, or tourism. Furthermore, there is a need to strengthen adaptation in land-use management and practice and to strengthen the role of ecosystems. Land-use change is one of the main drivers of the degradation of water resources and vulnerability to extreme events. Because of the close link between human activities to land cover, land use and the hydrology of a river basin there is a need to consider long-term impacts of climate change. Harnessing nature’s capacity to absorb or control impacts from extreme events, for instance, by improving the soil’s water storage capacity and conserving water in natural systems, helps alleviating the effect of droughts and preventing floods, soil erosion and desertification. This ecosystem-based approach is mostly a more efficient way of adapting than simply focusing on physical infrastructure. Such changes in land use may be considered as strategic. Its implementation may experience much resistance and take much time. If combined with other environmental goals steady progress may be expected. However, the potential of this measure is not fully explored, mainly because the priorities for land use differ (e.g. housing, agriculture).

In order to react to the above mentioned issues the European Commission is developing a blueprint for European water management. The results from the ClimWatAdapt project are most likely to become a cornerstone for these policy interventions, demonstrating how important the link between scientific research and policy making is.

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