Driving forces of future water availability and water use within Europe

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Abstract

This paper provides the first opportunity to inform the British hydrological community of the aims and objectives of a collaborative project to develop and evaluate European water scenarios up to 2050. The emphasis is on identifying driving forces and key issues, related primarily to socio-economic developments, that might influence future water availability and sectoral water demand within Europe, and so inform the scenario development process. These are population and economic growth, agricultural development and technological developments, as well as climate change and land use change, and also national and European policies and legislation. The outputs from the project should make a significant contribution to the development of water policy within Europe through more reliable assessments of future impacts of climate and other changes upon water resources which, in turn, will improve the cost-effectiveness of adaptation and mitigation strategies for sustainable development.

Introduction

Water use has almost tripled over the past 50 years and in some regions the water demand already exceeds supply (Vorosmarty *et al.,* 2000). The world is facing a 'global water crisis'; in many countries, current levels of water use are unsustainable, with systems vulnerable to collapse from even small changes in water availability. The need for a scientifically-based assessment of the potential impacts on water resources of future changes, as a basis for society to adapt to such changes, is strong for most parts of the world. Although the focus of such assessments has tended to be climate change, socio-economic changes can have as significant an impact on water availability across the four main use sectors, i.e. domestic, agricultural, industrial (including energy) and environmental. Withdrawal and consumption of water is expected to continue to grow substantially over the next 20–50 years (Cosgrove and Rijsberman, 2002), and consequent changes in availability may drastically affect society and economies.

Increasing human populations and their associated water demands give rise to shortages and conflicts between water use for the needs of humans and for the wider environment. A higher frequency of more intense storm events is likely to cause flooding that society is not prepared for, resulting in huge economic losses. Agricultural production may be affected by water availability for irrigation, which may be affected by climate change, and also by changes in cropping practices and in crop productivity. Manufacturing industries may also be affected by limited water availability, as will energy producers using water for cooling thermal power plants or for hydropower generation. Rural areas are often partly dependent on water ecosystem goods and services such as fishing, for which conditions may be completely altered if water temperature and flow regimes are changed. Another important aspect is changed conditions for fauna and flora, with possible reductions in biodiversity. Although effects on biodiversity may have only marginal short-term economic effects on society, and thus receive little political attention, they will undoubtedly have a significant long-term effect on mankind.

This paper considers the specification and quantification of the driving forces and key issues that might influence future water availability and sectoral water demand within Europe. Many of the driving forces relate to socio-economic development, such as: growth in population and migration; agricultural development and land use change; technological development; and economic growth; as well as environmental change including climate change. Other issues relate to policy and legislation, such as the Water Framework Directive (WFD), reform of the Common Agricultural Policy (CAP), and political change such as enlargement of the EU. Raised awareness of the current water situation in Europe and its challenges is crucial for sustainable water management, and will inform the vision for the future of Europe's water (EWP, 2008).

Assessing future water availability

The assessment of the future impacts of various environmental and socio-economic change scenarios on water resources requires the development of methods and models that are harmonised as far as possible across regions. Macro-scale hydrological models can provide insights into the inter-relationships between climate, water and the anthropogenic pressures upon water resources in a consistent and spatially-coherent manner, to enable the assessment of impacts and the prioritisation of adaptation measures within regions for the benefits of all the countries involved.

There are many uncertainties in our understanding of the global water cycle and how it will develop in the future. River basin hydrological models such as MGB-IPH (Collischonn *et al.,* 2007) and Grid-2-Grid (G2G; Bell *et al.,* 2007a; 2007b), and global water resources models such as GWAVA (Meigh *et al.,* 1999) and WaterGAP (Alcamo *et al.,* 2003a; Doll *et al.,* 2003) are some of the first attempts to produce regional and global syntheses, supported by the increasing availability of gridded datasets and model outputs which provide a new and valuable opportunity to assess components of the water cycle in a consistent and spatially coherent manner across regions. The requirement to manage water resources in an integrated and sustainable manner has, itself, become a driving force behind the use of such models in understanding how basin water resources will be affected by change (Alcamo *et al.,* 2003b; 2007; Meigh *et al.,* 2005; Folwell & Farquharson, 2006; Fung *et al.,* 2006).

However, in many of these models, hydrological processes have been only crudely represented. Thus, future changes in some components, such as precipitation, evaporation and runoff, have been captured in only a general fashion, and detailed changes in other components of the hydrological cycle, such as groundwater, snowmelt and wetlands, have been poorly resolved. In addition, several anthropogenic influences on the hydrological cycle (e.g. irrigation, abstractions, large water storage facilities) have not always been considered. The models have also traditionally focused solely on water quantity, although water quality and ecological flow aspects are beginning to be incorporated, in conjunction with improvements in existing model functionality. At the same time, the development of policy-relevant indicators which compare water demand and supply for the different use sectors and, thereby, identify vulnerable areas, is improving the way in which the scenario impacts are quantified in a consistent manner across Europe.

The SCENES project

The EU-funded SCENES project (water SCenarios for Europe and NEighbouring States) is using such models to evaluate scenarios of Europe's fresh waters up to 2050. SCENES (Kämäri *et al.,* in press) is a four-year (2006–2010) integrated project co-coordinated by the Finnish Environmental Institute (SYKE) and the German Centre for Environmental Systems Research (CESR) at the University of Kassel (see http://www.ymparisto.fi/default.asp?node=20627&lan=en). Figure 1 shows the geographical extent of the SCENES project.

The current first phase scenarios are based on the recent Global Environment Outlook (GEO4; UNEP, 2007) scenarios which include four elaborated European socio-economic storylines developed by stakeholders as well as quantified water scenarios for Europe. The scenarios are being enhanced by a pan-European panel of carefully selected experts representing researchers, decision-makers and stakeholders. The pan-European modelling work is being enriched by input from regional panels in four pilot areas: the Baltic, the Black Sea, the Lower Danube and the Mediterranean (see Figure 1). The pilot areas enable inclusion of a full range of climatic and socio-economic zones and issues (from irrigated agriculture in southern Spain to water quality in the Baltic), as well as reflecting the regions where the European Commission feels such research is needed and so incorporating the interests of

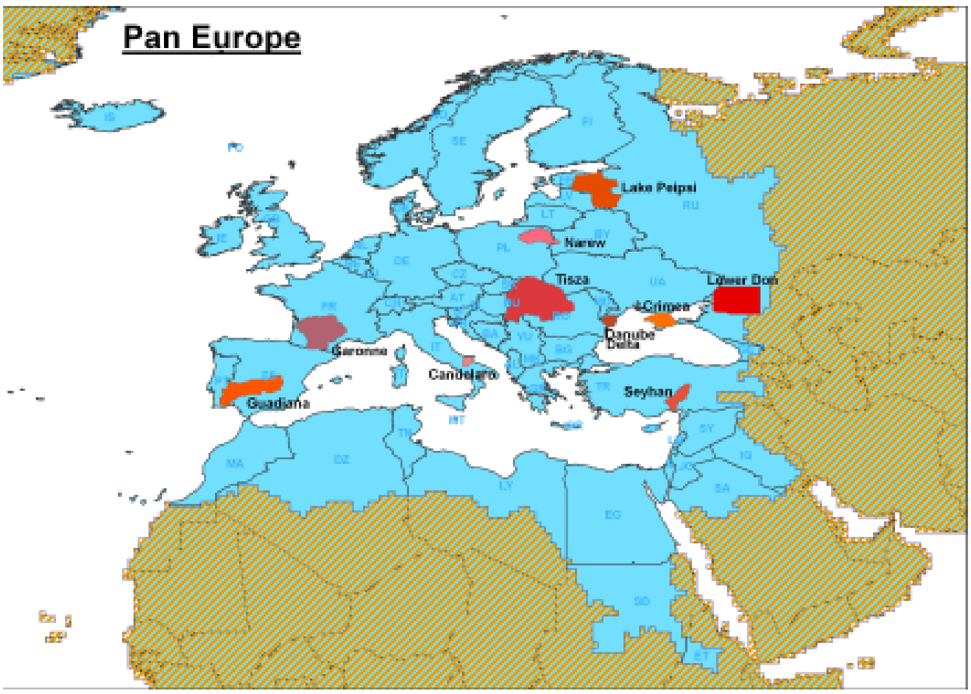

Figure 1 *Geographical extent of the SCENES project (Source: C. Schneider, CESR)*

project partners. The regional panels comprise a full spectrum of stakeholders who will contribute particularly to the provision of contextual information, including their problems, needs and institutional backgrounds, while evaluating the impacts in their basins in a wider context. This aspect recognises the increasingly acknowledged necessity for stakeholders and researchers to share a common vision of the river as a policy issue (Barraqué, 2008).

In the SCENES project, the qualitative scenario storylines from the pan-European panel will be translated into quantitative WaterGAP model inputs. The scenarios developed and used must be based on coherent and internally consistent sets of assumptions about all the external factors that might influence future water demands. Many of these factors will relate to socio-economic developments, land use change, technological development, and economic growth. However, pressures will also be political, policy or legislation-driven. Also influential will be global scale environmental pressures. Hence, modelling can check and maintain consistency in scenarios developed by committee from a wide variety of complex and interacting issues.

The model outputs will be used to assess the impact on large-scale water balances, as well as local scale based on detailed hydrological modelling in selected case study basins in the pilot areas. The resulting changes in water availability and water quality will be analysed for different use sectors, as will the general socio-economic consequences for each sector. The results will be fed back to the scenario panels to inform them during the first stage of the next iteration of the scenario development, model runs and impact assessment process.

Driving forces

Drivers for change are often of a long-term nature, such that there are many long-term impacts on the water environment (e.g. it takes many years to reverse pollution from nutrients such as phosphates), that the substantial investment in the changes needed requires long time scales for both planning and execution, and that behavioural change is likely to take time to be fully achieved (e.g. by households to reduce water use). Individual driving forces and pressures may each decrease or increase water demands in the future. Thus, predicting all the likely changes that may take place from combined forces and pressures between now and the 2050 SCENES time horizon, or even by 2015 when the WFD's environmental objectives must be achieved, represents a major challenge. Furthermore, there are recognised difficulties in allocating scarce resources in a sustainable manner when there are conflicts between different uses of water, whilst meeting environmental and future needs.

Many of the driving forces governing the dynamics of water use relate to socio-economic developments, such as growth of population and migration within Europe, agricultural development and land use change, technological development which may increase water efficiency, and economic growth which may lead to increased water withdrawals and wastewater discharges. Global scale environmental pressures such as climate change, with predictions of more extreme hydrological events, will also be influential. In order to carry out the pan-European modelling, the driving force elements of the qualitative scenario storylines must be translated into quantitative model inputs. In the SCENES project, the modelling tool being used is WaterGAP, the parameters of which govern the approach and required outcomes of the quantification exercise. Additional functionality is anticipated to be added to the model during the project which will extend the range of scenario components that can be considered.

Analysing past water use trends and predicting future water use behaviour in order to quantify the scenarios requires the evaluation of a wide range of spatially and temporally referenced data. Many of the issues vary considerably across Europe and the neighbouring states covered by the SCENES project, e.g. the coverage and quality of domestic water supply, and the level of connectivity to wastewater treatment works and type of treatment. Table 1 provides a list of some of the data types that will be handled during the SCENES project. The challenging task of assembling, coordinating and harmonising these data collected for this purpose, from many different sources and countries, by the SCENES project, and making them available to the project partners and researchers across Europe and in the four case study regions, is described in Kämäri *et al. (*in press).

Domestic sector (water for people)

Whilst the link between population and levels of domestic water demand and wastewater discharge is clear, it is also

Table 1 Examples of the range of data types handled during the SCENES project

Hydrological data	*Water use data (national)*	*Water quality data*	*Socio-economic data*
Rainfall	Domestic water demand	Nitrogen	Population (national)
Temperature	Domestic water use efficiency	Phosphorus	GDP (national)
River flow	Manufacturing water use efficiency	Total dissolved salts	
Groundwater recharge	Electricity generation water use	Biochemical oxygen demand	
Land use	Power station cooling types	Water temperature	
Lakes & reservoirs	Electricity production	Total coliform bacteria	
Wetlands	Crop types & irrigated areas		
Wastewater discharge points	Irrigation water use		
Type of sewage treatment	Livestock numbers		
	Livestock water use		

necessary to consider the number and size of households, the trend in many countries being towards a larger number of smaller households, increasing both water use and development pressure. Shifts in population, either semi-permanently through migration or seasonally for tourism, are also important factors. At the same time, behavioural changes in water use, linked to the economic development and lifestyle, and technological improvements in the efficiency of water use, can lead to decreases in *per capita* water use.

Agricultural sector (water for food)
Livestock water use can be simply estimated from the number of animals and water use per animal. Irrigation water use is more complex and depends on many factors, including climate, soil type, arable area, type of crop and cropping pattern. Technological improvements in irrigated field efficiency and the use of grey water are continual developments. Agriculture has also had significant impacts on water quality, contributing to diffuse pollution through fertiliser and pesticide use. Within parts of Europe, agricultural intensification has slowed in recent years, and the growth of organic farming and CAP reform are expected to consolidate this trend.

Industrial sector (water for utilities)
Economic activity, in the form of industry, is linked to abstraction and flow-related pressures, including many point sources of pollution and morphological changes. Although industry can be considered as a whole, some analysis of sector-specific water use may be valuable as different industries expand and contract. As well as the amount, type and output of industry, water use is again influenced by technological improvements in efficiency. Links between economic activities and diffuse pollution pressures are more difficult to determine, particularly for diffuse pollution from non-agricultural activities.

Energy sector (water for utilities)
Thermal electricity generation at oil, coal and gas fired power stations is a major user of freshwater (nuclear power stations generally using sea water). The important factors are the total electricity production, the type of cooling at the power stations (tower or not) and the water use of that type, and technological improvements in efficiency. However, for scenario development, the potential shift from thermal to non-thermal power sources including renewable energy will be significant, as will the growing interest in biofuels and the impacts of those.

Environmental sector (water for nature)
Environmental flows is the widely accepted term encompassing the whole flow regime required to maintain a river ecosystem in a state that delivers its ecological functions and services. The SCENES project will endeavour to adopt a standard approach to integrating the water for nature demand with other sectoral water users across Europe. Another environmental pressure that can result in loss of natural biodiversity and have significant economic impact is alien species i.e. non-native organisms that establish themselves in, and subsequently disrupt, native ecosystems.

Climate change
Climate change will affect all aspects of the water environment, but there remain many uncertainties about the impacts and their magnitude, and these will certainly vary across Europe. It is generally anticipated that rainfall and evaporation patterns may change, and the frequency and intensity of extreme events may increase, associated with changes in land use and water consumption, and deteriorating air quality and water quality. Even the more moderate possible changes in weather patterns could have an impact on the water environment.

Policy issues

It is necessary to analyse the driving forces information in conjunction with European policy and budgetary issues that might be relevant to scenario development, to inform the qualitative storylines developed by the scenario panels. These issues may be environmental, but other strategic developments at EU level may also impact indirectly upon the water environment e.g. the Lisbon Strategy for jobs and growth, the EU Sustainable Development Strategy, the goal for improved implementation of Community Law, and the new EU Reform Treaty. Also influential will be political pressures, such as those imposed by enlargement of the EU, and ever-changing relationships, both between Member States and with Accession Countries and non-member states.

Issues which may have possible major impacts on water demands, water quality and ecology include both direct EU policy legislation like the WFD and other Directives, and indirect policy such as Structural and Cohesion regional funding initiatives which may support environmental conservation and protection, and CAP reform.

Water Framework Directive (WFD)
The WFD provides comprehensive requirements for achieving good ecological status through analysis of pressures, developing measures to combat these pressures, and developing integrated river basin management plans. With the 2015 implementation deadline ever approaching, it is important to consider if the legal requirements of the WFD are sufficiently clear, how far the objectives of the WFD are achievable, how long Members States will seek to stretch out the implementation, and what will happen once this deadline has passed.

Other water quantity policies
A recent policy paper on addressing the challenge of water scarcity and droughts in the EU has highlighted a number of options focusing primarily on demand management activities. However, it remains to be seen how far Member States are likely to adopt significant measures to tackle water use and water scarcity. At the other extreme, the floods Directive on the assessment and management of flood risks will require investigation and assessment of likely ‘trade-offs’ between land use objectives such as housing and agriculture, and floodplain management.

Other water quality policies
Other EU policies of relevance to water quality include Directives restricting specific discharges (e.g. Dangerous

Substances, Urban Waste Water, Nitrates and Groundwater) and those aiming to achieve specific water quality (e.g. Fishlife and Bathing Waters).

Agricultural policies

The EU's agricultural policy has had major consequences for the environment. Reform of the Common Agricultural Policy (CAP) is likely to recommend changes to payment schemes, propose improved management practices, and address new challenges such as climate change, bioenergy, water management and biodiversity decline. It is uncertain how far the established positions of the Member States on the CAP can be altered, and what the implications of a failure to agree a way forward would be.

Biodiversity policies

The underlying objective of the EU biodiversity policy is to halt the loss of biodiversity in the EU, and reduce the loss rate worldwide, by 2010. EU policies of relevance to this include the Directives relating to habitats and birds, the Biodiversity Communication and Action Plan, and the establishment of the Natura 2000 network of protected sites. Of particular interest here will be the synergies and/or conflicts likely to arise between biodiversity conservations and issues such as water management, climate change, energy policy and CAP.

Other policy issues

The Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) Directives aim to mitigate the adverse impacts of activities on the environment, but it is unclear how realistic it is to expect these processes to bring a more strategic approach to issues affecting water quantity and water quality in land use planning, when they can become part of wider sustainability appraisals in which environmental impacts tend to be overshadowed by social and economic ones.

Concluding remarks

Results from the SCENES project, in the form of a set of rich, comprehensive and realistic scenarios about the future of Europe's water resources, will provide a baseline for longer-term strategic planning of basin water resource development and alert river basin managers and policy makers to emerging problems. This will contribute to the collaborative exchange of Integrated Water Resource Management research policy and practice across Europe and neighbouring regions, at the same time addressing relevant objectives of the EU Water Initiative and Millennium Development Goals. Key target groups for the outputs of the project will be national and regional water resource planners (Defra and the Environment Agency in the UK) and also the European Commission as, if significant regional pressures and 'hot-spots' are identified, there may a need for pan-European legislation or incentives to address such anticipated problems.

The specification and quantification of the key issues and driving forces that underpin the development of the future scenarios are central to the success of the SCENES project. This is involving an ongoing review of changes in general socio-economic variables, key sector policies that influence water use, economic growth and planned investment linked to existing water regulation, as well as assessment of how important water is to the economy and socio-economic development of the basin, and investigation of likely trade-offs between socio-economic development and water protection. One final key output of the project will be a series of tools and panels of expertise in development and use of scenarios to aid policy development and decision-making, with the hope that the project will generate sufficient interest and 'momentum' during its four year duration that the process is taken up by national and regional groups as an aid to sustainable development.

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