available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/envsci

Adapting to climate change: reducing water-related risks in Europe – EU policy and research considerations☆

Philippe Quevauviller *

European Commission, Directorate-General for Research and Innovation, Rue de la Loi 200, B-1049 Brussels, Belgium

ARTICLE INFO

Published on line 5 April 2011

Keywords:
Climate change
Adaptation
Water-related disasters
Risk reduction
Science–policy interactions

ABSTRACT

Climate change impacts on the hydrological cycle, e.g. leading to changes of precipitation patterns, have been observed over several decades. Higher water temperatures and changes in extremes hydrometeorological events (including floods and droughts) are likely to exacerbate different types of pressures on water resources with possible negative impacts on ecosystems and human health. In addition, sea-level rise is expected to extend areas of salinisation of groundwater and estuaries, resulting in a decrease of freshwater availability for humans and ecosystems in coastal areas. Furthermore, climate-related changes in water quantity and quality are expected to affect food availability, water access and utilisation, especially in arid and semi-arid areas, as well as the operation of water infrastructure (e.g. hydropower, flood defences, and irrigation systems). This paper serves as an introduction to the special issue of *Environment Science & Policy* dealing with climate change impacts on water-related disasters. It provides a brief background about relevant EU water policies and examples of EU-funded research trends which illustrate on-going efforts to improve understanding and modelling of climate changes related to the hydrological cycles at scales that are relevant to decision making (possibly linked to policy).

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC), there is ample evidence that freshwater resources are vulnerable towards climate change (Bates et al., 2008): impacts of observed warming over several decades are indeed reflected in changes in the large-scale hydrological cycle (e.g. effects on atmospheric water vapour content, and changes of precipitation patterns). Higher water temperatures and changes in extremes, including floods and droughts, are projected to affect water quality and exacerbate many forms of water pollution with possible negative impacts on ecosystems, human health, and water system reliability and operating costs. Furthermore, sea-level rise is projected to lead to increased salinisation of groundwater and estuaries, with a resulting decrease of freshwater availability for humans and ecosystems in coastal areas. Other impacts are also highlighted, such as on food safety/availability and water infrastructure (e.g. hydropower, flood defences, irrigation systems). In this context, climate change adaptation and mitigation options are currently discussed and designed to either ensure water supply during average and drought conditions or to reduce the magnitude of impacts of global warming on water resources (in turn reducing adaptation needs). Possible negative side effects such as, for example, increased water requirements for bio-energy crops, and reforestation are also considered. These options are closely linked to a range of policies covering different sectors, e.g. energy, health, food security, water and nature conservation, requiring that adaptation and mitigation

☆ The views expressed in this article are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

* Tel.: +32 22963351; fax: +32 22966825.
E-mail address: Philippe.Quevauviller@ec.europa.eu.

1462-9011/$ – see front matter
doi:10.1016/j.envsci.2011.02.008

measures are evaluated across multiple water-dependent sectors. This paper focuses mainly on EU water policies and highlights current trends in research in the area of climate change and water; it complements and updates recent publications by the author (Quevauviller, 2010a,b).

2. Climate change impacts on water

It is recognised that climate change impacts may interact with and potentially aggravate other anthropogenic pressures, which would then classify them as an anthropogenic pressure (Wilby et al., 2006). For example, both the availability of water and the demand for water for uses such as agriculture may be affected by changes in precipitation patterns (seasonal and spatial) and hotter/drier summer periods. Pollution patterns may also be altered as a result of lowered water levels (less dilution). Also, climate change mitigation efforts may result in pressures on water resources. Therefore, climate change has nowadays to be duly considered in the management of water resources among many other drivers, including land cover and increasing water consumption (Quevauviller, 2010a).

Climate change-related risks to water include effects of intense rainfalls that may lead to long-term threats to groundwater resources, resulting in surface flooding rather than infiltration to groundwater. This increased run-off may directly affect surface water quality (e.g. through nutrients and pesticides run-off from agricultural land into rivers and lakes). Climate change may also impact on the frequency and severity of drought events, which may have an impact on aquatic ecosystems, water demand (increased demand and/or differing patterns) and infrastructures (e.g. effects on water treatment), sewer network operations etc.

The assessment of climate change impacts on water resources requires a good knowledge of their global/regional distribution, including the identification of the most sensitive hydrological systems at the scale of river basins as well as the understanding of hydrological systems and processes (e.g. variables such as river flows, groundwater and lake levels, soil moisture, evapotranspiration, snow cover, glacier extent, and permafrost) and impacts on biodiversity (Wilby et al., 2006). Evaluating climate change impacts on water uses in different sectors is also essential, e.g. on agriculture (rain-fed and irrigated), forestry (including forest fires and deforestation), hydropower, navigation and water supply (domestic, agricultural and industrial). Finally, possible impacts on infrastructure, health, transport, financial services (e.g. insurance sector), energy and tourism should also be assessed. In doing so, an integrated approach is recommended in order to tackle multi-risk evaluations at the river basin scale, distinguishing land-use changes due to human activities from climate-induced changes, taking into account uncertainties of the evaluations and of future climate change projections (including the increased occurrence of extreme flood and droughts, socio-economic developments, model resolution etc.). At the present stage, attributing increasing hydrometeorological extremes to climate change is still uncertain because of a lack of accurate data and full scientific understanding of the functioning of the climate system.

3. European policy background

In the context of this paper, only EU water-related policies will be considered. International policies, in particular the Hyogo Framework for Action 2005–2015 (HFA) under the responsibility of the United Nations International Strategy for Disaster Reduction (UN-ISDR), are being dealt with separately in this special issue.

The main EU policies embedding water-related disasters are represented by the Water Framework Directive (2000/60/EC), the Flood Directive (2007/60/EC) and the Water Scarcity and Drought Communication highlighting current policy developments in this area. It should be stressed that climate change is not classified as an anthropogenic pressure in a narrow sense in the terminology of the Water Framework Directive (hereafter referred to as WFD), even if there is a general consensus among scientists that climate change is at least to a certain extent caused by human activities. This is due to the fact that these impacts cannot be mitigated by current programmes of measures (linked to the implementation of various EU directives) undertaken by water managers, which are essentially directed towards anthropogenic pressures (mainly pollution but also overexploitation of water resources).

The WFD enables to develop a robust integrated water resources management system in Europe, which is built upon the principles of river basin management planning (Chave, 2007; Quevauviller et al., 2008). In this context, all types of waters (surface and ground waters) and pressures that may affect them have to be considered, and programmes of measures (supported by extensive monitoring) have to be undertaken in order to achieve 'good status' objectives by 2015. Let us recall that the 'good status' according to the WFD is based upon chemical and ecological status for surface waters, and chemical and quantitative status for groundwater. Ongoing discussions pinpoint that climate change might influence all steps of WFD implementation, and thus on the status objectives (Wilby et al., 2006; Ludwig et al., 2009). These discussions are also reflected in a guidance document recently published by the European Commission, which examines river basin management in a changing climate (European Commission, 2009a).

Possible risks of water-related disasters (mainly floods and droughts) posed by climate change are not specifically addressed in the WFD. However, several articles of the directive provide a framework to include climate change impacts into the planning process. In particular, the requirement of the directive to collect information on the type and magnitude of 'significant pressures' affecting surface waters could be considered as including climate change with the consensus that it is at least to a certain extent caused by human activities (Wilby et al., 2006). Climate change might indeed potentially exacerbate existing or future anthropogenic pressures and should hence be considered within the policy framework. For instance, climate change might have impacts on river flow patterns, precipitations, water level fluctuations etc. (Wilby et al., 2006; Ludwig et al., 2009), which by the way would also impact on the achievement of the 'good status' objective of the WFD, e.g. extreme flood and drought events

leading to increased sediment loads and mobilisation of contaminated sediments. Potential climate change impacts on WFD milestones are discussed in the above referred guidance document (European Commission, 2009a) which has been built upon principles of the European Commission's White Paper on 'Adapting to climate change' (European Commission, 2009b). One feature of this document is the identification of adaptation strategies to increase the resilience to climate change of a wide range of sectors, including by improving the management of water resources and ecosystems.

Complementing the above policy framework, the Floods Directive (European Commission, 2007a) requires EU Member States to assess and manage flood risks, with the aim to reduce adverse consequences for human health, the environment, cultural heritage and economic activity associated with floods in Europe. This directive is coordinated with the implementation of the WFD from the second river basin management plan onward. It therefore provides a comprehensive mechanism for assessing and monitoring increased risks of flooding due to climate change and for developing appropriate adaptation approaches.

The increased frequency of droughts due to climate change is also considered in the policy context, which is illustrated by the EC communication on water scarcity and droughts (European Commission, 2007b) setting out a number of policy options. An annual European assessment of water scarcity and droughts is conducted by the European Commission to monitor changes across Europe and to identify where further action is needed in response to climate change. In addition, a review of the strategy for water scarcity and droughts is planned for 2012.

As noted in the 2009 Guidance document (European Commission, 2009a), the successive steps of the WFD River Basin Management Planning (RBMP) process provide a convenient structure for incorporating adaptation to climate-related water disasters through risk assessment, monitoring, environmental objective setting, economic analysis and action programmes to achieve well defined environmental objectives.

4. Current research

4.1. *Introduction*

The implementation of the WFD and of the Flood Directive and their operational features, including those linked to climate change adaptation and mitigation, represents huge scientific challenges and research needs. The section below provides a brief summary of research orientations developed within the EU Framework Programme for Research and Technological Development (for further details, see Quevauviller, 2010b). Gaps in climate change research and water and related recommendations are also discussed in UN Reports (United Nations, 2009a, b) and IPCC (Bates et al., 2008). The European Environment Agency has also identified research needs regarding policy support in a technical report (European Environment Agency, 2007). From the various reports, it is made clear that scientifically sound data and information are essential for making climate projections, while reducing their uncertainties, in particular for assessing water-related risks in vulnerable groups and regions. The section below provides a non-exhaustive snapshot of projects directly or indirectly addressing climate change impacts on water-related disasters (a summary is given in Table 1) as funded under the 6th Framework Programme (2002–2006)[1] and the on-going 7th Framework Programme (2007–2013)[2]. The projects described in this paper were all presented in the EU-ISDR International Workshop on ''Climate Change Impacts and Adaptation: Reducing Water-related Risks in Europe'', and some of them are subject to a paper included in the present special issue. Details on the projects can be found in the Workshop Proceedings (European Commission, 2011a). The list of selected projects is obviously not exhaustive: a more comprehensive list of projects is available in catalogues published by the European Commission (2009c).

4.2. *Research into climate change impacts on the water cycle and ecosystems*

At a large scale, the WATCH project (Global Change and Water – www.eu-watch.org) studies climate change impacts on the global water cycle with the aim to clarify the overall vulnerability of global water resources to climate change, in relation to the main societal and economic sectors; in particular, the project aims to increase the understanding of drought and large-scale flood development for the past and future climates through studies at different scales (global, regional, river basin). At a more regional level, climate change impacts on water resources are studied in the Mediterranean area through the CIRCE project (climate change and impact research: the Mediterranean environment – http://www.circeproject.eu), which investigates how strongly climate variations induce significant changes in the hydrological cycle and develops a regional climate model able to analyze the conditions in the Mediterranean area (Iglesias et al., in this issue). A more focused research is undertaken by the on-going ACQWA Project (assessing climate change impacts on the quantity and quality of Water – www.acqwa.ch), which investigates the consequences of climate change in mountain regions where snow and ice is currently an important part of the hydrological cycle. Numerical models are used to predict shifts in water amount by 2050, and how these changes will impact upon socio-economic sectors such as energy, tourism and agriculture (Beniston et al., in this issue). A related project is the HighNoon project (adaptation to changing water resources availability in Northern India with respect to Himalayan glacier retreat and changing monsoon pattern – http://www.eu-highnoon.org) which assesses the impact of Himalayan glacier retreat, explore possible changes of the Indian summer monsoon on water resources in Northern India and recommend appropriate and efficient response strategies for adapting to hydrological extreme events such as floods and droughts (Moors et al., in this issue).

[1] In particular projects funded under the 'Global Change and Ecosystems' sub-priority.

[2] In particular projects funded under the 'Environment (including climate change)' theme.

Table 1 – Overview of climate change and water projects and their links to relevant international and EU policies (the list is not exhaustive).

Projects	Themes	Supported policies	Starting and ending	Website and contact
(a)Research into climate change impacts on the water cycle and ecosystems				
ACQWA	CC impacts on water resources in vulnerable mountains	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.10.2008 End: 30.09.2013	www.acqwa.ch martin.beniston@unige.ch
CIRCE	CC impacts on the Mediterranean environment	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.04.2007 End: 30.06.2011	http://www.circeproject.eu antonio.navarra@bo.ingv.it
GENESIS	Groundwater and dependent ecosystems	WFD and its related Groundwater Directive	Start: 01.04.2009 End: 30.03.2014	www.thegenesisproject.eu Bjorn.Klove@oulu.fi
HighNoon	CC impacts on Himalayan glacier retreat and monsoon pattern	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.05.2009 End: 30.04.2012	http://www.eu-highnoon.org Eddy.Moors@wur.nl
MIRAGE	Mediterranean intermittent river management	WFD, including drought policy	Start: 01.01.2009 End: 31.12.2011	http://www.mirage-project.eu/index.php Jochen.Froebrich@wur.nl
REFRESH	Water management and climate change on the long term	WFD; EU Climate Change Adaptation policies	Start: 01.02.2010 End: 31.01.2014	Martin Kernan, University College London
SCENES	Water scenarios for Europe and neighbouring countries	WFD, including drought policy, and Flood Directive	Start: 01.01.2006 End: 31.12.2011	www.environment.fi/syke/scenes juha.kamari@syke.fi
WATCH	CC impacts on global water cycle	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.02.2007 End: 31.07.2011	www.eu-watch.org twarnaars@ceh.ac.uk
WETwin	Role of wetlands in IRWM and adaptation to CC	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 2007 End: 2013	http://www.wetwin.net/ Istvan.Zsuffa@vituki.hu
(b)Research into climate change impacts on water, security and resources, including drought				
CapHaz-Net	Social capacity building for natural hazards	Hyogo Framework for Action	Start: 01.06.2009 End: 31.05.2012	www.caphaz-net.org Annett.Steinführer@ufz.de
CLIMB	CC impacts on hydrology of Mediterranean basins	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.01.2010 End: 31.12.2013	http://www.climb-fp7.eu/ r.ludwig@lmu.de
ConHaz	Cost of natural hazards	Hyogo Framework for Action	Start: 01.02.2010 End: 31.01.2012	http://conhaz.org/ Reimund.schwarze@ufz.de
RESPONSES	European responses to climate change	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.01.2010 End: 31.12.2012	http://www.responsesproject.eu/ laurens.bouwer@ivm.vu.nl
WASSERMed	CC impacts on hydrology of Mediterranean basins	EU Climate Change Adaptation policies; UNFCCC; some links with EU water policies	Start: 01.01.2010 End: 31.12.2012	http://www.wassermed.eu/ roson@unive.it
XEROCHORE	Research needs and policy choices in the area of drought	WFD, including drought policy; Hyogo Framework for Action	Start: 01.05.2008 End: 30.04.2010	http://www.feem-project.net/xerochore/ Henny.vanLannen@wur.nl

Table 1 (*Continued*)

Projects	Themes	Supported policies	Starting and ending	Website and contact
(c)Research on extreme floods				
CORFU	Flood resilience in urban areas	Flood Directive; Hyogo Framework for Action	Start: 01.04.2010 End: 31.03.2014	http://www.corfu-fp7.eu/ s.djordjevic@exeter.ac.uk
FLASH	Short term forecasting of flash floods	Flood Directive; Hyogo Framework for Action	Start: 01.09.2006 End: 31.08.2010	www.flashproject.org cprice@flash.tau.ac.il
FLOODSite	Integrated flood risk analysis and management	Flood Directive; Hyogo Framework for Action	Start: 28.02.2004 End: 31.01.2009	www.floodsite.net p.samuels@hrwallingford.co.uk
FLOODproble	Technologies for improved safety of build environment to floods	Flood Directive; Hyogo Framework for Action	Start: 01.11.2009 End: 30.10.2013	http://www.floodprobe.eu/ Derk.vanRee@deltares.nl
FREEMAN	Resilience of communities in flood-prone areas	Flood Directive; Hyogo Framework for Action	Start: 01.09.2009 End: 31.08.2011	www.feem-project.net/freeman Jan.cools@soresma.be
HYDRATE	Hydro-meteorological technologies for flash flood forecasting	Flood Directive; Hyogo Framework for Action	Start: 01.09.2006 End: 30.04.2010	www.hydrate.tesaf.unipd.it marco.borga@unipd.it
IMPRINTS	Preparedness and risk management for flash floods and debris flows	Flood Directive; Hyogo Framework for Action	Start: 15.01.2009 End: 14.07.2012	http://www.imprints-fp7.eu/
SMARTeST	Technologies for improved safety of build environment to floods	Flood Directive; Hyogo Framework for Action	Start: 01.01.2010 End: 31.12.2012	www.floodresilience.eu GarvinS@bre.co.uk
THESEUS	Coastal technologies for safer European coasts	Flood Directive; Hyogo Framework for Action	Start: 01.12.2009 End: 31.11.2013	http://www.theseusproject.eu/ barbara.zanuttigh@unibo.it
UrbanFlood	Technologies for emergency management of floods	Flood Directive; Hyogo Framework for Action	Start: 01.11.2009 End: 30.10.2012	www.urbanflood.eu robert.meijer@tno.nl

Climate change impacts are also studied on vulnerable groundwater and dependent ecosystems through the GENESIS project (groundwater and dependent ecosystems – www.thegenesisproject.eu, Klove et al., in this issue) while the REFRESH project (adaptive strategies to mitigate the impacts of climate change on European freshwater ecosystems) focuses on climate-related and interacting pressures (increasing temperatures, changes in water levels and flow regimes and excess nutrients) with respect to lowland rivers, lakes and wetlands. The recently launched MIRAGE project (Mediterranean intermittent river management – http://www.mirage-project.eu/index.php) is specifically studying climate change impacts on intermittent river management. Another project called WETwin aims to enhance the role of wetlands in basin scale integrated water resource management, highlighting their key function for adapting to climate change. Finally, the SCENES project (Water Scenarios for Europe and Neighbouring Countries) develops and analyses a set of comprehensive (qualitative and quantitative) scenarios of Europe's freshwater futures up to 2025 and 2050.

4.3. *Research into climate change impacts on water, security and resources, including drought*

A recently launched cluster on 'Climate change impacts on water and security' builds up cooperation among EU countries and neighbouring Mediterranean countries (Roson et al., 2010); this cluster brings together three research projects, namely CLICO (Climate Change, Hydro-conflicts and Human Resources), CLIMB (Climate Induced Changes on the Hydrology of Mediterranean Basins) and WASSERMed (Water Availability and Security in Southern Europe and the Mediterranean) (Ludwig et al., in this issue). From another viewpoint, social capacity building in the field of natural hazards (including water-related hazards) is investigated in the framework of the CapHaz-Net project (Social Capacity Building for Natural Hazards) (Kuhlicke et al., in this issue) and research to improve the resilience of communities in flood-prone areas is developed under the FREEMAN project (Flood Resilience Enhancement and Management) (Schelfaut et al., in this issue).

Research specifically addressing water scarcity and droughts are discussed by the XEROCHORE Support Action (An Exercise to Assess Research Needs and Policy Choices in Areas of Drought – http://www.feem-project.net/xerochore/) which has established the state of the art of drought-related policies and identified research gaps on various drought aspects (climate, hydrology, impacts, management, and policy) and steps to take in order to fill them (Kampragou et al., in this issue). Networking is developed with close links to on-going initiatives, e.g. the European Drought Centre and relevant research projects which include drought components such as the WATCH, CIRCE and MIRAGE projects.

Complementing the above research portfolio, projects are investigating how to accelerate mitigation efforts while seeking to reduce risk associated with climate change impacts, an example of which is the RESPONSES project (European responses to climate change: deep emissions reductions and mainstreaming of mitigation and adaptation).

4.4. *Research on extreme floods*

Research in support of the development and implementation of the EU Flood Directive has been carried out since 2004 through, e.g. the FLOODsite Project (Integrated Flood Risk Analysis and Management Methodologies – www.floodsite.net), which integrated expertise from across the environmental and social sciences, as well as technology, spatial planning and management, and developed robust methods of flood risk assessment and management and decision support systems which have been largely tested in pilot sites. This core research activity is now complemented by several projects which have been presented at the EU-ISDR workshop (European Commission, 2011a). Starting with economic damages, the ConHaz project (Cost of Natural Hazards) investigates the way cost assessments of natural hazards, including floods and droughts, are being undertaken as well as costs and benefits of risk prevention and emergency response policies. Research on improving preparedness and risk management for flash floods and debris flow events is developed in the framework of the IMPRINTS project (Improving Preparedness and Risk Management for Flash Floods and Debris Flow Events – http://www.imprints-fp7.eu/, Cabello et al., in this issue), which is closely linked to the development of predictive scenarios carried out by the FLASH project (Observations, Analysis and Modelling of Lightning Activity in Thunderstorms, for use in Short Term Forecasting of Flash Floods – www.flashproject.org) on the basis of the collection and analysis of lightning data and precipitation observations (Price et al., in this issue).

Parallel research is focusing on flood resilience in urban areas through the CORFU project (collaborative research on flood resilience in urban areas), which looks at advanced and novel strategies and provides adequate measures for improved flood management in cities, focusing on Europe–Asia cooperation (Djordjevic et al., in this issue). This research is complemented by the UrbanFlood project (UrbanFlood – www.urbanflood.eu), dealing with the development of technologies to help emergency management of flood conditions that become more severe in most scenarios of climate change.

From the viewpoint of risk assessment and infrastructure, several research initiatives develop multidisciplinary approaches to study extreme events exacerbated by climate change. One example deals with coastal flooding through the THESEUS project (innovative coastal technologies for safer European coasts in a changing climate, Zanuttigh, in this issue). Other technological flood-related projects focus on improved safety of the built environment in relation to flood events, e.g. the FLOODprobe project (van Ree et al., in this issue) and the SMARTeST project (technologies for improved safety of the built environment in relation to flood events). Finally, technologies are also developed for improving flash flood forecasting through the HYDRATE project (hydro-meteorological data resources and technologies for effective flash flood forecasting, Borga et al., in this issue).

5. Conclusions

Adapting to climate change, in particular regarding water-related impacts, remains one of the most difficult challenges lying ahead in the context of EU water policies. Needs to tackle climate change adaption at river basin scale are being recognised in Europe through the Water Framework Directive but much remains to be done and supporting research is deemed essential in this respect. Effective actions will be closely linked to our capacity to integrate scientific knowledge in the EU water and climate policy cycle, which requires the development of science–policy interfacing mechanisms (Quevauviller, 2010c). This has been recently discussed in the framework of an international conference held in Lille (Quevauviller et al., 2011) and in the EU-ISDR workshop which is subject to the present special issue (European Commission, 2011b).

Acknowledgements

Participants in the EU-ISDR workshop ''Climate Change Impacts and Adaptation: Reducing Water-related Risks in Europe'' are gratefully acknowledged for the constructive dialogue and views, some of which are reflected in this special issue. Thanks are also due to the UN-ISDR, in particular Paola Albrito and Demetrio Innocenti, as well as colleagues from the European Commission Research Directorate-General, namely Elisabeth Lipiatou and Denis Peter, for their inputs into the discussions and effective support in the workshop organisation.

REFERENCES

Bates, B.C., Kundzewicz, Z.W., Wu, S., Palutikof, J.P. (Eds.), 2008. Climate Change and Water, Technical Paper of the Intergovernmental Panel on Climate Change. IPCC Secretariat, Geneva, p. 210.
Beniston et al., Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2010.12.009.
Borga et al., Environ. Sci. Pol., in this issue.
Cabello et al., Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2011.03.003.
Chave, P., 2007. The EU Water Framework Directive. IWA Publishing.
Djordjevic et al., Environ. Sci. Pol., in this issue.
European Environment Agency, 2007. Climate change and water adaptation issues, Technical Report No. 2/2007, Copenhagen.
European Commission, 2011a. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, Official Journal of the European Communities, L 327, 22.12.2000, p. 1.
European Commission, 2007a. Directive 2007/60/EC of the European Parliament and of the Council of 23 October 2007 on the assessment and management of flood risks, Official Journal of the European Communities, L 288, 6.11.2007, p. 27.
European Commission, 2007b. Communication to the European parliament and the council—addressing the challenge of water scarcity and droughts in the European Union, COM/2007/04141 final.
European Commission, 2009a. River basin management in a changing climate, Common Implementation Strategy for the Water Framework Directive, Guidance document No. 24, ISBN 978-92-79-14298-7, 2009.
European Commission, 2009b. White Paper ''Adapting to climate change: towards a European framework for action'', COM (2009) 147 final.
European Commission, 2009c. European Research Framework Programme: research on climate change, European Commission, EUR 23609.
European Commission, 2011b. Climate change impacts and adaptation: reducing water-related risks in Europe, Proceedings of the EU-ISDR Int. Workshop, Brussels, 6–7 July, EUR Report 10620.
Kampragou et al., Environ. Sci. Pol., in this issue.
Klove et al., Environ. Sci. Pol., in this issue.
Iglesias et al., J. Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2011.02.007.
Ludwig, F., Kabat, P., van Schaik, H., van der Valk, M. (Eds.), 2009. Climate Change Adaptation in the Water Sector. Earthscan, London.
Ludwig et al., Environ. Sci. Pol., in this issue.
Moors et al. Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2011.03.005.
Price et al., Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2011.03.004.
Quevauviller, Ph., 2010a. Water Sustainability and Climate Change in the EU and Global Context – Policy and Research Responses, IEST vol. 31. RSC Publlishing, Cambridge, pp. 1–24.
Quevauviller, Ph., 2010b. Aqua Mundi 1, 23–28.
Quevauviller, Ph. (Ed.), 2010c. Water Systems Science and Policy Interfacing. RSC Publishing, Cambridge, ISBN: 978-1-84755-861-9p. 430.
Quevauviller, Ph., Borchers, U., Thompson, K.C., Simonart, T. (Eds.), 2008. The Water Framework Directive – Ecological and Chemical Status Monitoring. John Wiley and Sons Ltd., Chichester, ISBN: 978-0-470-51836-6p. 476.
Quevauviller, Ph., Borchers, U., Thompson, K.C., Simonart, T. (Eds.), 2011. The Water Framework Directive – Action Programmes and Adaptation to Climate Change. RSC Publishing, Cambridge, ISBN: 978-1-84973-053-2p. 214.
Roson, R., Ludwig, R., Zografos, C., 2010. Climate change impacts on water and security, cluster of CLIMB / WASSERMed /CLICO projects, 7th Framework Programme. In: Int. Conf. on Integrated River Basin Management under the WFD, Lille, 26–28 April 2010.
Schelfaut et al. Environ. Sci. Pol., in this issue, doi:10.1016/j.envsci.2011.02.009.
Kuhlicke et al., Environ. Sci. Pol., in this issue.
United Nations (2009a) Reducing Disaster Risks through Science: Issues and Actions, the full report of the ISDR Scientific and Technical Committee 2009.
United Nations (2009b) Drought Risk Reduction – Framework and Practices: Contributing to the Implementation of the Hyogo Framework for Action, UN-ISDR, Geneva, Switzerland, 213 pp.
van Ree et al., Environ. Sci. Pol., in this issue.
Wilby, R.L., Orr, H.G., Hedger, M., Forrow, D., Blackmore, M., 2006. Environ. Int. 32, 1043.
Zanuttigh, Environ. Sci. Pol., in this issue.

Philippe Quevauviller obtained a 3rd University Cycle Doctorate in Oceanography in 1987 and a PhD in environment chemistry in 1991 at the University of Bordeaux (France), and a HDR degree (Habilitation à Diriger des Recherches) in chemistry in 1999. He has

been associate researcher at the Portuguese Environment Ministry in Lisbon (1984–1987) and then at the Dutch Ministry for Public Works (Rijkswaterstaat) in 1988–89. From 1989 to 1999, he was Scientific Officer at the European Commission's Research General Directorate in Brussels at the Measurements and Testing Programme, and then became responsible for strategic aspects of the Competitive and Sustainable Growth Programme. From 2002 to 2008, Philippe Quevauviller moved to the Environment Directorate-General where he has been responsible for the development of a new Groundwater Directive (2006/118/EC) and its implementation (maintaining close links with the scientific community). Since the end of 2008, he is back to DG Research where he manages projects concerning climate change impacts on water. Dr. Quevauviller has published more than 220 papers in peer-reviewed international journals and several books. Besides his career at the European Commission, he is associate professor at the Vrije Universiteit Brussel (VUB) where he teaches Integrated Water Resource Management in an international master.