

Water Scarcity: Research opportunities for competing and conflicting demands

Dionysis Assimacopoulos

Environmental and Energy Management Research Unit, School of Chemical Engineering, National Technical University of Athens, Greece

Introduction

Water scarcity is a major resource problem that negatively impacts on all social and economic sectors. Numerous definitions of water scarcity exist, all emphasizing on the imbalance between water supply and demand. The UN (2006) define scarcity as *“the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully”*, whereas the EC Water Scarcity Drafting Group (2006) defined water scarcity using more simple terms, as *“a situation where there is **insufficient** water to satisfy **normal** requirements”*.

Two orders of water scarcity are broadly distinguished. **Physical scarcity** refers to limited access to water resources, attributed either to climate conditions (water shortage) or to the unsustainable management of resources (e.g. overabstraction). When financial and technical resources are sufficient, physical scarcity is mainly tackled through structural measures, such as long-distance water transfers, storage reservoir construction and desalination. Physical scarcity is often followed or aggravated by **socio-economic scarcity**, which corresponds either to the economic inability of a society to develop (additional) water resources or to the lack of societal capacity to adapt to the conditions imposed by physical scarcity (see Turton and Ohlsson, 1999; Appelgren and Klohn, 1999). Along the same line, Rijsberman (2006) addresses the question of whether water scarcity is a fact or fiction, by highlighting the complexity of the socio-economic system that leads to water scarcity and the adaptive, integrated and cooperative management required to address the problem and mitigate its impacts.

In spite of the definition nuances and the interchangeable use of terms, it is clear that water shortage, water scarcity, water stress and drought are all interrelated. Drought can lead to water shortage or induce temporary water scarcity and stress; similarly, regions where water is scarce, are often more vulnerable to droughts.

The increasing number of cases where available water resources fail to meet “normal” water requirements manifests that conflict over the access and use of water resources will be a reality in the near future. Coping with the various levels of water scarcity requires adaptive behaviour and action, both by decision makers and the society at large. Responses typically incorporate strategies for supply enhancement and strategies of demand management, allocative in nature (Turton and Ohlsson, 1999). The main challenge remains to effectively implement options in order to address water scarcity, drought and water stress. At the same time, the adopted responses should ensure minimal negative impacts on water resources, and safeguard social stability, equity and economic growth.

Coping with water scarcity: The guiding principles

Adopting the simplest definition of water scarcity, the overall water management goal is to provide sufficient water to meet the normal needs of the society. This statement could be further analyzed into the need for: (i) adequate water supply of appropriate quality for all water uses, including the environment, (ii) satisfactory access of all water users to water, and (iii) effective and efficient institutional structures and procedures for water allocation and management.

As the World Bank (2007) points out, although natural conditions determine the physical availability of water, it is the institutions and policies that determine the usage level of water resources and the effectiveness of water management, and therefore the technical and social availability of water. Along this line, Pereira et al. (2002) acknowledge the need for a new conceptual thinking in coping with water scarcity, which should take into account the social, environmental, economic and cultural value of water and the alleviation of underlying causes. Furthermore, they pinpoint the importance of innovation in technology and policies for addressing the challenges imposed by rapidly changing conditions. In this regard, Table 1 summarises the key or emerging challenges in policy-making and research in the water scarcity area and the mitigation of its impacts on society and environment.

Table 1: Coping with water scarcity – A non-exhaustive list of challenges

Challenges in policy making	<ul style="list-style-type: none"> • Adaptation to climate change • Adaptation to rapidly changing socio-economic environments • Achievement of the Millennium Development Goals • Financing/rehabilitation/improvement of infrastructure, improvement of efficiency in end-use, change in intra- and inter-sectoral water allocation policies • Ensuring equity in access to water and on the social impacts of water allocation policies • Solving the dilemmas: energy production vs. agricultural production; food security • Management & resolution of conflict among water uses and water users • Protection of ecosystems and biodiversity • Shift from reactive, crisis-based management to proactive, risk-based management • Increase of the adaptive capacity of societies • Fostering of integrative action (inter-sectoral and multidisciplinary approaches) • Development of effective & consistent governance systems (technical, financial, and administrative capacity) at all levels of society (national, regional and local) • Inclusive participatory and transparent decision-making • International cooperation for transboundary water management
Research challenges	<ul style="list-style-type: none"> • Definition of regional/local thresholds for scarcity and drought • Technology innovation for demand management and alternative water supply sources (desalination, reuse etc.) • Analysis of climate change impacts (environmental, social, economic...) • Development of monitoring systems and early-warning tools for drought • Risk assessment and management tools, vulnerability assessment • Social learning processes, development of methods and tools for socio-economic impact analysis • Sharing of knowledge • Regional cooperation in research and development (e.g. multi-sectoral collaboration, partnership, and networking)

Addressing water scarcity in the EU: Policy and Research Initiatives

Water resource management and protection is an integral part of the EU environmental policies and its relevance with other policy agendas is widely recognized (e.g. the CAP, Spatial Development Policies). In acknowledgement of the problems and the challenges all European countries are bound to face under scarcity conditions, the EU has initiated an in-depth assessment and analysis of water scarcity in Europe. The effort concluded to a set of policy priorities for addressing water scarcity (e.g. EC, 2007). On the other hand, several research activities focus on developing innovative solutions for water supply and demand management and on supporting multi-disciplinary policy-related research for water scarcity mitigation.

EU policies

The guiding policy of the EU for water resources is the Water Framework Directive (WFD) 2000/60. Recognizing the increasing significance of water scarcity, the EC fostered in 2003 the preparation of a technical document on water scarcity under the framework of the Common Implementation Strategy of the WFD. This effort provided recommendations on drought management and water scarcity mitigation for the EU water competent authorities. The main conclusions of this assessment were (EC Water Scarcity Drafting Group, 2006):

- Different actions and measures are required to address the different cases of water deficit problems;
- Management should be risk-based rather than crisis-based;
- Prioritizing uses, including environmental use is important;
- Management should be knowledge-based;
- The WFD can be used as an instrument for addressing drought and managing water scarcity.

In 2007, the EC adopted a Communication on water scarcity that highlights the policy priorities for addressing water scarcity. Emphasis is given to the synergies between policy and research, in an effort to disseminate and further exploit results and encourage technology research on water scarcity.

The EU Framework Programmes for Research & Technological Development

The EU Framework Programmes for Research and Technological Development (FP) are the main funding instruments for research activities. FP1 was launched in 1984 and currently FP7 is ongoing. Throughout this period, research activities have been a fundamental component of EU actions, continuously monitored and evaluated in terms of effectiveness, impact and outreach (e.g. ECE, 2007, EC, 2006). Environmental research was first introduced in FP2; since then the scope and orientation of the FPs developed continuously, following the evolution of principles for the sustainable management of natural and man-made systems. Table 2 summarizes key points of EU research programmes on water-related issues.

Table 2. Focus of EU-funded research programmes on water management (Source: CORDIS)

FP	4	5	6	7
Period	1994-1998	1998-2002	2002-2006	2007-2013
Theme	Environment & climate	Energy, Environment & sustainable development	Sustainable development, global change & ecosystems	Environment (including climate change)
Scope	Enhancement of scientific knowledge over environmental issues	Promotion of IWRM with enhanced participation of stakeholders	Promotion of innovative technologies, development of tools and strategies for mitigating impacts on water resources	Emphasis on the global change impacts on water resources, support to EU policies
Water key action	Research into the natural environment, environmental quality and global change	Sustainable management and quality of water	Water cycle, including soil-related aspects	Sustainable management of resources
Issues addressed	Basic mechanisms of the climate and natural systems and their impact on natural resources	Integrated management at the catchment scale, ecological quality, treatment and reuse, pollution prevention, monitoring and forecasting, arid and semi-arid region, standardisation	Hydrology and climate processes, ecological impact of global change, soil functioning and water quality, Integrated management strategies and mitigation technologies, scenarios of water demand and availability	Conservation and sustainable management of natural and man-made resources and biodiversity, management of marine environments

Earlier efforts emphasized more on the development of scientific knowledge to support environmental quality standards and objectives, focusing on situation analysis supported by data collection, validation and decision support tools. The 5th Framework Programme (FP5, 1998-2002) invested more than 250 million Euros in water-related projects, resulting in important scientific and technological insights and policy contributions in the field of hydrology, ecosystem dynamics, water quality and monitoring issues, innovative technologies for wastewater treatment and environmental rehabilitation. Several projects funded through FP5 focused on Integrated Water Resources Management (IWRM), adopting a multi-disciplinary, stakeholder-driven approach and recognizing or integrating social and economic aspects. An effort was also made to support relevant EU policies, and especially the implementation of the Water Framework Directive.

The water programmes of FP6 and FP7 were formulated in accordance with the Lisbon Agenda and are characterized by the emphasis on IWRM and the increasing participation of end-users from the public and the private sector, including non-EU partners. In relation to water scarcity, the evolution in

EU water-related research is marked by the gradual transition from water supply to demand management and to constructively engaged integrated water allocation and management. The increasing concern over global change and the need for proactive management in view of extreme hydro-climatic events ask for the integration of research into policy. In this perspective, FP7 focuses more on developing synergistic links, addressing the need to effectively connect local knowledge with technical support, socio-economic development aspects, policy orientations, stakeholder and implementation bodies.

Examples of EU-funded research activities on water scarcity

Water-related research encompasses technological, economic, social and policy aspects and aims at contributing to the sound and sustainable management of water systems. Technology-oriented research supports the development of innovative technologies, tools and methods that contribute to the efficient use and management of water resources. On the other hand, policy-oriented research aims at providing a scientific basis to assess wider impacts of currently applied or potential water management options. Both approaches are complementary in nature: through the use of quantitative and qualitative methods and tools, policy-oriented research combines technological innovation with economic, social and political concerns in order to provide effective support to policy-making.

Research projects in support of technological innovation

In dealing with water scarcity, technological and scientific innovation seeks to develop or integrate scientific tools and methods for enhancing knowledge on water systems or to develop new and improve existing methods for supply augmentation, efficient water use and water quality management. This paragraph briefly presents seven research projects on the development of innovative methods for (a) water reclamation and artificial aquifer recharge, (b) desalination, and (c) improved irrigation management.

Water reclamation & artificial aquifer recharge – The RECLAIM-water & Gabardine projects (FP6)

RECLAIM-water (“*Water reclamation technologies for safe artificial groundwater recharge*”) focuses on new and improved water reclamation and reuse technologies, emphasizing on municipal wastewater production. It develops new analytical methods to monitor emerging chemical contaminants and pathogens, and evaluates the potential of soil aquifer treatment for groundwater recharge. **Gabardine** project (“*Groundwater artificial recharge based on alternative sources of water: advanced integrated technologies and management*”) investigates the impact of large-scale artificial recharge on present and future groundwater quality. The project’s research strategy encompasses the development of (a) an integrative methodology for evaluating aquifer vulnerability to contamination factors, precipitation variability etc., and (b) technologies for the storage of waters of various qualities.

Advancing desalination processes – The MedCoDesal (FP4), the MEDINA and the MEDESOL projects (FP6)

Water desalination was the main research topic of the **MedCoDesal** project (*Mediterranean cooperation for water desalination policies in the perspective of a sustainable development*). Through the development of a GIS-based decision support system and data collection, the project analysed water scarcity conditions in test sites located in the eastern Mediterranean region. The main outcome was a set of recommendations for the large-scale integration of decentralized renewable energy powered desalination in areas facing water shortage problems. The **MEDINA** project (“*Membrane-based desalination: An integrated approach*”) seeks to develop a membrane-based integrated desalination process by addressing frequent problems and drawbacks of the widely applied Reverse Osmosis (RO) process. Research addresses feed water characterization, RO module settings, fouling and scaling problems, optimization of post-treatment processes, reduction of energy consumption through advanced energy recovery and renewable energy sources and minimization of brine disposal impacts. **MEDESOL** (*Seawater desalination by innovative solar-powered membrane-distillation system*) aims at developing an environmentally friendly, improved-cost desalination technology based on multi-stage membrane distillation using solar collectors. Three prototype systems are developed by the project and tested using brackish water under real working conditions, in order to evaluate the technical and economic feasibility of the process.

Irrigation management – The PLEIADeS & Flow-Aid Projects (FP6)

The **PLEIADeS** project (“*Participatory multi-Level EO-assisted tools for Irrigation water management and Agricultural Decision-Support*”) applies new technologies (Earth observation, Geographical

Information Systems, Information and Communication Technologies, and Decision Support Systems) for improving and optimizing irrigation and drainage systems. It introduces a participatory approach for supporting decision making and integrated water management at the farm and basin-scale levels, effected through spatial information and innovative networking tools. **Flow-Aid** (*"Farm Level Optimal Water Management: Assistant for Irrigation under Deficit"*) contributes to sustainable irrigation by developing, testing and fine-tuning through feed-back, an irrigation management system that can be used at farm-level in situations where there is limited water supply and water quality. The project integrates innovative sensor technologies into a Decision Support System for irrigation management; new concepts for irrigation under deficit are evaluated in four test sites with different conditions (e.g. irrigation structures, crop types, water quality).

Research projects in support of policy development

Policy-oriented research has evolved over time; at present, the majority of projects, even those mostly concerned by technical aspects, include a policy component, aimed at widely disseminating outcomes and developing synergies with end-users, including decision-makers. The examples below showcase that water scarcity-related research gradually developed from data collection, analysis, decision support tools and individual policy recommendations to multi-disciplinary perspectives and integrative approaches, in order to effectively support the evolution of the relevant EU policies.

The ARID Cluster and the ASTHyDA Projects (FP5)

EC-funded research clusters aimed at fostering communication, exchange of knowledge and integration of results among interrelated research projects. In the above perspective, the ARID Cluster supported the collaboration among three FP5 research projects on water management in arid and semi-arid regions:

- 1) The WaterStrategyMan project (*Developing Strategies for Regulating and Managing Water Resources and Demand in Water Deficient Regions*), which primarily aimed at developing water management strategies for alleviating water stress in Southern European regions, addressing also WFD implementation aspects. Strategy formulation and evaluation was supported by the development of a prototype Decision Support System, specifically oriented towards the simulation of water systems facing scarcity conditions and the estimation of the corresponding financial, resource and environmental costs;
- 2) MEDIS (*Towards Sustainable Water Use on Mediterranean Islands: Addressing Conflicting Demands and Varying Hydrological, Social and Economic Conditions*), which derived recommendations for equitable and sustainable water management in Mediterranean islands, based on scientific investigations and on stakeholder demands and experience; and
- 3) Aquadapt (*Strategic Tools to Support Adaptive, Integrated Water Resource Management under Changing Utilisation Conditions at Catchment Level: A Co-evolutionary Approach*), which generated knowledge in support of strategic planning and management of water resources in semi-arid environments under changing supply and demand patterns.

The complementarity of the different research approaches, methodologies, tools, and policy recommendations was highlighted in the ARID Cluster book publication "Water management in arid and semi-arid regions: Interdisciplinary perspectives" (Edward-Elgar Publishing Ltd, 2006).

Similarly, the ASTHyDA Project (*Analysis, Synthesis and Transfer of Knowledge and Tools on Hydrological Drought Assessment*) fostered the development of a network to disseminate knowledge and identify research needs in relation to drought monitoring and impact mitigation.

The AquaStress project (FP6)

The AquaStress Integrated Project (*"Mitigation of Water Stress through new Approaches to Integrating Management, Technical, Economic and Institutional Instruments"*) deals with the diagnosis and mitigation of water stress. It adopts a stakeholder-driven, multi-disciplinary approach for selecting and evaluating mitigation options. Options and tools are tested in eight (8) case studies in Europe and North Africa, characterized by a range of circumstances leading to different degrees of water stress. The main project outcomes include: (i) new knowledge management and learning tools, and (ii) guidelines for integrated water stress mitigation to support policy making at the local, regional and European levels.

The INECO project (FP6)

The INECO project (*Institutional and Economic Instruments for Sustainable Water Management in the Mediterranean Region*) focuses on capacity building for constructively engaged IWRM. The project fosters a social experiment in capacity building and policy framing in Mediterranean Countries, emphasizing on public participation. It will develop policy guidelines on economic and institutional instruments in support of improved water management.

The Xerochore project (FP7)

Drought is the main research topic of the FP7 Xerochore project (An Exercise to Assess Research Needs and Policy Choices in Areas of Drought). The project's objective is to support EU policy making for drought preparedness and mitigation, mainly by identifying gaps in policy making and research in the field of drought planning and management. Xerochore follows an interactive information exchange approach among renowned research institutions in Europe and an external network of drought experts and decision-makers, which will be facilitated through a series of workshops.

Concluding remarks

Water scarcity is becoming a reality in many EU regions, irrespectively of climatic conditions. It calls for innovative solutions in terms of both technology and policies, which will support the adaptation of water management to global change.

There is a growing need for developing new and further advancing existing technologies for supply enhancement (e.g. rainfall harvesting, desalination, wastewater recycling and reuse, use of drainage water, improved storage), and efficient end-use (improved irrigation scheduling and technologies, leakage detection and repair), in order to improve their effectiveness and cost. At the same time, technological innovations need to be widely disseminated and assessed in terms of social, economic and environmental impact, so as to facilitate their swift implementation.

As water scarcity results in increased competition and conflicts, which in turn create wider socio-economic and cultural challenges, many research projects adopt a multi-disciplinary approach. In this perspective, the early involvement of stakeholders is crucial to success, as it helps in the identification of causes, impacts, and solutions and in the building of consensus for policy recommendations. However, adaptive capacity building and development of a society resilient to water scarcity are continuous processes that require strong and durable links among researchers, end-users, stakeholders, policy-makers and the public.

Past failures in the uptake of water-related research pinpoint that there is need for more effective communication of results. On the other hand, the need for policy innovation implies that the whole cycle of the EU water-related research should be evaluated with regard to its long-term impact and contribution, and possibly revisited according to an adjusted vision that addresses the rapidly changing conditions in the water sector and the emerging needs of societies and the environment.

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