Redouane Choukr-Allah · Ragab Ragab
Rafael Rodriguez-Clemente *Editors*

Integrated Water Resources Management in the Mediterranean Region

Dialogue Towards New Strategy

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Foreword

Most Mediterranean countries face challenges on two fronts, with regard to managing water resources in a sustainable manner and ensuring affordable and reliable water service delivery to farmers, households and industries. In general, water management in southern Mediterranean countries has suffered from poor accountability (both external to service users and internal within resource management and service delivery organizations). More and more investments are being required to remedy the deferred maintenance of already installed hydraulic infrastructures in the region.

As early as 2015, almost all southern Mediterranean countries will be below the level of severe water scarcity at less than 500 m^3 per capita per year. Nine countries will be below 200 m^3, six of which below 100 m^3 and climate change will worsen the situation. Over 85 % of fresh water is used for agriculture, with more than half wasted due to inefficient use practices. Efficiency levels of water for human use are also low, even in countries under chronic stress. Water availability is a prerequisite for the sustainable development of the Mediterranean region, which is characterized by water scarcity and extreme events of droughts and floods. Major current and future problems with fresh water resources in this region arise from the pressure to meet agricultural, human and industrial needs of a fast-growing economy that generates growing imbalances between water demand and supply. Management of limited water resources has taken many different forms and directions throughout the Mediterranean, but the continuous interaction between the peoples living on its shores has produced a common history and culture. In this context, there is an urgent need for action in order to integrate water management in national development plans, promote water considerations within cross-sectoral policies, and to introduce mainstream climate change adaptation into IWRM planning. This necessitates developing appropriate tools, improving the capacity building of water managers, raising public awareness and promoting water-sensitive environmental education, as well as setting up water partnerships at regional and national levels.

The objective of this book is to put together the knowledge developed on both sides of the Mediterranean about the issues related to Integrated Water Resources

Management. This has been carried out by compiling several experiences produced in a number of reports, books, and conceptual frameworks describing the results of the internal and external debates organized within the Mediterranean region. The main aim of this book is to review the results of MELIA deliverables and the results of discussions that took place among a large spectrum of stakeholders and the recommendations to facilitate dialogues between Mediterranean countries on national IWRM planning, effective water governance, water and climate relationship, water demand management, water financing and the involvement of the private sector, as well as river basin management and transboundary water resources. We hope that the topics addressed by the different chapters will give additional value to our knowledge in this field and contribute to *the improvement of the regional water planning and management under scarcity conditions in order* to enhance sustainable development in the Mediterranean region.

The book is structured into four main parts, covering a wide range of topics related to Integrated Water Resources Management in the Mediterranean region.

The chapters of this book are organized so that they present observations and analyses of various aspects of IWRM through:

- First, and most significant, is to focus on the IWRM in the Mediterranean in the light of the European Water Framework Directive experience gained and the lessons learnt. It includes an assessment of water availability and water management and countries' strategies and adaptations to water scarcity conditions.
- Second, to discuss the impact of climate and land use changes on the Mediterranean region's water resources management, what strategy needs to be adopted to face these changes, and also what tools and guidelines are used to promote the sustainable water management, including the application of the integrated hydrological modelling system, IHMS and appropriate agricultural practices.
- Third, to tackle the manifold aspects of *water quality deterioration in the Mediterranean* through securing sufficient water knowledge and advancing monitoring and data collection efforts. The aim is to create a comprehensive regional and national assessment plan and to draw practical management solutions to face the emerging challenges and the existing key obstacles. In this part, we evaluate the potentials of wastewater reuse in the Mediterranean region, and the measures towards depollution of the Mediterranean Sea and the perspective of ecological sanitation scheme as a solution for rural areas.
- Fourth, to promote widely agreed solutions and *promote the convergence* of the water policies in the Euro-Mediterranean region on the basis of the Water Framework Directive recommendations. This part addresses water policies, governance and social issues in the Mediterranean countries and identifies risks, actions and opportunities for a water long-term strategy in the Mediterranean. We also share the common knowledge in relation to the water governance conceptual frameworks and analysis of gender roles in connection with water resources management and develop water security for food security nexus.

We hope that the book will be of interest to a wide audience involved in water resources management, NGOs, operators, politicians, water authorities and researchers working in this field.

Finally, we would like to thank all the authors of this book for their time and effort in preparing this comprehensive compilation of research papers.

Redouane Choukr-Allah
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Preface

The Mediterranean region is characterized by the limited and irregular availability of water resources, both in time (summer drought, interannual droughts) and in space (dry in the south). The region accounts for 10% of the world population with renewable water resources of less than 1,000 m^3 water/inhabitant/year. The continuous growth in urbanization, tourism, irrigation and population increases tensions among sectors and causes conflicts in many countries and in regions where consumption has already reached or exceeded the amount of available water resources.

The Mediterranean countries are also the most vulnerable to global climate change. Studies have shown that the people of the Mediterranean can expect more forest fires and loss of agricultural land than any other region in the world. In the future, the region is expected to deal with more frequent and severe water shortages. Southern Mediterranean countries have a constant or shrinking water supply, but demand from competing users is rising steadily. Tourism rises steadily year after year, with the Mediterranean accounting for approximately one-third of all international tourism. Also increasing is the water demand to meet the steadily growing population requirement. The stable, ageing population in the northern Mediterranean is countered by a rapidly rising population in southern countries. But the biggest drain on resources is agriculture. Farming is the largest industry in terms of jobs in many Mediterranean countries. It is also one of the most water intensive human activities, with irrigation accounting for up to 60 % of all water usage. Simply rising populations, the growing tourism trade and agriculture have led to a greater demand for water. Depending on where in the region, the Mediterranean contains arid or semi-arid areas, regularly having to deal with water scarcity and extreme events such as droughts and floods. This is a significant problem now, but when climate change is also factored in, water is expected to become a commodity which has the potential to become an acute problem for Mediterranean countries. With all of these considerations in mind, water managers are left with the daunting challenge of not only meeting the current demand for water but also sustaining supply as demand grows. In order to discuss these issues in response to such water problems in the Mediterranean, MELIA, the Mediterranean Dialogue for Integrated Water Management project, financed by the 6th Framework Programme of the European Commission, was launched in 2006.

The scale of the project is considerable: “The MELIA Consortium had 45 partners representing 17 countries from both the EU (Italy, Spain, Cyprus, Greece, Belgium, Malta, Austria, the Netherlands) and the Mediterranean (Turkey, Morocco, Algeria, Tunisia, Egypt, Syria, Lebanon, Jordan, Palestine). These members are split into many different categories which included Research Institutions, Decision-Policy Makers, Water Users, International and Intergovernmental Organizations, NGOs, River Basin Authorities, Water Providers for different users and private companies.”

MELIA is part of a broader EU INCO-Med programme, which aimed at creation of opportunities to contribute high-quality and relevant scientific knowledge to issues of mutual concern in European and Mediterranean countries. Water management and other major issues such as risk and conflict prevention, environmental management and food security are addressed through collaboration among the scientists in the EU INCO-Med projects. Sometimes collaborative projects offer scientific knowledge, often without resulting in impacts of the challenging situation on the collaborating countries. Such projects lack dialogue between the researchers and all the interested stakeholders. In 2000, the EU issued the Water Framework Directive (WFD), outlining a framework and legislation related to Integrated Water Resources Management (IWRM). This document was the result of 10 years of dialogue and collaboration between the key European stakeholders. It considers water quantity and quality management on an international scale and as a political process. It is generally regarded as a model and reference point for water management issues. MELIA hoped to use the knowledge and experiences gained in creating the Water Framework Directive in combination with local knowledge and shared culture to drive Integrated Water Resources Management in Mediterranean countries. The main aims of MELIA were as follows: to build a knowledge base for Integrated Water Resources Management planning based on the general frame set out by the EU Water Framework Directive and to propose participatory mechanisms and prevention tools to avoid competition for resources between regions, states and different end users.

Secretary General of CIHEAM Francisco Mombiela Muruzabal
Director IAM Bari Cosimo Lacirignola

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Part I
IWRM in the Mediterranean Region

Transboundary IWRM Attempts in the Mediterranean Emphasis on the Drin River Case and the Involvement of Stakeholders

Michael Scoullos

Abstract Integrated Water Resources Management (IWRM) is a holistic, participatory approach with involvement of all relevant stakeholders to address effectively water issues at river basin level within either a national or transnational framework. In the EU countries, the EU WFD provides for cooperation of riparians with stakeholders toward this end. In the wider Mediterranean region, very few relevant attempts have been made, with limited results. This chapter briefly refers to three cases with different "models" and level of involvement of stakeholders: The NW Sahara Aquifer System with rather limited stakeholder involvement, mostly, from the research and academic community; the Sava River case with a stakeholder involvement added, rather late, in the process; and the Drin River case, where the stakeholder involvement was – to a certain extent – one of the driving forces, integrated from the beginning into the process. The latter case is analyzed in detail, explaining the main specificities of the Drin Basin system, the international framework within which the Drin Dialogue was developed, the key players, the NGO and other stakeholders' role and contribution, and the important results until now, including the adoption of a Memorandum of Understanding among the riparians.

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1 Introduction

All around the Mediterranean, big and small rivers and other surface or groundwater bodies are shared between two or more countries. Given the increasing pressures on them generated either by demands for servicing increasing populations and food security needs (Benoit and Comeau 2005) or by droughts linked to climate change (Black 2009), etc., the integrated management of transboundary waters has been repeatedly recognized as a very high priority at global (GWP 2000), regional, and subregional level (Scoullos et al. 2002). Within the EU, the Water Framework Directive (European Commission 2000) provides for coordinated action by the riparians toward this scope. An important component of the WFD is the stakeholders' (local authorities, users, CSOs, NGOs, etc.) involvement.

Despite the universal endorsement for transboundary Integrated Water Resources Management (TIWRM or – simplified – TWRM) as powerful tools to bring riparians closer together (Wolf 1998; Zeitoun and Warner 2006), the systematic attempts to translate intentions into concrete measures throughout the Mediterranean basin, and in particular outside the EU, are extremely limited. This is due mainly to the fact that transboundary waters were traditionally dealt with by governments as integral part of their international/bilateral political negotiations focusing entirely on allocation of specific water quantities to the riparian according to "quotas"; in other words, the emphasis was – and still is – in sharing or "distributing" water resources.

2 The Mediterranean Scene

Several authors have examined transboundary systems in the Middle East, North Africa, and Europe such as the Jordan and Orontes Rivers, the Euphrates and Tigris Rivers, and the Nubian Sandstone Aquifer System (NSAS), as well as the basins shared between Spain and Portugal (Gleick 1994; Conley and van Niekirk 2000; Feitelson 2002; Scoullos and Tomassini 2003, etc.). The new tendency suggests that IWRM and TWRM's aim should, primarily, be at "sharing the benefits" of water resources. This shift is advocated by a particular sector of the emerging discipline of environmental diplomacy, the so-called hydrodiplomacy (Comair 2009), which is becoming progressively more important in bilateral relationships between riparians. Another reason for slow progress in TWRM is the lack of experience in participatory planning and processing water management plans especially when multistakeholder consultations across boarders are requested.

A number of traditional approaches have been attempted in the past including major rivers and aquifers in North Africa (the Nile River, the Nubian Aquifer), the Middle East (e.g., the Jordan and the Orontes Rivers), and the Balkans (Evros/ Maritsa and Nestos/Mesta Rivers). In all these cases, negotiations have been started long ago, but, in general, progress is very slow and, in principle, interrupted with little – until now – concern on integrated management and little, if any, active stakeholders' participation in most of them. All the aforementioned cases were initiated "top down" by governments. In some cases, parallel initiatives have been developed by stakeholders/NGO (see, e.g., for Nestos/Mesta River by GWP-Med and for the Jordan River by FoE-ME – under development – as a pilot case of the SWIM project).

Informal attempts – even when successful – have by their nature a "complementary" character to that of formal negotiations among riparians. In cases of opposition or reservation expressed about them by any of the parties involved, the added value of informal attempts is minimized, and their results may become very limited. However, when there is an "in principle" willingness for cooperation and genuine acceptance on the nonstate contributions, stakeholders' involvement and participation (particularly of organizations of regional character) could become a very positive element catalyzing, facilitating, enhancing, and stabilizing cooperation.

Reviewing the transboundary water management scene in the Mediterranean, three cases have been indentified, where considerable progress/success can be recorded, representing different types of negotiation background and modalities and with different role and character of the stakeholders involved. These cases are:

- The NW Sahara Aquifer System
- The Sava River
- The Drin River

A brief outline of these three cases was presented by the author in the recent Mediterranean Water Forum in Marrakesh (2011).

2.1 The NW Sahara Aquifer System

The *NW Sahara Aquifer System* among Algeria, Libya, and Tunisia is the main source of water for approximately five million people (see Fig. 1). The collaboration among the three countries was started already in the 1960s, based on scientific grounds. It was continued in the 1980s and the 1990s through some technical projects, and in 2002, a temporary mechanism of collaboration was put in place. A more formal consultative structure and an *ad hoc* scientific committee were established after 2007. The collaboration was built step by step and owes a lot of its progress to the enabling conditions created by the Sahara and Sahel Observatory (OSS) which has acted as the technical facilitator of the process. The OSS involvement has enabled a number of scientists and experts to communicate, agree, and work together. In this case, the basis of cooperation was the sharing of scientific experience and data in view of serving appropriate modeling needs. The role of other state stakeholders (national agencies) and the responsible scientists was minimal if any.

Fig. 1 The NW Sahara Aquifer System

2.2 *The Sava River*

The *Sava River* case is an example of a top-down process initiated by the riparian governments (Bosnia and Herzegovina, Croatia, Montenegro, Serbia, Slovenia) which were in the past, member states of Yugoslavia (see Fig. 2). After a period of turbulence, they came together to manage navigation in the river and some other key aspects of river management. The launching of the Sava River Initiative was done in the framework of the Stability Pact for SEE in June 2001. The Framework Agreement on the Sava River Basin (FASRB) was signed at Kranjska Gora, Slovenia, on December 3, 2002 and entered into force on December 29, 2004. The establishment of the International Sava River Basin Commission (ISRBC) took place in Zagreb in June 2005. Six months later (January 2006), the ISRBC Secretariat was established in Zagreb. ISRBC is composed of representatives of the parties nominated by the governments (two country representatives per party: a member and a deputy member). No other stakeholders were involved for the establishment, but the role of international organizations and donors was instrumental. The objectives of the FASRB are defined as follows:

- To establish an international regime of navigation
- To establish sustainable water management
- To prevent/limit hazards (floods, ice, droughts, accidents) and to eliminate/reduce their consequences

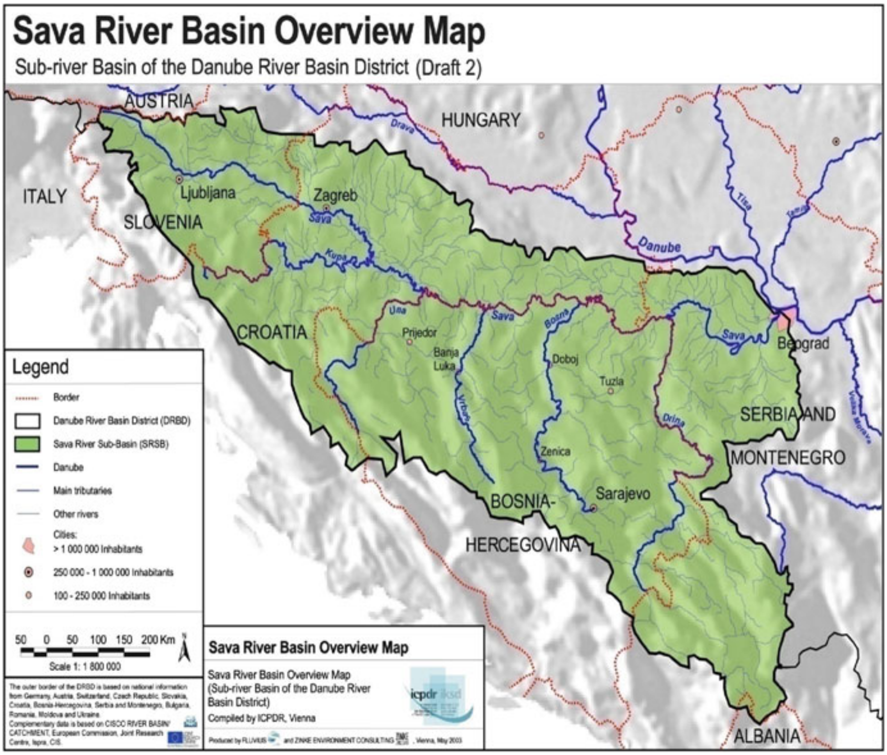

Fig. 2 The Sava River Basins

The tools chosen for the implementation of the FASRB are the creation and realization of joint plans and development programs for the Sava River Basin and the facilitation of harmonization of the national legislation with that of the EU, etc. A number of principles guide the cooperation of the parties. These are sovereign equality; territorial integrity; mutual benefit; good faith; mutual respect of national legislation, institutions, and organizations; cooperation in accordance with the EU Water Framework Directive; and regular exchange of information within the Sava River Basin on a number of issues such as the water regime, the regime of navigation, relevant legislation, organizational structures, and administrative and technical practices.

The FASRB provides also for the cooperation with international organizations (ICPDR, DC, UNECE, EU), the reasonable and equitable use of water, the regulation of all issues related to securing integrity of the water, the regime in the Sava River Basin, and the elimination or reduction of the transboundary impacts on the water of the other parties caused by economic or other activities.

The ISRBC is responsible for the implementation of the Framework Agreement on the Sava River Basin and realization of the objectives through a set of activities, including the preparation of a joint/integrated Sava River Basin Management Plan, the establishment of an integrated information system, the preparation of a number of priority projects as well as of studies and other strategic documents, and the implementation of activities on navigation and water management.

Sava was always a river with developed navigation, where internationally agreed rules have to be in place for obvious reasons. This has helped a lot, and the commission formed has mandate to decide and regulate on navigation issues. The other aspects of management were gradually carefully added as secondary, and the commission in all other issues (i.e., water management) offers advice and provides recommendations.

The role of nonstate stakeholders was at the beginning very limited but is increasing steadily following related initiatives of the ISRBC. Several NGO initiatives have been organized (see also the Sava River Day), in some of which MIO-ECSDE was involved. Actions for the structured participation of the stakeholders are ongoing; UNESCO Venice office, GWP-Med, and others collaborate with the Secretariat in this regard. The involvement of the international community has been important in the past by supporting projects and initiatives, some of which involve stakeholders. This support is expected to continue in view of the fact that the Sava River case is considered as one of the most successful in the region with genuine potential to enhance participatory processes for interested stakeholders including civil society organizations.

2.3 The Drin River

The *Drin River* collaboration is a clear case where in a very complex and “difficult” region such as the Southeast Europe (Western Balkans), the stakeholders’ involvement and role have played a decisive role in setting the scene and in creating the enabling environment for the riparians to come closer together and act jointly. This is why in this chapter, we do focus on this particular case which may inspire other similar attempts, elsewhere.

3 The Drin River Case

3.1 The SEE/Western Balkans and the Petersberg Phase II/Athens Declaration Process

It is obvious that integrated management of transboundary water bodies is of paramount importance for Southeastern Europe (SEE), where 90 % of the area is falling within shared basins. More than 50 % of these basins are shared by three or more riparians, while more than 50 transboundary aquifers exist, many of which are interlinked with surface water bodies. Significant differences in rainfall and in water availability; urban, agricultural, and industrial pollution of several of the aquatic subsystems involved; and increasing demands for development uses of various conflicting sectors (hydropower, tourism, etc.) are among the key challenges for the water management of the region. Furthermore, differences in governance regimes and legal frameworks in the various SEE countries add to the complexity. Enhanced cooperation among riparian countries and eventual adoption of related multilateral arrangements have been recognized as necessary in order to ensure effective protection and sustainable use of the transboundary water resources.

Actions to bring up the benefits of cooperative integrated management have been proposed as a useful “instrument” that could assist in enhancing cooperation. Such approaches have been promoted in the region through the systematic activities undertaken within the joint Petersberg Phase II/Athens Declaration Process. The main joint objective of the process is to build capacity and share experience on Integrated Water Resources Management (IWRM) and to develop IWRM plans for shared water bodies in SEE, south of Danube, as a response to the targets of the 2002 Johannesburg Summit. The “Petersberg Process” was initiated in 1998. It focuses on cooperation for the management of transboundary waters. The Petersberg Process – Phase II is intended to provide support to translate into action the current developments and opportunities for future cooperation on transboundary rivers, lakes, and groundwater management in SEE. It is supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and the World Bank. The “Athens Declaration” Process concerning *Shared Water, Shared Future and Shared Knowledge* was initiated in 2003. It provides a framework for a long-term process to support cooperative activities for the integrated management of shared water resources in the SEE and Mediterranean regions. It is jointly supported by the Hellenic Ministry of Foreign Affairs and the World Bank.

The two processes progressively came together in order to generate synergies and maximize the outcomes for the benefit of the SEE region. The Global Water Partnership – Mediterranean (GWP-Med) provides the Secretariat and is the technical facilitator of the related activities playing an important catalytic role.

The process supports a series of complementary activities that provide a forum for transboundary water management issues in the region. The activities revolve around the political, economic, social, and environmental benefits that can be realized through effective cooperation in the management of transboundary waters.

GEF IW:LEARN2 (2005–2008) has contributed substantially and supported the process in developing and implementing a dynamic regional dialogue on TWRM issues in the SEE countries, which includes a series of related activities.

The initiation of an official dialogue among the riparian countries of the Drin River Basin has been among the most important and tangible results of the process. Solidly based on the willingness of the riparians to explore ways to enhance cooperation, the process complements the EU integration processes and other ongoing initiatives in the region. It contributes directly to the scope and objectives of the Mediterranean Component of the EU Water Initiative (MED EUWI) and the Global Environmental Facility (GEF) MedPartnership, and it has been supported (apart from Germany, Greece, and the GWP-Med) also by external “convening partners” including GEF, UNECE, and Sweden while UNDP has pledged its support for developing future actions.

3.2 The Drin Basin System

The "extended" Drin Basin (see Fig. 3) is an interconnected hydrological system comprising of the transboundary subbasins (components) of the Prespa Lake, Ohrid Lake, Shkoder/Skadar[1] Lake, and Drin River, including its tributaries Black Drin[2] and White Drin[3] as well as the Buna/Bojana[4] River (outflow of Shkoder/Skadar Lake in to the Adriatic Sea).

Each of the components is of paramount ecological importance as it hosts unique biotopes with many indigenous species, important from a European and international conservation perspective.

The basin includes five riparians, namely, Albania, the former Yugoslav Republic of Macedonia (FYR Macedonia), Greece, Montenegro, and Kosovo (*UN administered territory under UN Security Council resolution 1244*). Diverse and often conflicting and unsustainable management approaches have been followed for many years; this leads to ecosystems' degradation and inhibits sustainable economic growth in the entire region.

Some action toward Integrated Water Resources Management has been initiated at national level, driven or stimulated mainly by the prospect of EU accession. The parties are at various stages of transposition and implementation of the EU Water Framework Directive (EU WFD) and respectively differ in the available administrative capacities.

Bilateral or trilateral agreements among the riparians form the basis for water resources and ecosystem management related cooperation in each one of the three lake components of the Drin system. Coordinated action at the basin level has been recently established through the Memorandum of Understanding signed by the riparians, as the result of the Drin Dialogue process described below.

3.3 The Drin Dialogue Process

For the first time, the overall concept for an eventual enhanced cooperation among the riparians for the management of the Drin Basin was discussed by representatives of the competent ministries together with other key stakeholders during the International Roundtable on "Integrated Management of Shared Lake Basins in Southeastern Europe" organized under the Petersberg Phase II/Athens Declaration Process and GEF IWLEARN in Ohrid, FYR Macedonia (October 12–14, 2006).

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[1] The lake is called Skadar in Montenegro and Shkoder in Albania.

[2] The river is called Drini i Zi in Albania and Crn Drim in the former Yugoslav Republic of Macedonia.

[3] The river is called Drini i Bardhë in Albania and Beli Drin in Kosovo.

[4] The river is called Buna in Albania and Bojana in Montenegro.

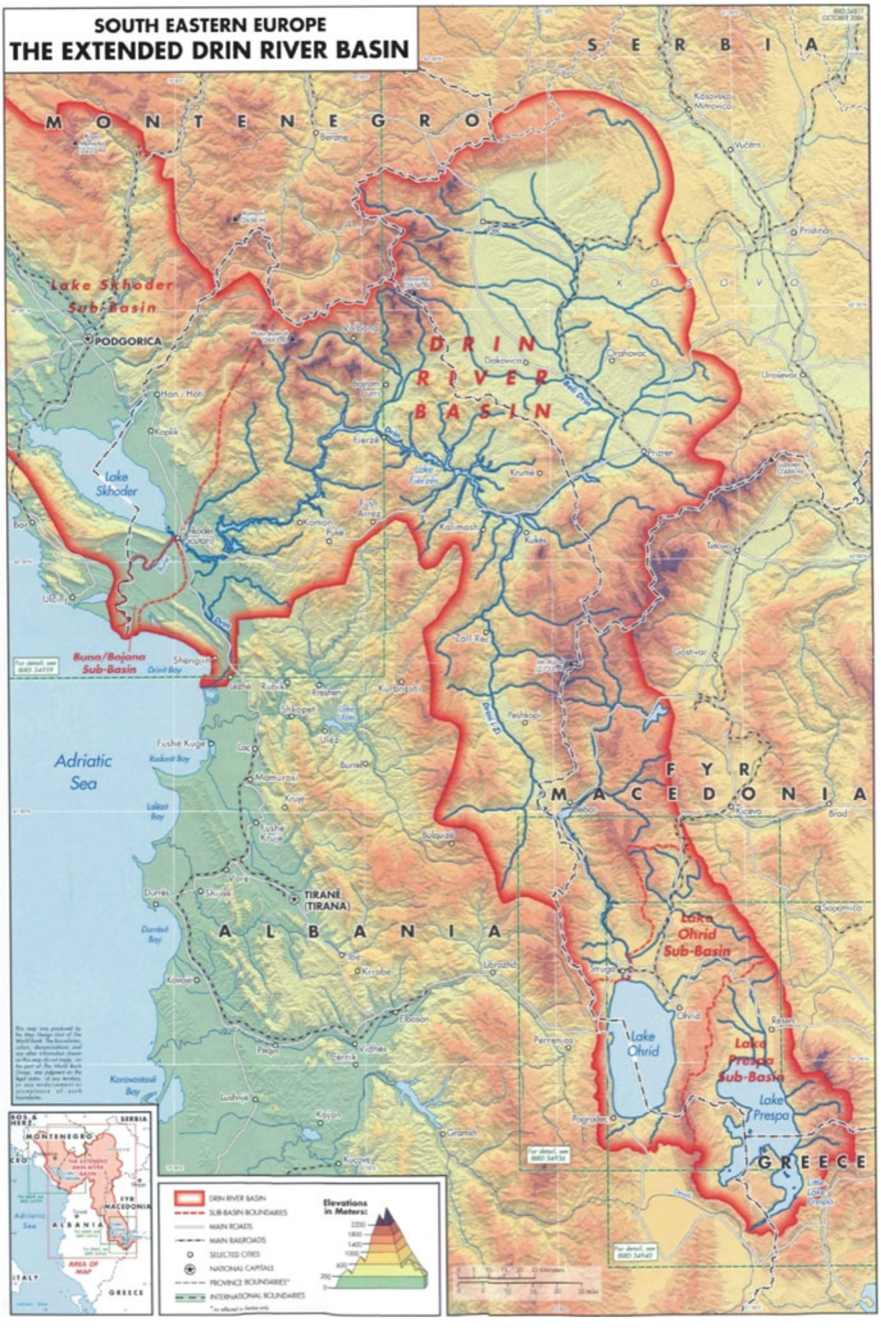

Fig. 3 The Extended Drin River Basin

Based on the conclusions of the roundtable and as a response to the related expression of interest and support by stakeholders, a "Consultation Meeting on Integrated Management of the Extended Drin River Basin" was organized by UNECE and GWP-Med and the Albanian Ministry of Environment, Forestry and Water Administration with the financial support of the Swedish Environmental Protection Agency and the German Ministry for Environment, in Tirana, Albania, on November 24, 2008. The meeting gave a clear mandate to the partners the Petersberg Phase II/Athens Declaration Process and UNECE to facilitate the establishment of a "Shared Vision" for the coordinated management of the basin.

The multistakeholder process for the establishment of the Shared Vision, called the *Drin Dialogue,* was formally launched during a meeting organized on December 1, 2009 held in Podgorica, Montenegro (*the Podgorica meeting*). The meeting brought together representatives of the water resources management competent ministries of Albania, FYR Macedonia, Greece, and Montenegro as well as the existing Joint Management Commissions/Committees of the lakes of the Drin system. It was decided that the UNECE and the GWP-Med will facilitate the implementation of the Drin Dialogue, and the Mediterranean Information Office/(MIO-ECSDE) – the main NGO federation active in the region – volunteered to facilitate and organize with its own resources a series of NGO consultations to contribute to the dialogue.

The *Drin Core Group (DCG)* was established by the Podgorica meeting as an informal structure to facilitate communication and cooperation among the riparians and coordination of the implementation activities of the Drin Dialogue. The catalytic role of stakeholders was fully recognized by the riparians, and therefore it was decided that the DCG will comprise of dully nominated representatives of the:

1. Competent ministries of the riparians:
   - Ministry of Environment, Forestry and Water Administration, Albania
   - Ministry of Environment, Energy and Climatic Change, Greece
   - Ministry of Environment and Physical Planning, the former Yugoslav Republic of Macedonia
   - Ministry of Sustainable Development and Tourism, Montenegro
   - Ministry of Agriculture and Rural Development, Montenegro
   - Ministry of Environment and Spatial Planning, Kosovo (UN administered territory under UN Security Council resolution 1244)
2. Joint Lake Basin Commissions/Committees, namely, the:
   - Prespa Park Management Committee
   - Lake Ohrid Watershed Committee
   - Lake Skadar-Shkoder Commission
3. United Nations Economic Commission for Europe (UNECE)
4. Global Water Partnership – Mediterranean (GWP-MED)
5. Mediterranean Information Office for Environment Culture and Sustainable Development (MIO-ECSDE)

The European Commission, the Swedish Environmental Protection Agency, and the United Nations Development Programme (UNDP)/Global Environment Facility (GEF) were welcomed to participate as observers. Furthermore, the Podgorica meeting discussed and agreed on the content of the Drin Dialogue, its objectives, activities, and time frame and initiated a project for its support to run from May 1, 2010 until November 30, 2011.

The outputs of the project include the following:

- Identification and brief analysis of key issues in the basin, linked with water resources management
- Facilitation of the work of the "Drin Core Group"
- Implementation of the Drin Dialogue through national and regional consultation
- Elaboration and facilitation of process for the development of a long-term Strategic *Shared Vision* for the management of the Drin Basin

The aforementioned were pursued through the:

- Preparation of a situation analysis
- Organization of the Drin Core Group meetings
- Organization of consultation meetings at national and transboundary level

(a) Organization of three national consultation meetings
(b) Organization of one transboundary consultation meeting at the Drin Basin level (the 2nd Drin Transboundary Consultation Meeting)

- Preparation of the "Strategic Shared Vision" document ion

A "Ministerial Declaration on the management of the extended Drin Basin" in preparing and finalizing the Shared Vision and announcing their intentions to work together was made by the competent ministries responsible for waters in a meeting invited by the relevant minister of FYR Macedonia in Ohrid, on April 18, 2011.

3.4 Empowerment of the NGOs in the Drin Basin to Effectively Contribute to the Drin Dialogue

In parallel to the formal procedure, MIO-ECSDE undertook the commitment to contribute to the establishment of a common understanding and shared vision of NGOs for the Drin River Basin and enhance their ability and capacity to act in such transboundary initiatives in a constructive way. MIO-ECSDE's activities came as direct follow-up of previous actions in Southeast Europe, where together with other partners active in the region organized a series of targeted capacity-building activities, focusing on methodologies and experiences on addressing issues of transboundary water resources management. MIO-ECSDE's contribution was particularly valuable in creating an atmosphere of cooperation and trust through communication/awareness-raising actions (newsletters, bulletins, press releases, etc.) and a series of events (e.g., workshops, networking meetings) back to back with all Drin Dialogue meetings

(Ohrid, November 2010; Tirana, April 2011; Podgorica, September 2011; Tirana, November 2011). These activities were carried out within MIO-ECSDE's annual work program of 2010 and 2011, as well as in synergy with two major Mediterranean initiatives, in which MIO-ECSDE is a key partner: (a) The UNEP/MAP-GEF Strategic Partnership for the Mediterranean Large Marine Ecosystem (the MedPartnership) and (b) The ENPI Horizon 2020 Capacity Building/Mediterranean Environment Programme (CB/MEP). In addition, MIO-ECSDE developed and proposed (a) a preliminary approach for baseline communication activities and (b) a leaflet on the Drin Dialogue (http://www.mio-ecsde.org/_uploaded_files/news/drin-leaflet.pdf).

3.5 The Memorandum of Understanding

The long-term Strategic *Shared Vision* for the management of the Drin Basin as well as a plan of action for the promotion of multilateral coordination and cooperation that has been elaborated and discussed by the riparians formed the basis of the so-called memorandum of understanding (Drin MoU) (see Annex) signed by the water resources competent ministers of all the riparians or their representatives in Tirana, Albania, on November 25, 2011. The ministers agreed *to promote joint action for the coordinated integrated management of the shared water resources in the Drin Basin, as a means to safeguard and restore, to the extent possible, the ecosystems and the services they provide and to promote sustainable development across the Drin Basin.*

The Drin MoU as means for the implementation of the Shared Vision identifies the main transboundary issues and provides for short-, medium-, and long-term steps toward the integrated management of the basin. It prolongs and expands the mandate of the DCG to facilitate communication and cooperation among the parties for the implementation of its provisions and describes the functions and responsibilities of DSG; decisions should be taken unanimously by the representatives of the riparians. The ministers will be meeting on an annual basis to review its implementation. GWP-Med was appointed as the Secretariat of the DCG, providing technical and administrative support.

The Drin MoU requests the continuation of the support of the Petersberg Phase II/Athens Declaration Process, UNECE, and GWP-Med.

As requested by the ministers, the elaboration of an action plan for the implementation of priority activities will be prepared in early 2012.

4 Conclusions

Water has the potential to fuel wider conflicts but also to act as an effective bridge for cooperation among riparians. Sharing the benefits deriving from proper management of water resources in a sustainable way, rather than the resources themselves, shall become the major practice and driving force for preventing or overcoming conflict. In this respect, hydrodiplomacy is a key tool.

In the Mediterranean, though some cases of collaboration already established or advanced/in the "pipeline" can be documented, we have not reached yet too far nor too fast. In the three "success" cases mentioned in this chapter, namely, the NW Sahara Aquifer System, the Sava River, and the Drin River, the driving forces and the key actors were of different nature. From the three, the Drin River case has a much more important stakeholder participation built in from the very beginning. Based on this experience, one could suggest that stakeholders' involvement can assist substantially, if a well-structured dialogue is secured, facilitated, and capacitated appropriately.

Such capacitating in the Drin River case was very effective, provided by a flexible international framework (The Petersberg/Athens Process) and experienced actors (GWP-MED, UNICE, etc.) and following some basic criteria and rules. The involvement of NGO federations or platforms (such as MIO-ECSDE) and their capacity-building work in support of the dialogue was very helpful.

Key criteria for the success include provisions that ensure human development and environmental considerations to be adequately integrated in transboundary management; replace unilateral approaches with multilateral cooperation, supported by capacitated human resources and information infrastructure; and provide for mechanism(s) facilitating implementation of agreed actions/measures including monitoring and sharing of data and experience. The Drin River case is clearly transferable and replicable, provided that similar conditions and criteria are met.

Annex

The Drin: A Strategic Shared Vision

Memorandum of Understanding for the Management of the Extended Transboundary Drin Basin

Preamble

1. *Mindful* of the Ohrid Declaration of 18 April 2011 in which we, the water and/or environment competent Ministers of the Drin Riparians (hereinafter, the "Ministers"), committed to negotiate and adopt a Shared Vision document on the coordinated management of the Extended Transboundary Drin Basin (hereinafter the "Drin Basin")
2. *Expressing* our political will towards basin-wide mutual understanding in water management as a precondition for cooperation towards sustainable development
3. *With full appreciation* of the work of the Drin Core Group whose establishment in 2009 signalled the initiation of the Dialogue among the stakeholders for the

management of the Drin Basin (Drin Dialogue) and *taking fully into consideration* the outcomes of the Drin Dialogue

4. *Confirming* our commitment to sustainable development in the Drin Basin that can be brought about in a coherent way through transboundary cooperation, in accordance with the principles of the European Union integration process
5. *Aware* that the Drin River is the connecting agent of an extended shared watershed, including a number of shared water bodies and an adjacent sea, the Adriatic, linking these into a hydrologic system that supports a variety of ecosystems within the Drin Basin
6. *Considering* that the Drin Basin is of international importance, due to its morphology and biological diversity, including the habitats within its Sub-Basins that are vital for the conservation of numerous rare species, many of which are endemic and/or globally endangered
7. *Considering* environmental protection and conservation, and sustainable use of the natural resources of the Drin Basin, including water, to be an integral part of the development process aimed at meeting the needs of the present and future generations on an equitable basis
8. *Recognising* that sustainable development in the Drin Basin should include a balanced and reconciled development of vital economic sectors such as tourism, agriculture, energy production, fisheries and forestry
9. *Acknowledging* the need for sustainable and integrated management of the shared water resources in the Drin Basin and stressing our joint responsibility in this regard
10. *Being guided* by the principle of reasonable and equitable use of water resources
11. *Convinced* of the need for promoting adequate institutional arrangements and capacity building for sustainable and integrated water resources management in the Drin Basin
12. *Recognising* the need to coordinate management efforts across the Sub-Basins in this regard, while making use of the existing cooperation schemes that have been established for some of the Sub-Basins, namely Prespa Park Management Committee, Lake Ohrid Watershed Committee and Lake Skadar-Shkoder Commission
13. *Convinced* of the need of structured stakeholder involvement as part of sustainable basin management
14. *Recognising* the need for the Parties to meet the obligations arising from relevant international agreements, particularly the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (17 March 1992 – hereinafter referred to as “UNECE Water Convention”) and its Protocols, the Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar, 2 February 1971), the Convention for the Protection of the Mediterranean Sea Against Pollution (16 February 1976) and its Protocols and taking into consideration provisions of the UN Convention on the Law of the Non-Navigational Uses of International Watercourses (21 May 1997)

15. *Conforming* to the principles and legal framework of the European Union, in particular the Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy (23 October 2000 – hereinafter referred to as "EU WFD")
16. *Acknowledging* the contribution of the UNECE, GWP-Med and the Petersberg Phase II/Athens Declaration Process, that support the Drin Dialogue, in reaching the signing of this MoU

Now, therefore, the Ministers and their representatives hereby enter into this Memorandum of Understanding (hereinafter, "MOU"), to be referred to as *The Drin: A Strategic Shared Vision*.

Article 1. Definitions

1. The "Sub-Basins" consist of the respective geographical areas of each of the following basins: the Prespa Lakes, Lake Ohrid, Lake Shkoder/Skadar (collectively, the "Three Lake Areas"); the Black Drin River (Crn Drim or Drini i Zi); the White Drin River (Beli Drin or Drini i Bardhë); the Drin River (Drim or Drini or Drini i madh) and the Buna/Bojana River.
2. The "Extended Transboundary Drin Basin" or "Drin Basin" is the geographical area consisting of the integrated geographical areas of all the Sub-Basins.
3. The "Parties" are the five water and/or environment competent Ministries of the Drin Riparians represented by the respective Ministers and their representatives.
4. The "Drin Core Group" (hereinafter, "DCG") is the informal body established in 2009 to provide a forum for coordination among the Parties to enable communication and cooperation among them and the key stakeholders and for the coordination and the facilitation of implementation of the Drin Dialogue, comprising of representatives of the Parties, Prespa Park Management Committee, Lake Ohrid Watershed Committee, Lake Skadar-Shkoder Commission, United Nations Economic Commission for Europe (hereinafter referred to as the "UNECE"), Global Water Partnership – Mediterranean (hereinafter referred to as the "GWP-Med") and Mediterranean Office for Environment Culture and Sustainable Development (hereinafter referred to as the "MIO-ECSDE").
5. The "Drin Dialogue" is a coordinated and structured consultation process, initiated in 2009, among the Parties, the existing joint commissions/committees in some of the Sub-Basins and stakeholders, towards the development of a Shared Vision for the enhancement of transboundary cooperation and sustainable management of the Drin Basin in compliance with existing regional and international legislation in particular the provisions of the UNECE Water Convention, the EU Water Framework Directive (hereinafter referred to as the "EU WFD") and other related multilateral agreements, facilitated by the UNECE and the GWP-Med and conducted within the frameworks of the UNECE Water Convention and the Petersberg Phase II/Athens Declaration Process.

Article 2. Objective

The Parties, through their Ministers and their representatives, commit to promote joint action for the coordinated integrated management of the shared water resources in the Drin Basin, as a means to safeguard and restore to the extent possible the ecosystems and the services they provide and to promote sustainable development across the Drin Basin.

Article 3. Common Concerns for Sustainable Development of the Drin Basin

The Parties hereby should undertake concrete actions to address problems identified as affecting sustainable development in the entire Drin Basin or in one or more of the Sub-Basins:

(i) Improving access to comprehensive data and adequate information to fully understand the current state of the environment and the water resources and the hydrologic system (including surface, underground and coastal waters) as well as ecosystems of the Drin Basin
(ii) Establish conditions for a sustainable use of water and other natural resources
(iii) Develop cooperation and measures to minimise flooding especially in the lower parts of the Drin Basin
(iv) Improve management and appropriate disposal of solid wastes
(v) Decrease nutrient pollution deriving from untreated or poorly treated waste-water discharges and unsustainable agricultural practices
(vi) Decrease pollution from hazardous substances such as heavy metals and pesticides
(vii) Minimise effects of hydro-morphologic interventions that alter the nature of the hydrologic system and the supported ecosystems, resulting in their deterioration

Article 4. Priority Actions at National, Bilateral and/or Multilateral Levels

1. In the short term (to 2013), a set of minimum, "No Regret" measures should be initiated and carried out to promote integrated water resources management, also at national level, and facilitate enhancement of cooperation, including:

   a. Elaboration of coordination enhancement mechanisms among the Parties. The Drin Core Group will be used for this purpose.
   b. Enhancement of the knowledge basis about the Drin Basin that will allow planning of management and implementation of the EU WFD at national, Sub-Basin and Drin Basin level as well as enhanced cooperation among the Parties in the future. This may be achieved through the characterisation of the Drin Basin in accordance to the EU WFD and the analysis of the hydrological patterns integrating consideration of (i) the results achieved in the Three Lake Areas through previous and ongoing GEF-funded projects, (ii) the results of other ongoing and past relevant projects, (iii) the karstic nature of large

sections of the Drin Basin, (iv) the surface/groundwater interaction patterns and conjunctive uses throughout the Drin Basin and (v) the coastal ecosystems, transitional waters and shallow marine environment. The characterisation of each Sub-Basin should be done either at the national level or through bilateral or multilateral coordination or cooperation on the basis of related existing agreements among the Parties concerning the management of each Sub-Basin. This information will be available to all Parties through the system indicated in point 4.1.c and potentially in the future through this indicated in point 4.2.d.

c. Improvement of information exchange through the establishment of a system for regular exchange of relevant information among the competent authorities of each Party.
d. Enhancement of cooperation in the field of flood risk preparedness, management and mutual support. This may be achieved through the preparation of different options for the establishment of cooperation at technical level in this regard, by a working group comprising of representatives of the competent authorities of the Parties under the coordination of the Drin Core Group.
e. Institutional strengthening in the field of integrated water resources management targeting managers; practitioners; relevant officers of national, regional and local authorities; other stakeholders, etc. Towards this end, capacity building activities could be foreseen in fields of priority such as (i) integrated basin planning and management in accordance with the EU WFD; (ii) practices of transboundary water cooperation in accordance to the UNECE Water Convention; (iii) GIS and spatial planning; (iv) Environmental Impact Assessments and industrial site inspections; (v) flood management; (vi) natural wastewater treatment systems; (vii) best agricultural practices; (viii) avoidance and containment of invasive species; (ix) environmental monitoring system design and management; (x) enforcement of water quality, water abstractions, recharge area protection and biodiversity regulations; (xii) groundwater management; and (xiii) sustainable tourism.
f. Promotion of public participation and stakeholder's engagement. This may be achieved through the preparation and implementation of a Stakeholders Involvement Plan.

2. In the medium term (till 2015), actions undertaken should allow the establishment of instruments to be used for the sustainable management of water resources in the Drin Basin, including:

   a. Achievement of a science-based consensus, among the Drin Riparians, on key (Drin Basin) transboundary priorities including climate change scenarios, and also main drivers of change and indicators of sustainable development for the basin, based on the knowledge basis established (see 4.1.b. above)
   b. Preparation of an elaborated water balance for the Drin Basin as a useful decision support tool at national and transboundary levels
   c. Establishment of a harmonised Drin Basin Water Monitoring Program compatible with the UNECE Guidelines on Monitoring and Assessment of

Transboundary Rivers, the relevant provisions of the EU WFD and the Shared Environmental Information System (SEIS) of the EEA

d. Making use of the efforts described under 4.1.c. and establishment of an Information Management System (IMS) that will enable authorities to collect, store and share data and information produced through the Drin Basin Water Monitoring Program
e. Establishment of basin-wide cooperative management on the basis of an agreement among the Parties and the establishment of a Basin Commission

3. In the long term (after 2016), the instruments that will allow the Parties to work towards sustainable management of the water resources in the Drin Basin are expected to be in place, including:

   a. Development of a Drin Basin Management Plan in accordance with the EU WFD and the UNECE Water Convention that will serve as the guidance document for the development and implementation of river/lake basin management plans for each of the Sub-Basins at national and transboundary level in accordance with the bilateral and multilateral agreements among the Drin Riparians

Article 5. Implementation and Monitoring

1. Pursuant to point 4.1.a, the mandate of the DCG is prolonged and expanded to facilitate communication and cooperation among the Parties for the implementation of the provisions of the present MoU. The functions and responsibilities of the DCG are defined in the Annex to this MoU.
2. Understanding the need for the implementation of the Strategic Shared Vision to reflect the views of the stakeholders, the Parties call for an annual meeting of stakeholders from the Drin Riparians and appreciate and accept the offer of UNECE and GWP-Med to facilitate its organisation.
3. Aiming at the enhanced and structured engagement of stakeholders in the implementation of the MoU, the Parties encourage the establishment of the "Drin Water Partnership" as a mechanism that will facilitate (a) awareness raising, (b) information exchange, (c) communication, (d) capacity building and (e) consultation and active participation if need be.
4. The Parties request GWP-Med in cooperation with MIO-ECSDE to elaborate on such a scheme and explore possibilities to establish under the auspices of GWP-Med such a Water Partnership.
5. The Parties ensure the participation of their respective governments, within their possibilities, to provide resources for the implementation of the provisions of this MoU and call upon and invite the EU, Global Environment Facility and other donors to join and provide support in this regard. The DCG shall initiate, stimulate and coordinate activities in this regard.

6. The Parties request the continuation of the assistance provided under the Petersberg Phase II/Athens Declaration Process, coordinated by the German and Greek governments and the World Bank, as well as under the UNECE Water Convention.
7. The Parties urge UNECE and the GWP-Med to continue providing their technical support and facilitation of the process.

Article 6. Meetings of the Parties

The Ministers responsible for the management of water resources and/or environment of the five Parties shall meet ANNUALLY to review progress in the implementation of the present MoU and its provisions.

Article 7. Legal Effect

The present MoU shall not affect the status of bilateral relationships and rights and obligations of the Parties under prior Memoranda of Understanding and/or all International Agreements concluded among them.

Article 8. Validity

The present MoU becomes valid from the date of signing.

Article 9. Withdrawal

A Party may withdraw from this MoU by giving written notice to every other Party, which shall become effective with respect to such Party 30 days after receipt of such notice by all Parties.

Article 10. Termination

This MoU may be terminated by a majority decision of the Parties. Such termination shall take effect six months after such a decision by the Parties.
Done at Tirana this twenty fifth day of November two thousand and eleven, in 5 copies, one for each Party, in the English language.

Minister Fatmir Mediu	Minister Abdilaqim Ademi	Deputy Minister Velizar Vojinovic	Deputy Minister Ilir Mirena	Special Secretary Andreas Andreadakis

Annex. Setup, Functions and Responsibilities of the Drin Core Group

The setup, functions and responsibility of the DCG are the following:

(i) The DCG will be comprised of the nominated representatives of the: (a) Parties (hereinafter referred at as the "representatives of the Parties"), (b) Prespa Park Management Committee, (c) Lake Ohrid Watershed Committee, (d) Lake Skadar-Shkoder Commission, (e) UNECE, (f) GWP-Med and (g) MIO-ECSDE.
(ii) GWP-Med will serve as the Secretariat of the DCG providing technical and administrative support.
(iii) The institutions and bodies participating in the DCG may alter their repreen-tatives in the DCG through a formal letter to the DCG Secretariat.
(iv) The decisions of the DCG will be taken by the representatives of the Parties on the basis of consensus.
(v) The DCG shall meet on a regular basis and not less than once per year. The next meeting of the DCG will be organised within 6 months from the signing of the MoU. The dates and the frequency of the meetings to follow will be decided by the DCG itself.
(vi) A non-scheduled meeting of the DCG may be called at the request of any of the representatives of the Parties upon submission to the Secretariat of a written request including explanation of the reasons for such meeting, which shall be promptly distributed to all DCG members.
(vii) The venue of the meetings will be decided by the DCG. The meetings shall be chaired by the representative of the Party in which they are held.
(viii) The DCG shall amend as necessary in conformity to the aforementioned in this article and in accordance to the requirements stemming from the MoU, its internal rules of organisation and Terms of Reference (ToR) decided at Podgorica on 1 December 2009.
(ix) Possible changes in the setup, functions and responsibility of DCG are decided by the meeting of the Parties.

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Integrated Water Management in Tunisia: Meeting the Climate Change Challenges

N. Omrani and M. Ouessar

Abstract As a southern Mediterranean country, Tunisia is located under an irregular climate. With a mean annual rainfall of 230 mm, the country sustains a water scarcity context. While the present annual water resource average is estimated to be 450 m^3 per capita, it is expected to be barely 315 m^3 beyond 2030. With the increase of the living standards as well as the development of the agriculture, industry, and tourism sectors, the water shortage will be exacerbated. Given that situation, the Tunisian water policy had been engaged toward an integrated approach. Coordination between the main stakeholders involved in the water management became effective. One of the main tools of this strategy is already the demand management. It assumes an important issue for the case of the agriculture sector consumption (more than 83 % of the available water resources). However, Tunisia is also strongly concerned by the climate change. Official forecasts report an expected increase of the annual average temperature by 1.1 °C (0.9 °C in the north and 1.6 °C in the south), a loss of nearly 20 % of the arable lands and a decrease in the water resources by more than 28 % beyond 2030. It seems evident that the national integrated water policy will require further commitment with the spectra of the climate change impacts. The preparedness of Tunisia to meet such challenge is a precondition to its water resources reliability.

Keywords Tunisia • IWM • Irrigated sector • Climate change • Water policy reform

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1 Introduction

Regarding its geographical context, Tunisia has to constantly cope with the climate uncertainties. Surrounded at the south by the Sahara and the Mediterranean Sea at the north, the annual rainfall differs highly in time (between seasons) and space. The main value in the north is 594 mm, 296 mm in the center, and less than 100 mm in the extreme south (Aquastat 2005). Nearly two thirds of the total area is located under semiarid to arid climate. The country is often submitted to drought sequences that could be regional or generalized. Under such climate, the irrigated sector is still obviously the most threatened by the water scarcity (Omrani and Ouessar 2008b). The annual evaporation ratio is 1:200 mm while it reaches 1:800 mm in the southern part with the occurrence of quasi-permanent hydric deficit.

Considering these precipitation gradients, four natural regions had been identified (Fig. 1). The extreme north with less than 3 % of the total country area contributes with a surface water amount of 960 million m^3, which represents 36 % of the national country potential. The north represented by the basins of *Medjerda*, Cap Bon, and *Meliane* contributes with regular surface water inputs estimated to be 1,230 million m^3 that is equal to nearly 46 % of the total surface water potential. The center entitling the basins of Nebhana, Marguelil, Zeroud, and Sahel is presenting irregular water surface inputs with 320 million m^3 or 12 % of the national potential. The fourth region is the south which has the lowest surface water potential, nearly 190 million m^3 or 6 % of the total water surface potential; nevertheless, it encloses more than 58 % of the underground water resources potential (MAREH 1998).

Added to the limited water resources, the future water policy should manage with permanent desertification risks across the center and the southern country. Moreover, the climate change impacts that had been already perceptible are definitely a new challenge to be taken. The institutional traits of the integrated water policy will certainly shape the potential for the adaptation to climate change over the coming decades.

To tackle the coming challenges for the national water policy, it became mandatory to undertake a drastic reform toward more water service performance (Horchani 2007).

In the irrigated sector as well as for the drinking water, the key element of the future water policy would be the demand management and the efficiency guarantee.

The rehabilitation of the hydraulic facilities remains insufficient in the absence of the user's community engagement. The intensification of the water-saving campaigns in the irrigated sector coupled with the drinking water supply network diagnosis had been in that sense conclusive.

More than the technical approach, Tunisia water policy needs to formulate large-scale program of water valorization. The integrated resource management remains the key tool of such policy with stronger commitment and participatory approach in the decision-making process. For the coming decades, the decentralization in the water management seems to be highly recommended. Nevertheless, such step should be strongly prepared by the allowance of the needed capabilities in terms of budget and technical know-how.

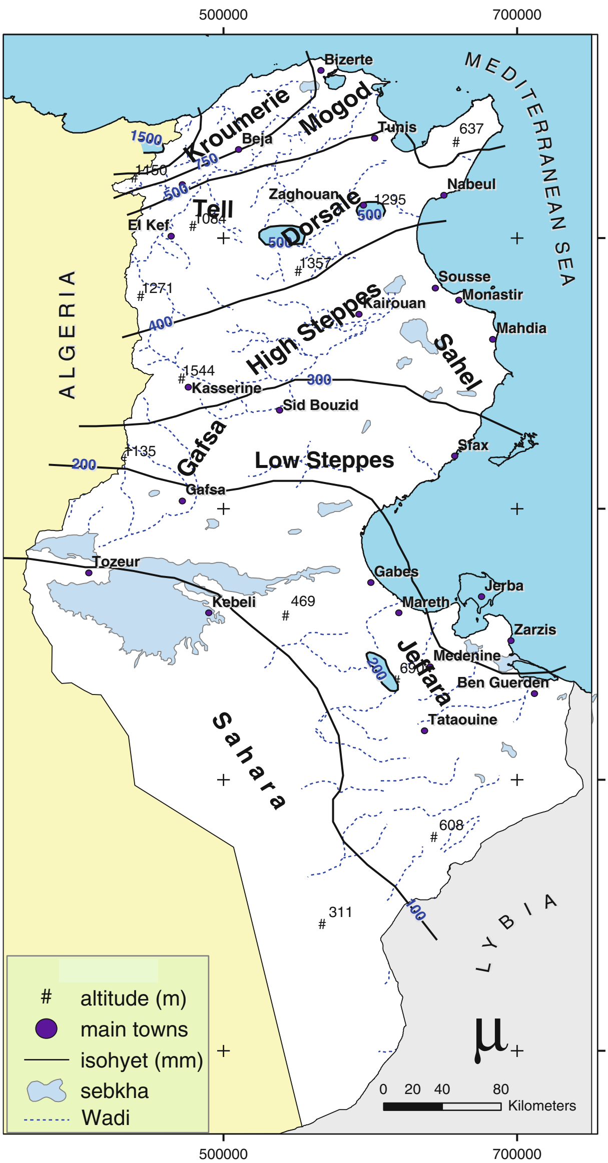

Fig. 1 Annual rainfall gradient and natural regions in Tunisia (MEAT 1998)

The prevailing context of the irrigated sector as a concrete case study clearly revealed the weakness and the quasi absence of self-reliance by the farmer groups or GIC. The lack of capacity building and the absence of strong institutional support to such initiative condemned these groups to be permanently tributary to the development authorities for the maintenance of the irrigation facilities.

Our approach in this chapter aims to emphasize on the achievements of the water policy as well as an inventory attempt of the real weakness that could be omitted. Indeed, the capabilities of the Tunisia water policy to cope with the climate change impacts remain tributary to the effectiveness of the integrated water management approach as well as the relevance of the reform measures to be implemented.

2 Tunisia Integrated Water Management

Through successive decades of water mobilization, Tunisia had acquired a relevant experience in the water resources management. The establishment of an institutional framework to the water policy dates back to 1971 with the institution of the water code. It represented the legal framework that will thereafter define the main milestones of the Tunisia water policy. An assessment of the available water resources allowed the institution of three-director water plan for the north, the center, and the southern country. While the north and the center water plan focused on the development of large dam's facilities and their networking and the multiplication of the collinear lakes in the center, the southern Tunisia observed a tremendous development of the underground resources exploitation. This mobilization phase allowed satisfying the growing water demand without having to ration water even during periods of acute drought.

The total available water resources range from 2,700 to 3,100 million m^3; therefore Tunisia water strategy is targeting to master the demand at 2,800 million m^3 beyond 2030 (Fig. 2). Maintaining such balance between will certainly require an integrated water policy that encloses all sectors involved in the water management. To promote such policy, several measures had been implemented in order to reform the water

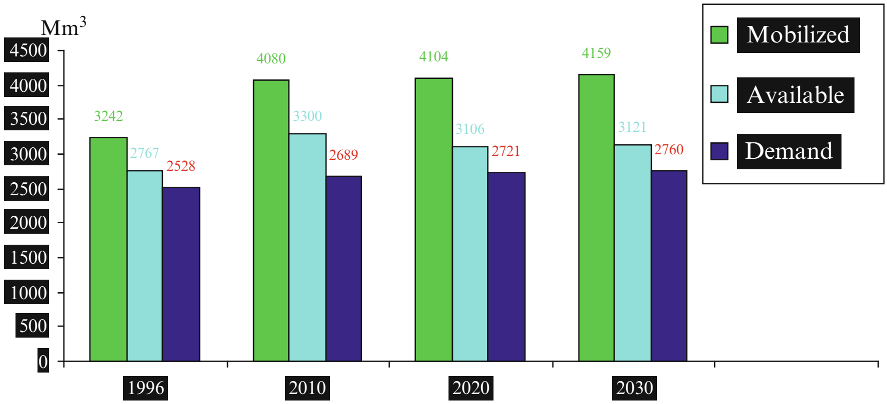

Fig. 2 Available water resources in Tunisia and projected future water demand into 2030 (MAREH 2009)

sector and to enhance the water productivity, especially in the irrigated sector where the efficiency and intensification still facing many institutional and technical hindrances.

In this regard, the mobilization of water resources phase had been followed by several measures to promote more efficient water management. The introduction of the water-saving plan aimed to enhance the distribution efficiency with the introduction of water-saving methods and to decrease the demand by 30 %. The financial subsidy allocation contributed to perform such approach, and more commitment from farmers had been gained (Louhichi 1999). Nevertheless, the necessity of an integrated water reform had been progressively recognized as a precondition to a sustainable development of the water resources. The high concurrency between all sectors in the water consumption reinforced that choice and imposed a close collaboration between all sectors. An integrated reform that takes into account technical, economical, and institutional aspects seemed to have significant impacts on the water management and conservation (GTZ 2007).

2.1 *Treated Wastewater Reuse*

Since 2000, Tunisia undertook further measures toward an integrated water resources management. With the increasing water demand among the different sectors and the climate uncertainties, the recourse to the nonconventional water resources became a key tool of such strategy. The reuse of treated wastewater for irrigation became progressively a viable option with the development of the treatment wastewater facilities as well the water supply reliability, and the implementation of the wastewater treatment station across the country highly reinforced the capabilities of the wastewater reuse plan. The competent authorities managing the treated wastewater in Tunisia are represented by the ONAS which is the National Sanitation Utility. It supervises the functioning of nearly 106 operating plants with a total volume of 238 million m^3 of treated wastewater which is equal to 5 % of the total mobilized water resources. Such contribution is enhancing crescendo and expected to reach 480 million m^3 or 10 % of the total mobilized resources at the horizon 2030. The portion used for reuse ranges between 20 and 30 %, while the rest remains released into the natural environment. The major used water comes from the domestic use (80 %) while the industry and tourism sectors contribute with, respectively, 15 and 5 %. The major reuse fields are the agriculture irrigation, the golf course irrigation, and landscape irrigation in urban areas as well as the aquifer recharge. The total area irrigated by the treated wastewater represents 8,065 ha divided into 27 irrigation schemes and dispatched between 15 governorates across the country. The development of the wastewater reuse had been shaped under control of strict legislation that defined the legal framework of such water resource reuse. Indeed, since 1975, the reuse of raw wastewater for comestible vegetable irrigation had been prohibited. In 1989, a decree defined the outline of the treated wastewater in agriculture through the following prerogatives: (a) strict interdiction for vegetable irrigation, (b) the reuse of the treated wastewater should be authorized from the agriculture ministry in agreement with the environment ministry, and (c) severe bacteriologic standards have to be fulfilled through frequent monitoring of the water sampling (monthly for physical-chemical parameters, 6 month for trace elements, and every 2 weeks for helminth eggs).

For the coming decade, the wastewater treatment capabilities are called to be reinforced with the creation of 18 new treated wastewater irrigation schemes (7,010 ha) as well as the extension (1,480 ha) and the rehabilitation (5,000 ha) of some existing schemes. On the other hand, more than 30 million m^3 will be used for artificial groundwater recharge.

Despite the relevant efforts consented into the development of the treated wastewater plan in Tunisia, a strong reluctance from the population that still persists. On other hand, the state of art indicates the necessity of further improvement of the treatment process toward friendlier environment approach. Recurrent conflicts remain being signaled in several governorates; in the absence of long-term utility storage, the huge effluent production amounts became out of sight of some treatment plants and could resume the ongoing situation of the treated wastewater reuse in Tunisia. Furthermore, the modernization efforts of the treatment plants have enormous costs that would certainly remain uncovered regarding the low potential use of the treated wastewater. It is also evident that, as long as the impacts on human health remain not yet clearly identified, such reluctance is called to subsist. The national experience in the treated wastewater reuse remains laudable and aspires to play greater role in the coming decade with the development of the treating technologies. For the case of Tunisia, more research efforts should be deployed for better assessment of the treatment plants on the local environment. The integration of the socioeconomical dimension is also highly recommended for more sustainable integration of the marginal water use in the irrigated sector.

2.2 Drainage Water Reuse

As the irrigation practice, the implementation of the drainage networks is a secular practice within Tunisia irrigated lands. Since the 1980s, the entire irrigated perimeter had been equipped by dense drainage network (open surface canal and buried pipes) to evacuate the excess water toward the depression surfaces.

The maintenance of these networks is subscribed within the farmer groups' attributions, and their dredging is regularly scheduled before the winter season when the water flow becomes important. Nevertheless, with the continuous extension of the irrigated areas, the shallow water table significantly rises up (Ben 2003; Mamou 2009). Such situation became drastically alarming in the southern Tunisia oases. Indeed, while the multiplication of the private parcels enhances the pressure on the underground water resources and contributes to create a chronic waterlogging context, their consumption slips totally through the development of authority controls (Omrani and Burger 2011a, b). Important drainage water amount is still

Fig. 3 Important drainage water amount collected in downstream oases in southern Tunisia (Prinz and Loeper 2008)

being collected downstream the irrigated lands. They represent imminent risks of backflow toward the farmer's plots and threaten the soil contamination by high-saline water (Zammouri et al. 2007; Schmidt et al. 2006) as illustrated in Fig. 3.

There is a real awareness about the potential of this water as complementary resource to be exploited (Edmunds et al. 1995). The possible mixing with the irrigation water for the irrigation of salt-tolerant crops could be a viable option to be followed. Moreover, the use of this marginal water for the irrigation of some tree species as a green barrier in the struggle against the desertification is already effective in several regions and could be qualified as conclusive action in the valorization of such resource.

Despite the promising potential of the drainage water, there are some technical constraints that should be treated as a prerogative to their sustainable reuse in irrigation. Indeed, the intermittent regime of this water availability builds yet a relevant constraint to their valorization. While their volume becomes important in winter with suitable quality, it considerably decreases in the summer period with an important rise in their salinity. Furthermore, the importance of the collected drainage water amount remains de facto tributary to the drainage network performance and directly submitted to the irrigation good governance as well (Prinz et al. 2005). Nevertheless, with the development of the social conditions and the technical evolution, the drainage network cleaning out had been progressively neglected from the local population. The financial allocation provided to their maintenance by the farmer groups is still rudimentary and at the latest priority. Such low performance influences on the drainage water use sustainability and does not facilitate its implementation as a concrete option in the marginal water reuse.

In this regard, more promotion of such alternative will also pass through the enhancement of the drainage network efficiency. Such task should be further followed from both research and development stakeholders.

3 The Irrigated Sector Reform

The irrigation sector had been always a key tool of the national water strategy. Under the intensive tempo of the water resources development, the irrigated area observed a tremendous extension. From nearly 143,000 ha in 1976, it evolved to

380,000 ha in 2001 and estimated to be more than 400, 000 ha today with a surface water system fully operational. More than 226,000 ha are irrigation systems under public management. The private systems, created around shallow wells, cover 175,000 ha. About 52 % of the irrigated area is located in the northern part of the country, 31 % in the center, and 17 % in the south. More than 40 % of the irrigated area is used for fruit trees (40 %) and about 36 % for vegetables (21 % tomatoes and 15 % potatoes) production. The cereal cultivation extends to over 14 % of the irrigated area, while the feed crops cover 10 %. It contributes also with 95 % of the vegetable production, 77.5 % of the fruit production, 30 % of the dairy products, and 25 % of the national cereal yields. The irrigated sector also contributes 20 % of the agricultural export value and employs about 26 % of working forces (Al Atiri 2007).

Knowing that the irrigated sector contributes with nearly 35 % in the total agricultural production, such contribution is expected to reach 50 % in the coming decade with the development of the irrigation network (Horchani 2007).

On the organizational aspect, the main irrigation systems are collectives and have a regulated water service. They are managed by the public administration. About 62 % of the irrigated areas under public administration are supplied from dams, while 38 % are irrigated from deep groundwater wells and treated wastewater. Listed by the nature of the water source, the irrigated perimeters under public administration consist of 142,000 ha irrigated from dams, 47,000 ha (only intensive) from groundwater abstractions, 30,000 ha are oases irrigated by deep groundwater abstractions, and 8,000 ha from treated wastewater. The private perimeters are supplied from shallow wells made by farmers (Al Atiri 2007). This variety has led to differences in the sizes and configurations of equipment and diversity in the management of individual irrigation schemes. As a result, production and productivity levels vary, depending also on local and regional climatic and socioeconomic conditions (Hamdane 2004, 2008).

The current agriculture consumption ratio is more than 83 %; it represents the highest sector of water consumption and indicates by far the pressure that could be applied on the water resources within a context of growing demand and acute concurrency between the tourism, agriculture, and industry sectors. As a response to such evolution, a reform of the irrigated sector toward more efficient performance became evident. The first step in that direction already undertaken by the development actors could be qualified as a rehabilitation phase. Since 1990, a program of irrigation water conservation had been established. The main focus aimed to rehabilitate the irrigation facilities and to reinforce farmer's skills for more efficient water management mode (Seddik 2009). Through the experience feedback, it became clearly evident that a technical approach could not overcome the different constraints that strangle the irrigated sector development. The implementation of an integrated approach could bring to bear more efficient solutions and will definitely contribute to meet the expected objectives.

The irrigated sector reform could be conclusive only by further active commitment from the farmer's community. Relevant efforts have been consented before to engage the farmer groups as active partner in the irrigation water management. The creation of the common interest group (GIC) contributed to involve the farmers in the irrigation network management (SAPI 2005; Sanyo Consultants Inc 1996). Such initiative strongly reinforced the cooperation between development authorities and farmer groups. The introduction of more efficient irrigation techniques became easier as the farmer groups became a real partner in the irrigated area development. Despite such advances, many constraints still exist such as the low technical skills of some farmer groups and the absence of the private sector in the irrigation equipment services and maintenance.

For the coming decade, the irrigated sector reform should associate more the farmer community in the decision-making process. Furthermore, the decentralization has to be preceded by relevant irrigation technical skills building. The state disengagement could be then progressively undertaken.

The enhancement of the water productivity as well as the water cost recovery should be strongly targeted within such reform. Indeed, the ongoing water-pricing policy is not covering the real costs of the water mobilization and does not militate for more water resource valorization.

The achievements of the irrigated sector require further engagement from both of the development and the farmer's community to reach a sustainable development of such sector. The isolated technical approach should be replaced by more integrated farmer-oriented initiatives. The improvement of the farmer groups' income and their irrigation practice skills reinforcement are precondition of their commitment.

4 Climate Change Challenges

Beyond the water demand satisfaction, the integrated water management policy in Tunisia is called to deal with further challenges; the most important is the climate change impacts. Indeed, as a southern Mediterranean country, Tunisia is located in transition geographical zone between a tempered and arid climate; the management of natural resources and especially the water remains always a crucial task in a context of permanent fragility. On the other hand, the downscaling of the climate change impacts for the Mediterranean region revealed that Tunisia had been strongly concerned. The official forecasts of the IPCC (Intergovernmental Panel on Climate Change) are expecting a steady rise in the mean temperature (Fig. 4a) and more frequent drought sequences with also a steady decrease in the main annual rainfall (Fig. 4b) for the long term (2050).

Under such context, the first sector that would be affected is definitely the agriculture. The water resources management in the irrigated sector is called to undertake ambitious measures given the importance of the prevailing challenges. The first prospective of the climate change impact on the agriculture revealed severe impacts to be observed with the horizon 2030 with an increase in annual average temperature by 1.6 °C in the south and 0.9 °C in the northern country. The first declared impact would be a decrease of nearly 28 % in nonrenewable underground resources. The production in dry periods is expected to decrease by 50 %; this is equal to 800,000 ha for rain-fed agriculture with an estimated loss of nearly 20 % in arable land (GTZ 2007). These impacts will be considerable also on livestock

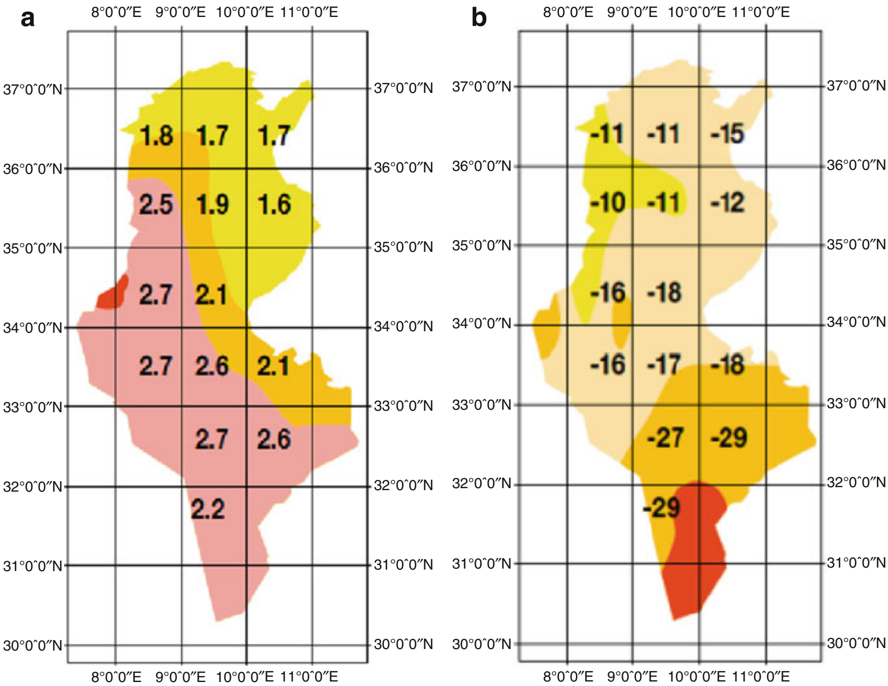

Fig. 4 Scenario of the mean temperature and the annual rainfall evolution in 2050 (GTZ 2007). (**a**) rise in the mean temperature (°C) (**b**) variation in the mean annual rainfall (%)

production which is predicted to decrease by 80 %, both in the center and southern country (OSS 2009a, b).

To tackle these impacts, Tunisia elaborated a national strategy of adaptation to climate change with first declared objective decreasing the agriculture and the water resources vulnerability to such phenomenon with the research and application of efficient tools toward strengthening the adaptation capacity of these sectors to the coming changes. In the elaboration of such adaptation strategy, the development of the mean climate indicators will be taken into account for the future natural resources management plan. The alert systems for both flood and drought events are already established, with a network of climatic and hydrological stations across the country.

Furthermore, as key tool of the national adaptation strategy, the water resources management is called to play greater role in such adaptation strategy. The first declared priorities would be the intensification of the water-saving plan in the irrigated sector. The implementation of more efficient irrigation system remains out of expectation (Treyer 2000). The situation remains extremely critical in the southern Tunisia, where the oases irrigation management problems seem to persist despite the several successive rehabilitation projects (Omrani and Burger 2011b).

Despite the different subsidies allowed to the farmer groups for the introduction of the water-saving techniques at the plot scale (irrigation equipments cost coverage of an average of 40, 50, and 60 % to extensive, middle, and small farmer's plots, respectively), the water consumption inside parcels remains extremely high. Current practice of water use on parcels demonstrates that the applied water volume is more than the effective crop requirement. Traditional irrigation methods are still widely used within farmers' parcels. The absence of any field leveling and the overapplication of water during irrigation, up to three times the actual crop requirements, cause relevant water losses (Mechergui and Van Vuren 1998). The water is still not enough valorized, and the prevailing water-pricing policies are still forfeited and do not militate for a water-saving approach.

With the reform of the irrigated sector, the national adaptation strategy emphasizes also on the institutional change in the water management aspects. The ongoing collaboration between the agriculture and the environment ministries requires further coordination. It needs also further transparency and good governance approach for the following steps.

5 Concluding Remarks

With a relevant experience in the water management, Tunisia is called to confirm the precious progress in the water policy achievements. The learned lessons from the multiple decades of water resources mobilization should define the outline of the future orientations.

Indeed, the water in Tunisia represented definitely a precious and scare resource that had been always the angular stone of the development program. Within a context of fragility, it had been and certainly remains primordial to guarantee the water supply among the concurrent development sectors. Nevertheless, the country had been always self-sufficient in that task and had been able to guarantee the water security even during the most acute drought sequences avoiding the recourse to the water rationing.

For the coming decades, the water policy should be strongly reconsidered within the framework of an integrated approach. The prevailing situation of the irrigated sector spots the light on such reform evidence. Indeed, the critical exploitation ratio that is the soil and water resources sustaining became alarming and announces an uncertain future. The current mode of natural resources management shows an evident gap between the traditional farmer's knowledge and the technological transfer into practice. This assessment is particularly addressed to the irrigation stakeholders. The approach followed to resolve the irrigation problems remains isolated as well as strictly on the technical level and still not supported by a global approach. The conciliation between both engineering thinking and farmer's group perception should be implemented in the future orientations.

The new challenges addressed to water policy development (climate change, population, and standard growth) invoke a drastic reform of the water resources management. Moreover, it should certainly pass through the strengthening of the social and human aspects in the decision-making process. The improvement of the social conditions within the irrigated perimeters seems to be a key issue to guarantee the population involvement and to reach the sustainability quest. An appraisal of the main local population expectations should be engaged to set the main development milestones.

As one of such strategy reform tools, the role of the capacity building should be strengthened for the farmer groups. They still represent the first stakeholders effectively managing the water resources, and their cooperation with the research development partners remains occasional.

The implementation of such approach would require more funds from the current allocation budget; it should also to control the dependency to foreign donors' agency, and a strict survey of the financing modalities remains crucial to avoid any eventual corruption practices.

In order to achieve the water resources management policy goals, taking into consideration the particular environmental context of the agriculture sector is still irrevocable (more than 83 % of the water resources). The high social impact of every action should be considered before its effective implementation.

In order to tackle the future climate change uncertainties, Tunisia water resources sustainability depends heavily on the effectiveness of the undertaken measures into more water value promotion. While the major efforts had been consented to the irrigation sector development, the future options have to focus on the productivity enhancement and the water cost effective recovery (Sghaier 1995). However, as a precondition of such policy achievement, the orientation toward more prepared decentralization process will bring to bear more efficient and adequate solutions to the water user's community.

The prevailing political context in Tunisia should also not be omitted regarding the new opportunities that are being created to the coming generations. The water policy in Tunisia would definitely be a key tool of the next development strategy and should be in a democratic way clearly discussed. The definition of the strategic choices could be in further collaboration and participatory approach with the population mandated. Nevertheless, the need of a successful decentralization in the water resources management remains clearly evident and requires the commitment of all partners involved in the water management. Finally, the achievement of more decentralized and autonomous water resources management in Tunisia seems to be a crucial precondition to meet the future challenges such as the climate change impacts.

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Improving Agricultural Water Productivity: A Viable Response to Water Scarcity in the Dry Areas

Theib Y. Oweis

Abstract Water resources in the dry areas are limited. Most of the available water is tapped, and only limited new water is expected from nonconventional sources. As more water will be needed for other priority sectors, less water will be available for agriculture. This decline comes to challenge the attempts to increase food production and to enhance food security. Climate change adds to this challenge in the dry areas as precipitation is expected to decline and drought to intensify. Agriculture as a result must cope with the increasing demand for food, feed, and fiber but with less water. It is, therefore, essential that substantial changes be made in the way water is valued and managed to help overcome water shortages.

The logical response is to produce more with less water, that is, to improve water productivity (WP) which is the return for a unit of water consumed or depleted. WP in the dry areas is generally low, and there is a great potential for its improvement. There are three primary ways to enhance agricultural WP:

1. Reduce nonproductive water depletion
2. Improve plant, animal, etc., productivity per unit of water beneficially consumed
3. Allocate water to the more water-productive options

Substantial and sustainable improvements in agricultural water productivity can only be achieved through integrated management at all scales. On-farm water-productive techniques include deficit irrigation, supplemental irrigation, water harvesting, and precision irrigation. Improved techniques if coupled with improved irrigation management, better crop selection and appropriate cultural practices, improved genetic make-up, and timely socioeconomic interventions will help to achieve this objective. Conventional water management guidelines should be revised

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to ensure maximum water productivity instead of land productivity. Policy reforms and empowered new institutional setups can ensure sustainable improvement in water use in agriculture.

Keywords Water productivity • Water-use efficiency

1 Introduction

The availability of freshwater is one of the great issues facing humankind today. Water shortage and needs are increasing, and the competition for water among urban, industrial, and agricultural sectors is growing more intensive. Mining groundwater is now a common practice in the dry regions, risking both water reserves and quality. In many countries, securing basic human water needs for domestic use is becoming an issue not to mention the needs for agriculture, industry, and environment. The average annual per capita renewable supplies of water worldwide is about 7,000 m^3. The threshold for water poverty level is 1,000 m^3 which looks ample for countries like Jordan, where the annual per capita share has dropped to less than 200 m^3 (Margat and Vallae 1999). With rapid industrialization, urbanization, and population increase, economic realities seem certain to reallocate water increasingly away from agriculture to other sectors. Moreover, opportunities for large captures of new water are now few. Most river systems suitable for large-scale irrigation have already been developed. Unacceptable depletion of the flow to downstream users will become increasingly difficult to avoid.

The water scarcity situation in the dry areas is getting worse every day. Over the coming years, this situation will worsen with increasing demand, given the fact that the possibility of new supplies is limited. If the world's population keeps growing at the current rate (about 90 million each year), we are facing the challenge of feeding eight billion people very soon – in 2025. More than 80 % of these people live in developing countries. This implies that with nearly the same water and other natural resources base, we must produce food for two billion more people as well as supply expanding domestic and industrial water needs. The increasing pressure on this resource will, unless seriously tackled, escalate hydropolitical conflicts and seriously damage the already fragile environment in the region.

Agriculture is by far the largest user of water, accounting for about 70 % of all withdrawals from rivers, lakes, and aquifers and up to 95 % in many developing countries. The water needed for crops amounts to 1,000–3,000 m^3/ton of cereal harvested. It takes 1–3 ton of water to produce 1 kg of grain. Furthermore, it is estimated that only 45 % of the water used in agriculture are effectively used by crops (UN/WWAP 2003). The other 55 % is partially lost by either evaporation or by losing quality while joining salt sinks. The other part recharges aquifers or flow downstream to be reused. Therefore, agriculture is not seen as the most efficient water user. The ever-growing competition among water-using sectors is certainly forcing agriculture to give up part of its share to higher-priority uses, especially the domestic and industrial sectors. Meanwhile, agriculture must cope with the increasing demand for food, feed, and fiber but with less water. It is, therefore, essential that substantial changes be made in the way water is valued and managed to help overcome water shortages. Under these circumstances, it is crucial that the role of water in securing food supply is understood and the potential for improving overall agricultural productivity with respect to water fully realized.

It has been widely accepted that the most promising option to achieve food security and sustain acceptable standard of living in the water scarce areas is to improve the efficiency of water use or productivity. There are three primary ways to enhance agricultural water productivity: (1) to increase effective use through improved water management, (2) to increase crop yields through agricultural research, and (3) to reform policies and increase investment, particularly in rainfed areas. Improving agricultural water productivity implies getting more output or return per unit of water used. However, sustainability issues must be carefully taken into consideration. Water will be the key agent in the drive to raise and sustain agricultural production. Therefore, agriculture policies and investments will need to become much more strategic. They will have to unlock the potential of agricultural water management practices to raise productivity, spread equitable access to water, and conserve the natural productivity of the water resource base.

This chapter addresses major issues, concepts, and methodologies related to agricultural water- productivity/use efficiency and its improvement. Special emphasis will be given to the evolution of these concepts and the new directions associated with them.

2 Water Efficiency and Productivity Concepts

2.1 Irrigation Efficiencies

The term "*efficiency*," in general, reflects the ratio of output to input. It is widely used in irrigation systems design, evaluation, and management. Farm irrigation performance is based on three fundamental and interrelated efficiency terms: conveyance, application, distribution, and storage efficiencies (Hansen et al. 1980; Jensen 1981; Walker and Skogerboe 1987; James 1988; Keller and Bliesner 1990):

1. Water conveyance efficiency (WCE) is the ratio of water diverted from the source to that delivered to the farm. It reflects water losses from the conveyance system mainly in seepage, evaporation, and weed consumptive use.
2. Irrigation application efficiency (IAE) is the ratio of the water stored in the plant's root zone to that applied to the field. It mainly reflects losses of water in deep percolation and in runoff.
3. Irrigation distribution efficiency (IDE) refers to how uniform water is distributed in the plant's root zone. It however does not indicate any water losses or how full the root zone is.

4. Irrigation storage efficiency (ISE) is the ratio of water stored in the plant's root zone to the amount needed to fill it. It reflects how full the root zone is but does not indicate how uniform irrigation is or how much water is lost in deep percolation and/or runoff.

These irrigation-related efficiencies are engineering terms necessary for sound design, monitoring, and performance evaluation of irrigation systems. The output (numerator) and input (denominator) components of these irrigation-based efficiencies use the same units and are expressed in percentage (%) with a maximum value of 100 %. Values less than 100 % imply *losses* during the process.

Losses of water reflected in the above irrigation efficiency terms are mostly paper, not real losses. Seepage from irrigation canals and field deep percolation losses are largely recoverable through joining groundwater or springs. Runoff losses can be recycled in the field's downstream. Drainage water is also recycled and used several times before becoming too saline. Despite that most of these losses are recoverable, engineers strive to minimize them as reuse implies some costs to the user and probably other side implications. In addition, efficiency terms do not indicate how productive irrigation water is.

2.2 Water-Use Efficiency

Water-use efficiency reflects how good water is used in agricultural production. The term has been defined in the literature in various ways by hydrologists, physiologists, and agronomists depending upon the emphasis that one wishes to place on certain aspects of the problem. In general, it is the ratio of the yield to the unit of water used. The most confusing thing about this term is evaluating the unit of water used. Some use applied water; others use evapotranspiration or even transpiration alone. The term is restricted to biophysical return to water, ignoring other types of return such as socioeconomic or environmental. Production could also be grain, biomass, or any other components. It becomes difficult with this to compare efficiencies at different places or under other practices unless the production and the water used are well defined and evaluated (Hansen et al. 1980; Hanks 1983; Howell et al. 1990; Gregory 1991; Joshi and Singh 1994).

2.3 Water Productivity

As mentioned before, irrigation and water-use efficiencies, although useful in addressing many aspects of water management, do not reflect well the various types of return to water and the water used in the production. Water productivity, defined as the return per unit of water consumed in the production, can overcome those deficiencies. The return to water can be:

(a) Biomass, grain, milk, meat, etc.
(b) Economic benefits (i.e., net income)

(c) Environmental benefits (i.e., carbon sequestration)
(d) Social benefits (i.e., employment)
(e) Energy (i.e., calories)
(f) Nutrition (i.e., protein)

The water consumed is meant to be the water depleted from the production system rendering the return. Water depletion is the use or removal of water (from a domain, particularly a basin) that renders it unavailable for further use. Water may be depleted by evaporation, flows to sinks (such as sea or saline groundwater), or incorporation into products (such as bottling water). Therefore, it is important to distinguish between water depleted and water diverted or applied, because not all water diverted (or supplied) to irrigation is depleted. Recoverable losses (such as surface runoff, deep percolation…) from any WP level or domain's boundaries can be reused within the same domain or higher levels. More specifically, depleted water includes: evaporation, transpiration, water quality deterioration, and water incorporated in the product or plant tissues. Water recycled in the farming system may not be totally lost as implied by evaluating irrigation efficiencies. Water quality is important as water with various qualities has different productivity. It is now well understood that the issue of water productivity is multidisciplinary and scale or level dependent (Molden et al. 2003, 2010; Molden 1997).

3 Agricultural Water Productivity

Figures 1, 2, 3, and 4 show a range of water productivities for some agricultural products based on biophysical, economic, nutrient, and energy returns (Molden et al. 2010). The wide range of values, from low to high, reflects the great potential for improvement. The figures show that depending on the production purpose and local conditions, the selection of the product can make a great difference in the return for the water. One can also notice the low water productivity in producing beef compared to crops.

It is important to note that WP is not only scale and user specific but also site and management specific. A cubic meter of water is expected to produce more biomass in a cool than in a hot, dry environment. Soil type, water quality, crop variety, production input, and water and crop management are among the factors impacting WP. Market prices affect economic WP. For meaningful comparison of WP at different locations and/or environments, there is need to normalize the values of WP (Oweis and Hachum 2003).

3.1 Scales and Drivers

WP is addressed at different scales (plant, farm, project, and basin levels), and a conceptual framework for better understanding of WP and water accounting across scales is introduced. It has been pointed out that the highest WP at one scale is not

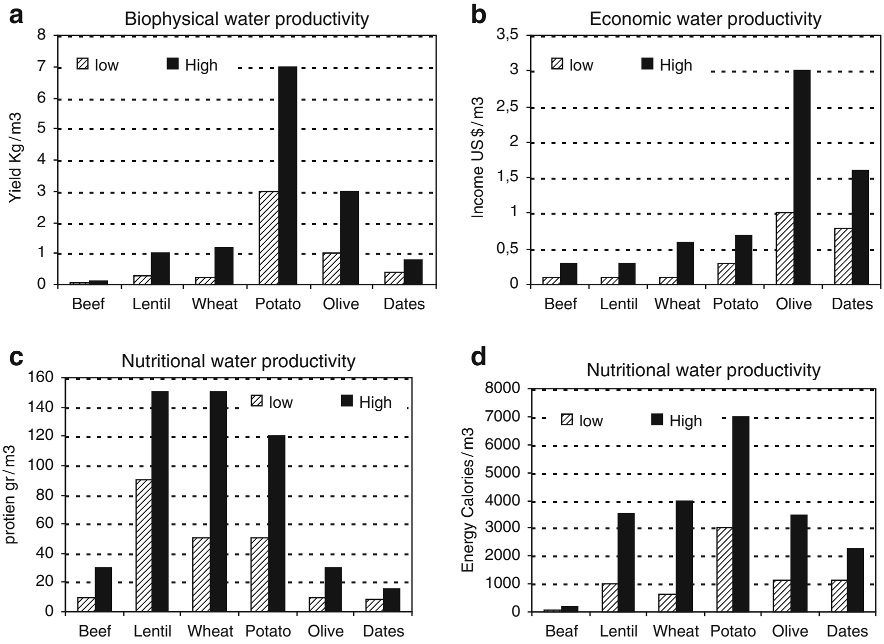

Fig. 1 Estimates of a range of water productivity values (from low to high) of some agricultural products: (**a**) biophysical WP, (**b**) economic WP, (**c**) nutritional WP (protein), and (**d**) energy WP (Molden et al. 2010)

necessarily the result in highest WP at another scale. Economic productivity and opportunity cost of water make the undertaking far more complex. Nevertheless, the major drivers at each scale are:

(a) At the basin level, competition among uses (agricultural, domestic, environmental,…), conflicts between countries, and equity issues (upstream–downstream users).
(b) At the national level, drivers are food security, hard currency, and socio-politics.
(c) At the farm level, one driver is maximizing economic return (crop and allocation selection).
(d) At the field level, the driver is maximizing biological output (maximizing resources productivity).
(e) At the plant level, the driver is maximizing nutrient content and quality of harvest.

3.2 Potential WP Improvements

Figure 2a shows, worldwide, ratio of biomass and yield of common small grain crops to transpiration, T, along with yield/ET ratio for two selected regions. The slope of the second line from top is greater than the slope of the top line that indicates

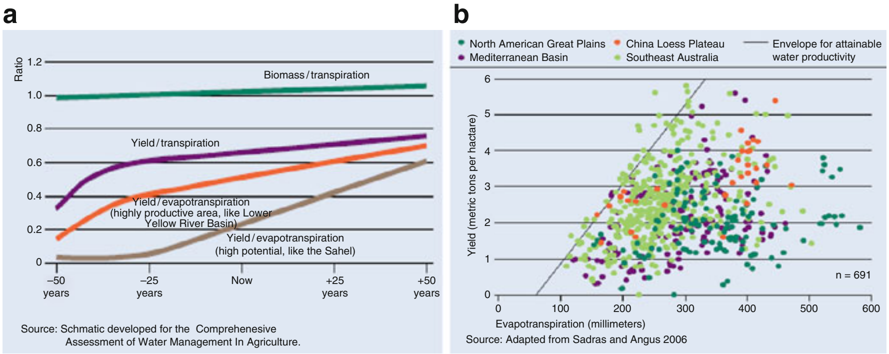

Fig. 2 Potential improvements in water productivity. (**a**) Projected potential improvements of WP with various means and regions and (**b**) water yield relations of wheat grains in major regions of the world (Molden et al. 2010)

potential improvement in harvest index. The two lower lines in the figure indicate that improvements in water productivity are possible through improved management that increases the ratio of yield to evapotranspiration (slope of line). But in many of the most productive areas of the world, such as the lower Yellow River Basin, large improvements have already been made, and the remaining scope is small. The implication is that for these areas, achieving higher yields will require more evapotranspiration. The areas with the highest potential gains are those with very low yields, such as sub-Saharan Africa and South Asia. These are also areas of extreme poverty, with the largest concentration of poor people and high dependence of the poor on agriculture (Molden et al. 2010; Rockstrom et al. 2007).

Breeding, targeting early growth vigor to reduce evaporation, and increasing resistance to drought, disease, or salinity could all improve water productivity per unit of evapotranspiration. But there are several indirect means to improve water productivity in which biotechnology can play a role:

1. Targeting rapid early growth to shade the soil and reduce evaporation.
2. Breeding for resistance to disease, pests, and salinity.
3. Boosting the harvest index for crops such as millet and sorghum that have not received as much attention as the green revolution's grains.
4. More value per unit of evapotranspiration can be achieved by improving the nutritional quality of crops and by reducing agrochemical inputs by planting disease- and pest-resistant crops.

Figure 2b illustrates significant variability in yield due to differences in biophysical conditions (particularly evaporation and other climatic conditions) among sites in addition to differences in management of natural resources. Variability due to management practices gives hope for potential improvement in water productivity especially at low yield domain. It shows that the potential to improve WP is substantial in many areas, and mainly management can achieve this improvement.

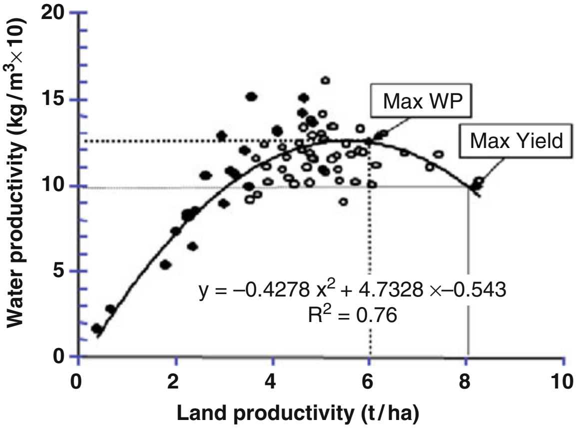

Fig. 3 Relationship between water productivity (WP) and land productivity (LP) for durum wheat in Mediterranean environment (Oweis et al. 1998)

3.3 Trade-Offs Between Water and Land Productivities

In conventional irrigation, water is applied to maximize crop yield per unit of land. This is the case when land availability is limiting. In the most of the dry areas, land is not, anymore, the most limiting factor to agricultural production. Rather, water is increasingly becoming the most limiting factor. The objective, therefore, should be maximizing the return per unit of water instead per unit of land. This should yield higher overall production, since the saved water can be used to irrigate new land with higher production. However, high WP does not come without high land productivity (LP). Fortunately, both water and land productivities increase at the same time as improvement to on-farm management is introduced. However, this does not continue all the way. At high yield level, additional incremental yield increase requires higher amounts of water to achieve. This means that water productivity drops as yield increases near its potential. Figure 3 shows the relation between LP and WP for wheat in the Mediterranean region. When this relation is curvilinear, maximum WP occurs at less than maximum LP which is not the case for all crops and conditions (Oweis et al. 1998).

Attaining higher yields with improved WP should ensure that increased gains in crop yield are not offset by increased costs of inputs and running costs. The curvilinear WP–yield relationship emphasizes the importance of attaining relative high yields for efficient use of water. A policy for maximizing yield and/or net profit should be looked at very carefully under water scarcity conditions. Guidelines for recommending irrigation schedules under normal water availability (Allen et al. 1998) may need to be revised when applied in areas with limited water resources.

When water is short of providing full SI to the whole farm, the farmer has two options: (a) to irrigate part of the farm with full SI leaving the other part rainfed or

Table 1 Wheat grain production scenarios for 4-ha farms with various strategies of supplemental irrigation in Syria (Oweis and Hachum 2003)

Management strategy	Rainfed	Farmer's	Full SI	Deficit SI
Total water applied (m^3)	342 mm	2980	2220	1110
Grain yield (ton/ha)	1.8	4.18	4.46	4.15
Water productivity (kg/m^3)	0.53	0.70	1.06	1.85
Possible 4-ha farm production (ton) if water is not limiting	7.2	16.7	17.8	16.6
4-ha farm total production (ton) under limited water available (50 % of full requirements)	7.2	10.8	12.5	16.6

(b) to apply deficit irrigation to the whole farm. In northern Syria, water-short farmers are advised to apply 50 % deficit SI to their wheat fields. By so doing, the area under SI is doubled using the same amount of water, and total farm production is higher. A farmer having a 4-ha farm would on average produce 33 % more grain from his farm if he adopted deficit irrigation for the whole area, than if full irrigation was applied to half of the area (Table 1).

4 Approaches for Improving Water Productivity

The following are major approaches for improving agricultural water productivity (Viets 1962; Stanhill 1986; Monteith 1986; Oweis et al. 1998).

4.1 Increasing the Productivity Per Unit of Water Consumed

- *Improved crop varieties* to new crop varieties that can provide increased yields for each unit of water consumed, or the same yields with fewer units of water consumed.
- *Alternative crops*; by switching from high- to less-water-consuming crops or switching to crops with higher economic or physical productivity per unit of water consumed.
- *Deficit, supplemental, or precision irrigation*; with sufficient water control, higher productivity can be achieved using irrigation strategies that increase the returns per unit of water consumed.
- *Improved water management*; to provide better timing of supplies to reduce stress at critical crop growth stages leading to increased yields or by increasing water supply reliability so that farmers invest more in other agricultural inputs leading to higher output per unit of water.

– *Optimizing non-water inputs*; in association with irrigation strategies that increase the yield per unit of water consumed, agronomic practices such as land preparation and fertilization can increase the return per unit of water.
– *Policy reform and public awareness*; policies related to water use and valuation should be geared towards controlling water use, reducing water demand, safe use and disposal of water, and encouraging the collective approach in using and managing water by users.

4.2 Reducing Non-beneficial Water Depletion

- *Reducing evaporation from water applied* to irrigated fields through specific irrigation technologies such as drip irrigation or agronomic practices such as mulching or changing crop planting dates to match periods of less-evaporative demand
- *Reducing evaporation from fallow land*, decreasing the area of free water surfaces, decreasing non- or less-beneficial vegetation, and controlling weeds
- *Reducing water flows to sinks*—by interventions that reduce irrecoverable deep percolation and surface runoff
- *Minimizing salinization of return flows*—by minimizing flows through saline soils or through saline groundwater to reduce pollution caused by the movement of salts into recoverable irrigation return flows
- *Shunting polluted water to sinks*—to avoid the need to dilute with freshwater, saline or otherwise polluted water should be shunted directly to sinks
- *Reusing return flow* through gravity and pump diversions to increase irrigated area

4.3 Reallocating Water Among Uses

- *Reallocating water from lower- to higher-value uses*. Reallocation will generally not result in any direct water savings, but it can dramatically increase the economic productivity of water. Because downstream commitments may change, reallocation of water can have serious legal, equity, and other social considerations that must be addressed.
- *Tapping uncommitted outflows* to be used for productive purposes.
- *Improving management of existing facilities* to obtain more beneficial use from existing water supplies.
- *Policy, design, management, and institutional interventions* may allow for an expansion of irrigated area, increased cropping intensity, or increased yields within the service areas.
- *Reducing delivery requirements* by improved application efficiency, water pricing, and improved allocation and distribution practices.

- *Adding storage facilities infrastructures* to store and regulate the use of uncommitted outflows, which is usually the case during wet years, could be considered so that more water is available for release during drier periods.

5 Highly Water-Productive Technologies

5.1 Deficit Irrigation

When water is limiting production, the rules of scheduling should be modified for improved water productivity. In intensive irrigation development, all efforts including research and advancement in technology development are geared towards achieving maximized yield per unit of land. However, in water scarce areas, water, not land, is the most limiting factor to improved agricultural production. Irrigating for less than maximum yield per unit land (deficit irrigation) could save substantial amounts of water for irrigating new lands and hence producing more food from the available water. Deficit irrigation is not the only practice that has shown good potential, but other ways are available to modify water management principles to achieve more water-efficient practices. New guidelines for crop water requirements and irrigation scheduling to maximize water productivity are yet to be developed for the important crops in the dry areas (Fig. 4).

Deficit irrigation is an optimizing strategy under which crops are deliberately allowed to sustain some degree of water deficit and yield reduction in order to maximize the productivity per unit of water used. One important merit of deficit supplemental irrigation is the greater potential for benefiting from unexpected rainfall during the growing season due to the higher availability of storage space in the crop root zone. Results on wheat, obtained from farmers' field trials conducted in a Mediterranean climate in northern Syria, reported significant improvement in

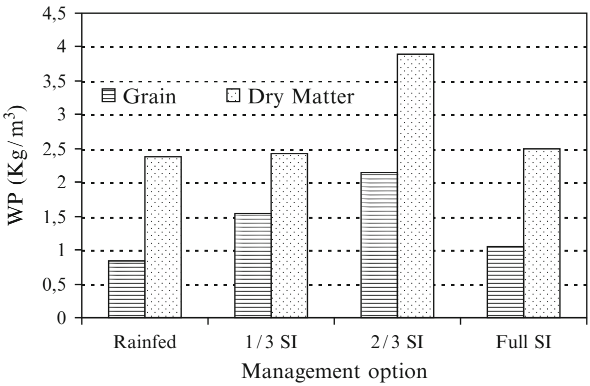

Fig. 4 Water productivity (WP) of wheat grains under rainfed, full, and deficit irrigation (SI) in northern Syria (Oweis et al. 2004)

SI water productivity at lower application rates than at full irrigation. Highest water productivity of applied water was obtained at rates between one-third and two-thirds of full SI requirements, in addition to rainfall.

5.2 Water Harvesting

The drier environments, "the steppe" or *badia*, occupy the vast majority of the dry areas of the world. The natural resources of these areas are subject to degradation, and the income of the people, which depends mainly on livestock grazing, is continuously declining. Due to harsh conditions, people are increasingly migrating from these areas to the cities, with associated high social and environmental costs. Precipitation in the drier environments is generally low compared to crop basic needs. It is unfavorably distributed over the crop-growing season and often comes with high intensity. As a result, rainfall in this environment cannot support economical dryland farming. In the Mediterranean areas, rain usually comes in sporadic, unpredictable storms and is mostly lost in evaporation and runoff, leaving frequent dry periods during the crop-growing season. Part of the rain returns to the atmosphere by evaporation after it falls, and part usually flows to swamps or to "salt sinks," where it loses quality and evaporates (Oweis et al. 1999).

Water harvesting in agriculture is based on the principle of depriving part of the land of its share of rainwater and adding it to the share of another part. This brings the amount of water available to the target area closer to the crop water requirements so that economical agricultural production can be achieved and thus improving the water productivity. Thus, water harvesting may be defined as "*the process of concentrating precipitation through runoff and storing it for beneficial use*."

Without water harvesting intervention, all rainwater and land production are lost, while part of the land and most of the rainwater are in production and beneficial. Thus, rainwater productivity is immensely increased. Notable wealth of indigenous knowledge on water harvesting is available and documented. Indigenous systems such as *jessour* and *meskat* in Tunisia, *tabia* in Libya, *cisterns* in north Egypt, *hafaer* in Jordan, Syria, and Sudan and many other techniques are still in use (Oweis et al. 1999, 2001, 2004). Water harvesting may be developed to provide water for human and animal consumption and domestic and environmental purposes, as well as for plant production. Water harvesting is also effective in combating land degradation and desertification.

Unfortunately, the introduction of systems which have been tested under various climatic, soil, land tenure, and socioeconomic conditions is usually not accepted by the target groups. The most significant problems and constraints hindering the integration of water harvesting in the agricultural production are:

- Technology inadequacy to meet the local conditions
- Lack of acceptance, motivation, and involvement among beneficiaries
- Lack of adequate hydrological data and information for confident planning, design, and implementation of water harvesting projects

– Insufficient attention to social and economic aspects such as land tenure, unemployment, and return of water harvesting system
– Inadequate institutional structures, beneficiary organizations, and government training programs for farmers, pastoralists, and extension staff
– Absence of a long-term government policy

5.3 Supplemental Irrigation

Shortage of soil moisture in the dry rainfed areas often occurs during the most sensitive growth stages (flowering and grain filling) of the crops. As a result, rainfed crop growth is poor, and yield is consequently low. Supplemental irrigation can, using a limited amount of water, if applied during the critical crop growth stages, result in substantial improvement in yield and water productivity. Therefore, supplemental irrigation is an effective response to alleviate the adverse impact of soil moisture stress during dry spills on the yield of rainfed crops. Unlike full irrigation, the timing and amount of SI cannot be determined in advance owing to rainfall randomness. Supplemental irrigation in rainfed areas is based on three basic aspects (Oweis and Hachum 2003): Water is applied to a rainfed crop that would normally produce some yield without irrigation, irrigation is only applied when rainfall fails to provide essential moisture for improved and stable production, and the amount and timing of irrigation are scheduled to ensure a minimum amount of water available during the critical stages of crop growth.

Average WP of rain in producing wheat in the dry areas of West Asia and North Africa (WANA) ranges from about 0.35–1.00 kg grain/m^3. However, water used in supplemental irrigation can be much more efficient. ICARDA found that a cubic meter of water applied at the right time (when crops suffer from moisture stress) and good management could produce more than 2.5 kg of grain over the rainfed production. This extremely high WUE is mainly attributed to the effectiveness of a small amount of water in alleviating severe moisture stress during the most sensitive stage of crop growth. This stress usually causes a collapse in the crop development and seed filling and reduces the yields substantially. When SI irrigation water is applied before such conditions occur, the plant may reach its high potential.

In comparison to the productivity of water in fully irrigated areas (rainfall effect is negligible), we find greater advantage with SI. In fully irrigated areas with good management, wheat grain yield is about 6 ton/ha using a total amount of 800 mm of water. This makes WP about 0.75 kg/m^3, one-third of that under SI with similar management (Fig. 5). This suggests that water resources are better allocated to SI when other physical and economic conditions are favorable.

In the highlands of WANA region, frost conditions occur in the winter and put field crops into dormant. Usually, the first rainfall, sufficient to germinate seeds, comes late resulting in low crop stand when the frost occurs. Rainfed yields, as a result, are much lower than when the crop stand pre-frost is good. Ensuring a good crop stand in December can be achieved by early sowing and applying 50–100 mm

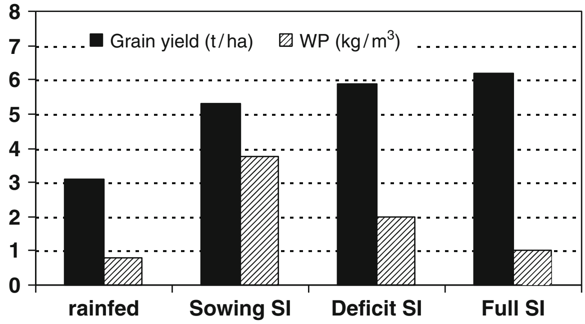

Fig. 5 Water productivity and yield of wheat grains under various water management strategies: rainfed, full supplemental irrigation, deficit irrigation, and sowing irrigation (Ilbeyi et al. 2006)

of supplemental irrigation early in the season. SI, given at early sowing, dramatically increased wheat yield and water productivity. Applying 50 mm of SI to wheat sown early has increased grain yield by more than 60 %, adding more than 2 ton/ha to the average rainfed yield of 3.2 ton/ha (Ilbeyi et al. 2006). Water productivity reached 3.7 kg grain/m^3 of consumed water compared to water productivity values of wheat of 1–2 kg/m^3 under traditional practices (Fig. 5).

5.4 *Alternative Cropping Patterns*

Due to increased water scarcity, globalization, and climate change, current land use and cropping patterns should be modified if more food is to be produced from less water. Water is likely to be the major constraint, and new land use systems that respond to external as well as internal factors must be developed based on available water. This should include adopting water-efficient crops, varieties, and sound combinations of crops in the farming system. In cases of extreme water scarcity, the concept of importing virtual water becomes viable. We do not encourage adopting this concept as a national policy in developing countries as it affects food security. Caution should be taken when evaluating the returns for water in income, social, and environmental aspects and the best crops to be adopted for maximum benefits. Furthermore, modifications of cropping patterns should be introduced gradually with appropriate policies to encourage its adoption.

5.5 *Precision Irrigation*

Improved technologies that already exist may at least double the amount of food produced from present levels of water use, if applied in the field. Implementing precision irrigation, such as micro- and sprinkler irrigation systems, laser leveling, and others techniques, contributes to substantial improvement in water application and distribution efficiency. It is true that water lost during conveyance and on-farm application is not an absolute loss from a basin perspective, but its quality may deteriorate and its recovery comes at a cost. To account for these losses, the size of the irrigation system will significantly increase, and this again comes at a very high cost. Policies to implement and transfer these technologies are vital. There is a need to provide farmers with economic and more efficient alternatives to on-farm water management practices with incentives that can bring about the needed change.

6 Other Considerations

6.1 Environmental Water Productivity

Now, it has been globally understood and accepted that *environment* is a water-using sector, which is strongly linked to the sustainability of water resources development and management. This is a complex issue for both rich and poor countries. It is technically challenging and often entails difficult trade-off among social, economic, and political considerations. Strategies to reduce poverty should not lead to further degradation of water resources and ecology. Environmental water needs and that for food production should be complementary for sustainable livelihoods.

6.2 Enabling Environments

Lack of appropriate policies and institutional setups are main obstacles for adoption of improved water management options. Valuating water is essential if productivity is to improve. Socio-political constraints do not allow water pricing, but alternatives to pricing can be developed. Water trading through goods is an old practice. It can be used in countries with extreme water scarcity to reduce inefficient water use, but agricultural practices of rural communities should be protected. Water management institutions such as user associations and community cooperatives are weak in the region and need strengthening. They should be allowed to participate in the decision making regarding water issues. Their capacity is also poor, and training is essential to improve skills and participation. It is about time for these vital changes in order to unlock the potential of water management in agriculture.

7 Conclusions and Recommendations

In the dry areas, water is the most limiting resource for agricultural production and is increasingly declining. As more food is needed with less water available, the only option available is by increasing agricultural water productivity. Focusing on water productivity in addition to land productivity is therefore a recommended strategy. To achieve this, more efficient water management techniques must be adopted.

On-farm water-productive techniques, if coupled with improved irrigation management options, better crop selection, appropriate cultural practices, improved genetic make-up, and timely socioeconomic interventions will maximize water productivity. Major needed changes to achieve this objective include water allocation to more water-efficient crops/techniques, more water-efficient land use, water valuation to truly reflect its value, trade policy to import high water demand goods, regional corporation for combating water scarcity, and new policies to address water scarcity issues.

It is essential that substantial changes be made in the way water is managed to help alleviate poverty, promote economic growth, and overcome potential conflicts. Substantial and sustainable improvements in water productivity can only be achieved through participatory and integrated farm resources management. More investment in rainfed agriculture, in reallocating water resources to higher water-efficient options, such as SI and WH, and in improving WP through appropriate policies and institutional setups, is recommended.

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Conceptual Frame on Technological Perspective for Water Resources Management in the Mediterranean Region

Ayman Rabi, Isabel Martín, and Rafael Rodriguez-Clemente

Abstract The availability of fresh water supplies in most of the Mediterranean countries is falling short to meet the growing demand. This situation often creates conflicts among the various sectors and places much more pressure on the natural and ecosystems supporting such resources. Therefore, the challenge of water use and allocation is already a major political concern in the Basin and will most likely amplify in the coming years.

This chapter presents a summary of the main criteria recommended for the appropriate technologies to attain sustainable water management in the Mediterranean region as defined within the MELIA project. It also addresses the main social, cultural and institutional constraints facing adopting new technology and concludes with some recommendations on how to mitigate such constraints.

Keywords Appropriate water technologies • Integrated water management • Stakeholder involvement • Initial stage • Mature stage • Demand management • Criteria • Water scarcity

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1 Introduction

Most of the Mediterranean Basin countries in North Africa, Middle East and Southern Europe has many similarities in terms of growing water shortage, increased drought events, increased pollution threats, increased overexploitation of groundwater resources and increased threat of seawater intrusion, rapid population growth and rapid tourism growth. In addition, natural surface and groundwater resources do not recognize frontiers, and many of them are shared by more than one country, incorporating another complication to the sustainable management of water. The common feature of the Mediterranean area is that water is one of the limiting factors for sustainable development, increased quality of life and peace.

The regional average annual per capita renewable water dropped significantly over the last 40 years from 3,300 m^3 in 1960 to 1,250 m^3 in 1995 and is projected to drop to 650 m^3 in 2025. Projections of the World Resources Institute (1996) suggest that by 2025, some Eastern Mediterranean countries will be among the 45 countries worldwide which will suffer chronic water stress. An increasing proportion of surface and groundwater resources in the region are polluted mainly due to inappropriate disposal of municipal wastewater, infiltration from onsite sanitation facilities and excessive use of fertilizers and pesticides in agriculture. Due to severe shortages in agricultural water, reuse of wastewater has become unavoidable in many countries such as Jordan and Syria. Untreated wastewater was and still is used sometimes in agriculture without adequate health safeguards.

Trends in most European countries indicate that the supply of water to the population is threatened by man-made pressures and that water ecosystems are undergoing severe processes of quality deterioration (Berbel and Gutiérrez 2004). About 20 % of all surface water in the European Union is seriously threatened with pollution. Groundwater supplies around 65 % of all Europe drinking water, and 60 % of European cities overexploit their groundwater resources. Furthermore, 50 % of Europe's wetlands have "endangered status" due to groundwater overexploitation, and the area of irrigated land in Southern Europe has increased by 20 % since 1985 (European Commission 2002). In recent years, there has been a growing concern throughout the EU regarding drought events leading to water scarcity problems, especially in the Mediterranean countries. The competition between various uses, especially agriculture and tourism, which are major components of this area's economy, make trade-off allocation decisions very often too difficult. Hence, conflicts over water are increasing, and they are becoming more complex, involving competition among alternative uses, among geographical regions with disparate water endowments and between water resource development and other natural resources lost due to that development.

The challenge of water use and allocation is already a major political concern and will most likely amplify in the coming years. This is why integrated water resources management (IWRM) and the search for appropriate technologies are coming high on the policy agenda to help overcome such long list of problems. Such technologies will certainly range from the supply side to the demand side management and address both quantity and quality of water. The identified relevant technologies certainly have to look into the enhancement of available supply through the use and reuse of available resources in the most efficient way and develop management techniques that are integrated and comprehensive. The legal and institutional aspects are also an integral part of the country's efforts towards overcoming their water problems and helping reduce poverty and attain food security and economic growth whilst maintaining sustainable ecological system and their services (Gbadegesin 2008).

Over the last decade of the twentieth century, new strategies for the management of water resources have been promoted. These strategies are recommended in several chapters of Agenda 21, and they are also confirmed in the first paragraph of the UN Program on Integrated Water Resources Development and Management, which states that the "development of appropriate water management requires the application of new sustainable technologies both in terms of analysis and engineering".

2 Water Management Techniques and Technologies

The rapid advancement in developing various water technologies, whether those related to large pumping equipment, drilling technology and ability to tap very deep aquifers and filtration and treatment technologies, has enabled more easy access to water resources and increased the pressure over the sustainable utilization of these resources. In many northern countries, the over utilization and unsustainable use of the resources during the 1940s has left large rivers and lakes heavily polluted and left some aquifers extremely overexploited during the 1960s in some southern parts of the Mediterranean.

These alarming incidents and many similar ones worldwide have drawn the attention of water scientists, and they started addressing the necessity of using the resources in a sustainable way. The Mar del Plata conference in 1977 was the first to address this issue. Then the famous Dublin principles came in 1992 in the preparation for the UN conference on the concept of sustainability that was organized in 1992 in Rio de Janeiro. After that, the IWRM concept has become the norm in managing water resources in general, and in line with this development, attention starts to be given to the importance of developing more efficient technologies that ensures the sustainable use of the resources whilst achieving the anticipated social, economic and environmental benefits aimed at from the utilization of such resources.

It also became clearer that management and utilization of available water resources during this stage where demand exceeds supply cannot be run in the same way that used to be run in the past when the resource capacity was much higher than the demand and the inter-sectoral conflict over the use of resources hardly existed.

Randall (1981) has distinguished two stages in the development and management of the resources, the initial or expansive stage and the maturity stage. During the initial stage of resource development, the volume of economically and technically available natural resources exceeds the demand. Accordingly, the competition was

Table 1 Major water resources development stages

Aspect	Stage: Initial	Stage: Maturity
Increasing long-term supply through exploiting new natural resources	Mostly possible	Extremely difficult
Water demand	Low and expanding	Strong and expanding
	High elasticity at low price and inelastic at high price	Medium elasticity at low price and inelastic at high price
Physical conditions of engineering infrastructure	Most of them are almost new and in good condition	Large part is old and expensive to repair and renew
Competition for water among different users	Minimal	Intense
Socio-economic and environmental problems	Minimal, competition for economic resources (public infrastructure)	Intense, competition for the resource itself
Social cost stemming from subsidized water, especially for agricultural purposes	Very low, very low levels of cost recovery	High and expanding, increasing cost recovery schemes

low and the engineering works were designed to allocate water in the areas where water rights were established. He also summarized the characteristics of water resources development and management during the two stages as shown in Table 1.

Clearly, depending on the stage of the development and management of water resources (initial or mature stage), some solutions will be more successful than others. We can deduce that, during the initial stage, focus will be more to the supply side management and to the actions that aim at increasing the supply, whilst during the maturity stage the demand side management of existing available resources is much more important. During this stage, water management has, on the one hand, an engineering dimension that aims at meeting demand with the most efficient water use possible, and, on the other hand, it must address socio-economic and environmental aspects that can even lead to the reallocation of the resources, provided pre-existing rights are respected or duly compensated (López-Martos 2008).

It was also clear that during the initial stage of water resource development, the main and almost only activity is to quantify and tap the available resources (surface and groundwater). The advancement in developing sophisticated technologies and tools such as remote sensing, GIS and various quantity and quality modelling techniques has fostered the level of understanding and improved the knowledge about the physical as well as other characteristics of the water resources. However, when the pressure over the resources increases, management of the resources in a conjunctive and efficient way becomes a necessity in order to ensure the sustainability of these resources in terms of their quantity and quality.

This implies that the technology should focus on all possible demand management aspects. Such aspects may vary from improving the main water transmission networks and water supply systems (reducing losses) and adopting low flow appliances at household and farm level (efficient irrigation techniques) to developing proper pricing policies that capture the true value of the supplied water, as well developing regulations that support the efficient and proper allocations among the different users. In the meantime, more attention is given to the development and utilization of the unconventional water resources or even to consider various other options such as virtual water. Furthermore, good water governance and efficient institutional setup becomes a must in order to ensure a balanced and participatory approach in managing these resources. Such approach shall ensure the representation of the interest of all stakeholders in a given watershed or a river basin or those who benefit from the same resource in a given territorial unit. The importance of this approach becomes more challenging in the water scarce areas. Spain, for example, was the first country to introduce the notion of watershed or river basin as a legal concept of water management, whereby watershed was considered as the territorial unit for planning and management of water resources. This has ever since been adopted by other countries including the USA and others. It has also been used by the European Water Framework Directive (European Commission 2000) for the entire EU.

During the mature stage, the development and utilization of unconventional water resources (wastewater reuse and/or desalination of seawater or brackish water) becomes an integral part of the overall management of the resources, and they are considered as part of the water resources budget in a given watershed. This becomes especially significant in areas with water shortage.

Despite the fact that the development of these unconventional resources requires expensive and energy-intensive technologies, yet, the need for their integration within the overall resource budget is a must. Here, the relation between water production and energy requirement for the process becomes one of the key determining factors. However, the advancement in technology and engineering has so far managed to develop these resources at a reasonable cost. Yet, if this achievement in technological advancement is not met with proper governance, institutional setup and regulatory structures that can ensure the integration of these resources in the overall management policies, they may become a burden and may lead to the failure of the overall water management in a given area.

In addition to that, stakeholder involvement in various stages of planning, adaptation and management of these resources is very crucial in order to ensure social and cultural acceptability of some of these resources (especially the reuse of treated effluent). To ensure efficient engagement of stakeholders, more awareness programs about these resources and their potential use advantages and disadvantages are needed alongside with more capacity-building programs tailored towards improving the knowledge of the stakeholders about these resources and the technologies involved in their management.

Based on the considerations mentioned above, any technology used for water resources development and management, whether in the initial stage or mature stage, should fulfil the following requirements:

1. New and sustainable technologies should have the capacity to address the challenges with which we are faced but with full respect to the ecological considerations.
2. Technical skills and expertise necessary for the implementation of these technologies are available.
3. To ensure public engagement in the development of such technologies. For example, technologies resulting from public-private partnership may be looked favourably.
4. Technologies should be cost effective.
5. To make sure that the new technologies developed/adopted in agriculture are tailored towards saving more water and may include:

   (a) Efficient irrigation technologies
   (b) Possibility of earlier planting
   (c) Shorter crops cycle
   (d) Improved drought resistance capacity
   (e) Salinity resisting crops

The organization of the 2nd MELIA project workshop in Marrakech in November 2008 came to address a lot of these issues listed above, and the debates regarding the technological perspectives for a sustainable integrated water resources management in the Mediterranean region have addressed several issues ranging from the technologies used for enhancing water supplies and those related to preserving the quality of the resources to other issues that address the social and cultural aspects of water management and also addressed the institutional, governance and policy aspects and emphasized the importance of the technical tools developed to assist in better management (GIS and remote sensing).

The debate also addressed the various regulations and directives concerned with the management of the resources and also addressed the new challenges facing the management especially the global and climatic changes, the changing world economy and social and economic disparity of southern and northern Mediterranean countries and how such gap can be addressed reasonably in a way that the resources can be managed sustainably in the Mediterranean Basin. The debate resulted in the identification of some key concepts and recommendations of criteria on the appropriate technologies that should be tailored towards sustainable management of the scarce water resources in the Basin which can be listed as follows:

Criteria for Appropriate Technologies

The criteria can be classified under several categories as follows:

1. Technical viability

   - Easy to be operated and maintained
   - Technically efficient
   - Address a real need for people

2. Economic feasibility
   - Cost effective at the particular socio-economic conditions
   - Affordable, people can afford its adaptation
3. Environmentally sound
   - Producing no environmental harm
   - Appropriate to the local environments where they will be applied
4. Socially and culturally acceptable
   - Developed in a real participatory way among all actors (stakeholders)
5. In line with the national standards and regulations
6. Institutional setup is adequate for its accommodation and customization

It is important to note that even in the case of fulfilling the criteria mentioned above, the implementation and adaptation of any new technology will face certain constraints. Among those, the following can be listed:

Constraints to implement new and more efficient technologies:

1. Large knowledge gap between scientists, practitioners, policymakers and the public about the different technologies in place
2. The format and language that describe the technologies are too technical to be understood by the public and sometimes by policymakers (lack of appropriate communication language)
3. Lack of mechanisms to create sufficient concerns about the problems and mechanisms to propose appropriate solutions
4. Lack of people's capacity and reluctance to adopt new technologies.
5. Bad experience of people in applying certain technologies which affects their willingness to adopt other useful technological application – no public debate on different alternatives
6. Lack of funds
7. Lack of responsible and independent media coverage
8. Poor governance conditions

These constraints are common in hindering the possible adaptation of the technology. However, mitigation measures can help overcome such constraints, and they can include the following:

1. A compulsory institutional involvement in costs and maintenance and, specially, in training the staff is needed.
2. Feasibility and demonstration studies at local conditions are needed in order to assess their applicability according to the real needs and possibilities.
3. Dissemination and communication strategies to raise public awareness regarding the importance of treating wastewater, and the consequences of its absence, must be established.
4. Enhancing North-south scientific collaboration and knowledge transfer in this field.

5. Enhancing public participation in social aspects through interaction with end users, administrators and stakeholders.
6. Regular information to the end users of the costs and difficulties encountered in the handling of new technologies, if any.

3 Conclusions

- More work is needed to enhance on farm water use efficiency.
- More work is needed to assess the climate and global change over the resources and what type of adaptation measures should be taken by MED Basin.
- More research is needed to explore the utilization of the renewable energy in water management-related technologies in the Mediterranean Basin.
- Policy alignments among the different countries in the Basin are needed to ensure better integrated management of the resources.
- Water and energy conserving technologies are not well promoted in the Basin.

4 Recommendations

In order to overcome the constraints to develop new technologies and promote their public appropriation, the following measures could be proposed:

1. Select the technology that best fits the local conditions, and do not consider the technologies successful somewhere else to be necessarily successful in another place.
2. Enable all actors to be involved in the experimental platforms development. Scientists and administrations have to work together. The public should be able to follow the technology adoption debates.
3. Promote broad dissemination of successful scientific results to the public, end users and all concerned agents (translate scientific outputs into simple common language).
4. Promote the participatory approach in decision making.
5. Increase of training opportunities for technical and non-technical staff.
6. Need of institutional and economic support to enhance public awareness on regular basis, not on an ad hoc basis.
7. Promote lobby groups to ensure that policymakers properly understand the problems of IWRM, and adopt the appropriate means to handle it.
8. Use unconventional channels to convey the message to as wide audience as possible (e.g. use football teams, actors).
9. Show the consequences of not taking any action.
10. Develop a communication strategy with media involvement.
11. Improve knowledge sharing among practitioners through the following means:

- Enable their participation in the different scientific events as well as in the experimental work.
- Build their theoretical capacities to enable them to pass from theory to practice.
- Report on success and failure stories that they witness and what lessons were learnt.
- Provide communication venue.
- Enable exchange of expertise (facilitate barriers such as funds, language, etc.).

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Part II
Water Resources Management Under Climate and Land Use Changes in the Mediterranean Region

Water Resources Management Under Possible Future Climate and Land Use Changes: The Application of the Integrated Hydrological Modelling System, IHMS

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Abstract The Integrated Hydrological Modelling System, IHMS, has been developed to study the impact of climate and land use changes on water resources. The system comprises three models: the distributed catchment scale model DiCaSM, which deals with the unsaturated zone; the MODFLOW model, for saturated zone and groundwater flow; and the SWI model, for seawater intrusion in coastal areas. These models can be applied either together or separately. Four sites were considered in this study.

In the first site, the DiCaSM application on Candelaro catchment in the Apulia region, Italy, proved the ability of the DiCaSM to successfully simulate the stream flows (2001–2002). When applying the possible future climate change scenarios for southern Italy as reduced winter rainfall by 5–10 %, reduced summer rainfall by

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15–20 %, winter temperature rise by 1.25–1.5 °C and summer temperature rise by 1.5–1.75 °C, the results indicated that, by 2050, the groundwater recharge in the Candelaro catchment would decrease by 21–31 % and the stream flows by 16–23 %. The model's results also showed that the projected durum wheat yield up to 2050 is likely to decrease between 2.2 and 10.4 % due to the reduction in rainfall and the increase in temperature. The results also indicated that, by 2050, the harvest date for this crop would be between 10 and 14 days earlier than at present due to the increase in temperature leading to early maturity of the crop and early harvesting.

In the second site, the DiCaSM model has been applied on Mimoso catchment in the Brazilian North East region. The model successfully simulated stream flows (2000–2008) and soil moisture (2004–2007). Based on a range of climate change scenarios for the region, the DiCaSM model forecasted a reduction of 35, 68 and 77 %, in groundwater recharge, and of 34, 65 and 72 % (average of high- and low-emission scenarios) in stream flow for the time spans 2010–2039, 2040–2069 and 2070–2099, respectively. These reductions would produce severe impact on water availability in the region. Introducing castor beans as a biofuel crop to the catchment would increase the groundwater recharge and stream flow, mainly if the caatinga areas (forests) would be converted into castor beans production. Changing an area of 1,000 ha from caatinga to castor beans would increase the groundwater recharge by 46 % and the stream flow by 3 %. If the same area of pasture is converted into castor beans, there would be an increase of groundwater recharge and stream flow by 24 and 5 %, respectively. Such results are expected to impact on environmental policies for the Brazilian Northeast and to the biofuel production perspectives in the region.

In the third site, DiCaSM model was applied on a second catchment in North East Brazil, Tapacurá catchment. The model successfully simulated stream flow (1970, 2000, 2004 and 2005) and the soil moisture (2004–2007). When applying the possible future climate change (low-emission scenario B1) scenarios on the catchment, the results indicated a possible reduction in water availability by −13.9, −22.63 and −32.91 % in groundwater recharge and by −4.98, −14.28 and −20.58 % in surface flows for the time spans 2010–2039, 2040–2069 and 2070–2099, respectively. Changing the land use by reforestation of part of the catchment area, i.e. replacing current use of arable land, would decrease groundwater recharge by −4.2 % and stream flow by −2.7 %. Changing land use from vegetables to sugarcane would result in decreasing groundwater recharge by around −11 % and increasing stream flow by 5 %. In the fourth site, the IHMS was applied on the Kouris and Akrotiri catchments in Cyprus. DiCaSM and MODFLOW models were applied. The system was successfully tested against the stream flow (1990–1997) and groundwater levels (2000). When applying the possible future climate change scenarios, the model showed that, by 2050, the amount of groundwater and surface water would decrease by 35 and 24 % for Kouris and 20 and 17 % for Akrotiri, respectively.

The four catchments represented a wide range of environmental conditions and land use. The results of possible climate and land use changes showed that these changes would have great impact on water resources availability. These results are useful for planners, water authorities and policy makers to balance the current and future supply and demand. In that respect, the Integrated Hydrological Modelling System, IHMS, could be used as a reliable water resources management tool.

Keywords Semi-arid regions • Catchment scale modelling • Integrated water resources management

1 Introduction

The Integrated Hydrological Modelling System, IHMS (Ragab and Bromley 2010), has been developed to study the impact of changes in climate, land use and water management on groundwater and seawater intrusion into coastal areas. The system (Fig. 1) comprises three models: DiCaSM, Distributed Catchment Scale Model (Ragab and Bromley 2010), the groundwater flow model MODFLOW (Harbaugh et al. 2000) and SWI, Sea Water Intrusion model (Bakker and Schaars 2005). In addition to estimating all water balance components, DiCaSM produces the recharge data that are used as input to MODFLOW. Subsequently, MODFLOW generates the head distribution and groundwater flows that are used as input to the SWI model. Thus, any changes in land use, climatic conditions (rainfall, temperature) and water management (groundwater or surface water abstraction, etc.) at the surface are first handled by DiCaSM, then by MODFLOW and finally by the SWI model. The three models operate at different spatial and temporal scales. For example, groundwater moves slower, and therefore the time step of the groundwater model is larger than the one of the unsaturated zone model, which is more dynamic due to the fast interaction between the atmosphere and soil plant top layer. In order to make

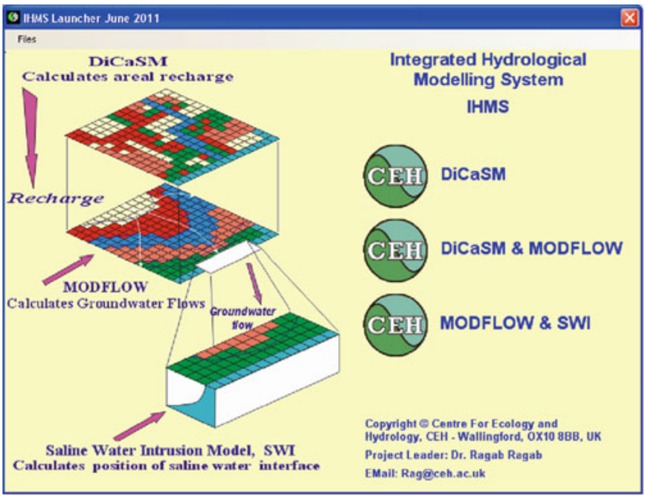

Fig. 1 The components of the Integrated Hydrological Modelling System, IHMS

these models to communicate at different spatial and temporal scales, facilities (interface utilities linking the three models) to aggregate/disaggregate input/output data between models to meet a desired spatial and temporal scale have been developed and are part of the software.

DiCaSM produces distributed and time series outputs of all water balance components including potential evapotranspiration, actual evapotranspiration, rainfall interception, infiltration, plant water uptake, transpiration, soil water content, soil moisture deficit, groundwater recharge rate, stream flow and surface runoff. The DiCaSM model has been developed using the Pang catchment (UK) data as a test site. Tests using the stream flow and scaled soil moisture contents showed that the model was able to simulate soil water movement and subsequently the soil moisture of the surface and subsurface soil layers (Ragab and Bromley 2010).

The main objective of this chapter is to summarize the results obtained from four investigations on the impact of possible future climate and land use changes on water resources in four different catchments depicting a variety of climatic and land cover conditions.

2 The Study Sites

Four sites were selected, two catchments in Cyprus, one catchment in the south of Italy and two catchments in the north east of Brazil.

2.1 Italy (South)

The DiCaSM model has been applied to the Candelaro catchment. The catchment is located in the northern part of the Apulia region (Fig. 2). It is representative of a situation that characterizes southern Italy with its frequent drought events which put agriculture at risk. In southern Italy, and especially in the Apulia region, irrigation is the main water resource for agriculture. The main river of the catchment, the Candelaro, is 67 km long and, with its tributary rivers, covers an area of about 1,778 km^2.

The Candelaro catchment area is now under a "water emergency" condition, which has worsened by a decrease of 30 % in precipitation over the past 40 years and by the conversion from the traditional extensive grain crop to highly water-demanding horticultural farming. The area suffers a chronic and substantial gap between water demand and supply, and a continuous abstraction of groundwater has led to intrusion of seawater, especially in coastal areas. The catchment area is characterized by intensive agriculture and pasture. Rain-fed crops occupy about 65 % of the total land and are mainly found in the Alto Tavoliere and Basso Tavoliere areas. The predominant crop is durum wheat, followed by other cash crops like vegetables, sugar beet, orchards, olive trees and vineyards. In the Apennines area of the Candelaro catchment, pastures and forests are dominant (D'Agostino et al. 2010).

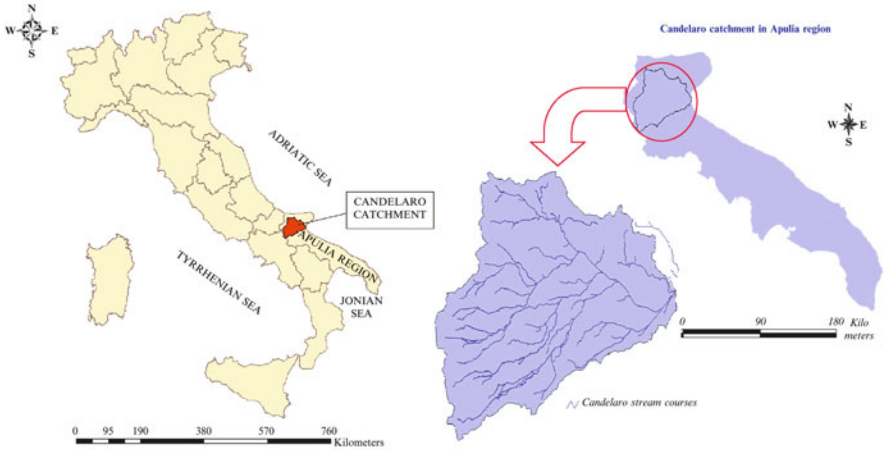

Fig. 2 Location of the Candelaro catchment in the Apulia region, Italy

2.2 Brazil Site 1

The Ipanema catchment is part of the São Francisco River basin, and it is located in the Brazilian semi-arid region. An experimental (Jatobá) and representative (Mimoso) catchment have been monitored as part of the Brazilian network for semi-arid hydrology, as highlighted in Fig. 3. Those catchments are part of the Ipanema River basin (Montenegro and Ragab 2010).

The Mimoso representative catchment is located in Pernambuco State. It has an area of 149 km^2, comprising non-perennial rivulets and an alluvial valley, which is exploited for small-scale irrigation in the area, mainly for vegetables. Vegetation cover is mainly caatinga biome, a typical denomination of the Brazilian semi-arid vegetation, with different cover densities and pasture. The natural vegetation covers are close arboreal caatinga, close arboreal-shrubby caatinga, open arboreal-shrubby caatinga, valley caatinga, pasture, grassland and vegetable arable lands restricted to the lowlands in the valley.

2.3 Brazil Site 2

The Tapacurá River catchment is located in Pernambuco State, in North Eastern Brazil, and covers an area of 470.5 km^2 (Fig. 4). The original Atlantic rainforest was extensively cleared during the twentieth century. Some caatinga still remains but most of the area is now used for small holder agriculture, cattle ranching and poultry farms. Small holders grow staple food, fruit and vegetables. Crops include beans, corn, cassava, vegetables and fruits. Sugarcane is grown in larger areas as a rain-fed crop without irrigation (Montenegro and Ragab 2011). Following the Forest Code

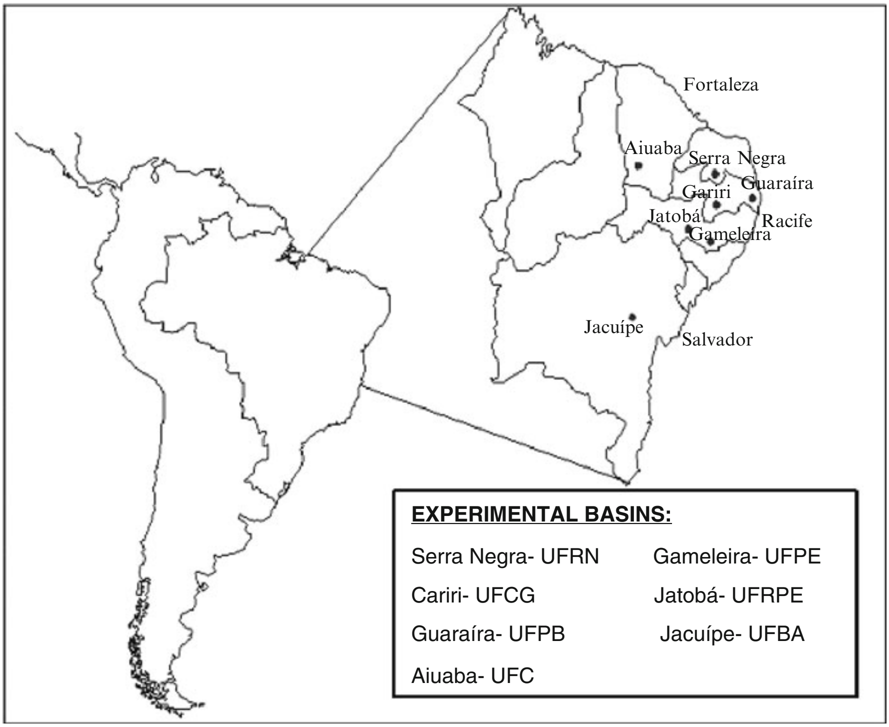

Fig. 3 Experimental catchments of the Brazilian network for semi-arid hydrology

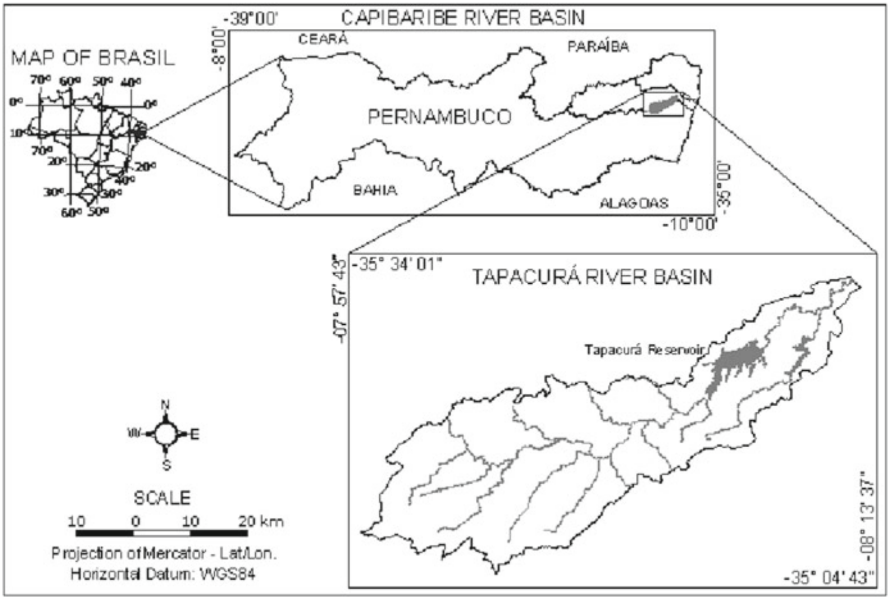

Fig. 4 Tapacurá catchment, Brazil

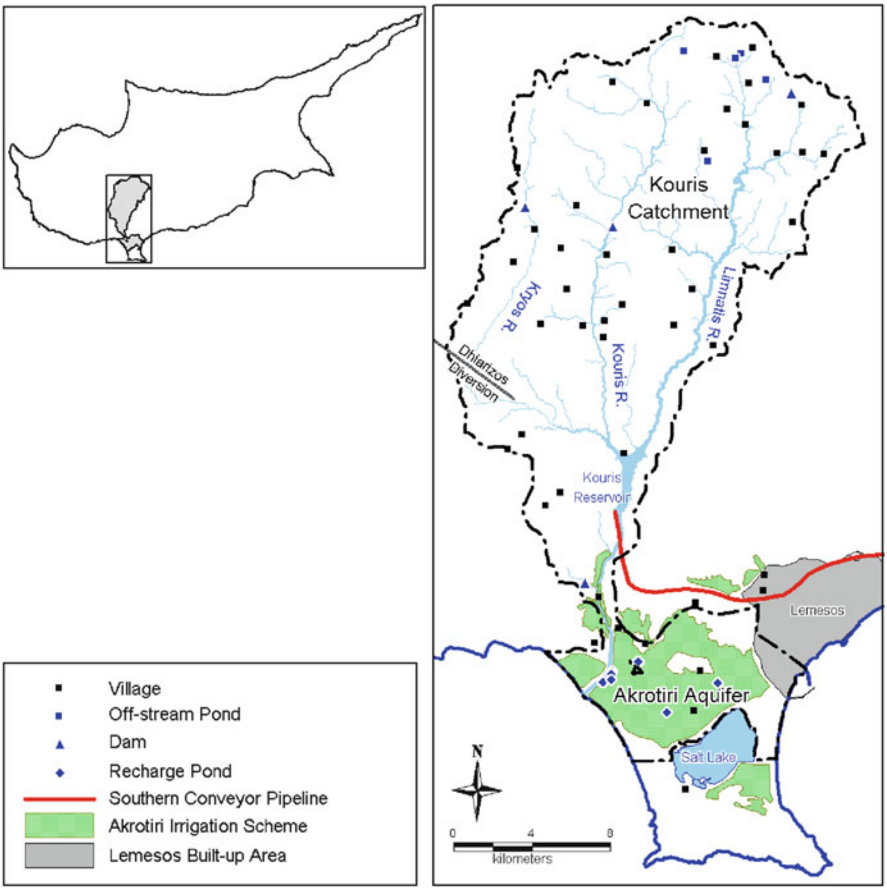

Fig. 5 The study sites in Cyprus

of the Brazilian legislation, a reforestation project in the catchment is being carried out by the Northern Ecology Society in Brazil (SNE).

2.4 Cyprus

Two study areas were selected, as the water resource problems in these areas were representative of those being faced in the island as a whole. The two sites (Fig. 5) offer a sharp contrast in terms of geology and water use. Whereas the Kouris catchment is geologically ancient, mountainous, partly cultivated and sparsely populated; the Akrotiri region is of recent geological origin, flat lying, heavily cultivated and densely populated. The two areas therefore represent the extremes of physical, economic and social conditions existing within Cyprus (Ragab et al. 2010).

3 Model Applications

3.1 Italy

DiCaSM model was run for the 2001–2002 period. The model simulated the different components of water balance. Some selected examples such as groundwater recharge (Fig. 6), surface runoff, infiltration (Fig. 7) and soil moisture content (Fig. 8) and soil moisture deficit (Fig. 9) are shown bellow.

Climate change scenarios: The UK Hadley Centre Global Climate model HadCM2, scenario IS92a results for south of Italy (Ragab and Prudhomme 2002) predicted that by the year 2050 rainfall will be reduced by 5–10 % during the winter and 15–20 % during the summer, while the temperatures are expected to increase

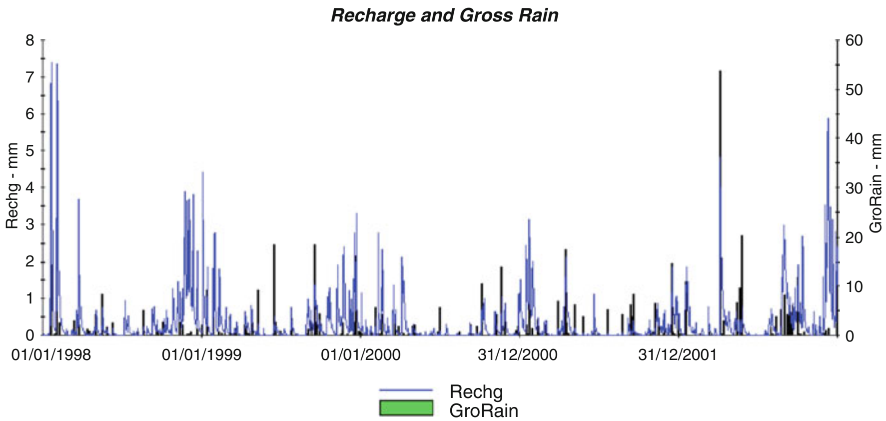

Fig. 6 Groundwater recharge in Candelaro catchment, Italy

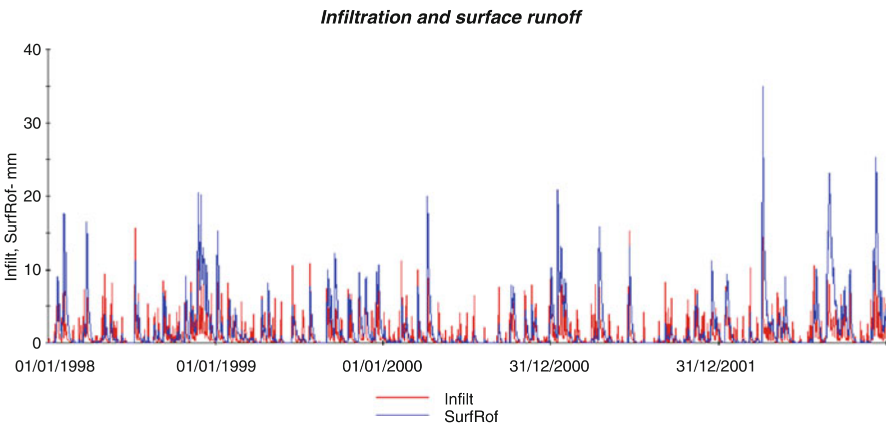

Fig. 7 Surface runoff and infiltration in Candelaro catchment, Italy

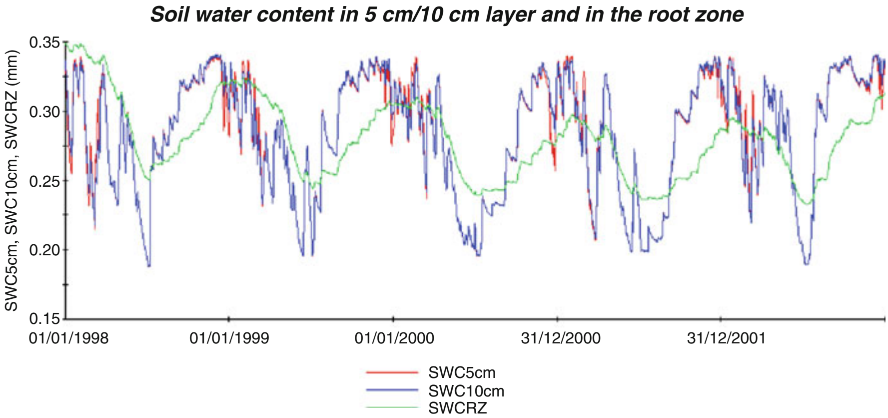

Fig. 8 Soil moisture at different depths in the Candelaro catchment, Italy

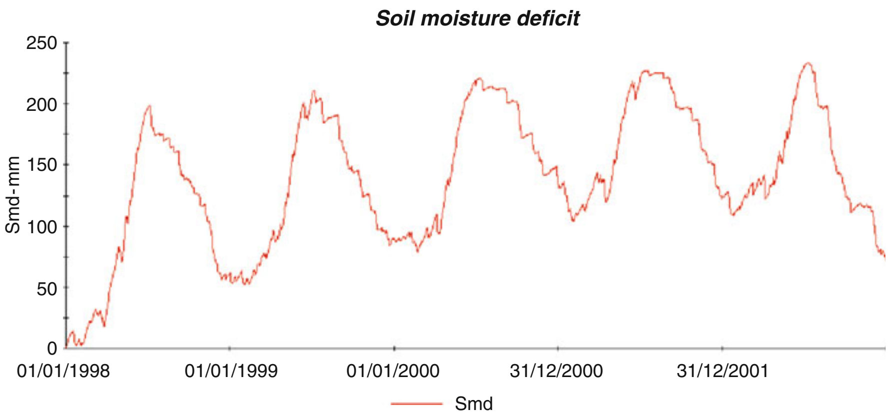

Fig. 9 Soil moisture deficit in the Candelaro catchment, Italy

Table 1 Climate change scenarios for the Candelaro catchment, Italy

	Temperature (°C)		Rainfall (%)	
Scenario	Summer	Winter	Summer	Winter
A1	+1.75	+1.5	−20	−10
A2	+1.5	+1.25	−20	−10
A3	+1.75	+1.5	−15	−5
A4	+1.75	+1.25	−155	−5

between 1.25 and 1.5 °C during the winter and between 1.5 and 1.75 °C during the summer. Subsequently, it has been possible to build four different scenarios: A1, A2, A3 and A4 as shown in Table 1.

Land use change scenarios: Four land use change scenarios were considered: LC1 – 20 % of the tomato area is replaced by durum wheat, LC2 – 20 % of tomato

Table 2 Climate change scenarios for Mimoso catchment, Brazil

Scenario	GCM	Time span	Emission scenario	Oct–Mar		Apr–Sept	
				R%[a]	*T*[b]	*R*%[a]	*T*[b]
CC1	CSMK3	2010–2039	A2	−10	+1.0	−4	+1.0
CC3	CSMK3	2040–2069		−36	+2.5	−11	+2.0
CC5	CSMK3	2070–2099		−32	+4.0	−12	+3.0
CC7	CSMK3	2010–2039	B1	−19	+1.0	−1	+1.0
CC9	CSMK3	2040–2069		−28	+2.0	−5	+1.5
CC11	CSMK3	2070–2099		−45	+3.0	−6	+2.0

[a]*R*% percentage change in rainfall
[b]*T* temperature change in °C

area is replaced by sunflower, LC3 – all sugar beet is replaced by sunflower and LC4 – all sugar beet is replaced by oilseed rape.

3.2 Brazil Site 1

Climate change scenarios: According to IPCC (2000), the A2 scenario (high emission) and B1 (low emission) were considered. A2 is based on the assumption of high population growth and slow economic development, whereas B1 (low-emission scenario) describes a world with moderate population growth and intermediate levels of economic development.

The performance of GCMs (global circulation models) available at the CEH portal (CEH 2008) has been assessed through the comparison of monthly average rainfall predicted by the models and the baseline reference values of the catchment for the period 1961–1990. The precipitation change scenarios for short-, medium- and long-term future time-slices (2010–2039, 2040–2069 and 2070–2099, respectively) predicted by the GCM model (CSMK3) were selected, and their forecast scenarios (see below) were implemented in the DiCaSM model (Table 2).

Land use change scenarios: In order to investigate the impact of land use change on the hydrological behaviour of the catchment, the following scenarios have been adopted: scenario 1, castor = 250 ha, replacing caatinga; scenario 2, castor = 500 ha, replacing caatinga; scenario 3, castor = 750 ha, replacing caatinga; scenario 4, castor = 1,000 ha, replacing caatinga; and scenario 5, castor = 1,000 ha, replacing pasture.

3.3 Brazil Site 2

The DiCaSM model was run and the simulated stream flow was compared with the observations for the 1970 and 2000–2005 periods, while the scaled soil moisture (the wetness index) was simulated and compared with the observations for the period between 2004 and 2007.

Table 3 Climate change scenarios for Tapacurá catchment, Brazil

Scenario	Time span	GCM	Emission scenario	Oct–Mar		Apr–Sep	
				T^a	R^b	T^a	R^b
CCS1	2010–2039	CSMK3	B1	+3	−18	+2	−1
CCS3	2040–2069	CSMK3	B1	+3	−28	+2	−5
CCS5	2070–2099	CSMK3	B1	+3	−45	+2	−5

[a] *T* temperature change in °C
[b] *R%* percentage change in rainfall

Climate change scenarios: The low-emission scenario (B1) was considered. Variation in temperature (*T*, °C) and rainfall (*R*, %) for the simulations of climate change scenarios (CEH 2008) are given hereunder (Table 3).

Land use change scenarios: A simulation scenario changing the current use in several grid cells of the model from arable, livestock and poultry farms to forest was considered (LUC1). A total area of 841 ha was considered for reforestation. This represents an increase of 133.3 % in the current forest area within the catchment. A second land use change scenario based on using part of the catchment area currently cultivated with vegetables to be converted into sugarcane area (LUC2) was considered. It is worth noting that, over 300 years, forest was destroyed in favour of sugarcane plantations.

3.4 Cyprus

DiCaSM model was run for the 1990–2004 period. The simulated stream flow and groundwater were compared with the observations. Examples of model calculations of distributed groundwater recharge in Kouris and Akrotiri (Fig. 10) are shown here.

Climate change scenarios: The UK Hadley Centre Global Climate model HadCM2, scenario IS92a, a forcing scenario that assumes an increase in level of CO_2 of 1 % per annum, has been applied on several regions including the Mediterranean region (Ragab and Prudhomme 2002). For Cyprus, the climate change model predicted that by the year 2050 rainfall will be reduced by 15 % during the winter and 10 % during the summer, while the yearly temperatures are expected to increase by 1.5 °C.

4 Results

4.1 Italy

The DiCaSM has been applied on Candelaro catchment in order to simulate stream flows and water balance components and to account for the impacts of possible

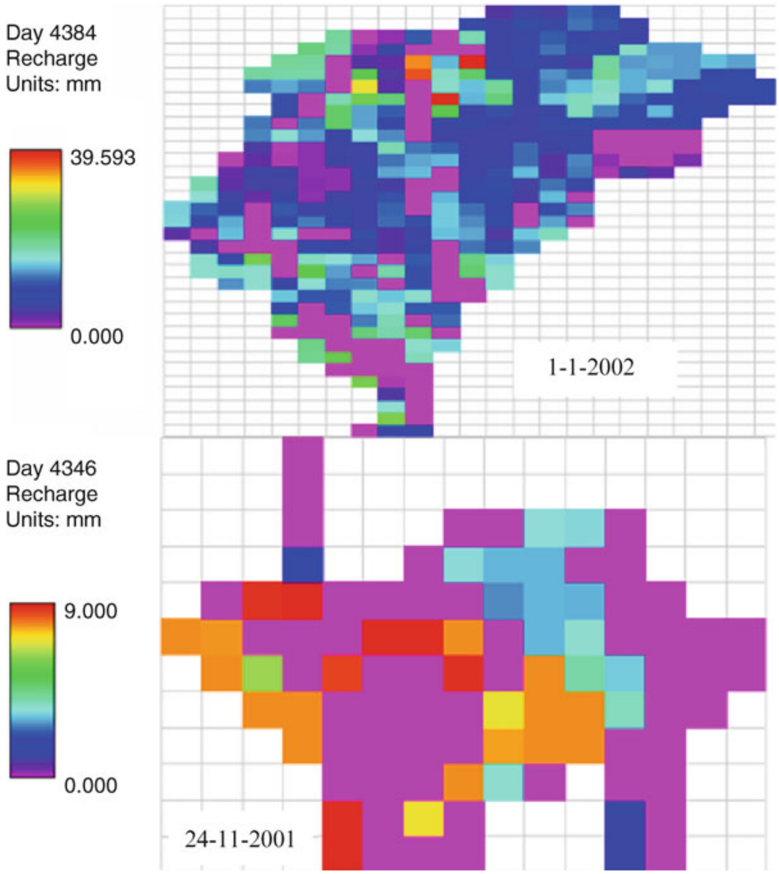

Fig. 10 Example of model calculations of distributed groundwater recharge in the Kouris and Akrotiri catchments, Cyprus

future climate and land use changes on water flows; the model simulated reasonably well the catchment water balance components (evapotranspiration, groundwater recharge, soil moisture, water uptake, stream flow, etc.). DiCaSM model was run for the 2001–2002 period. The simulated stream flow was successfully compared with the observations (Ragab et al. 2010).

Climate change scenarios: The DiCaSM model was run with the climate change scenarios as shown in Figs. 11 and 12 (Ragab and Prudhomme 2002) for southern Italy, i.e. reduced winter rainfall by 5–10 %, reduced summer rainfall by 15–20 %, winter temperature rise by 1.25–1.5 °C and summer temperature rise by 1.5–1.75 °C. The results indicated that by 2050, groundwater recharge in the Candelaro catchment would decrease by 21–31 % and stream flows by 16–23 % (Table 4).

Land use change scenarios: The model results showed that the projected durum wheat yield up to 2050 is likely to decrease between 2.2 and 10.4 % due to the future reduction

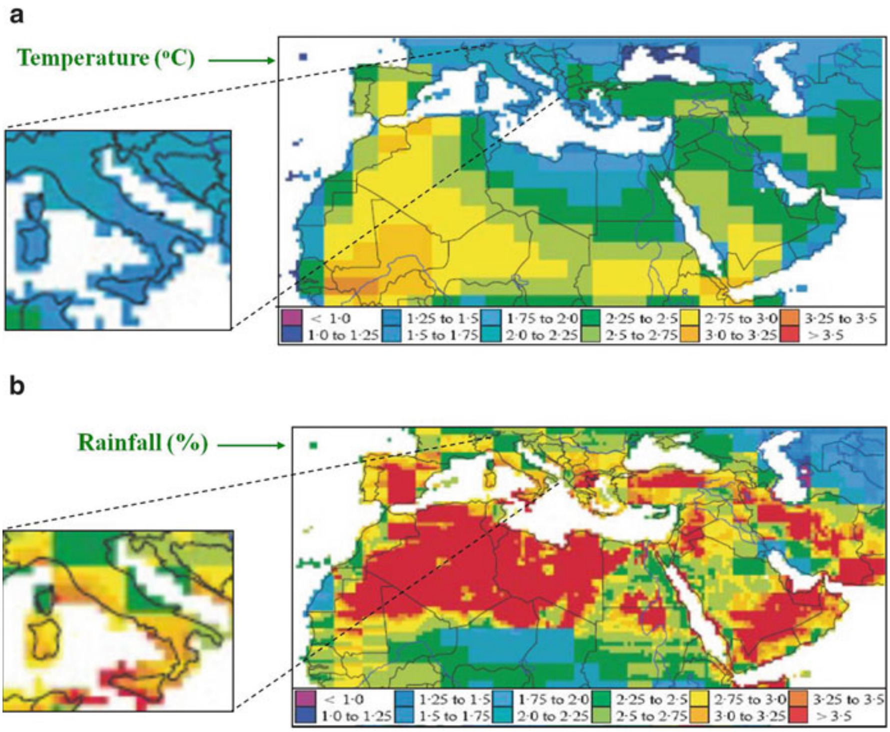

Fig. 11 Climate change scenario for southern Italy up to 2050 (April–September)

in rainfall and increase in temperature, respectively. The results also showed that by 2050 the harvest date for this crop would be between 10 and 14 days earlier than at present due to the possible early maturity due to the increase in temperature (Table 5). There is also a possibility that sowing date based on degree days will be earlier under warmer climatic conditions. The hypothetical assumption, substitution of one-third of durum wheat by olive trees (scenario LC1), grass (scenario LC2) and barley (scenario LC3), showed that in scenario LC1, groundwater recharge could increase by 1.7 %, while for stream flow, there would be a slight but insignificant decrease. In scenarios LC2 and LC3, groundwater recharge would be almost the same as standard conditions, while stream flow would increase by 1.3 %. In scenario LC4, groundwater recharge could decrease by 3.5 %, while stream flow would show a small increase.

Changes in future water demand: The total water demand is assumed to increase by 15 % up to 2050 in the area of Candelaro catchment. This assumption was based on the following:

- Necessity of more irrigations due to decrease of rainfall, as a consequence of future climate change, as rainfall was estimated to be reduced between −20 and −15 % during the summer and between −10 and −5 % during the winter. This should mean that there will be a need for more irrigation.

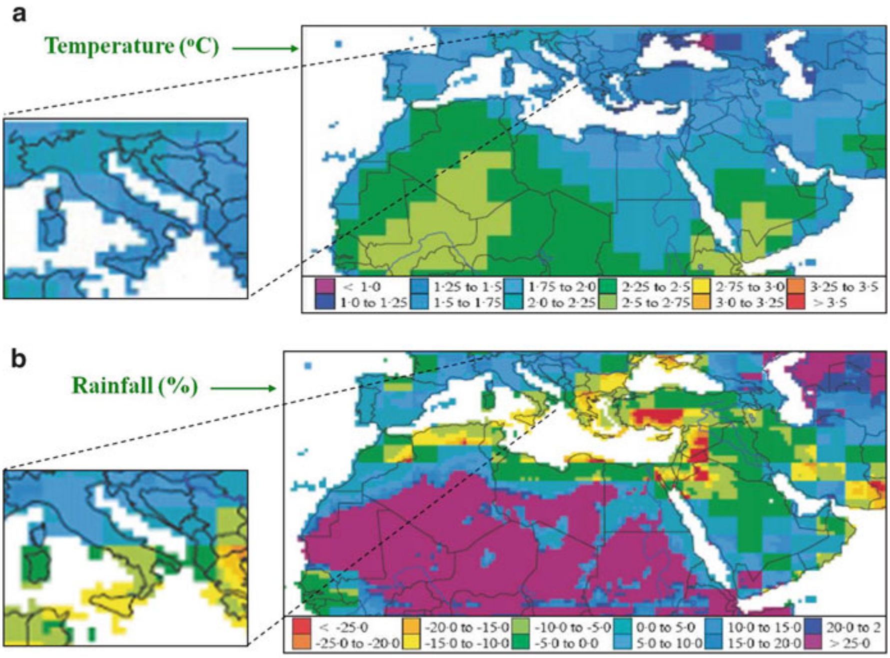

Fig. 12 Climate change scenario for southern Italy up to 2050 (October–March)

Table 4 Climate change scenarios' impact on groundwater and surface water for Candelaro catchment, Italy

	Scenario A1	Scenario A2	Scenario A3	Scenario A4
Factors	% variation (%)			
Future water demand	15	15	15	15
Groundwater supply	−31	−30.70	−22	−21
Surface water supply	−23.40	−23	−16.20	−16

Table 5 The impact of climate change scenarios on the harvest date of durum wheat in Candelaro catchment, Italy

Harvest date				
Standard condition	Scenario 1	Scenario 2	Scenario 3	Scenario 4
29/06/1999	15/06/1999	17/06/1999	15/06/1999	17/06/1999
04/07/2000	22/06/2000	24/06/2000	22/06/2000	24/06/2000
25/06/2001	11/06/2001	13/06/2001	11/06/2001	13/06/2001
10/07/2002	27/06/2002	29/06/2002	27/06/2002	29/06/2002

- Increase of the evaporation from the soil, as a consequence of expected increase in temperature and reduction in rainfall will mean less water available for the plants because of the greater soil moisture deficit.

- Increase of the transpiration from the vegetation, as a consequence of expected increase in temperature, means that the plants will lose more water and will need more irrigation water.
- Increase of population by 4 % (ISTAT) means more demand for domestic and potable water.

Plotting these values against the projected percentage of future water demand, for the Candelaro catchment area, one can see that the gap between water demand and water supply (groundwater and surface water decreasing up to 2050) has increased by up to 15 % over time as shown in Fig. 13 for the four different scenarios.

4.2 Brazil Site 1

The DiCaSM model was run from 2000 to 2008, and the stream flow was simulated. The DiCaSM model has successfully predicted stream flow for the Mimoso catchment, with overall average of Nash-Sutcliffe efficiency factor of 0.73.

Climate change scenarios: The DiCaSM model predicted a 4.36 % increase in potential evapotranspiration for each 1 °C increase in temperature. Such change drastically reduced stream flow by 42 %. This means that future climate change scenarios are expected to drastically affect water resources in the region.

The temperature increases would produce a higher potential evapotranspiration, although actual crop transpiration would be expected to decrease, for scenarios with reduction in rainfall. For example, the dry climate change scenarios assumed for the time-slice 2010–2039 (scenarios CC1 and CC7, Table 6) would reduce groundwater recharge by 27 % and stream flow by 26 %, for the high-emission scenario; for the low-emission scenario in the same period, groundwater recharge would be reduced by 43 % and stream flow by 41 %.

For the period 2040–2069, dry scenarios CC3 (high emission) and CC9 (low emission) have predicted a decrease in groundwater recharge by 74 and 61 % and in stream flow by 72 and 58 %, respectively. Over the long term (2070–2099 period), reduction in rainfall could decrease groundwater recharge by 71 and 82 % and stream flow by 68 and 76 %, for high-emission and low-emission scenarios, respectively (scenarios CC5 and CC11, respectively).

Land use change scenarios: Converting caatinga area to castor beans (Fig. 14) for biofuel production increased both groundwater recharge and stream flow. If 750 ha of caatinga would be changed to castor beans, an increase of 30 and 2.5 % would occur for groundwater recharge and stream flow, respectively. Changing the pasture area to castor beans also produced impacts on groundwater recharge and stream flow. Replacing 1,000 ha of caatinga by castor beans would increase groundwater recharge and stream flow by 46 and 3 %, respectively, while if 1,000 ha of pasture would be converted to castor beans, an increase of 24 and 5 % would occur for

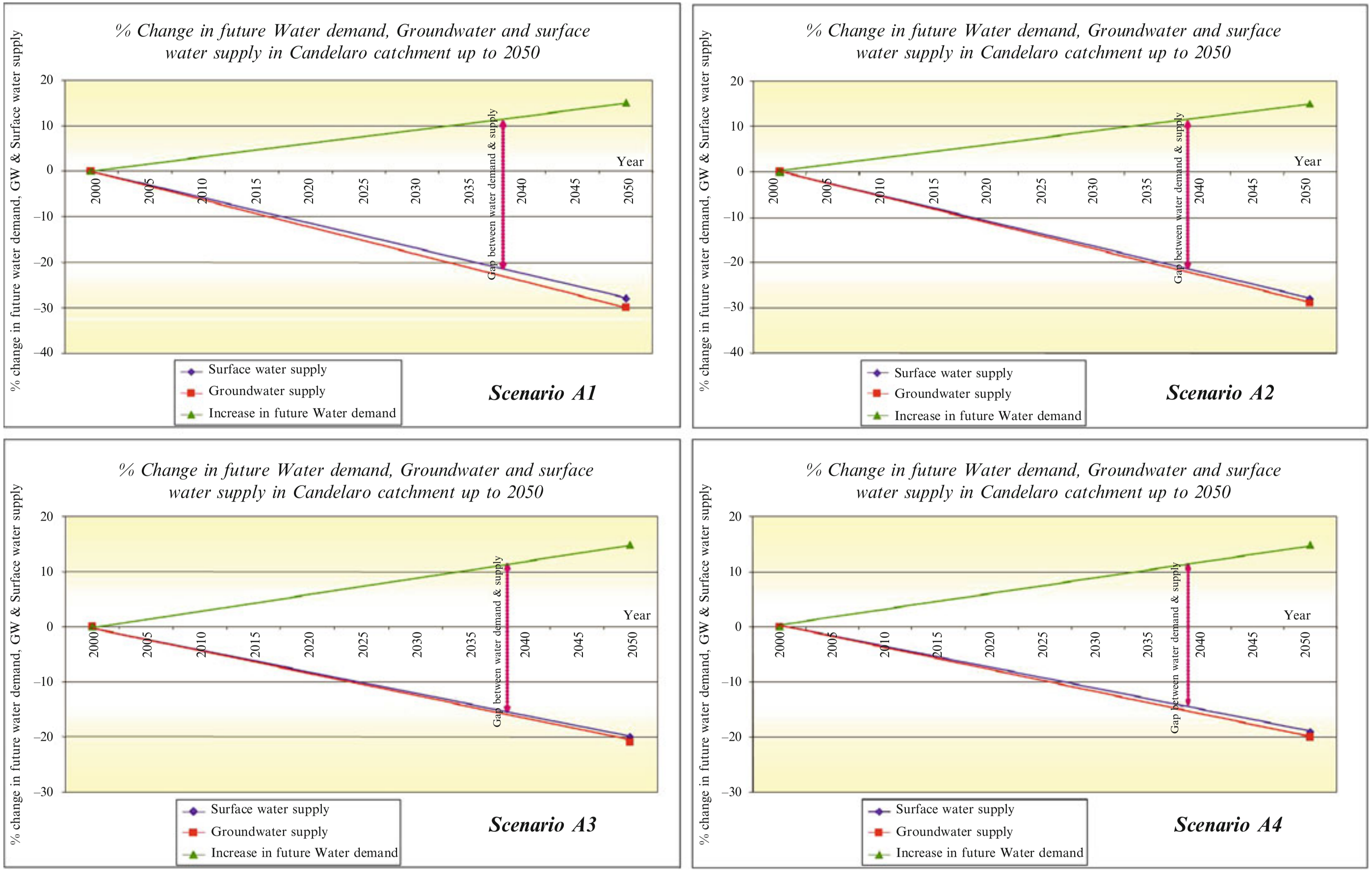

Fig. 13 The gap between water demand and supply up to 2050 in Candelaro catchment, Italy

Table 6 The impact of climate change on surface and groundwater on Mimosa catchment, Brazil

Simulation scenario	GCM	Future time span	Emission scenario	Oct–Mar $R\%$[a]	Oct–Mar T[b]	Apr–Sept $R\%$[a]	Apr–Sept T[b]	Change in groundwater recharge %	Change in stream flow %
CC1	CSMK3	2010–2039	A2 high emission	−10	+1.0	−4	+1.0	−27	−26
CC2	CSMK3	2040–2069		−36	+2.5	−11	+2.0	−74	−72
CC3	CSMK3	2070–2099		−32	+4.0	−12	+3.0	−71	−68
CC4	CSMK3	2010–2039	B1 low emission	−19	+1.0	−1	+1.0	−43	−41
CC5	CSMK3	2040–2069		−28	+2.0	−5	+1.5	−61	−58
CC6	CSMK3	2070–2099		−45	+3.0	−6	+2.0	−82	−76

[a] *R* rainfall
[b] *T* temperature

Fig. 14 Castor beans for biofuel production in Mimosa catchment, Brazil

groundwater recharge and stream flow, respectively; these increases are associated with the adopted fallow period of 115 days for castor beans cropping. In particular, for the January–March period, high-intensity rainfall events may occur, and hence significant groundwater recharge is likely to take place.

4.3 Brazil Site 2

The Distributed Catchment Scale Model, DiCaSM, was calibrated and validated for the stream flows (1970, 2000, 2004 and 2005) of the Tapacurá catchment. The model performance was further tested by comparing simulated and observed scaled soil moisture (2004–2007). The results showed the ability of the model to simulate the stream flow and the scaled soil moisture.

Climate change scenarios: The simulated impacts of climate change of low-emission (B1) scenarios indicated the possibility of reduction in surface water availability by 13.90, 22.63 and 32.91 % in groundwater recharge and by 4.98, 14.28 and 20.58 % in surface flows for the time spans 2010–2039, 2040–2069 and 2070–2099 (Table 7 and Fig. 15), respectively. This would cause severe impacts on water supply in the region.

The impact of land use changes: Under LC1, reforestation of part of the catchment area (841 ha: an increase of 133.3 % in forest area) would lead to a decrease in both recharge and stream flow by 4.22 and 2.72 %, respectively. The land use change scenario that replaces the current area under vegetables with sugarcane from 6,500 ha, at present, to 25,400 ha (LUC2) would result in decreasing groundwater recharge by around 11 % and increasing stream flow by almost 5 % (Fig. 16). Sugarcane, like maize, is known to be a high water-consuming crop with high

Table 7 The impact of climate change on surface and groundwater resources in Tapacurá catchment, Brazil

Simulation scenario	Time span	IPCC scenario	GCSM model	Oct–Mar		Apr–Sept		% Change in groundwater recharge	% Change in surface flow
				T	P	T	P		
1	2010–2039	B1	CSMK3	+3	−18	+2	−1	−13.90	−4.89
2	2040–2069	B1	CSMK3	+3	−28	+2	−5	−22.63	−14.28
3	2070–2099	B1	CSMK3	+3	−45	+2	−5	−32.91	−20.58

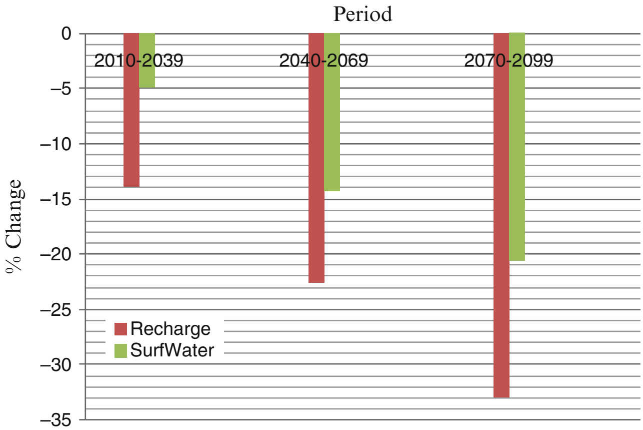

Fig. 15 The impact of climate change on surface and groundwater resources in Tapacurá catchment, Brazil

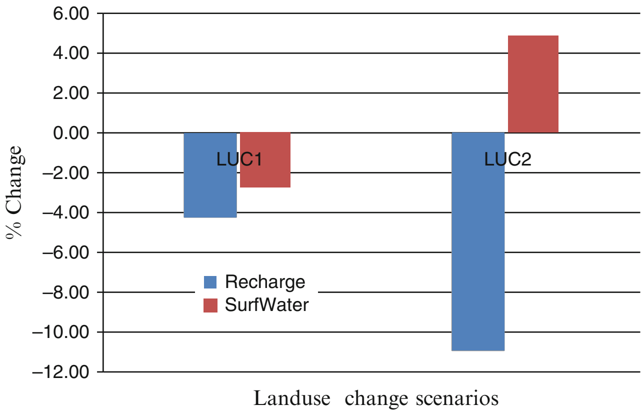

Fig. 16 The impact of land use changes on surface and groundwater resources in Tapacurá catchment, Brazil

transpiration rate due to the large leaf area index. This would deplete the root zone further than other crops would, leaving limited water available for the groundwater recharge. In addition, it has a longer growth season when compared with vegetable crops. This decrease in recharge could have been less than 10 % if the period of the soil being left fallow was longer. At present, the fallow period is 65 days under sugarcane, compared with 115 days under vegetables. The longer the fallow period is, the more groundwater recharge is expected. The combination of possible impacts of climate change and land use requires a proper plan for water resources management and mitigation strategies.

4.4 Cyprus

The DiCaSM unsaturated zone model was successfully calibrated and validated against stream flows (1990–1997) with reasonable values for goodness of fit as shown by the Nash-Sutcliffe criterion. Groundwater recharge obtained from the successful tests was applied at various spatial and temporal scales to the Kouris and Akrotiri catchments in Cyprus.

These recharge values produced good estimates of groundwater levels for the year of 2000 in both catchments (Ragab et al. 2010). The model was run using a number of possible future climate change scenarios. The results showed that by 2050, groundwater and surface water supplies would decrease by 35 and 24 % for Kouris and 20 and 17 % for Akrotiri, respectively. The gap between water supply and demand showed a linear increase with time in similar way to the Candelaro catchment (Fig. 13). The results suggest that IHMS can be used as an effective tool for water authorities and decision makers to help balance demand and supply and reduce the gap on the island.

5 Conclusion

The studied catchments represented a wide range of environmental conditions and land use. The climate change and the land use change have great impact on water resources availability. Although the climate prediction has some degree of uncertainty, regardless the accuracy in terms of amounts, the model predictions of possible trend and impact on water resources are plausible. The modelling results are a good indication of what is likely to happen in the future and give the water authorities and policy makers the chance to plan a proper water resources management to balance the supply and demand.

The study highlighted the following:

1. The combination of possible impacts of climate change and land use requires a proper plan for water resources management and mitigation strategies.
2. Water resources management needs to be handled with an integrated approach that takes into account
   - The water resources availability (quantity and quality)
   - The land use
   - The demand
   - The climate change
3. The Integrated Hydrological Modelling System, IHMS, is a useful tool to quantify water resources (surface and groundwater); investigate the impact of land use and climate changes on water resources, plant biomass and harvest and sowing dates; and quantify the gap between water supply and demand. Therefore, it is an important tool for water authorities and policy and decision makers to set up the right strategies for water and land resources management.

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Challenges and Issues on Measuring, Modelling and Managing the Water Resources Under Changing Climate and Land Use

Ragab Ragab

Abstract This chapter highlights some challenges and issues facing those involved in the area of water resources management. In order to have a proper plan for water management, we need to accurately quantify the size of the available water resources. In this regard, we face issues related to the scale of the measurements and their representation. The chapter briefly describes the new technologies in some areas and presents two examples of suitable management models at field and catchment scales. It also highlights issues related to the sustainable water use and offers practical solutions to manage water more efficiently at field scale, where agriculture is the greatest water consumer. In addition, a reference is made to a possible increase in water supply through the use of non-conventional water resources and different rainfall harvesting techniques at different scales, up to catchment scale. Using the resources more efficiently has been highlighted as an important issue as well as the need for water policies to accommodate the new changes related to climate and land use taking into account the concepts of green economy, water footprint and water-food-energy-environment security in an integrated water resources management approach.

1 Introduction

In managing water resources, one might face some challenges and issues that could make it difficult to achieve the main goal of sustainable water resources management. These issues and challenges could be related to:

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1. Measurements: quantification of water resources elements
2. Modelling
3. Water resources management
4. Water policies, including issues related to water for food, fuel and the environment: the delicate balance

Water is currently classified as ‘green water’ and ‘blue water’. Green water is defined as the water used at the point where rain falls. It is of low cost and usually there is no competition for the use of this water. Blue water is the water abstracted from rivers, lakes and groundwater. It is taken from the renewable water resources and different users compete to use this water for a variety of uses. These two different waters have different management.

Water resources sometimes present us with some critical problems. Too much could cause flood, while too little could cause drought. Poor distribution could cause famine. Poor quality could cause health hazards. Poor management could lead to competition and conflicts.

This chapter highlights the challenges and issues and, wherever possible, suggests some solutions.

2 Challenges and Issues

2.1 Issues Related to Measurements

In order to manage the water resources properly, one needs to have accurate data and information on the different components of the hydrological cycle elements that have direct impact on water resources quantity and quality. Some important elements like evaporation, groundwater recharge, run-off to streams and soil moisture need to be accurately measured for better estimation of available water resources in a catchment or a region. The issues with the measurements are related to:

- Variability/heterogeneity: how representative the point measurements are for a mosaic of various vegetation and soil types present in a catchment or a region.
- Difficulties in measuring some hydrological parameters especially in semi-arid regions, e.g. groundwater recharge, which in arid/semi-arid regions, sometimes is estimated using isotopes due to insufficient rainfall and insignificant infiltration, leaks from river beds (e.g. in Cyprus), the flow of temporary rivers (dry in summer).
- The instruments technology did not advance as much as the modelling, e.g. point measurements versus model area results.

Two examples of measurements at different scales are discussed hereunder: soil moisture and evaporation. Soil moisture is usually measured at point scale using destructive methods such as taking soil cores from the field, which are then taken to the laboratory to determine the soil moisture content. In addition, there are point scale non-destructive methods which include neutron probe (with radioactive source) and profile probe (with no radioactive source) and similar systems such as

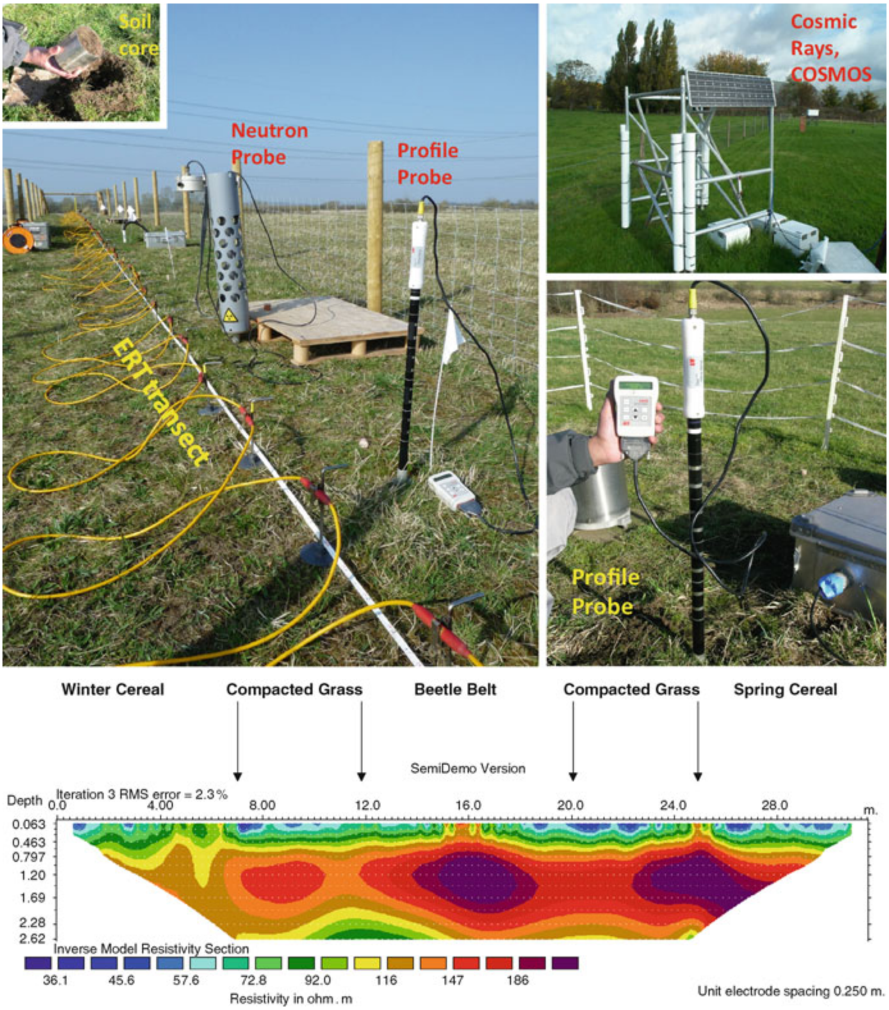

Fig. 1 *Top*: Soil moisture measurement methods operating at different scales. *Bottom*: example of soil moisture variation under a transect using the ERT method, 64 electrode array showing resistivity which is convertible to soil moisture through calibration. The shown effects are due to variations in both soil type and soil moisture

time-domain reflectometry, TDR. These point measurements with limited replications cannot cover adequately the variability of soil moisture in the field or the catchment. A recently developed method, electrical resistivity tomography (ERT), allows soil moisture to be measured along transects (each transect is 32 m long with 64 electrodes) and presents soil moisture variability at surface and with depth. The most recent technique for area-based measurements (radius of 300–700 m) is based on the use of the natural cosmic rays and known as COsmic-ray Soil Moisture Observing System, COSMOS. Figure 1 shows the different methods.

This new technology would correctly estimate the soil moisture and soil moisture deficit at larger scale to account for soil variability. Soil moisture is a key parameter in controlling the infiltration capacity and subsequently the groundwater recharge, overland flow to streams, and it is also important to improve the irrigation performance in irrigated agriculture.

Evaporation or evapotranspiration is commonly calculated from equations using meteorological data of temperature, radiation, wind speed, relative humidity and some other parameters. The calculated value is known as potential evapotranspiration, ETp. This value is used by groundwater hydrologist to estimate the groundwater recharge as the difference between ETp and rainfall. This approach could result in underestimation of the recharge in areas where the actual evaporation is significantly below the actual evaporation. A better estimation would be based on actual evaporation, rather than the potential, as the actual evaporation is linked to the soil moisture status which is a key element in splitting the rainfall between infiltration, and subsequently groundwater recharge, and overland flow/run-off.

In irrigated agriculture, the current determination of the crop water requirement, how much water to apply, usually relies on potential evapotranspiration (ETp) calculations as the actual evaporation measurement technologies are in short supply. This has led to overestimation and excessive irrigation. The new technology using the infrared light beams (scintillometers) can help to determine the actual evapotranspiration (ETa). The scintillometer is the latest technology and can cover a transect up to 10 km long and would produce the actual evaporation of a mixed or a single vegetation cover over the area. It has a transmitter and receiver installed at the two ends of the measured area. These new technologies, when applied together with reliable models, can lead to a better quantification and management of water resources and help in reducing significantly water losses by soil evaporation and deep percolation in irrigated agriculture as well as better estimates for the groundwater recharge. Figure 2 shows the latest technology, scintillometers.

2.2 Issues Related to Modelling

Models are useful tools in water resources management. When calibrated and successfully tested, they can be used to predict the impact of changes (land use, climate, land management, irrigation, etc.) on water resources without resorting to expensive field experiments and huge labour costs. However, these models are designed for different scales: field scale, catchment scale, regional scale, continental and global scale, Table 1.

There are some issues related to model applications such as:

- Representation of the hydrological processes at large scale.
- Most of distributed models are based on point scale equations and results obtained at each square are aggregated to catchment scale.
- Lumped models use large scale equations but are site specific.

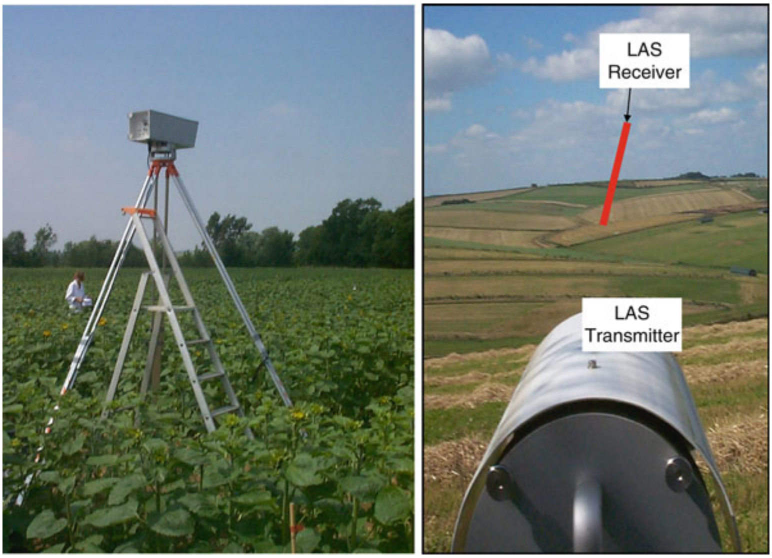

Fig. 2 Measuring the actual evaporation using the large aperture scintillometers

Table 1 The scales used in the water resources studies

Spatial scale	Length	Area
Point scale	<10 cm	
Field or hill slope scale	100 m	
Catchment scale	3–100 km	$10–10^4$ km^2
Regional scale	100–1,000 km	$10^4–10^6$ km^2
Continental or global scale	>1,000 km	$>10^6$ km^2

- Difficulties in calibration of models especially for un-gauged catchments, data adequacy/gaps and scale mismatch between model output and measurements.
- Most models struggle with accounting for heterogeneity in soil and plant cover. The majority considers the most dominant soil type or land cover. This is not realistic.
- There is a question mark on using similar gauged catchment to calibrate un-gauged catchments.
- Most of the calibration is focused on the stream flow or groundwater levels. However, these values integrate the variability within the catchment. It could also be interesting to study the variability as well.
- Most of model results do not come with uncertainty bounds.

In the following section, two examples of water management models will be discussed, a field scale and catchment scale model. Both models can simulate the impact of climate and land use changes.

2.2.1 Field Scale Model

SALTMED model will be given here as an example of model application at field scale. The model is one of the few available generic models that can be used to simulate crop growth with an integrated approach that accounts for water, crop, soil and field management. It is a physically based model using the well-known water and solute transport, evapotranspiration and water uptake equations.

The SALTMED model (Ragab 2002, 2010a; Ragab et al. 2005a, b) has proved its ability to simulate several crops and agricultural situations. It has been developed to account for different irrigation systems, irrigation strategies, different water qualities, different crop and soil types, N-fertilizer applications, fertigation and impact of abiotic stresses such as salinity, temperature, drought and the presence of shallow groundwater, drainage system and crop rotations. The current version would allow real-time simultaneous (all at once) of 20 fields, each of which would have different irrigation systems, irrigation strategies, crops, soils, N-fertilizer, etc. The model simulates the dry matter production, crop yield, soil salinity and soil moisture profiles, salinity leaching requirements, soil nitrogen dynamics, nitrate leaching, soil temperature, water uptake, evapotranspiration, groundwater level and its salinity and drainage flow. It is a user-friendly model, benefiting from the Windows™ environment. The model was first tested with examples of applications using data from literature (Ragab 2002), then has been calibrated and validated with field data for crops such as tomato, under drip and furrow irrigation (Flowers et al. 2005; Ragab et al. 2005a, b), and sugarcane (Golabi et al. 2009). In 2009, an enhanced version of the model was published: SALTMED 2009 (Ragab 2010a), with more sub-models and options. This new version has been successfully subjected to calibrations and validations (Montenegro et al. 2010; Hirich et al. 2012). The model is a free download, together with its supporting document and examples, at the EU funded project SWUP-MED website at: http://www.swup-med.dk/SALTMED.aspx. Figure 3 shows the model and an example of model output.

2.2.2 Catchment Scale Model

An example of a catchment scale model is the Integrated Hydrological Modelling System, IHMS (Ragab and Bromley 2010) (Fig. 4). The system comprises three models: the Distributed Catchment Scale Model, DiCaSM, which deals with the unsaturated zone; the MODFLOW model, for saturated zone and groundwater flow; and the SWI model, for sea water intrusion in coastal areas. These models can be applied either together or separately. In addition to estimating all water balance components, the Distributed Catchment Scale Model, DiCaSM, produces the groundwater recharge data that are used as input to the MODFLOW groundwater flow model. The latter subsequently generates the head distribution and groundwater flows that are used as input to the sea water intrusion model, SWI. Thus, any changes in land use, climatic conditions (rainfall, temperature) and water management (groundwater or surface water abstraction, etc.) at the surface are first handled by DiCaSM, then by MODFLOW and finally by the SWI. This is a true integrated water management scheme.

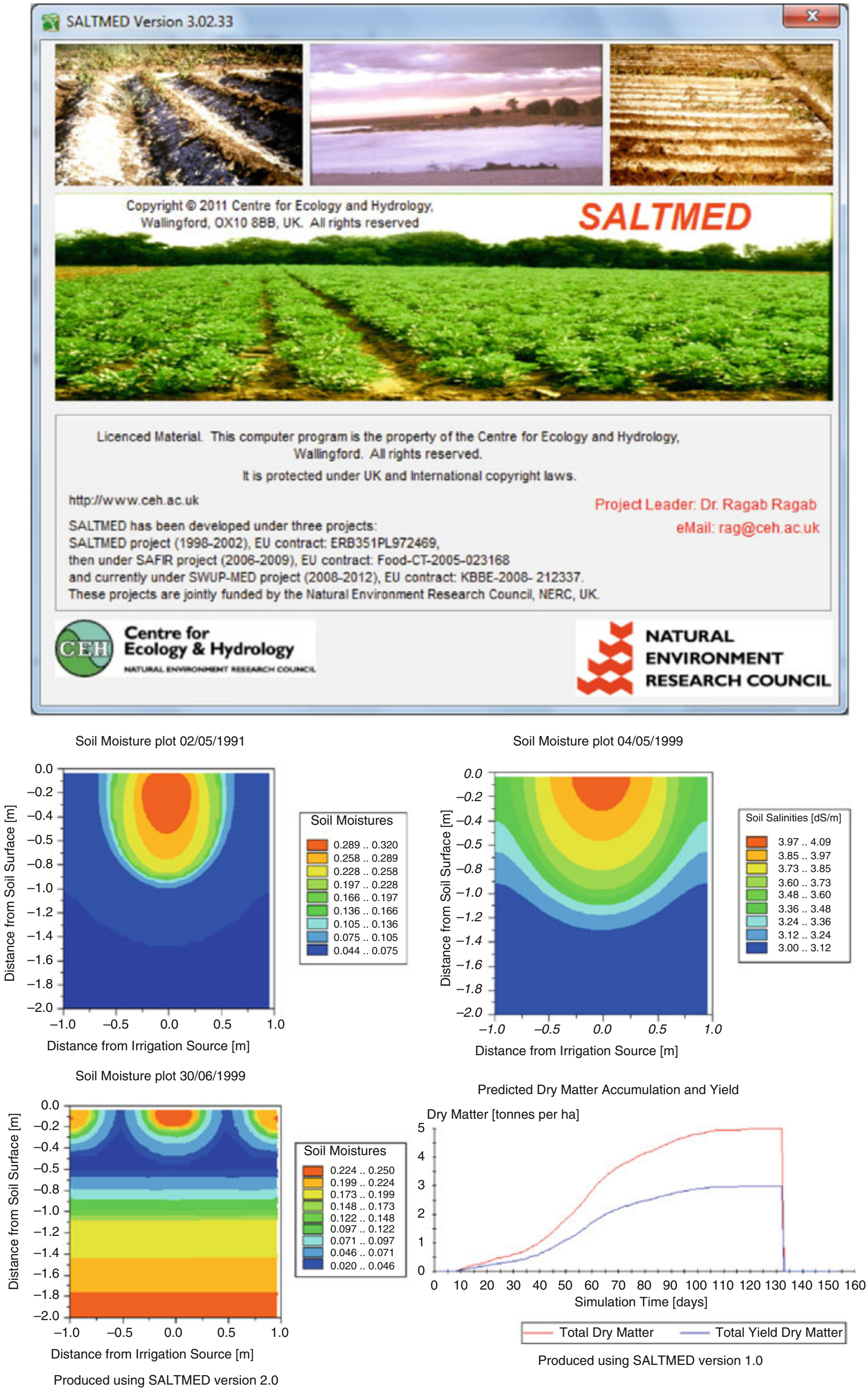

Fig. 3 *Top*, SALTMED Model opening slide (developed under EU-funded projects: SALTMED, SAFIR, SWUP-MED). *Bottom*, example of some output; soil moisture under drip and multiple drip system using the partial root drying method, PRD, soil salinity and dry matter and yield

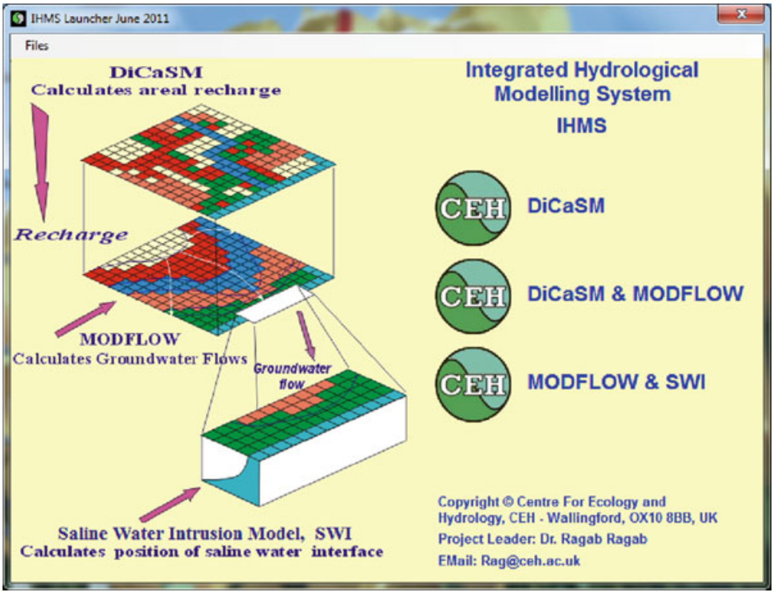

Fig. 4 The integrated hydrological modelling system, IHMS

The issue of heterogeneity in soils and plant covers has been dealt with in different way from other models. Most of the other models, account only for the most dominant soil type or vegetation cover. In DiCaSM, the different soil types and land covers are represented based on their relative areas. This required a special submodel to deal with the issue of heterogeneity within each grid square.

DiCaSM produces distributed and time series outputs of all water balance components including potential evapotranspiration, actual evapotranspiration, rainfall interception, infiltration, plant water uptake, transpiration, soil water content, soil moisture deficit, groundwater recharge rate, stream flow and surface run-off. The DiCaSM model has been developed using the Pang catchment (UK) data as a test site. In addition, four other catchments represented a wide range of environmental conditions, and land use in Cyprus, Italy and Brazil were selected to study the climate change and the land use change impact on water resources (Ragab et al. 2010; D'Agostino et al. 2010; Montenegro and Ragab 2010). The model quantified the possible impact on water resources availability in these four catchments. At the same time, the model was able to project the gap between water availability (water supply) and projected water demand up to 2050. The example of Cyprus is shown in Fig. 5. The modelling results are a good indication of what is likely to happen in the future and give the water authorities and policy makers the chance to plan a proper water resources management to balance the supply and demand.

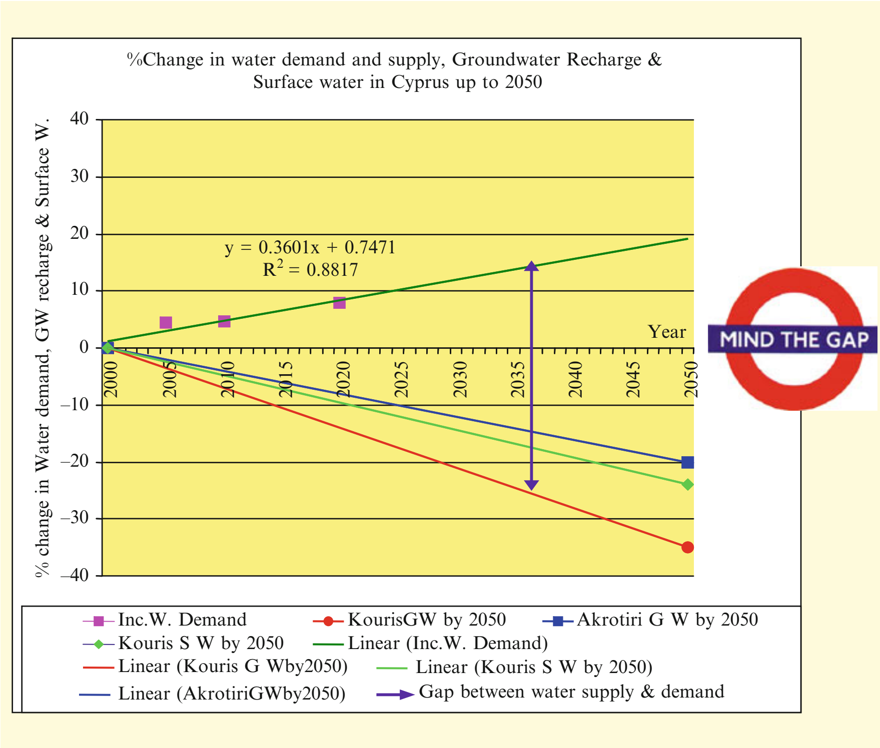

Fig. 5 IHMS projection for water supply and identifying the gap between the projected water demand and water supply up to 2050 for Cyprus

2.3 Issues Related to Water Resources Management

Water resources management is always associated with the word 'sustainability':

- Sustainability is a difficult term to apply, especially to groundwater resources, as the recharge is difficult to estimate and its forecast over a long period of time is a challenge.
- Sustainability is not for eternity, it should be associated with a time span. The majority of the scientists like the time span to be rather short, with a maximum of 50 years.
- Enough attention should be paid to the sustainability in relation to 'water security': the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production; coupled with an acceptable level of water-related risks to people, environments and economies.
- There is also a need to adopt the concept of the 'green economy' in the water management, where growth in income and employment is driven by investment that reduces carbon emissions and pollution, enhances energy and resource efficiency and prevents loss of ecosystem services.

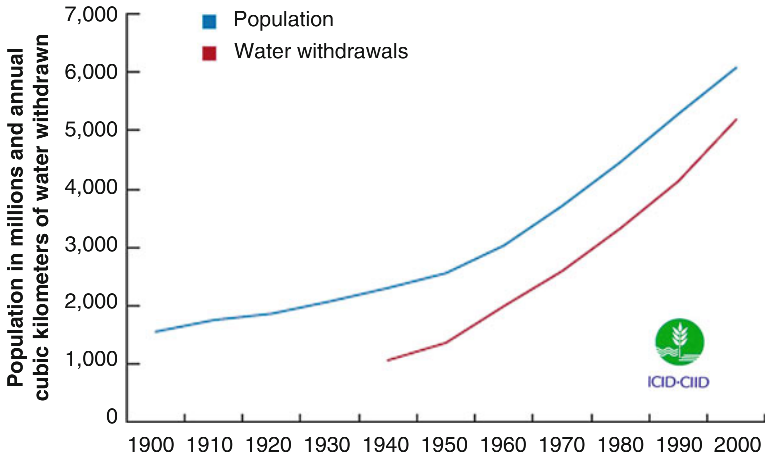

Fig. 6 Population increase is matched with water abstraction increase

- Supply-led management is unsustainable. A sustainable demand-led approach is required to manage the water resources with focus on conserving water and using it more efficiently and accounting for the need for a healthy fresh water ecosystem.

2.3.1 Reasons for the Current and Future Increasing Demand for Water

- Population increase, which leads to increased demand for food and subsequently water use (Fig. 6)
- Changing diets – there is greater demand for 'thirsty' crops, meat and dairy products
- Increased demand for out-of-season crops (e.g. melons, strawberries, etc.) with greater 'blue' water demand
- Changing climate, with more frequent drought events
- Increased demand for biofuel crops

Proper management of water resources requires greater use efficiency of the resources at field, catchment and regional scales in all sectors. In the field of agriculture, which is the biggest water consumer, the efficiency seems the lowest among the sectors. Figure 7 shows how the efficiency drops on the way from the reservoir to the field due to poor management.

At field level, the efficiencies could differ significantly due to the irrigation system and the method of water application (strategy) (Ragab 2010a, 2002, 2006, 2010b). Figure 8 shows that alternating subsurface drip/furrow to be more efficient in water use than normal drip or sprinkler. The alternating subsurface drip irrigation sometimes known as Partial Root Drying Method, PRD, is one of the most efficient water-use systems (Fig. 9).

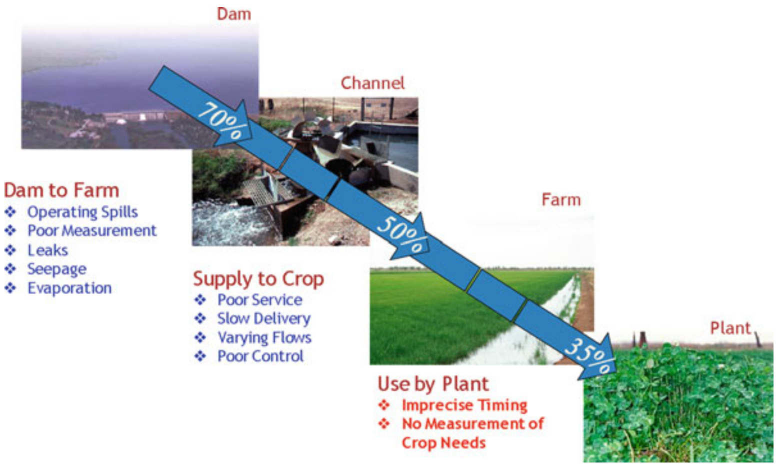

Fig. 7 Efficiencies from storage to the field: irrigation – a managed water cycle

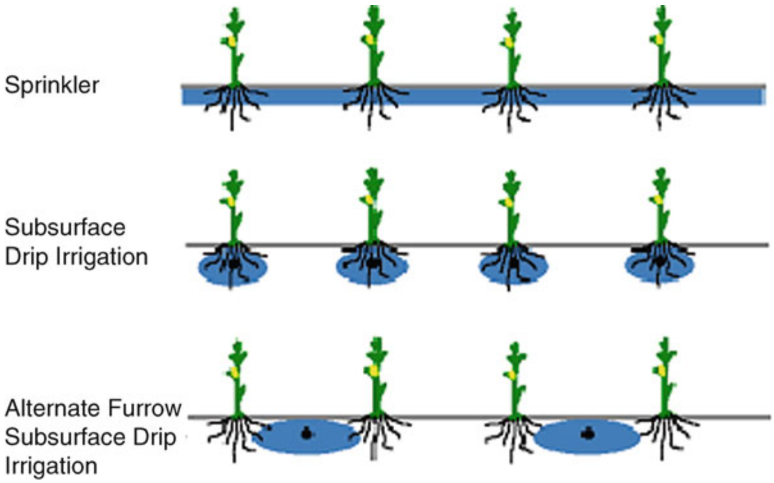

Fig. 8 Irrigation efficiency varies according to the irrigation system and strategy

2.3.2 Improving Water-Use Efficiency

'Water-use efficiency' is a dimensionless term; this means it is a ratio of output to input, both having the same units. This is different from 'water productivity' term that has a unit of yield, e.g. kg per unit of water used, e.g. m^3. Sometimes, the agronomists wrongly refer to water productivity as water-use efficiency.

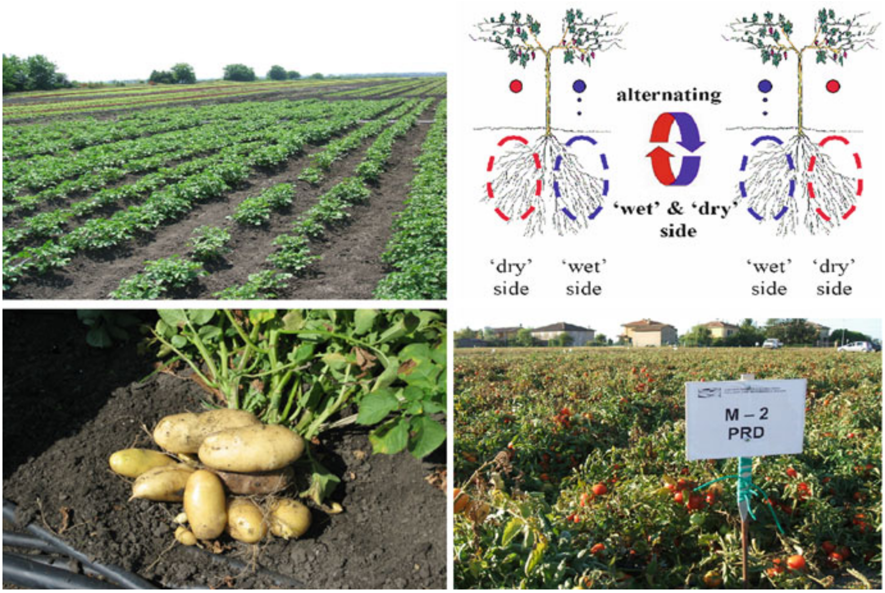

Fig. 9 Water saving through irrigation with drip subsurface irrigation system, PRD technique (only one half of the vertical root zone is irrigated at a time then alternate irrigation with the dry half). Saving in water is significant, ~40 %, which means 40 % more food can be produced (Ragab 2010b)

There is a critical need to improve the water-use efficiency, especially in agriculture. Technical and management options to improve productivity include:

- Developing new crop varieties with higher yields per unit of water, e.g. crops with comparable yields but shorter growth periods.
- Switching to crops that consume less water or use water more efficiently, Fig. 10.
- Improving soil management, fertilization, pest and weed control.
- Improving the reliability of water supplies at critical crop growth periods; this would encourage farmers to invest more in other inputs and lead to higher output per unit of water.
- Promoting deficit irrigation, which can increase productivity per unit of water by providing less-than-full irrigation requirements.
- Promoting supplemental irrigation, which uses limited irrigation at critical periods to supplement rainfall.
- Use of non-conventional water resources (Huibers et al. 2005; Ragab and Koo-Oshima 2006) such as agriculture drainage water, sea water, brackish groundwater, domestic wastewater (Figs. 11 and 12).
- Use new crops that are drought and salinity tolerant such as quinoa and amaranth (Fig. 13).

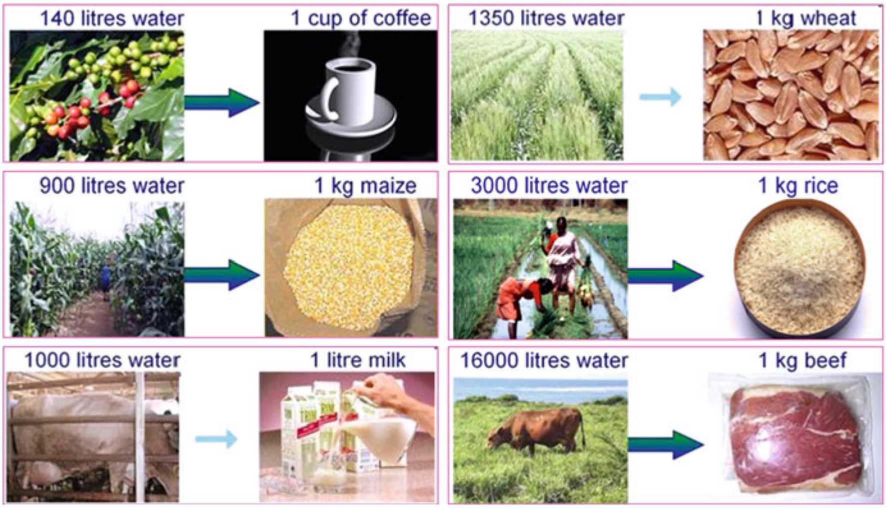

Fig. 10 Virtual water for some important products

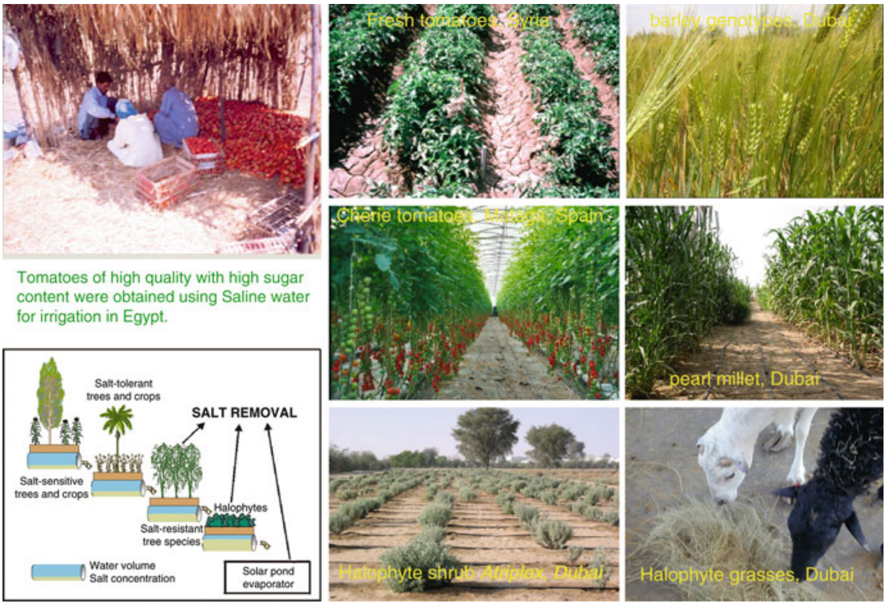

Fig. 11 Saline water and brackish groundwater can be used to produce food and fodder some varieties of tomato, sugar beet, barley and Bermuda grass are also salt tolerant

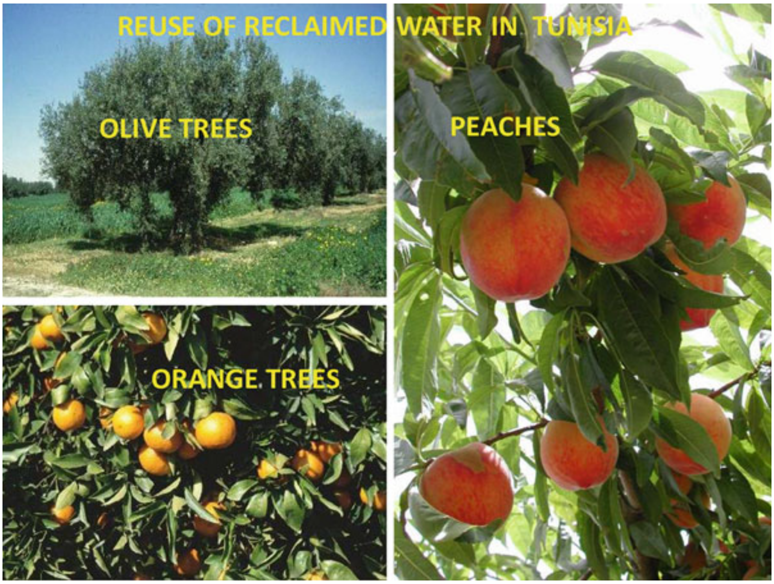

Fig. 12 Treated waste water used in fruits production

Fig. 13 The drought and salinity tolerance crop, quinoa (*left*) and amaranth (*right*)

2.3.3 Water Savings and Increasing Water Supply

This can be carried out at different scales, house roofs, field and catchment scales (Fig. 14). The techniques include bunds, zays, underground dams and surface reservoirs. As mentioned above, the use of non-conventional water resources can be a valuable additional water supply.

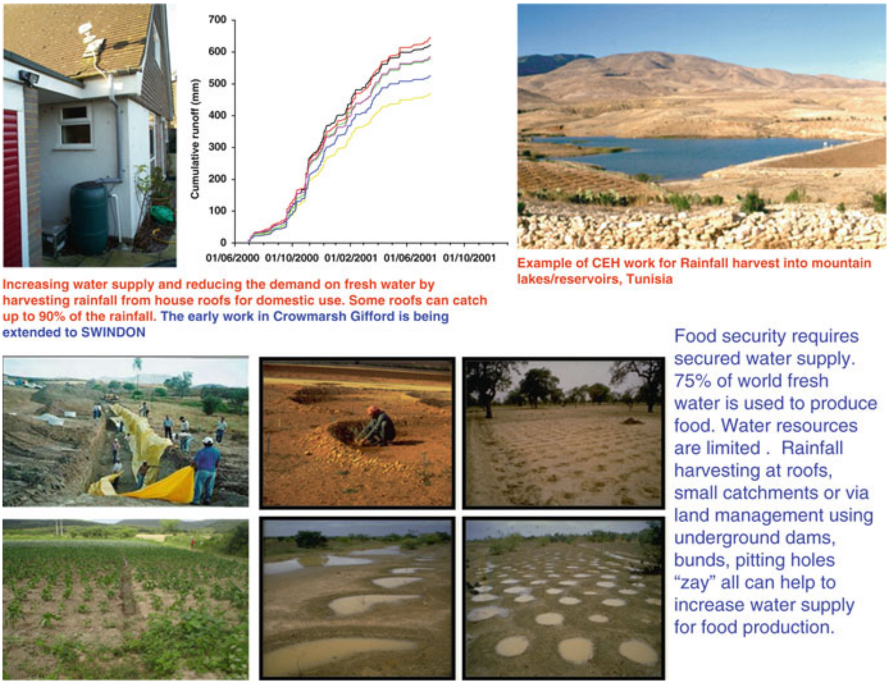

Fig. 14 Rainfall harvesting at different scales, house roofs, field and catchment scales

2.4 Issues Related to Water Policies

Water resources management requires sound water policies and legislations. The current policies need to have:

- Links between water quality, land use and water resources.
- A link between water scarcity issues to agricultural policies.
- A policy with regard to biofuel/energy crops and their impact on water availability and food security (Fig. 15).
- A policy on the use of waste water at the times of shortages, and the use of less water demanding and drought tolerant crops to cope with drought periods.
- Proactive management of drought, which so far was reactive.
- Demand management strategies should be promoted as obligatory measures in the water policy.
- Assessing the risks and impacts of alternative water supply options such as desalination, brackish water and wastewater reuse.
- A forecast of water scarcity and drought events for the year ahead.
- There is a need to improve water use efficiency among all users.
- Effective and harmonized/unified trans-boundary monitoring systems for data comparability.
- Adoption of a joint policy on water security, food security, energy security and environment security.

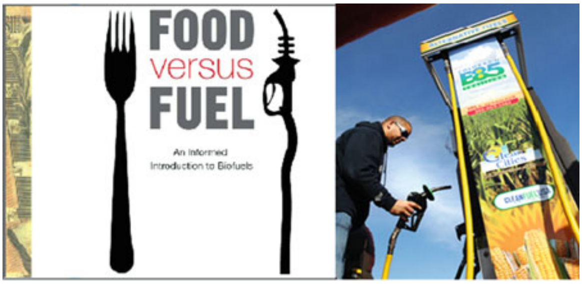

Fig. 15 Biofuel crops affect the water availability. Need to consider the delicate balance between water, food and energy security

- A shared vision among stakeholders (water users, polluters, scientists, government and private sector) to make collective informed decisions and collectively manage the water resources.
- Raising the awareness of consumers. An eco-label regulation will help in choosing products with lower water consumption/water footprint. A water footprint is the total volume of freshwater that is used to produce the goods and services (expressed as m^3).

3 Conclusion

The combination of possible impacts of climate change and land use requires a proper plan for water resources management and mitigation strategies. There is a delicate balance between food security and energy security when changing the land use from crops to biofuel. Land use changes, if coinciding with droughts, could lead to desertification. Water resources management needs to be handled with an integrated approach that takes into account the water resources availability (quantity and quality), the land use, the water demand and the climate change.

The Integrated Hydrological Modelling System, IHMS, and SALTMED models are useful tools to quantify water resources; investigate the impact of land use and climate changes on water resources, plant biomass, harvest and sowing dates; and quantify the gap between water supply and demand.

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Water Valuation in Agriculture in the Souss-Massa Basin (Morocco)

Fouad Elame and Rachid Doukkali

Abstract Water resources become increasingly scarce, scarcity that will become acute in the coming years due, among others, to a reduction in water supply, as a result of climate change, and the increase in demand, accentuated by the population increase and the requirements of economic growth and development. In this context of scarcity, Morocco is confronted with the need to adapt its water management policy from a supply management to a demand management one. Implementing such a policy requires the adoption of new policy instruments and decision making support tools that take into account the complexity of the current and future situation, as well as allowing the assessment of the economic, social, and environmental impacts of various water resources allocation alternatives at the overall river basin level. This chapter compares several methods for calculating the water value and proposes an integrated economic water management model at the river basin scale. This model takes into account the economic, institutional, hydrological, and agricultural aspects as well as the behavior of various agents involved in water resources management and the competition among sectors. One major contribution of this model is a detailed disaggregation by spatial units (hydrological units, cropping areas, and grazing land), by agricultural production systems (irrigated and rainfed crops), and by farm sizes. Basically, it is an optimization model with a nonlinear objective function and using the positive mathematical programming method technique for its calibration. Given the conjunctive use of water at the river basin level, the model results show the tremendous impact of surface water management on the overexploitation of the ground water and the risk of its depletion. A management policy of surface water based on administrative pricing, pumping cost, and water

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supply marginal cost is proven inadequate for a sustainable resource management since it underestimates the overall water scarcity at the river basin level.

Keywords Water resources • Scarcity • Surface water • Water value • Positive mathematical programming • River basin • Integrated economic model • Groundwater • Depletion

1 Introduction

In Morocco, agriculture is considered as a strategic sector for socioeconomic development. However, this sector faces many challenges, water management among others. In fact, drought years combined with aquifer depletion trend, economic growth, and increasing demands pressure make water resources very scarce. These limited water researches are not generally well allocated (Bzioui 2004; Akesbi 2005).

The various local agents involved in water policy and their interests, often conflicting, generate use conflicts and excessive water demand that cannot be controlled only by using an integrated, decentralized, and concerted water resources management AGR (1996, 2003). Such management could be conceived only on a river basin scale where exhaustible are water resources, and through developing policies and tools that allow an efficient and an equitable management between different stakeholders Montginoul (1997). Indeed, the river basin assembles all physical features and human activities and where the main focus of interest conflicts around water management between various agents having a direct effect on the system.

Water valuation policy is becoming an imperative for decision makers especially in the Mediterranean region and this for many reasons:

– Water scarcity: economic development, urbanization, etc.
– Climate change and its impact

From an economic standpoint, several methods have been suggested in order to guide this political assessment of water use efficiency: residual method, market chain analysis, and more recently other optimization methods were introduced. However, there is more confusion in interpreting the results of these methods.

– Generally, there is confusion between the private interest and the collectivity one (producers interest and community interest): the farmer tries to maximize its profit, but the community is more interested in water valuation.
– Confusion between competitiveness and water efficiency.

The choice of the Souss-Massa basin is guided by the economic position that occupies that basin and the acute water scarcity which it faces. In addition, tourism development and the important place of this basin in the national agricultural exports (leader in export of off-season fruit and vegetables) combined with population growth pressure and urbanization make water resources increasingly scarce in that basin (Agence du Bassin Hydraulique de Souss-Massa, PDAIRE 2007).

The Souss-Massa basin is characterized with limited and irregular surface water resources. It includes two aquifers overused. In fact, imbalance between a limited water supply and an increasing water demand has led in recent years to a water shortage alarming situation and to an overuse of groundwater resources beyond 260 Mm^3/year of deficit.[1]

2 Methodological Approach and Previous Studies in Applied Economic Modeling for Irrigation

To support the effort of a better allocation of irrigation water use, several studies have been undertaken. These works contribution is undeniable since it informs policymakers about the need to support technical decisions and policies with economic and social evaluations. In addition to classical studies based on assessment methods of investment projects that have accompanied almost all irrigation investment projects, we can distinguish other tools for supporting decision making that were developed for Morocco and were devoted to optimal allocation of irrigation water use.

We can distinguish among these groups of tools, the market chain approach (*l'approche filière*) (Ben Gueddour 1998; Benabdellah and Rachid 2000; Doukkali and Tourkmani 2001; Elkazdar and Passoulé 2009). All these studies focused on measuring differences of water valuation by irrigated crops and comparing the competitiveness of these crops. However, this approach has some limitations knowing that it ignores institutional constraints, resource availability, or access to technology in farms.

Another type of tools based on farm models Hazell and Norton (1986) method that has economically derived demand functions for irrigation water of different farm types in different situations and has calculated the shadow price to evaluate water pricing at a given irrigation area (Bathaoui 1991; HFID 1999; Diani 2001; Doukkali et al. 2003, 2004; Petitguyot et al. 2005).

Applied modeling to agricultural sector (Essadi 2002; He et al. 2006) demonstrated differences in water efficiency and economic prices between different agro-ecological zones. However, these models have led to limited results because they do not integrate other sectors of the economy.

In addition to the tools already mentioned, the general equilibrium models with different levels of disaggregation more or less advanced were applied to study various issues faced by irrigated agriculture. One of these important works has focused on studying the impact of adjustment implementation and liberalization, evaluation of the National Irrigation Program and 2010 strategy set up for rural development (Doukkali et al. 1999), irrigation water pricing study (Tsur et al. 2004), and potential profits from decentralized water allocation at the national economy level in the context of a large spatial heterogeneity (Diao et al. 2005). This type of model

[1] ABHSM, Stratégie de préservation des ressources en eau souterraine dans le bassin de Souss-Massa, novembre 2005

has highlighted the links between policy instruments and allocation of water resources and was used to assess economic policy instruments impact.

To complement these efforts and overcome the limitations of economic models mentioned above. This study proposes an economic integrated river basin model stemming from modeling studies at the international level, notably by IFPRI (International Food Policy Research Institute) (Rosegrant et al. 2000a, b; Cai 1999; Cai et al. 2006; Ringler and Nguyen 2004). The model is integrated in the sense that it takes into account hydrological, agronomic, economic, and institutional components while apprehending the behavior of various demand sectors (irrigation, municipal water demand…) and stakeholders involved in water resources management in the basin. In this model, the basin is represented by spatial and functional units or nodes of water resources management through an exchange of water flow between these units; among units, reservoirs, and aquifers; and finally between these units and water demand sites. The links between the different elements and units simulate water flow between these different components along the river. For the agricultural sector, irrigation water is allocated according to crop water requirements and the profitability of each crop. Various spatial scales allow the generation of reasonable results compared to actual observed data, including water flows downstream, water losses, water supply, irrigated areas, yields, productions, etc. (Heckelei 1997; Heidecke and Kuhn 2006; Rosegrant et al. 2006; Elame and Farah 2008).

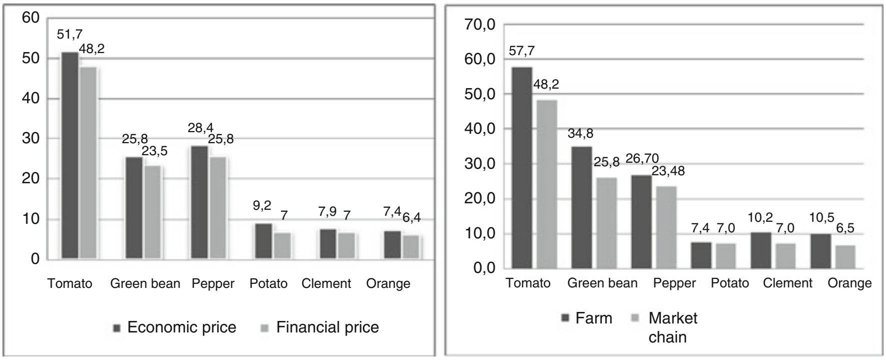
The proposed approach is based on nonlinear optimization techniques. It is a hydrological and economic model that uses water resources so as to maximize the value added in agriculture while taking into account a set of constraints which are divided into hydrological, agricultural, and resource availability constraints. The model calibration is based on positive mathematical programming "*PMP*" (Howitt 1995; Chantreuil and Gohin 1999).

3 Results and Discussion

The purpose of this part is to analyze the results and compare several methods of water value study. Indeed, we will discuss irrigation water valuation by calculating water residual value and analyze results of the financial and economic market chain analysis of some important fruits and vegetables in the Souss-Massa area. Then we will assess the relationship between crops and water valuation then between production systems and water efficiency. Finally, we will present the results related to water value study by the modeling approach of integrated economic water management.

3.1 Irrigation Water Valorization by the Residual Value Approach

Graph 1 shows that water valuation by the economic price, for all crops, is greater than water valuation by the financial price. If we take the case of clementine for export and potatoes for the local market which have the same financial price,



Graph 1 Water valuation, at farm and market chain level regarding economic and financial price

we notice that from an economic perspective export crops are not those that valorize more water resources.

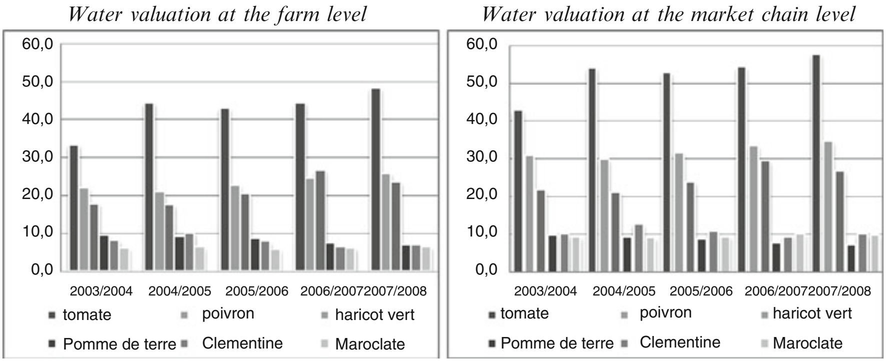
The community interest is to maximize water valuation and create a value added. However, the farmer sees things from another angle which sometimes may be different from the community view. The diagram above shows that the community would be indifferent between potato and clementine choice, while the producer would prefer clementine. In the case of green beans and peppers, views of the producer and the community would be opposed as the community will opt for pepper while the producer will choose beans from which the interest of a better information to help get a proper choice and judgment of public authorities.

Water valuation at the market chain level and the farm level is not the same as the graph above shows. A crop that appears to be less efficient at the farm level can be more efficient if we take into account the whole market chain and vice versa: case of citrus compared to potato. Water value accounting must include the entire market chain.

Analyzing these results, we find that the residual value method of water value accounting has some limitations. In fact, this method does not apprehend time changes for the value added or the market chain competitiveness. In addition, water residual value does not take into account the interaction between crops and production systems and the actual water scarcity measured by the water economic value (shadow price).

3.2 *Water Efficiency and Competitiveness of Market Chain Over Time*

Water valuation should not be limited at the farm level since a given crop can have effects on the upstream and downstream of the Market chain. To better compare different crops, it is necessary to take into account, in addition to the farm, the wealth created by other agents in market chains in particular seed plots and packing stations (Graph 2).



Graph 2 Water valuation in the farm and market chain level

Comparing the two graphs, we see that water valuation changes over time at the farm level and market chain level. In general, water valuation by potato at the farm level is more important than clementine, while at the market chain level, water valuation by clementine is better. An allocation decision of water resources which involves the future should not be based on an observation point and must take account of market dynamics.

Domestic resource cost coefficient (DRC[2]) compares the opportunity cost of domestic production to the value added calculated in equivalent foreign currency. The purpose of calculating the domestic resource cost is to analyze the relative competitiveness of the market chain and assess the relationship between water efficiency and competitiveness.

The two graphs below show that competitive crops are not necessarily those with high water valuation. Competitiveness trend may not be positively correlated with better water efficiency.

Clementine competitiveness in the first two seasons (2003/2004 and 2004/2005) and that of potato in 2003/2004 were higher than tomato competitiveness, although water valuation by tomato is much higher than clementine and potato. Likewise, during the first three seasons, the competitiveness of potato was higher than that of green beans and pepper. However, green beans and pepper water valuation is much higher than that of potato.

Competitiveness does not reflect water valuation by crops. In other words, a high level of competitiveness does not mean better water efficiency.

We should notice that water use efficiency also depends on agricultural areas and farm size.

In addition to the limitations mentioned before, the residual method and the market chain method:

– Assume fixed production coefficients (no inputs substitutability especially between water and other agricultural inputs). From which the need of a method that takes into account inputs substitutability

[2] N.B.: low DRC means a competitive crop.

– Do not take into account speculations substitutability within a production system.
– Assume unlimited water availability and do not take into account water constraint and water resources competition.

3.3 Economic Integrated Model of Water Management of the Souss-Massa

Complexities of water allocation and water use across the basin require a holistic approach for water resources management and planning in order to get optimal and sustainable water and at the same time, an efficient and an equitable water use (McKinney et al. 1999).

The model developed in this study belongs to the integrated river basin models category. It is a more detailed model that includes hydrologic, economic, and agronomic components of the basin. The advantage of this type of model is its ability to reflect the relationship and links between these various components listed above and to simulate the economic consequences due to policy choices. The model represents an efficient and useful tool for decision support on policy choices on water allocation and setting priorities for institutional and incentive reforms that guide water resources allocation.

The proposed integrated economic and hydrologic river basin model is based on real links between different spatial units of the hydrological network and connected by interconnections or nodes. Spatial units represent river flows, reservoirs, aquifers, or water demand sites (agricultural demand area, drinking water, industrial water, etc.). In the case of surface water, basic units are nodes distributed across the basin and represent water supplies, storage entities, and water demand of different sectors, while for groundwater, nodes represent different aquifers used for agricultural, municipal, and industrial purposes (Fig. 1).

The model maximizes the agricultural value added at the basin level taking into account a set of hydrological, agronomic, and resources availability constraints (water, land, labor, etc.).

These components described above are integrated into a consistent structure of water allocation, taking into account the functioning of hydrological systems, rules for allocating water at demand sites level, and assessment of the environmental consequences and the economic viability of such allocation. Water demand is determined endogenously based on empirical yields and crops production functions. At each agricultural sector, water is allocated to crops according to their growth stages and crops requirements.

Water supply is obtained from the water supply-demand balance, result of maximizing the total value added in the basin under physical, technical, and political choices constraints.

We use the positive mathematical programming method "PMP" for the calibration of this model. The PMP can perfectly calibrate the model using a restricted data set. This calibration process allows apprehending missing data and ensures that the model reproduces the allocation of land for the basic year (a normal year).

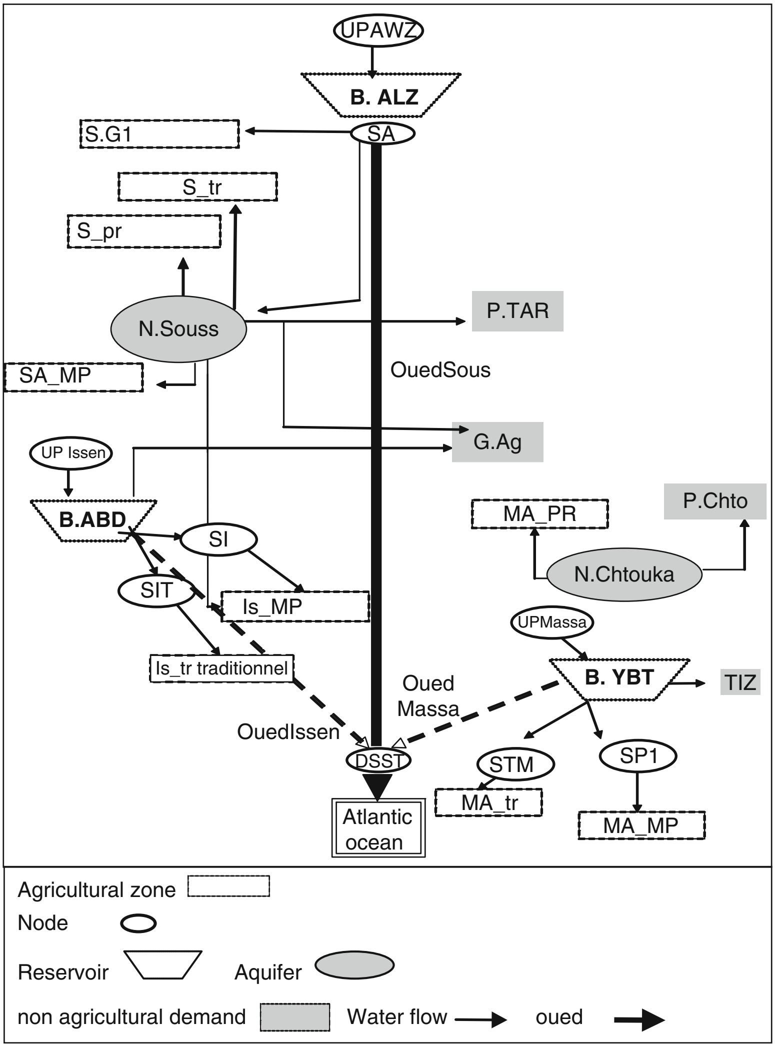


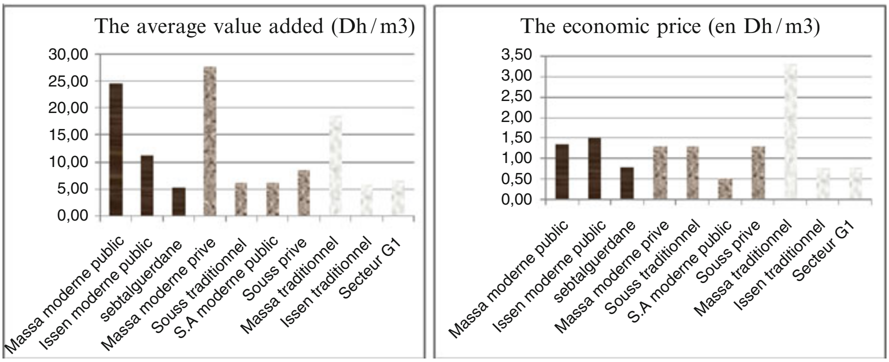
Fig. 1 A schematic representation of the various components and interconnections of the Souss-Massa basin

3.3.1 Results Analysis of the Proposed Model

The two graphs show that water valuation changes depending on water access conditions. However, the value added does not reflect water resources scarcity. The approach used in calculating water value should reflect the actual scarcity of water resources (Table 1; Graph 3).

Table 1 Water economic price by farm size and subbasin

Water sources	Farm type Area	Less than 3 ha	Between 3 and 5 ha	Between 5 and 10 ha	Between 10 and 20 ha	More than 20 ha
Conjunctive water	Massa moderne public	1.44	1.36	1.33	1.14	1.50
	Issen moderne public	1.60	1.46	1.24	1.37	1.65
	Sebt al guerdane	0.50	0.45	0.73	0.66	1.08
Groundwater	Massa moderne privé	1.31	1.31	1.31	1.31	1.31
	Souss traditionnel	1.31	1.31	1.31	1.31	1.31
	S.A moderne public	0.52	0.52	0.52	0.52	0.52
	Souss privé	1.31	1.31	1.31	1.31	1.31
Surface water	Massa traditionnel	2.39	3.31	6.06	1.64	3.15
	Issen traditionnel	0.41	0.48	0.29	0.41	2.95
	Secteur G1	1.11	0.72	0.98	0.31	0.54



Graph 3 The average value added and the economic price

If we analyze the following table according to farm types and water access conditions, we conclude that:

– For farms that combine surface water and groundwater, large farms have the highest economic price.
– For farms that use surface water, farms with high economic prices depend on production systems and agricultural areas.
– Farms that exploit only groundwater behave as if the resource is unlimited since there is no constraint limiting groundwater resources use, from where the need to take into account the actual scarcity of water resources.

Drought Impact on Surface and Groundwater

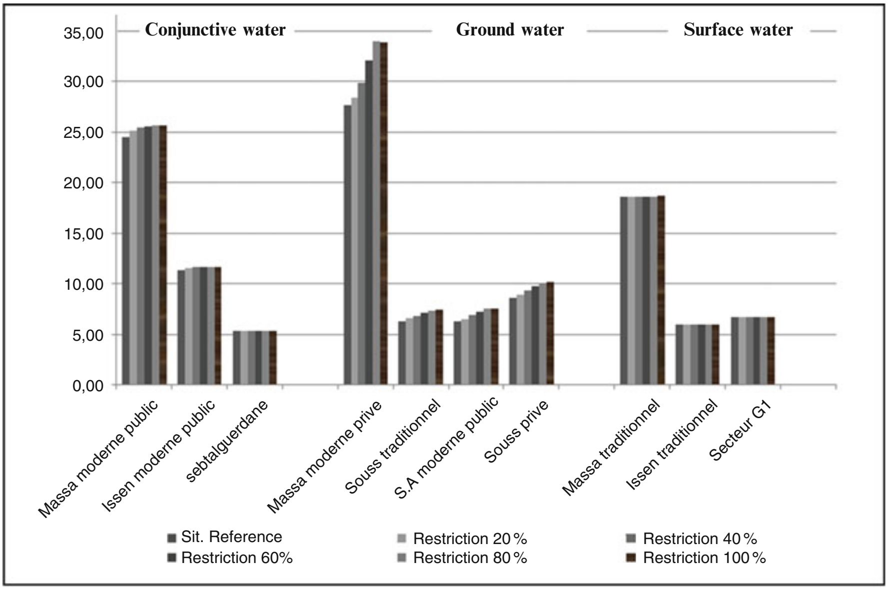
The effect of drought is felt differently depending on agricultural zones. In case of drought, farms with access to groundwater continue to behave as if the resource is unlimited. They balance the lack of surface water by more water pumping from the aquifer. Farms using only surface water are more likely vulnerable to drought.

In addition to differences between areas, the impact of drought is felt differently depending on farm types. Indeed, applying the same simulation of drought for areas using surface water, the economic price changes depending on farm types (Graph 4).

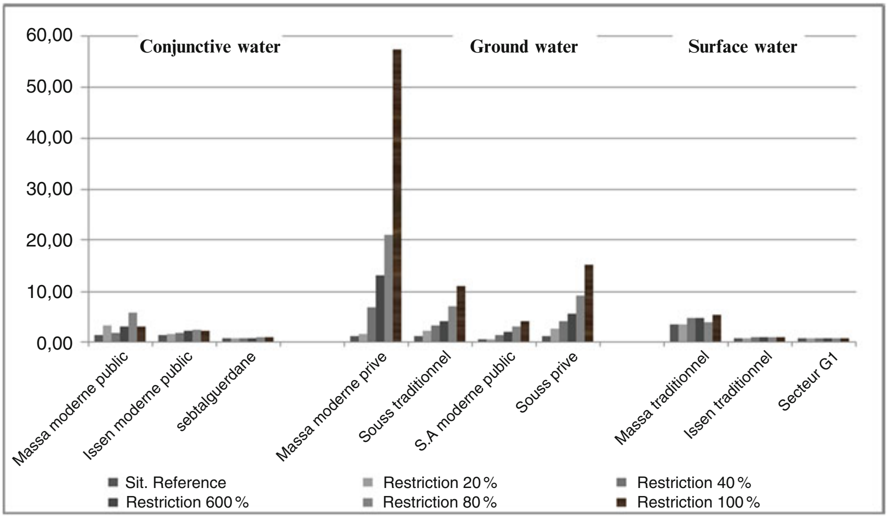
Applying restrictions on groundwater by progressive decreasing of the groundwater overexploitation, we notice that for areas that use surface water, restrictions on the groundwater overexploitation did not influence the average value added, while for areas that use groundwater, as restriction increases, the average value becomes high, which means that the more limited is the resource, the better is water valuation (Graph 5).

Applying restrictions on groundwater, we notice a significant increase of the economic price which better reflects the actual scarcity of the resource. A resource allocation policy must take into account the actual scarcity rather than the summary assessments of water value (Graph 6).

This simulation enables to calculate the effect of groundwater restrictions on the value added generated by agricultural sector.



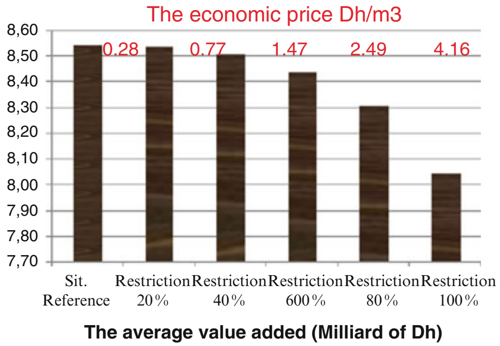
Graph 4 The average value added (Dh/m^3): comparison between a normal year (reference) and situations of gradual reductions of groundwater overexploitation from 20 to 100 %



Graph 5 Variation of the economic price (in Dh/m^3): comparison between a normal year (reference) and situations of gradual reductions of overexploitation of groundwater by 20–100 %

A restriction of "up to 40 % of groundwater overexploitation" has basically no effect on the value added generated by agriculture. It begins to decrease significantly at "over 40 % of restriction." An overuse of groundwater in an average year allows an annual gain in the short term of 500 million dirhams; in parallel, the economic

Graph 6 Short-term gains of groundwater overexploitation



price reaches 4.16 Dh/m^3. However, it is important to ask whether this gain justifies groundwater depletion risk with all the consequences that may have on the incomes and the environment.

4 Conclusion

In Morocco, groundwater resources remain overexploited. Most aquifers are suffering from an unprecedented decline, especially in the Souss-Massa region where most of exported crops are located. In this context of water scarcity, authorities show volition to increase exports and are therefore required to allocate water resources to crops with high water use efficiency.

This chapter compares several methods for calculating water value and analyzes the results of different approaches. In addition, this study proposes a nonlinear programming model (Chantreuil and Gohin 1999) that takes into account water flows and relationships between the various components of the basin, which shed light on the reality of water resources use and exploitation in the Souss-Massa basin.

The accounting method of water value has some limitations. In fact, this method does not apprehend time changes for the value added or the competitiveness of market chain. In addition, water residual value does not take into account the interaction among crops, production systems, and real water scarcity represented by the shadow price. Likewise, water valuation should not be limited to the farm level since a given crop leads to effects on upstream and downstream of the market chain. This study shows as well that the competitiveness does not reflect crop water use efficiency.

Analysis of the Souss-Massa basin integrated model results shows that water valuation differs depending on access conditions to water resources and adopted production systems.

Imposing and setting restrictions on groundwater use causes a significant decrease, but less than proportional, of irrigated areas and the net value added of agriculture as it induces an improvement of irrigation water use efficiency through a better allocation of this resource.

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Part III
Non Conventional Water Managements and Pollution Control

Perspectives of Wastewater Reuse in the Mediterranean Region

Redouane Choukr-Allah

Abstract The Mediterranean region only accounts for just over 2 % of the world fresh water resources, most of them (70 %) are concentrated within the northern shore countries. All the southern and eastern Mediterranean countries, except Turkey, are currently under water stress, with less than 1,000 m^3/person/year of annual renewable water resources.

In most countries of the Mediterranean, the vital importance of treating and safely reusing wastewater is being more and more recognized. Reused treated wastewater contributes considerably to the water budget in several countries, particularly those suffering from water scarcity. Important projects are being developed, and wastewater reclamation and reuse facilities are established following the local and/or national guidelines (Morocco, Jordan, France, Tunisia, Cyprus, etc.). However, only 75 % of the wastewater generated is treated, and only 21 % of the treated volume is formally reused. Regulations on wastewater reclamation and reuse are essential. They help to protect public health, develop cooperation among countries, increase water availability, prevent coastal pollution and enhance public policy on water resources and nature conservation. Also, they help every prospective user to be aware of existing limitations. Unifying regulations in Mediterranean countries would contribute to economic security and tourist exchanges in the region. Even within the individual countries, there is an ongoing controversy among defenders of strict water quality standards and those willing to put more emphasis on water reuse practices, suggesting less restrictive water quality standards particularly for undrinkable water uses.

Expansion of treated wastewater reuse in the region is linked to a number of issues and constraints. The high cost of treatment and management of reclaimed wastewater is one of the major limitations facing the weak economy of most countries. Unclear polices, institutional conflicts and lack of regulatory frameworks constitute other important constraints that hinder implementation and proper operation of

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wastewater reuse projects. The manpower capacity differs from country to country, but additional training and capacity building are generally needed throughout the region. Using the treated effluent for irrigation purposes adds an economic driving force for investments in wastewater treatment. Another economic advantage of choosing agricultural irrigation as a final disposal solution for the treated effluent is that it permits low quality demands, especially with regard to nutrients removal.

This chapter will address the integrated approach for reclamation and reuse of treated wastewater, the criteria and standards that should be applied for wastewater reuse in agriculture, the appropriate treatment technologies to be used for the Mediterranean areas, the viable options for reuse of wastewater, the most prominent constraints (technically, institutionally and financially), and the use of treated wastewater for agriculture within the parameters of socio-economic development in the Mediterranean region, including sustainability issues.

Keywords Wastewater reuse • Treated wastewater • Mediterranean region • Perspectives

1 Introduction

Most of the Mediterranean countries are characterized by severe water imbalance and uneven rainfall. Meanwhile, over the last two decades, there has been an increasing demand for irrigation and domestic water use as a result of expending urban population and tourist industry. This region only accounts for just over 2 % of the world fresh water resources, most of them (70 %) concentrated within the northern shore countries. Although water is recycled in the global hydrological cycle, much smaller-scale planned local water recycling and reuse have become increasingly important in the Mediterranean region.

Evaluating the challenges and opportunities for using marginal-quality waters will help in guiding investment and management decisions pertaining to land and water management in agriculture. Considering the growing water shortage in the Mediterranean countries and history of water use, it is expected that the use of marginal-quality waters for various purposes will be more common in the foreseeable future. Key decisions are needed in the short and long terms in relation to the use of such water resources to support achievements of the United Nations' Millennium Development Goals to enhance food security and environmental quality during the next 50 years. In addition, there is a need to address the current situations where marginal-quality waters are already used for food production, especially in resource-poor environments, where regulations need to be realistic and feasible.

Agricultural reuse of treated wastewater should be integrated into comprehensive land and water management strategy, taking into count water supply, type of treatment technology, final reuse and the social and economic aspects. The reuse of treated wastewater enhances agriculture productivity in several Mediterranean countries; however, it requires public health protection, appropriate treatment technology, public acceptance and participation. This chapter assesses the current situation regarding significance of wastewaters use in agriculture and also provides

Table 1 Volumes of wastewater produced and the percentage of wastewater treated and reused

Country	Wastewater produced 10^6 m^3/year	% of wastewater treated/wastewater produced	% of wastewater reused/wastewater produced	Year of WWR
Algeria	820.0	85.4	3.2	2011
Cyprus	30.0	100.0	83.3	2008
Egypt	4930.0	60.3	60.3	2001
France	7910.0	91.0	5.2	2004
Greece	719.0	62.6	1.0	2008
Israel	450.0	62.9	62.2	2008
Italy	7731.0	31.0	3.5	2008
Jordan	82.0	90.2	85.4	2010
Lebanon	249.0	1.6	0.8	1991
Libya	546.0	20.1	7.3	1999
Malta	19.0	115.8	50.0	2008
Monaco	7.3	82.5	0.0	2009
Morocco	700.0	25.3	11.4	2007
Palestinian territories	50.0	53.8	20.0	2004
Slovenia	168.5	68.4	4.1	2009
Spain	5204.4	86.8	10.1	2008
Syria	825.0	66.7	66.7	2002
Tunisia	240.0	89.6	14.1	2001
Turkey	4289.0	57.9	23.3	2006
Total	34970.2	63.9	18.1	

Source: Guardiola et al. (2011)
WWP wastewater produced, *WWT* wastewater treatment, *WWR* wastewater reuse

insight into the technological, institutional and policy options that might help in increasing its advantages and opportunities, while reducing possible negative impacts on people and the environment.

2 Potential of Treated Wastewater Use in the Mediterranean Basin

The volume of wastewater increases with increasing population, urbanization and improved living conditions (Raschid-Sally et al. 2005). Considering 20 % as the depleted fraction from urban water use and anticipating growth in urban water supply coverage as a proxy for amounts of wastewater generated, it is revealed that in spite of reliance on onsite sanitation, wastewater from Mediterranean cities pollutes large volumes of water for the downstream agriculture (Scott et al. 2004). In most developing countries, urban drainage and disposal systems are such that wastewater generated by different activities gets mixed, and the resulting effluent may be disposed of in a wastewater treatment plant, in a water body or diverted to farmers' fields as treated, partly treated, diluted and/or untreated form (Qadir et al. 2007). Table 1 shows the volume of wastewater produced and percentage of treated and reused in the Mediterranean region.

3 Wastewater as Additional Water Resource

There are several benefits of treated wastewater reuse. First, it preserves the high quality, expensive fresh water for the highest value purposes, primarily for drinking. The cost of secondary-level treatment of domestic wastewater in the Mediterranean countries, on average, is 0.2–0.5 US/m^3, cheaper, in most cases, than developing new supplies in the region (World Bank 2007). Second, collecting and treating wastewater protects existing sources of valuable fresh water, the environment in general and public health. In fact, wastewater treatment and reuse (WWTR) not only protects valuable fresh water resources but it can supplement them, through recharging the aquifer. In reality, enormous, benefits for environmental and public health protection if correctly factored into economic analyses, wastewater collection, treatment and reuse would be one of the highest priorities for using the scarce public and development funds. Third, if managed properly, treated wastewater can sometimes be a superior source for agriculture, compared with some fresh water sources. It is a guaranteed water source, and the presence of nitrogen and phosphorus in the wastewater usually results in higher yields than freshwater irrigation and without additional fertilizer application (Pettaa et al. 2007). Research projects in Tunisia have demonstrated that treated effluent had superior non-microbiological chemical characteristics when compared with groundwater, for irrigation. Mainly, the treated wastewater has lower salinity levels (World Bank 2007).

Estimates of the extent to which wastewater is used for agriculture worldwide reveal that at least 2×10^6 ha are irrigated with treated, diluted, partly treated or untreated wastewater (Jimenez and Asano 2004, Bahri and Brissaud 2004). The use of untreated wastewater is intense in areas where there is no, or little, access to other sources of irrigation water and is being practised in several southern Mediterranean countries.

4 Wastewater Reuse Status in Selected Southern Mediterranean Countries

The European Union (EU) has so far not invested heavily in wastewater reuse. France has issued wastewater reuse criteria in 1991. The current acute drought in Spain, Greece and other countries besides the local water shortages, increasing environmental constraints and pervasive pollution everywhere in Europe is generating renewed interest in wastewater reuse. Because irrigation is by far the largest water use in the world and the quality requirements are usually the easiest to achieve among the various types of wastewater reuse, irrigation is by far the largest reuse application in terms of volume.

Countries in the region which practise wastewater treatment and reuse include Jordan, Lebanon, Tunisia, Israel, Cyprus, Syria, Morocco, Spain, France and Egypt (Choukr-Allah and Hamdy 2004). However, only Tunisia, Israel, Cyprus and Jordan already practise wastewater treatment and reuse as an integral component of their water management and environmental protection strategies. The main reuse projects in the Mediterranean region are related to agricultural and landscape irrigation and groundwater recharge.

4.1 Tunisia

In Tunisia, 238 million m^3 treated effluent is produced of which less than 30 % is reused to irrigate about 8,065 ha of orchards (citrus, grapes, olives, peaches, pears, apples and pomegranate), fodder, cotton, cereals, golf courses and lawns (Trad Rais et al. 2011). The agricultural sector is the main user of treated wastewater. Mobilization of treated wastewater and transfer or discharge are an integral part of the national hydraulic equipment programme and are the responsibility of the state, like all related projects. The advantage of this water resource is that it is always available and can meet pressing needs for irrigation water. Indeed use of wastewater saved citrus fruit when the water resources dried up (due to over-exploitation of groundwater) in the regions of Soukra (600 inhabitants) and Oued Souhil (360 inhabitants) since 1960 and contributed to the improvement of strategic crop production (fodder and cereals) in new areas.

The volume consumed differs greatly from one area to another, according to climatic conditions (11–18 million m^3/year). At present, treated wastewater is an available source of water for farmers, but on the one hand, it is not suitable for crops that are economically profitable, and on the other hand, it poses some health risks. The best levels of utilization are found in fruit crop areas, in areas with a tradition of irrigation and in semi-arid areas.

With a projected volume of 215 million m^3 by the year 2006, the utilization potential of this water was expected to be about 25,000 ha, which is 65 % of the areas that can be irrigated. This is based on the assumption that intensive inter-seasonal storage and a massive introduction of water saving systems would increase the mobilization rate to 45 %. It is expected that additional treatment of treated wastewater will improve the rate of use in irrigated areas (Trad Rais et al. 2011).

Agricultural reuse, however, will not see marked improvement, unless restrictions are lifted on pilot wastewater treatment plants with complementary treatment processes. This can only be decided when the stations are functioning with acceptable reliability. This will take a few years of experience. Nonetheless, in all cases, and regardless of the treatment method, technical and organizational measures should be introduced in order to systematically warn those managing the reuse of any breakdowns that may occur in the wastewater treatment plants and to avoid the flow of treated wastewater into the distribution network.

4.2 Jordan

In Jordan, the inclusion of wastewater reuse in its national water strategy since 1998 was a sign of placing high priority on the value of reclaimed water. Wastewater represents 10 % of Jordan's total water supply (WaDImena 2008), and up to 95 %

of its treated wastewater is being reused (MED WWR WG 2007). It should be noted however that in Jordan treated wastewater is mixed with freshwater and then used for unrestricted irrigation in the Jordan Valley.

In 2009, the new national water strategy was published, which put forward, among others, the following approaches to further support wastewater reuse in irrigation (MWI 2009):

- Introduction of appropriate water tariffs and incentives in order to promote water efficiency in irrigation and higher economic returns for irrigated agricultural products. Managing treated wastewater as a perennial water source which shall be an integral part of the national water budget
- Ensuring that health standards for farm workers as well as consumers are reinforced and that all wastewater from municipal or industrial treatment plants will be treated in such a way that the effluent meets the relevant national standard
- Periodical analysis and monitoring of all crops irrigated with treated wastewater or mixed waters
- Designing and conducting programmes on public and farmers' awareness to promote the reuse of treated wastewater, methods of irrigation and handling of produce

Actually, in Jordan, there are 23 domestic wastewater treatment plants generating more than 100 million m^3 of treated wastewater per year. These treatment plants were established in large cities and actually serve large areas surrounding these cities. All of the effluents of the existing treatment plants in Jordan are either directly used for irrigation or are stored first in reservoirs/dams that are used for irrigation. The Ministry of Water and Irrigation forecasts that the amount of wastewater used for irrigation will exceed 230 million m^3 by 2020, especially in the Jordan Valley (JMWI 2009).

Since 2002, the government of Jordan, with the support of international organization, has been implementing several direct water reuse activities (Aqaba and Wadi Musa projects) whose objective is to demonstrate that reclaimed water reuse can be reliable, commercially viable, socially acceptable, environmentally sustainable and safe. The Wadi Musa pilot farm project near the historic city of Petra uses the treated effluent of the Petra Regional Wastewater Treatment plant to grow a variety of agricultural crops (including alfalfa, maize, sunflowers, Sudan grass), tree crops (including pistachio, almond, olives, date palms, lemons, poplars, spruce and junipers), and many varieties of ornamental flowers (iris, geraniums, petunias and daisies).

4.3 Morocco

In Morocco, the reuse of raw wastewaters has become a current practice. They are reused in agriculture in several parts the country. These practices are mainly localized to the periphery of some big continental cities where agricultural lands are located in the downstream of treated effluent.

The irrigation of vegetable crops with raw wastewaters is forbidden in Morocco. In general, the volume of wastewaters that have been recycled does not represent more than 0.5 % of the water used in agriculture.

Since the early 1990s, many multidisciplinary projects concerning the treatment and reuse of wastewater in irrigation have been launched in Morocco. The aim was to address the major agronomic, health and environmental concerns. The results of these researches have made the local communities and the regional agriculture services to benefit from reliable data. The latter are necessary to conceive and to determine the right size of the treatment plants for the locals and to disseminate the best practices for reusing treated wastewaters in agriculture (Choukr-Allah 2005). However, the acquired experience in wastewater treatment and reuse projects has generated little progress in practice due to political and policy constraints (Chenini 2009). In 2008, the Moroccan government launched several reuse projects focusing mainly on providing irrigation water for golf courses and for landscaping purposes in the cities of Marrakech, Benslimane and Agadir covering a surface area of 3,000 ha.

The Moroccan government is focusing on demand-driven planning of reuse projects, and a good example for this is the partnership developed between the golf course of Agadir, and Marrakech in Morocco and the water agencies in those cities to supply them with continuous treated wastewater (Choukr-Allah 2008). This demand for treated effluent is driven by the scarcity of this resource in Marrakech, and to the high salinity of the ground water in the Agadir area.

4.4 Egypt

Egypt produces about 3.5 billion m^3/year of municipal wastewater, while current treatment capacity is in the range of 1.6 billion m^3/year. An additional treatment capacity of 1.7 billion m^3/year is targeted by 2017 (Tawfic and El Gamal 2008). Although the capacity increase is significant, it will not be sufficient to cope with the future increase in wastewater production from municipal sources, and, therefore, the untreated loads that will reach water bodies are not expected to decline in the coming years. The Delta Region alone generates more than 2 billion m^3/year, most emanating from Egypt's two greatest urban centres, Cairo and Alexandria. Treatment plants serve 55 % of the population in towns and cities (Tawfic and Gamal 2008). The total volume reused in 2002 was 3,508 million m^3/year. Most of the treated wastewater is reused to irrigate food crops, industrial, fuel, cosmetic crops (Jojoba), green belt, trees along the desert roads and woodland forest (AHT Group AG 2009).

The regulation of the reuse in Egypt is based on the Decree 44/2000 specifying the kind of soil, the method of irrigation and the crops to be irrigated.

5 Wastewater Treatment Technologies

The choice of the right wastewater treatment technologies is the most important parameter in planning the water reuse because they are the important way of decreasing or eliminating the environmental risk. The purpose of the wastewater treatment is to protect the consumer from pathogens and from impurities in the water that may be dangerous to human health.

Unauthorized irrigation with non treated wastewater was the main source of cholera outbreaks in Mediterranean countries (Choukr-Allah and Hamdy 2004) with many hospitalized people and many fatalities. Such outbreaks also caused a severe reduction in the tourism to some countries and may have affected the tourist industry in these countries for several years.

Communities in south Mediterranean countries have several features in common that guide the design and operation of wastewater treatment plants; they are:

1. Need for wastewater reuse for irrigation during the long dry summer months and the need for seasonal storage of wastewater from winter to summer
2. Have enough inexpensive available land area around and adjacent to the community
3. Have abundant sunlight in these regions, giving advantage to photosynthetic and other solar-energy-dependent processes
4. Have relatively concentrated wastewater due to limited per capita water consumption rate
5. Have relatively high pathogenicity of the wastewater due to endemicity of certain diseases and high proportions of carriers
6. Have shortage of capital investment
7. Absence, shortage or unreliability of electrical power
8. Need for minimal, simple and inexpensive operation and maintenance of facilities

The motivation for investments in wastewater treatment plants can be increased by using the treated effluent for agricultural irrigation. This will add an economical value force both for increasing capital investments and the expenses needed for proper operation and maintenance of the wastewater treatment facilities. Effluent quality aspects are also influenced by the decision to use the effluent for irrigation, since the demand for high removal efficiency of pollutants like nitrogen and phosphorous does not exist, while the treatment technology should be directed for high hygienic demands. By using the effluent for controlled irrigation (e.g. drip irrigation), much of the environmental risks caused by other effluent disposal alternatives (e.g. disposal to rivers, lakes, sea) are prevented, so it is obvious that both the farmers and the environment can be benefited from effluent reuse in small communities.

The selection of technologies should be environmentally sustainable, appropriate to the local conditions, acceptable to the users and affordable to those who have to pay for them. In developing countries, western technology can be more expensive and less reliable to control pollution from human domestic and industrial wastes. Simple solutions that are easily replicated, that allow further upgrading with subsequent development and that can be operated and maintained by the local community are often considered the most appropriate and cost-effective. The choice of a technology will depend to the type of reuse. The selection of reuse option should be made on a rational basis. Reclaimed water is a valuable but investment costs should be proportional to the value of the resource. Also, the reuse site must be located as close as possible to the wastewater treatment and storage facilities.

In the case of irrigation reuse, this involves the crop(s) to be irrigated, the aquifer characteristics below the crop, the soil, the method of irrigation and the irrigation water demand pattern. Each type of crop has different tolerances for certain pollutants, specific patterns for nutrient demand and limitations and different patterns of demand for irrigation water. Unconfined aquifers of limited capacity will be much more sensitive to irrigation water constituents that would percolate below the root zone and are flushed out to the aquifer surface than would be a confined aquifer or one of greater volume. Similarly, certain soils are more capable of removing dissolved constituents than others due to their physical and chemical characteristics and prior history of use.

Traditional criteria used for pond design are not normally of great importance in water-short areas like North Africa, since ponds are designed for BOD removal, not faecal coliforms or parasitic egg removal, the removals of faecal coliforms and nematode eggs control the design. Only when a wastewater with a very high BOD (800 mg/l or more) should BOD removal model be considered. Since the removal of pathogens is a time-related relationship, substitution of a constructed wetland for some of the maturation-pond time required in the lagoon system should be feasible; however, no studies have yet determined exactly what the equivalency ratio is.

In summary, the options for a small community and the choice of treatment for ultimate reuse will hinge on the following:

- Reuse requirements – If the reused wastewater is to be used for vegetables, citrus or other crops to be eaten raw, the options employing stabilization ponds and intermittent filters can be used, or a recirculating filter may be substituted with subsurface drip irrigation only.
- Land availability – If sufficient land is available, the other limitations stated above and below will control the options evaluated. If land availability is limited by economics or terrain or surrounding development, sand filter options should be chosen.
- Operational capability – If a sufficiently skilled management programme with electricity is available, all options are possible. If, as is often the case, only unskilled labour is locally available, only the pond-wetland or anaerobic lagoon-intermittent filter options are viable.

Southern Mediterranean countries face many problems in terms of the operation and maintenance of the full and partially full mechanical systems, due to a lack of requisite skilled labour. The high cost of operation and maintenance is also problematic and is caused by the high cost of the spare parts, or a lack of spare parts sometimes due to discontinued production by industry. However, the need for experts to operate and maintain these complicated systems and the need for continuous training of system operators are considered secondary to the problem of a lack of spare parts.

6 European and Mediterranean Wastewater Reuse Guidelines

The legal status of wastewater reuse is not uniform across Europe. Many European countries and northern African countries do not have specific regulations. Some of them have national regulations, laws, recommendations, etc. So far no regulation of wastewater reuse exists at a European level. The only reference made by the EU on the matter of wastewater is Article 12 of the European Wastewater Directive (91/271/EEC).

Recently, a group of experts in the water recycling have proposed international guidelines for recycled wastewater based on draft Australian guidelines. These guidelines are based on the level of faecal coliforms, intestinal nematodes, total soluble solids and treatment received by the wastewater. A preliminary study for establishing quality criteria of recycled wastewater in Mediterranean region has been undertaken by Bahri (2008).

The EU Wastewater Directive has proven to be very effective in promoting the collection and treatment of wastewater, but it does not promote the reuse of the generated wastewater. The directive only states that wastewater should be reused *wherever appropriate,* but there is no clear definition of what is appropriate. Similar directives are found in some southern countries of the Mediterranean.

Other important guidelines that exist for wastewater reuse are the ones published jointly by the World Health Organization (WHO) and Food and Agriculture Organization (FAO) and are mainly focused on the needs of developing countries. These guidelines specify the microbiological quality and the treatment method required to achieve this quality, which is limited to the use of stabilization ponds since it is cheaper and simpler and ensures removal of parasites which are the most infectious agents in the developing world. Those guidelines are more suitable to southern Mediterranean countries.

7 Realistic Standards and Regulations

An important element in the sustainable use of wastewater is the formulation of realistic standards and regulations. However, the standards must be achievable and the regulations enforceable (Abu-Madi 2004).

Unrealistic standards and non-enforceable regulations may do more harm than having no standards and regulations because they create an attitude of indifference towards rules and regulations in general, both among polluters and administrators. As the WHO microbiological guidelines expect certain levels of wastewater treatment, their enforcement in situations without any realistic option for treatment would stop hundreds or thousands of farmers from irrigating along increasingly polluted streams and put their livelihoods at risk but would also affect food traders and general market supply.

Without question, the enforcement of microbiological guidelines or crop restrictions remains important, but a better balance between safeguarding consumers' (and farmers') health and safeguarding farmers' livelihoods should be made, especially in situations where the required water treatment or agronomic changes are unrealistic. However, further research is needed into hygienic food marketing as well as the safe food preparation at home as important options to tackle the wastewater problem in low-income countries.

Most often, WHO guidelines have been used, or cited in isolation from the other protective measures. If water quality, however, cannot be guaranteed, agricultural engineers should investigate possibilities of alternative irrigation technologies and irrigation methods reducing farmers' exposure. Also, in certain case, additional treatment (up to tertiary level) to remove certain contaminants will help change farmers attitude, as this will allow them to grow cash crops (vegetables).

8 Conclusion and Recommendations

The Mediterranean region is characterized by the low level and irregularity of water resources, both through time (summer drought, inter-annual droughts) and through space (dry South). The region includes 10 % of the world population with renewable national natural resources of less than 1,000 m^3 water/inhabitant/year. The strong growth in urbanization, tourism, irrigation, and population can only increase tensions among users and sectors in many countries and regions where consumption has already reached or exceeded the amount of available resources.

Most Mediterranean countries are arid and semi-arid. They have low precipitation, mostly seasonal with uneven distribution. Moreover, due to the rapid development of urban and rural domestic water supplies, conventional water resources have been seriously depleted, and wastewater reclamation and reuse, particularly for irrigation, gained increasing role in the planning and development of water resources availability. The use of reclaimed wastewater for irrigation contributes to water conservation and, therefore, is an important component of a sound policy for water resources management in Mediterranean region.

It appears, from the several reuse projects in the Mediterranean region countries, that we should examine thoroughly whether uses of wastewater other than agricultural might also be economically interesting and ecologically sustainable. In fact, the reuse of wastewater in industry, recreational areas, in forestry and on golf courses seems to be more economical and could also increase the percentage of reused wastewater, in this way contributing to increasing the efficiency of the Mediterranean region's overall water use.

The full value of treated wastewater has been recognized in relatively few water-stressed Mediterranean countries (such as Tunisia, Jordan, Mata, Cyprus and Israel). In these countries, fully fledged local or state regulations supported by national guidelines set the basic conditions for wastewater treatment and safe reuse.

The use of treated wastewater should be regarded as a mean of increasing water availability and can contribute to the good quality status of water resources in the Mediterranean region and should therefore be considered as an option in the national water strategy plans.

Economic, social and environmental concerns must all be taken into account in accordance with the goal of sustainability. It is important to strengthen the capacity building of national and local hydrological research institutes to improve their links to environmental research as well as to institutions in the field of economic and social science, particularly in the field of urban studies and planning. The transfer of knowledge to local government decision-makers must be improved. Local governments must focus their policies on treating municipal wastewater to eliminate the rapid degradation in both surface and groundwater quality. In this regard, simple methods of wastewater treatment are to be recommended as realistic solutions; governments have to operate as well in order to strengthen the capacity building of both institutions and users. Efforts concerning domestic sewage must focus on promoting and further developing low cost, easy-to-handle, and, in general, regionally developed technologies with a low degree of complexity. Special attention must be paid on minimizing the energy needs for these technologies.

Monitoring and evaluation of wastewater use programmes and projects is a very critical issue, hence, both are the fundamental bases for setting the proper wastewater use and management strategies. Ignoring monitoring evaluation of parameters and/or performing monitoring not regularly and correctly could result in serious negative impacts on health, water quality and environmental and ecological sustainability.

To achieve general acceptance of reuse schemes, it is of fundamental importance to have active public involvement from the planning phase through the full implementation process. Cooperation between local governments and the non-governmental sector, which is now far below the level required, has to be enhanced and improved. In this regard, the involvement of the non-governmental organizations (NGOs) in the management of infrastructural institutions has to be strengthened, and the public participation and individual responsibility within the framework of urban water supply and wastewater treatment and use projects have to be mobilized.

Finally, in order to achieve meaningful implementation and to secure the necessary funding from donors, further research must be carried out to evaluate the feasibility and the cost-effectiveness of wastewater use and better estimates of the economic value of wastewater use in urban and peri-urban agriculture have to be made.

Therefore, wastewater reuse needs to be perceived as a measure towards three fundamental objectives within a perspective of integrated water resources management, assuring environmental sustainability, economic viability and a contribution to food security.

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Wastewater Production, Treatment and Reuse Around the Mediterranean Region: Current Status and Main Drivers

Maite Guardiola-Claramonte, Toshio Sato, Redouane Choukr-Allah, and Manzoor Qadir

Abstract Freshwater is unevenly distributed amongst the countries bordering the Mediterranean (MED) Sea. Accounting for almost 7 % of the global population, the MED region only has just over 2 % of the world's freshwater resources, with two-thirds of them concentrated within the northern Mediterranean countries. With agriculture being the main user of freshwater, the reuse of treated urban wastewater for agriculture could, at least, relieve current freshwater stress. However, the capabilities of treatment and the motivations for reuse of treated wastewater differ amongst the MED countries. Northern countries, which enjoy better economic status and have relatively less water stress condition, treat up to 90 % of their generated wastewater, but they are the lowest in reusing the treated wastewater in the region. Most southern and eastern MED countries treat lower percentages of wastewater but use significant volume of treated and even untreated (or poorly treated) wastewater for irrigation. There is an imperative need to consider water saving and recycling strategies as population grows and future climate predictions anticipate a significant

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decrease in available freshwater resources in the MED region. This chapter not only reviews current production, treatment and reuse of wastewater in each MED country but also analyses their main drivers and constrains for reuse.

Keywords Wastewater production • Wastewater treatment • Wastewater reuse • Mediterranean countries

1 Introduction

The Mediterranean region, with almost 7 % of the world population, has less than 3 % of the world's freshwater resources. The freshwater resources in the MED region are also unevenly distributed; 72 % is in the northern countries (Aquastat 2011), 20 % in the eastern countries and the remaining 8 % in the southern countries. These southern countries however account for over 35 % of the Mediterranean population (Aquastat 2011). Estimations suggest the southern population might increase to 37 % of the MED population, while global climate variability may further reduce the available amount of freshwater; so more people might have to share a smaller fraction of water resources (IPCC 2007). Current predictions anticipate not only increase in temperatures and in the frequency and intensity of heat waves (Meehl and Tebaldi 2004) but a pronounced decrease in precipitation (up to 20 %) in most of the Mediterranean region (Giorgi and Lionello 2008; IPCC 2007). The already limited water resources in the region are expected to become scarcer and polluted, as population increases and agglomerates in cities.

Reuse of treated wastewater (also referred to as recycled water, or reclaimed water) offers an additional, reliable and often constant source of water that seems to be gaining momentum amongst some of the Mediterranean countries. The Mediterranean region as a whole is currently producing 30 Mm^3/year of wastewater (Table 1), of which 73 % is treated. Twenty-one percent of the treated effluent is reused and not only for agricultural uses but also for landscape irrigation, golf courses and maintaining ecological flows. Its use might not solve the problem of water scarcity but can help in alleviating it. Its adoption as an additional water source greatly varies from country to country. Many efforts have been made to quantify the status of reuse and understand its main drivers and bottlenecks in countries around the Mediterranean (Ghneim 2010; Qadir et al. 2010; McIlwaine and Redwood 2010; Choukr-Allah 2010; Chenini et al. 2003; AQUAREC 2004, 2006a; Scheierling et al. 2010; Abu-Madi and Al-Sa'ed 2009; Angelakis and Durham 2008). Some of these studies relate reuse with the level of sanitation, economic status, legislations and available water resources, amongst others, as a means to better understand their trends of wastewater treatment and reuse. Others focus either only on European countries (Angelakis and Durham 2008; AQUAREC 2006b) or Middle Eastern and North African (MENA) countries (Qadir et al. 2010; Choukr-Allah 2010; Abu-Madi and Al-Sa'ed 2009; Ghneim 2010), but there are few critical studies that cover the complete MED region (Angelakis et al. 1999).

Table 1 Volumes of wastewater produced (WWP), treated (WWT) and treated reused (TWWR) in Mm³/year in Mediterranean countries

Country	WWP	Year	WWT	Year	TWWR	Year
Albania	477[a]	–	0[b]	2003	0	2003
Algeria	820[c]	2002	700[d]	2011	2.2[e]	–
Bosnia-Herzegovina	78.5[f]	2009	3.9[f]	2009	–	–
Croatia	324.8[g]	2009	206.0[g]	2009	–	–
Cyprus	24.0[h]	2005	22.4[h]	2005	25[i]	2008
Egypt	4,930[j]	2008	2,971	2001	2,971[c]	2001
France	7910[k]	2004	7,200[k]	2004	410.9[l]	2004
Greece	719[a]	2000	450[m]	2000	7.3[i]	2008
Israel	450[c]	2005	283[c]	2005	280[i]	2008
Italy	7,731[a]	–	2,400[n]	2004	270.6[i]	2008
Jordan	180[n]	2002	107.4[c]	2005	83.5[c]	2005
Lebanon	310[o]	2001	4[c]	2006	2[c]	1991
Libya	546[c]	1999	40[c]	1999	40[c]	1999
Malta	19[c]	2003	22[p]	2006–2007	9.5[i]	2008
Monaco	7.3[q]	2009	6.02[q]	2009	0[q]	2009
Montenegro	30.2[r]	2009	1.2[r]	2009	–	–
Morocco	700[s]	2011	177[s]	2010	80[s]	2001
Palestinian territories	71[t]	2001	26.9[o]	2004	10[c]	1998
Portugal	522[u]	2008	502[u]	2008	–	–
Slovenia	168.5[v]	2009	115.3[v]	2009	6.9[v]	2009
Spain	5,204.4[w]	2007	4,515.6[w]	2008	525.5[w]	2008
Syria	1364[c]	2002	550[c]	2002	550[c]	2002
Tunisia	187[c]	2001	238[x]	2011	21,0[c]	2001
Turkey	4,289[y]	2008	2,484[i]	2008	1,000[c]	2006

[a]Estimated from 85 % of total municipal water extractions from Aquastat (2011)
[b]INSTAT (2011). As in 2010, the first treatment facilities existing were still under construction (EEA 2010)
[c]Aquastat (2011)
[d]Hammouche (2011)
[e]According to Hammouche (2011), 4,310 ha is irrigated with treated wastewater with an average 5,000 m³ per ha; a total volume of 2.16 Mm³ is reused
[f]FBHFOS (2011)
[g]CBS (2011)
[h]SSRC (2007)
[i]Scheierling et al. (2010) adapted from Jiménez and Asano (2008)
[j]Loutfy (2010)
[k]IFEN (2011)
[l]Eurostat (2011)
[m]AQUAREC (2006a)
[n]USEPA (2004), but according to the Abusoud (2009), in 2008 only 100 Mm³/year of wastewater were collected
[o]Loizidou et al. (2004)
[p]WSC (2011)
[q]PMDE (2009)
[r]MONSTAT (2011)
[s]Bourziza and Makhokh (2011)
[t]PECDAR (2001) cited in Fatta et al. (2004)
[u]INE (2011b)
[v]SORS (2009)
[w]INE (2011a)
[x]Trad et al. (2011)
[y]Turkstat (2008)

This chapter reports the current situation of available water resources, volume of wastewater production, collection, treatment and reuse for all the Mediterranean (MED) countries. It critically analyses the main drivers and limitations for reuse in each country, contrasting this information with not only the country's available water resources but also looking at their national water policies with regard to water recycling.

2 The Mediterranean Region

There are 22 states that border the Mediterranean Sea. They are usually grouped into northern Mediterranean countries (Spain, France, Monaco, Italy, Greece, Malta, Slovenia, Bosnia-Herzegovina, Croatia, Montenegro and Albania), eastern countries (Turkey, Syria, Lebanon, Israel, Palestinian territories and Cyprus) and southern countries (Egypt, Libya, Tunisia, Algeria and Morocco). The current study focuses not only on these 22 states but also considers Jordan and Portugal, which, despite lacking Mediterranean coast, are often considered Mediterranean countries in a wider sense, as they benefit from a similar climate and face analogous water scarcity problems.

3 Main Drivers for Wastewater Reuse

There is a strong contrasting trend amongst MED countries in regard to the volume of wastewater treated and reused. On one hand, northern European countries treat in average 66 % of their collected wastewater (15.4 km^3), while eastern and southern countries only treat half of their collected wastewater (7.6 km^3) (Aquastat 2011). On the other hand, when it comes to recycling, the northern countries reuse 8 % of the treated wastewater (1.2 km^3) in contrast with the 67 % (5.1 km^3) of all treated wastewater in southern and eastern countries.

These tendencies become visible when plotting the normalized (with the population) fraction of wastewater treated, untreated and reused in the MED (Fig. 1). Most of the northern MED countries are grouped in the lower right corner, meaning countries with high rates of treatment but lower rates of wastewater reuse. South-eastern countries are grouped towards the left side of the diagram, indicating low levels of treatment but high volumes of reuse.

These different trends can be partially explained by the motivation and constrictions behind treatment and reuse. There are several factors that influence a country's treatment and/or reuse status like its freshwater resources availability, main water uses, economic status, the presence of a legal framework and public awareness, amongst the most relevant ones.

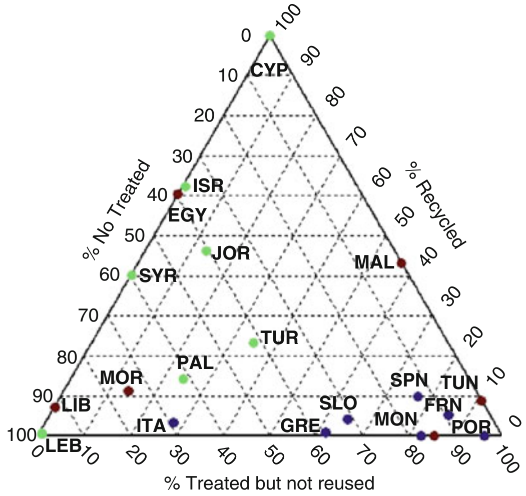

Fig. 1 Fraction of volume of wastewater produced per capita, which is recycled, treated but not reused and not treated. The *blue*, *green* and *red dots* correspond to northern, eastern and southern Mediterranean countries, respectively. Not all the Mediterranean countries are present because of missing data (see Table 1 for references). Collected volume of sewage has been assumed to be equal to treated when the literature estimates were smaller. The labels next to the dots represent the three first letters of the country, from *top down* and *left right*: Cyprus (*CYP*), Israel (*ISR*), Egypt (*EGY*), Jordan (*JOR*), Malta (*MAL*), Syria (*SYR*), Turkey (*TUR*), Palestine (*PAL*), Morocco (*MOR*), Spain (*SPN*), Tunis (*TUN*), Libya (*LIB*), Slovenia (*SLO*), France (*FRA*), Italy (*ITA*), Greece (*GRE*), Lebanon (*LEB*), Montenegro (*MON*), Algeria (*ALG*) and Portugal (*POR*) (see Table 1 for references of the data) (Color figure online)

3.1 Water Resources Availability

Only 28 % of the total renewable water resources available in the Mediterranean region are shared amongst the eastern and southern countries. It is not surprising then that the annual renewable water resources (ARWR) for each south-eastern country falls below the threshold value of 1,000 m^3 per capita (except for Turkey) (Fig. 2) (Aquastat 2011). It is thought that a country with ARWR below this threshold might suffer serious water shortages which may negatively impact on its economic growth, citizen's health and their well-being (Falkenmark and Linch 1993).

Reuse of treated wastewater is still not considered in all MED countries as a resource to reduce water shortage. With less than 100 m^3 ARWR per capita (Fig. 2), Libya is the most water-deficient country in the Mediterranean, followed very closely by Malta and Jordan (Aquastat 2011). Libya's government has pushed for building large hydraulic infrastructure dependent on their fossil groundwater resources rather than pushing for sustainable sources and reuse of treated wastewater (Wheida and Verhoeven 2007). Nevertheless, countries like Malta and Jordan, with

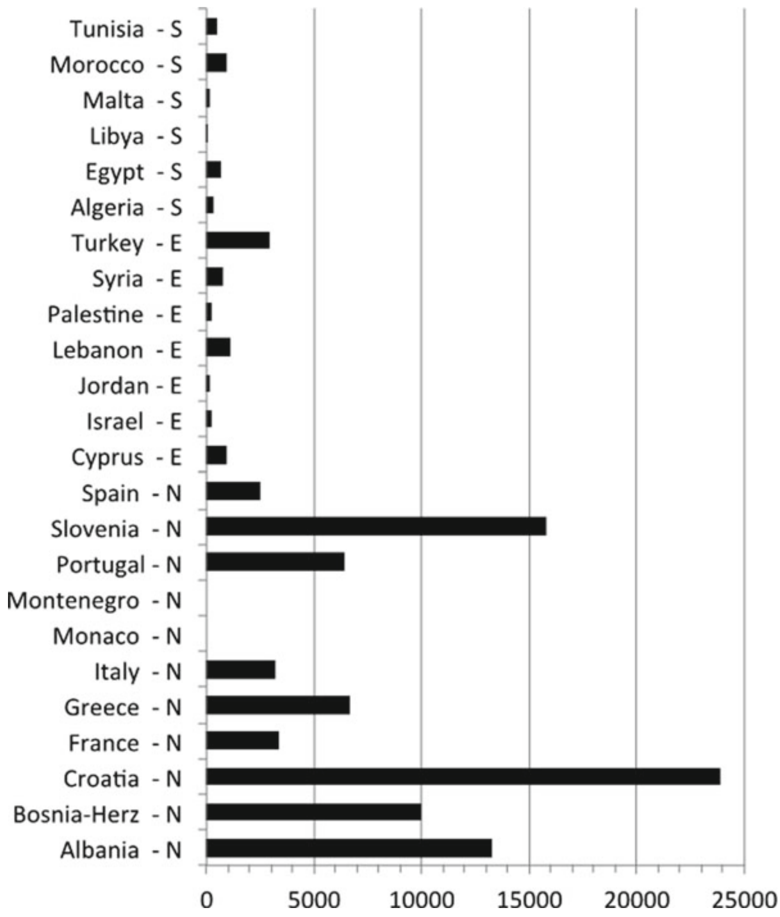

Fig. 2 Annual renewable water resources (ARWR) per capita (m^3) in Mediterranean countries (Aquastat 2011)

similar ARWR as Libya, have developed some of the highest wastewater reuse practices in the Mediterranean region.

Amongst the economically strongest countries, the lack of renewable water resources is a catalyst for reuse of treated wastewater, when their ARWR is low. The richest southeastern MED countries (highest Human Development Index, HDI[1])

[1] Human Development Index (HDI) is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development: (a) long and healthy life, as measured by life expectancy at birth; (b) knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one third weight); and (c) a decent standard of living, as measured by GDP per capita (purchasing power parity or PPP US$).

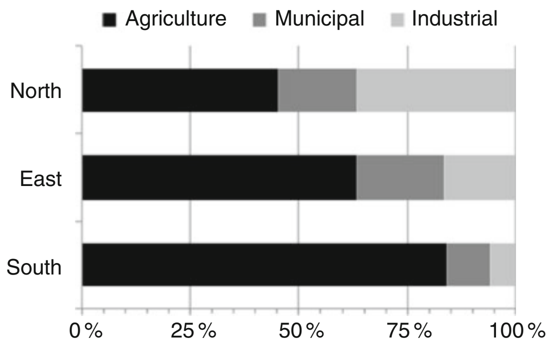

Fig. 3 Fraction of water extracted for agricultural, municipal and industrial use from the total annual extractions (Aquastat 2011)

Israel, Malta and Cyprus are highly proactive in wastewater treatment and reuse. It is not surprising that two of these countries are islands, where the access to water supplies is extremely limited and where the environmental equilibrium (quantity and quality of water) had been disturbed in the past due to over-abstraction of freshwater.

Despite their low ARWR, wastewater treatment and reuse of treated wastewater are limited in Syria, Egypt and the Palestinian territories due to economic and, in some cases, political reasons. Nevertheless, the use of inadequately treated or even untreated wastewater (direct or indirect) is common, as there are limited or no alternative water sources, indicating the acceptance by the population of using poor quality water for irrigation. It is thus expected that farmers would embrace the use of reclaimed, properly treated water for irrigation.

All northern MED countries have an ARWR per capita above 2,000 m^3, a value estimated to be needed to achieve adequate living standards (Postel 1993). However, along the Mediterranean coastal regions, water stress is common and is exacerbated during the dry summer months, when agricultural water demand overlaps with the water demand needed to support the touristic infrastructures. The coastal regions of France, Spain and Portugal have interesting projects on reclaimed water reuse, mostly devoted to agriculture but also for landscape and golf course irrigation (Afssa 2008).

Within Europe, the Mediterranean Balkan countries are the richest in terms of ARWR per capita, Croatia topping the list with almost 24,000 m^3 (Aquastat 2011). Water scarcity is not an issue at the national level but might locally be significant, as is the case for some islands of their coastal regions (UNEP and MAP 2000). Reuse is not a priority, as most of the Balkan countries still face low levels of sewage collection infrastructure that need to be solved if they would be integrated within the EU. Figure 3 shows the percent of water used by agriculture, domestic and industry in the north, east and south of the Mediterranean region (Aquastat 2011).

3.2 Water and Reclaimed Water Use

Although the volume of utilized reclaimed water varies extensively amongst the Mediterranean countries, the primary use for it in all countries is agriculture. This is not surprising as most of the freshwater extractions in the Mediterranean are already devoted to agricultural purposes. On average, for the entire Mediterranean basin, 60 % of all extracted water is used for agriculture, reaching up to 89 % in some cases (Aquastat 2011).

Recent estimates from Aquastat (2011) suggest Greece as the country with the largest fraction of their water extractions (89 %) going to agriculture closely followed by Cyprus (88 %), Syria (87 %) and Egypt (86 %). Syria does not only have one of the largest volumes of extraction of natural water for agricultural purposes in the Mediterranean, but it is estimated to top the list in the extension of land irrigated with raw or inadequately treated wastewater (over 30,000 ha) (Scheierling et al. 2010), while the neighbouring country, Israel, tops the list of countries irrigating the largest extensions with recycled water (65,000 ha), followed by Egypt and Cyprus with just below 40,000 ha (Scheierling et al. 2010).

The rest of the eastern and southern MED countries use over 50 % of their water extractions for agriculture. On the north shore of the MED, in addition to Greece, Portugal and Spain use 70 and 60 %, respectively (Aquastat 2011).

Ranking the countries according to their wastewater reuse index (WRI) (Abu-Madi and Al-Sa'ed 2009) gives further indications of countries' practices (Fig. 4). This index evaluates a country's reuse volume as a fraction of their total capacity of wastewater production. The WRI index ranges from 0 (no reuse) to 100 (full reuse). It takes into consideration the collection of wastewater as a fraction of the volume produced, the treated volume in relation to the wastewater collected and the reused volume as a fraction of the treated volume. Based on the information from Table 1 and considering that the fraction of collected wastewater was 93 % in northern Mediterranean countries (SEC 2009) and 80 % in eastern and southern countries (Abu-Madi and Al-Sa'ed 2009), we computed the WRI for all the MED countries. Cyprus and Israel topped the list with WRI of 100 and 62.2, respectively (Fig. 4). The maximum score of Cyprus is an artefact partly due to the lack of data availability. Nevertheless, the country is amongst the recycling leaders of the Mediterranean region. The inaccuracy is due to the wastewater production and treatment data being old and reporting lower volumes of recycled water than the actual ones.

The WRI exposes how eastern MED countries, followed by southern MED countries, are leading in wastewater reuse in the region. It is not a surprise that Spain ranks first amongst the northern MED countries, given its important water demand for irrigation and its lowest ARWR in Europe, features that make the country to have the highest reuse potential amongst the northern MED countries (Angelakis and Durham 2008; AQUAREC 2006b).

The log-negative relationship between WRI and ARWR ($r^2 = 0.21$) supports the observed trend that wastewater reuse prevails in water-scarce countries and countries that devote most of their water extractions to agriculture. For example, northern countries divert on average 45 % of their total water extractions to agricultural

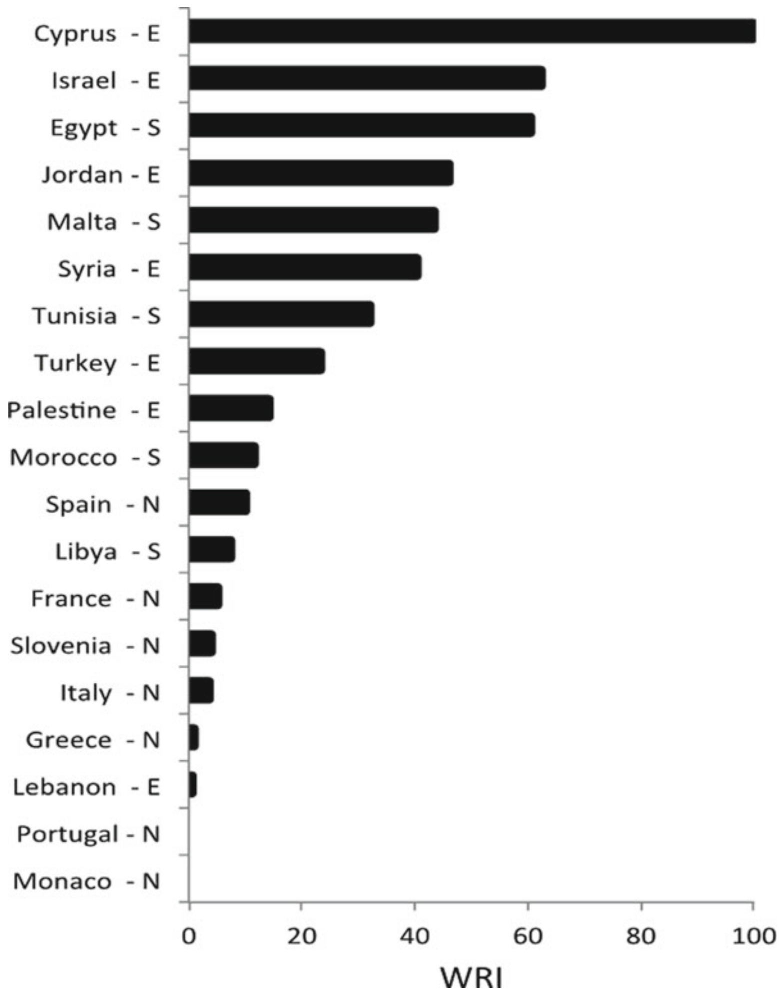

Fig. 4 The wastewater reuse index (WRI) for the Mediterranean countries with available data (see Table 1 for source of data). N, S and E indicate the location of the countries within the Mediterranean region as northern, eastern and southern Mediterranean countries, respectively

purposes (59 km^3), reusing 8 % of their treated wastewater, while irrigation accounts for 84 % (80 km^3) of the southern countries' water extractions but using 75 % of their treated wastewater for irrigation (Aquastat 2011).

The Mediterranean region is one of the leading tourist destinations in the world, with 364 million tourists in 2000. It is estimated that the number of tourists might increase to 637 million by 2025 (UNEP et al. 2005). Water demand by the tourist sector is not well established but appears to be significant. In Malta, Cyprus and Spain, tourism-related water use can reach a few percent of total domestic water use (Gössling 2006). However, tourist-related water demand peaks simultaneously as agricultural water demand when resources are at their lowest (UNEP et al. 2005), contributing to the water stress. Many MED countries, for example, Portugal, Spain and Tunisia, are pushing for reuse of water within the touristic sector, mainly for golf course irrigation (Bahri et al. 2001; Mujeriego 2007).

3.3 Economic Status

There is a relationship between a country's economic development and the volume of wastewater collected and treated. The MED countries show a weak but positive correlation ($r^2 = 0.22$) between the human development index (Aquastat 2011) and the volume of treated wastewater, when accounted per person and per year. Treatment levels amongst the northern MED countries are estimated to be around 66 % of their urban produced effluent. Their overall ARWR per capita are well above 1,700 m^3; thus, one of the main motivations behind treatment is to comply with the EU Wastewater Directive 91/271/EEC that imposes the full collection and treatment of wastewater in all settlement areas with a population of more than 2000. However, reuse of treated wastewater is low (8 % of the treated wastewater), as there is no enforcement by the EU legislation. Thus, unless the regional water balance is under stress, recycling is little practised.

3.4 Wastewater Reuse Legislations and Standards

International legislation and directives, such as the EU legislation, promote wastewater treatment encouraging its reuse. Some international organizations, like the World Health Organization (WHO), the Food and Agriculture Organization of the United Nations (FAO) and the United States Environmental Protection Agency (USEPA), have gone further and have even defined thresholds and recommendations for the safe reuse of wastewater for different purposes. These guidelines, despite not being accepted and used by all countries, have, in some instances, been adapted to meet country-specific socio-economic, cultural and environmental conditions and adopted as specific national legislations (Zimmo and Imseih 2011).

3.4.1 EU Legislation

Efforts for protecting the environment and natural resources in the Mediterranean region formally started in 1975 with the adoption by 16 coastal countries of the European Union of the Mediterranean Action Plan (MAP). Today, the contracting parties have expanded to the 21 shore countries (and the European Community), and they are not only determined to protect the Mediterranean Sea but also to achieve sustainability of their water resources under the 'Mediterranean Strategy for Sustainable Development'. One of their main objectives is to ensure the sustainable management of natural resources in the region, with emphasis on improving integrated water resources and water demand management (UNEP and MAP 2005).

As a means to protect and increase the existing water resources, in 1991 the European countries of the Mediterranean adopted the Urban Wastewater Treatment Directive (91/271/EEC) concerning the collection and treatment of urban wastewater according to the sensitivity of the receiving waters. This directive has greatly encouraged wastewater treatment in many European countries. For example, amongst the EU-15 countries,[2] the rate of wastewater collection is more than 95 % of the generated discharge. Only in Spain the volume of wastewater collected and treated doubled between 1999 and 2004 (INE 2011a). Wastewater collection in the countries that joined the European Union later (EU-12[3]) is above 70 %, with the exception of Cyprus (49 %) (SEC 2009). Amongst all the EU countries surveyed in 2009, 93 % of produced sewage was collected and 87 % treated up to secondary level (SEC 2009).

3.4.2 Wastewater Reuse Guidelines

As early as 1978, the state of California started its efforts to regulate the use of recycled water for agriculture, setting up very restrictive thresholds for microorganisms and chemicals (Angelakis et al. 1999). The USEPA, following the state of California's approach, published detailed guidelines for water reuse in 1992 (USEPA 1992) and updated them in 2004 (USEPA 2004). These guidelines set up restrictive thresholds for a range of reuse categories: urban, industrial, agricultural, environmental and recreational, groundwater recharge and augmentation of potable supplies (MEDAWARE 2005). The USEPA limits and thresholds adopted are, in some cases, very restrictive to realistically encourage wastewater reuse (and monitoring) in poorer countries, even though they are not always backed up by medical evidence. The 'safety first' philosophy of these guidelines has been adopted in Israel, as an exception around the Mediterranean region (Angelakis et al. 1999).

As a means to promote the safe use of wastewater but focusing mostly on water-scarce countries where use of untreated or poorly treated sewage is common, the WHO in 1989 and the FAO in 1985 published guidelines for the safe use of wastewater in agriculture. While the WHO focused on the health of farmers and consumers to set its thresholds, FAO based its guidelines on the suitability as irrigation water, given its salinity, infiltration rate and ion toxicity, amongst others. In 2006, these organizations, together with the United Nations Environmental Programme (UNEP), launched the third edition of the 'Guidelines for the Safe Use of Wastewater,

[2] The EU-15 refers to the member states before the 2004 enlargement and includes Austria, Belgium, Denmark, France, Finland, Germany, Greece, Ireland, Italy, Luxemburg, Portugal, Spain, Sweden, the Netherlands and the United Kingdom.

[3] EU-12 refers to member states who acceded to the EU in 2004 and 2007 enlargements and includes Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

Excreta and Greywater in Agriculture and Aquaculture' (WHO 2006). These guidelines, despite lacking legal status, are the most relevant document regulating wastewater reuse. They have been adopted and/or adapted by many countries as part of their legislation or as recommendations with additional criteria for treatment or reuse, or limitations to ensure public health (WHO 2006).

3.4.3 Current Legislations and New Initiatives

Countries like Israel, Jordan, Tunisia, Italy, Cyprus and France established treated wastewater guidelines before 1999. Spain had regional guidelines since 1994, but it was not until 2007 that they were established at national level. Currently, most Mediterranean countries have legislation or guidelines concerning reuse. The rest of the MED countries are under the auspices of the EU Directive (Albania, Bosnia-Herzegovina, Monaco, Montenegro) or candidates to join the EU (Croatia and Turkey); these countries must comply with the strict European Treatment Directive (91/271/EEC). The current prospects of joining the EU will likely soon increase their capabilities for treatment and possibly for even reuse of treated wastewater. Only Lebanon, Libya, Palestine, Algeria and Malta, amongst the southern countries, still lack legislation or guidelines.

However, the presence of national guidelines or legislation alone is not enough to favour reuse. It is imperative that the legislation, besides regulating the safe use of recycled water, also promote trust amongst users. Countries like Cyprus and Israel are leaders in this regard. Cyprus published Wastewater Reuse Guidelines and Code of Practice in the 1980s (Helmer and Hespanhol 1997). The combination of these well-established laws in Cyprus together with the EU Directive pushing for treatment and control of wastewater has been very effective in encouraging recycling and increasing the trust and the willingness of the farmers to pay for recycled water (Birol et al. 2007). Israel is currently the pioneer on wastewater reuse, not only because it has one of the oldest wastewater reuse legislation but also because its policies transmit confidence on reuse amongst its farmers (Qadir et al. 2010).

Many efforts have been made to develop unified Mediterranean guidelines for wastewater reuse. The first call was in 1999 (Angelakis et al. 1999), as a means to protect public health, increase water availability and prevent coastal contamination around the Mediterranean but also to unify guidelines that would secure economic and touristic exchange across the Mediterranean (Angelakis et al. 1999; Bahri and Brissaud 2002). There have been several projects in the last decades to encourage safe reuse of wastewater around the Mediterranean like MED-REUNET (2003); MEDA-Water (2007), and AQUAREC (2006b) amongst others (Bixio et al. 2006), but general guidelines for the region are still lacking. A compilation of the guidelines currently used in most of the Eastern Mediterranean countries can be found at WHO and CEHA (2006).

Legislations amongst the top wastewater users appear to be changing approaches from recycling to measures for water saving and water quality protection. These measures reduce the volume of wastewater to be treated but also the number and type of pollutants to be removed. Since the 1990s, Israel has prohibited the discharge of brines into the sewage network and has established standards to control the quantities of salts in washing powders, which are still part of their guidelines (MEP 2011; Angelakis et al. 1999). This measure prevents treated effluent from reaching high values of salinity, therefore restricting its use for agricultural purposes. Similar preventive measures should be encouraged to facilitate the sustainable reuse of treated wastewater.

More sophisticated double sewage systems to collect grey and black water separately are already being introduced in some countries. Amongst the MED countries, legislation and guidelines for greywater reuse already exist in Jordan and Cyprus.

3.5 Social Awareness

Legislations and master plans can be drivers for treatment and reuse (as above discussed) but also can result in bottlenecks for reuse. The presence of a legislation does not guarantee enforcement, monitoring and/or proper reuse of wastewater. This is the case of Syria, Morocco, Egypt and to a certain extent Tunisia. These countries have a published legislation and standards for wastewater reuse, but the capacity of treatment and monitoring does not match up with the current water needs. The quality of the irrigation water generally does not meet the established guidelines (Ayed et al. 2009; AHTGroup 2009), resulting in low willingness to use and/or pay if alternative water supplies are available (AHTGroup 2009). It is thus imperative that the legislation be adjusted to the country-specific capabilities for reuse and thus re-establish confidence in the government's monitoring systems and control.

Fast industrialization in some countries, with soft regulations and poor environmental monitoring, is leading to uncontrolled disposal of untreated industrial wastewater into the urban wastewater collection networks. Thus, the addition of large quantities of metals and metalloids contributes not only to public and environmental health risks but also to an increasingly negative view of water recycling in countries where the enforcement of the wastewater legislation is either weak or not existing (AHTGroup 2009). For example, in Turkey, discharges from the industrial sector are rapidly growing because of flourishing economy. However, the rate of industrial wastewater treatment has not been able to keep pace with the fast industrialization, resulting in the discharge of toxic substances in the environment. Fast industrialization is also currently occurring in Tunisia, which now faces similar problems with industrial wastewater treatment and disposal and the consequent limited social acceptance for reuse. Similar situations might occur in emerging economies like Egypt and Syria, where enforcement of the legislation is usually poor.

The presence in wastewater of new pharmaceutical chemicals, endocrine disrupters and popular drugs like caffeine is increasing (WHO 2011), and with this increase the doubts about their presence in the food chain if reclaimed water is used for irrigation (Muñoz et al. 2009; Siemens 2008). Furthermore, secondary treatment and even tertiary treatment are not always able to remove all these emerging pollutants from the effluent. The European Water Framework Directive has added some of these emerging pollutants in its regulation (WHO 2011), as there is an increasing concern by the general population about being in contact with these pollutants of unknown environmental and public health consequences (WHO 2011).

4 Current Wastewater Reuse Status Around the Mediterranean

In this section, we present, in alphabetical order, an overview of all the MED countries, their current status of recycling water, and their legislation.

4.1 Albania

Albania is a water-rich country with ARWR per capita over 13,000 m^3 (Fig. 1). The country is trying hard to adjust to the EU Water Framework Directive and comply with the EU environmental standards. The sewage networks are rapidly expanding, and most of the capital is covered. However, with regard to water treatment, the progress is slower. In 2000, Albania still did not have any wastewater treatment facility operational (UNEP and MAP 2000), and even the capital Tirana was discharging its sewage into the Lana River (Gjinali et al. 2011). Only in 2010 has the country inaugurated the first research-pilot project on constructed wetlands in an orphanage in Tirana (Gjinali et al. 2011).

Recent advances might have come as a result of the updated Water Law in 2008 and the creation of a working group for the evaluation of wastewater-related projects led by the Minister of Public Works.

4.2 Algeria

The old Algerian law (No. 83–17, 1983) obliges large cities (over 0.1 million inhabitants) to treat their effluents prior to any disposal or reuse. Raw wastewater is not allowed to be used for any type of agricultural irrigation and, even if treated, cannot be used to irrigate raw-eaten vegetable. Under specific authorization from the relevant authorities (Law No. 83-17, Art. 138), it can be used for fodder crops, pasture and trees. In the early 2000s, the Algerian government made efforts to encourage wastewater treatment, with the construction and rehabilitation of many wastewater treatment plants and stabilization ponds in the small communities (UNEP and MAP 2000). In 2002, the projections for wastewater reuse in Algeria were very optimistic and estimated a volume of 600 Mm^3 by 2010 (Kamizoulis et al. 2003). Available data show that volumes of wastewater treated exceeded this value in 2008, reaching an annual volume of 700 Mm^3 in 2011 (Hammouche 2011). The increase in treatment is partly due to the implementation of a new water law (Law No. 05–12) published in 2005 and the creation of a National Office for Sanitation (Office National de l'Assainissement, ONA 2011), devoted to provide wastewater services including wastewater treatment and monitoring. However, the old and new water laws have not been encouraging much water reuse. It is estimated that only 4,310 ha is currently irrigated with treated wastewater, which corresponds to approximately 2.16 Mm^3 of produced wastewater when accounting for 5,000 m^3/ha (Hammouche 2011). Reuse might be further enhanced with the current update of the National Water Plan under the auspices of the EU neighbouring countries (Eurojar 2011).

4.3 Bosnia and Herzegovina

Bosnia and Herzegovina has considerable amounts of water resources that are not being efficiently used. It was only in 2003 when the National Environmental Action Plan (NEAP) of the country was completed. One of the main objectives of the plan was to develop a long-term environmental protection strategy for the country to prevent an irrational use of its water resources. Amongst others, NEAP proposed the construction of wastewater treatment facilities (UNEP et al. 2007).

4.4 Croatia

Croatia is the richest ARWR country in the MED region. Unfortunately, the almost 24,000 m^3 of ARWR per capita (Aquastat 2011) are concentrated in the north part of the country. The karstic geology of the aquifers makes it especially difficult to balance the contrasting northern water-rich region with the drier southern coast, characterized by long summers without precipitation. Concentration of agricultural land and tourist resorts with increasing water demands during the dry season aggravates the existing water supply deficit.

Freshwater supply for tourist resorts and inhabitants of the coastal islands has been resolved by transporting freshwater through submarine pipes and small desalination plants (UNEP and MAP 2000). Until 2003, there were no plans for water recycling in the country. The main reason behind this was the poor infrastructure existing for sewage collection (UNEP and MAP 2000). In 2008, the country had only 47 % of the households connected to a sewerage system, with an addition of approximately 10,000 connections per year (Aquastat 2011; Crostat 2011). Fortunately, the prospect of Croatia joining the European Union in the near future is accelerating the construction of sanitation infrastructure and treatment facilities to meet the EU Wastewater Directive.

4.5 Cyprus

Cyprus, the third largest island in the Mediterranean, has always been confronted with inadequate volumes of water to meet its agricultural and domestic needs. Its geographical location, climate (semi-arid, with frequent droughts), economy and political situation exacerbate its water problems. Over 87 % of the island's water extractions, 96 % of which are coming from groundwater, are for agricultural purposes (Aquastat 2011). The salinization of the groundwater resources by overexploitation of the aquifers has led to the development of alternative water supplies. With desalination as an alternative to meet the water needs, the country has steadily been increasing the use of desalinized water, reaching an annual volume of 49 km^3 in 2009 (Eurostat 2011). Wastewater reuse is the second alternative; according to Aquastat statistics in 2005, 19 of the 22 Mm^3 of treated wastewater were reused. Later estimates (Jiménez and Asano 2008) suggest the volume of recycled water to be 25 Mm^3. Most of the wastewater reuse is diverted for agricultural purposes and landscape irrigation for the touristic infrastructures (Zimmo and Imseih 2011).

In Cyprus, Sewage Boards are responsible for the collection, treatment and disposal of wastewater, while the Water Development Department undertakes the management of recycled water. The country's wastewater quality guidelines for wastewater reuse date from 1990 and are stricter than the WHO (1989) guidelines (Angelakis et al. 1999; MEDAWARE 2005). Cyprus also has provisional criteria for the reuse of treated effluent, the 'Code of Practice for Wastewater Reuse and Sludge Application' (FAO 2003); both the guidelines and the Code of Practice have been adjusted to the specific considerations of Cyprus. The Code of Practice established a detailed set of procedures that need to be followed regarding continuous control of the effluent, distinct distribution network for recycled water, and specific irrigation methods depending on use and the level of treatment (MEDAWARE 2005). Cyprus has followed effective strategies towards improving the efficient use of water such as improvement in irrigation systems, conservation of groundwater, water pricing, campaigns of water awareness and reuse of treated sewage and greywater effluent, amongst others. This has resulted in a very efficient system of irrigation, with closed systems, and an overall conveyance efficiency averaging 90–95 % (UNEP et al. 2007).

After joining the European Union, the country is trying to comply with the Urban Wastewater Treatment Directive from the European Union (91/271/EEC) and achieve the integrated water resources management strategy by 2015 (Birol et al. 2007). However, in 2009 only 49 % of the produced wastewater was collected, with the country still in the early stages of implementing secondary treatment in the rural areas (SEC 2009). In the large cities the situation is different. All the major cities already apply secondary or tertiary treatment, using the effluent for irrigation (Birol et al. 2007). Acceptance of treated wastewater reuse amongst farmers seems to be good. A recent study (Birol et al. 2007) shows the farmers' greatest acceptance leading towards the highest-quality recycled water.

4.6 Egypt

Sewage farming is a common practice in the country (Zhu et al. 2000; UNEP and MAP 2000) with reported evidences of orchard irrigation around Cairo from as early as 1900 (UNEP and MAP 2000). Increasing discharges of urban wastewater into the irrigation drains pose an important pressure on the health of the Nile Delta. It was estimated that a volume of 2–3 km^3 of untreated sewage was yearly discharged in the river (Zhu et al. 2000; UNEP and MAP 2000). Wastewater effluents enter the Nile irrigation system by two different mixing processes: when raw wastewater is mixed with agricultural drainage (Mix-1) and when it is mixed with freshwater canals (Mix-2). Both waters are currently used for unrestricted irrigation, despite being highly polluted (Zhu et al. 2000; UNEP and MAP 2000).

The Law No. 48, released in 1982 concerning Pollution Protection of the River Nile and Water Channels, and its provisions issued the Decree 8/1983, details the main regulations and quality standards for water quality management in Egypt. For example, Articles 64 and 65 state the quality requirements of the water when discharged into freshwater canals and agricultural drainage canals, respectively. Later, the Ministry of Housing, Utility, and Urban Communities issued a new Ministerial Decree 44/2000 distinguishing water quality requirements for unrestricted and restricted irrigation, the type of soil, the method of irrigation and the crops to be irrigated (Choukr-Allah 2010; Xanthoulis 2010). Unfortunately, from the institutional perspective, the reuse and treatment of wastewater fall under seven different ministries, with unclear delineation of responsibilities limiting the efficiency of the system and the proper implementation of these laws (Zhu et al. 2000; UNEP and MAP 2000).

The Egyptian government, during the decade of the 2000s, has invested in improving the country's water and wastewater infrastructure. For example, the new Cairo wastewater plant will come into operation in 2012.

4.7 France

The reuse of sewage in France formally started as early as the nineteenth century (in the proximities of Achères) in what is called sewerage farms (UNEP and MAP 2000). Currently, reuse of recycled water is common on the southern coast of the country and on its islands. These regions suffer water deficit, mostly during the summer. Otherwise, France has enough water resources available and is, in overall, self-sufficient in this regard, with just over 3,400 m^3 of ARWR per capita annually. Interestingly, during the last 10 years, France has seen its total water extractions decreasing (Eurostat 2011) possibly linked to the water use efficiency technologies and public awareness of seasonal water scarcity in coastal regions.

France is interested in developing wastewater reuse, mostly to supply areas with water scarcity, like the Mediterranean or Atlantic coast, including the islands, for the high water demand related to tourism and agriculture, both coinciding in summer (Afssa 2008). Another reason for reuse is to maintain the ecological flows.

The first steps towards water recycling in France started in 1991, when sanitary recommendations concerning the use of municipal treated sewage were published (Ministry of Health Circular No. 51; July 22, 1991). These first standards were based on the WHO (1989) guidelines with additional requirements adapted to agricultural conditions of the country (UNEP and MAP 2000). But, it was in 2007 that France published the Code of the Environment, with the Article R211-23 regarding the reuse of treated wastewater for agriculture and landscape irrigation. This article transferred water reuse responsibility to the French Agency for Food, Environmental and Occupational Health and Safety (ANSES) that, amongst others, establishes the characteristics of the irrigation water and types of irrigation. ANSES published the report with all water-recycling specifications and monitoring in 2008 (Afssa 2008).

4.8 Greece

Water resources in Greece are characterized by the strong imbalance of precipitation between the semi-arid Mediterranean region and the interior of the country. Water stress in the coastal regions is accentuated by tourism and agriculture irrigation, both occurring during the rainless summer months. According to Angelakis et al. (2003), the country has already reached an exploitation rate of 100 % of their available water resources, estimated in 6,670 m^3 ARWR, with most of it allocated to agriculture. Aquastat (2011) estimated that Greece is the country that devotes the largest fraction of their water extractions to agriculture, reaching 89 %.

When joining the EU in 1981, Greece adopted the 271/91/EEC Directive and started building wastewater treatment facilities and reducing the disposal of untreated wastewater (Tsagarakis et al. 2001). The reuse of treated wastewater could relax the current stress on its available water resources. But the country still lacks national standards or guidelines for reuse. There have been, nevertheless, many attempts and suggestions for developing wastewater reuse guidelines appropriate for the country (Tsagarakis et al. 2004; Angelakis and Bontoux 2001; Angelakis et al. 2003; Gerba and Rose 2003) with the most formal attempt being the publication of a Wastewater Reuse Criterion (Andreadakis et al. 2003). These guidelines are realistic and appropriate to the Greek conditions. They restrict the direct or indirect potable reuse and push for aquifer recharge as a barrier for saltwater intrusion and reuse for agricultural purposes (Bakopoulou et al. 2011; Kalavrouziotis et al. 2011).

4.9 Israel

Israel, with only an average of 250 m^3 of ARWR per capita (Aquastat 2011), is one of the world leaders and pioneers of wastewater reuse, drafting its first regulations as early as 1953. Few years later, wastewater was considered a resource by their Water Law of 1959, and since then, it is an integral part of its water resources (Qadir et al. 2010). Already in 1986, Israel was recycling 35 % of its total produced sewage and declared wastewater reuse as part of its national policy (Shuval 1987). In 1992, the country published the first Wastewater Regulations on Effluent Quality Standards, following California criteria (Angelakis et al. 1999). These were last updated in 2010 as the Standards and Rules for Sewage Treatment (MEP 2011).

The proportion of collected wastewater currently treated is relatively high (75 %) (Qadir et al. 2010), and most of it is devoted to agriculture. The government encourages recycling wastewater with 20 % lower prices than freshwater, and it is this low cost that partially drives reuse in the country (Angelakis et al. 1999). The provision of technical and professional guidance to farmers (Qadir et al. 2010), together with the lack of additional water resources, helps public acceptance to reuse (Angelakis et al. 1999).

One of the major concerns regarding the quality of the reclaimed water in Israel is salinity. The risk of soil and groundwater salinization has led to extensive research on developing crops resistant to high concentrations of saline water (Kfouri et al. 2009). However, as a preventive measure for combating salinization, the Ministry of the Environmental Protection started a campaign in the early 1990s to reduce the addition of salts at the user's level. In 1999, the government set new standards for washing powders and prohibited discharge of brines from ion-exchange renewal, from food, tanning and textile industries and from hospitals.

Israel is also the Mediterranean countries' leader in water desalination. The country uses desalination as an alternative water source, with an estimated 140 Mm^3 desalinated water produced in 2007 (Aquastat 2011). Furthermore, the country just approved the financing of one of the world's largest desalination plants, expected to supply 150 Mm^3 of drinking water per year (JTA 2011).

4.10 Italy

With an estimated overall ARWR per capita of 3,200 m^3, Italy devotes 44 % of its yearly water extractions to agriculture (Aquastat 2011), a rather low volume compared to its neighbours Spain and Greece. Italy, like most of the Mediterranean countries, has a strong imbalance of available water resources between its northern region and the southern coastal areas. Sicily, Sardinia and Apulia in the south suffer from water shortages and lack of good-quality water (UNEP and MAP 2000). It is in the south that wastewater is seen as a possible answer to overcome water shortage.

Italy has a general legislation on wastewater quality which dates back 1977 (General Technical Standards – G.U. 21.2.77). Its strict parametric values have been a bottleneck to the development of water reuse projects in the country (Marecos do Monte 2007). The current norm with regard to reclaimed water is based on two national laws, the Legislative Decree No. 152/2006 and the Ministerial Decree

No. 185/2003. The initial Decree No. 185/2003 established the technical rules and strict standards for urban wastewater reuse. It promotes reuse mostly for irrigation, industrial or domestic use, depending on the regional needs (Caputi et al. 2005). This law also gives general provisions for protecting water resources from different types of pollution. One of the provisions imposes discontinuing wastewater discharge into subsoil, a rather frequent practice in Apulia region, in the south (Lopez and Vurro 2008). In the Legislative Decree No. 152/2006, a set of clearly specified standards was established and adapted to the different regions by modifying only a few parameters (Giungato et al. 2010). The new legislation encourages industrial reuse of treated wastewater to the extent that in some cases a separate supply network for industrial reuse has already been built, like in the case of Turin (MEDAWARE 2005).

Agriculture is the main activity interested in wastewater reuse. Many reuse projects sprouted in the early 2000s in the southern regions like Sicily, Sardinia and Apulia (Marecos do Monte 2007; Giungato et al. 2010; Lopez and Vurro 2008), including public health and environmental risk assessments.

4.11 Jordan

The low ARWR available in Jordan, with only 153 m^3 per capita in 2011 (Aquastat), placed the country amongst the top leaders in terms of wastewater policy framework and institutional support in the Middle East (Qadir et al. 2010). As early as 1971, the basic public health framework for wastewater control was established with the Public Health Law No. 21, on monitoring and regulating wastewater discharges and the design of wastewater facilities according to the standards issued by the Ministry of Health. In 1983, after reorganizing and merging several ministries, the national Water Authority of Jordan (WAJ) was established and started developing national standards for water and wastewater that were further consolidated under the 18/1988 Law. At this time, the WAJ had capacity to formulate water and wastewater policies, and regulate wastewater treatment. The Ministry of Water and Irrigation was created in 1992 to centralize the control of the overall water resources, including wastewater treatment and reuse.

There have been several standards and criteria for wastewater and sludge reuse. The first one was established in the WAJ 18/1988 law, but additions and amendments to this law regarding industrial discharges (202/1991), urban discharge (893/1995) and sludge reuse (1145/1996) were published in the following years.

The 893/1995 law became Jordan's standard, providing guidance for reuse and also a suit of regulations on how to manage irrigation of recycled water, for example, irrigation of raw-eaten vegetables with recycled water should stop 2 weeks before harvest (MWI 2001). Two years later, in 1997, the Jordan Water Strategy was adopted, promoting the use of reclaimed water for unrestricted agriculture to other non-domestic purposes, including groundwater recharge (MWI 2001). The current edition (third edition) of the Jordan Standards for Reclaimed Domestic Wastewater dates from 2002 (JS 893/2002) (Vallentin 2006).

Currently, in Jordan, all the effluents from its wastewater treatment plants are used either directly or indirectly for irrigation or stored in reservoirs for later use (Fatta et al. 2005). The planned direct use of reclaimed water is administrated by the WAJ, which has special contracts with the farmers formalizing their rights to use reclaimed water directly (Qadir et al. 2010). The King Talal Dam, in the Jordan Valley, stores more than two thirds of the effluent generated in the country. And it is in this valley where 80 % of the agricultural irrigation in the country takes place, with about 3,000 farmers irrigating their crops and vegetables with diluted reclaimed water (SIWI 2008).

One of the major concerns in the quality of the reclaim water in Jordan is its high salinity (Fatta et al. 2005), as the effluent comes mostly from urban discharges with a very low heavy metal content (Ammary 2006). The already saline drinking water (with TDS up to 1,200 mg/L) increases salinity following the high evaporation during the treatment process. Farmers' view of wastewater seems to mostly depend on their capacity to manage the agricultural challenges associated with the high soil salinity or the marketing of the produces rather than the presence of pathogens and associated health risks (Carr et al. 2010). Also, most of the irrigated land is under drip irrigation in combination with plastic mulching to reduce the microbiological health risk (SIWI 2008).

The Water Strategy of Jordan (2008–2022) aims to install wastewater collection infrastructure and treatment facilities to cover all the major cities and small towns in the country, meeting national and international standards by 2022. The Jordanian National Wastewater Management Policy requires that the price of reclaimed water covers at least the energy and maintenance cost of the reclaimed water delivery to the farmers (McCornick et al. 2001).

Jordan is encouraging the reuse of greywater at the household level and suggesting its use in home gardens to irrigate a range of plant species (Qadir et al. 2010; Al-Jayyousi 2003). Efforts to promote the use of greywater started in 2001 with some small-scale projects in few governorates (McIlwaine and Redwood 2010; Qadir et al. 2010; Al-Jayyousi 2003). Currently, the Center for the Study of the Built Environment (CSBE) has published some preliminary greywater guidelines as part of the Grey Water Reuse Project, funded by the Enhanced Productivity Program at the Jordanian Ministry of Planning (Abusoud 2009).

4.12 Lebanon

Regarding its available water resources, Lebanon has an ARWR per capita just over 1,000 m^3. Since the end of the civil war in 1990, one of the first challenges in the country has been to rebuild its infrastructure and economy. The often political and civil instability in the country has not helped in developing general environmental management actions.

The formal reuse of treated wastewater is still in its infancy, and the existing treatment infrastructure is established around the major urban settings (Kramer and Post 2006; World Bank 2010). The country's Ministry of Environment issued in 1996 standards for the minimum treatment of urban wastewater and, in 2001, established the Law No. 8/1 to set standards for wastewater discharge into the sea and into surface water bodies (MEDAWARE 2005). The recently inaugurated wastewater plants in Tripoli and Saida (2009 and 2010, respectively) discharge all their effluent to the sea (Ayoub and Chammas 2006).

The wastewater reuse potential in the country is large and should be encouraged to reduce the current stress in the country's water resources through reuse (Zimmo and Imseih 2011; Ray et al. 2010; Ayoub and Chammas 2006). Despite the lack of specific standards, there is a set of crop restrictions and recommendations for farmers when using untreated wastewater for irrigation (Choukr-Allah 2010). Unfortunately, the law is not properly enforced, and uncontrolled use of untreated effluent is not rare in the country (Zimmo and Imseih 2011; Ray et al. 2010).

Since 2009, FAO, through a project addressing wastewater reuse and sludge valorization (UTF/LEB/019/LEB), has been assisting the Lebanese government in improving capacity building and awareness in the field of wastewater and sludge reuse by the development of guidelines and in building national capacities so as to maximize the benefits and minimize the risks of reuse. It is expected that by 2020, 80 % of the population will be connected to a sewerage network and subsequent treatment of collected wastewater (Kramer and Post 2006). Recently, there has been a training workshop in the country to promote wastewater treatment and reuse, organized by the UNESCO-IHE Institute for Water Education and the Arab Countries Water Utilities Association (ACWUA) under the framework of the Horizon 2020 EU project.

4.13 Libya

With an ARWR per capita of less than 100 m^3, Libya is facing the most acute water scarcity. To resolve this extreme poverty in water resources and meet the agricultural demands, the government has implemented huge projects to divert fossil groundwater from the southern areas of the country to the urban areas in the north (Wheida and Verhoeven 2007).

According to a survey of domestic wastewater use in Libya, recycling started in 1963 with the construction of the first wastewater treatment facility. By 1999, 25 plants were built, covering almost all cities in the northern part of the country (Wheida and Verhoeven 2007). However, recent studies estimate that only 54 % of the population is covered with a sewerage system (Jagannathan et al. 2009) and only 20 % of the collected wastewater is treated with less than half of this volume recycled (Aquastat 2011). There have been water reuse projects since the early 1970s, always devoted to irrigation of agricultural lands (Wheida and Verhoeven 2007; Angelakis et al. 1999). Unfortunately, further information about the current infrastructure and water quality of the treated effluent is unavailable (Wheida and Verhoeven 2007).

4.14 Malta

Malta has 124 m^3 ARWR per capita (Aquastat 2011). This acute water stress is not new and has been fostered in the country's water harvesting and saving approaches for a long time. Subterranean storage of water or cisterns established in the rocks were found all over the island dating back as far as Roman, Punic and even Neolithic times (Sapiano et al. 2008). The Arabs, who later inhabited the island, introduced low water requirement crops (olive, citrus and figs) and earth or rock constructions to enhance water collection and conservation (Sapiano et al. 2008). The increase in population after the colonial period further stressed the need of additional water resources, resulting in overexploitation of the aquifer and deterioration of its quality. Currently, Malta's major water demand is for municipal use (55 % in 2003–2004), followed by agricultural demand (35 %) (Aquastat 2011). Water needs are fulfilled from desalination mixed with groundwater extractions (UNEP et al. 2007).

The promotion of wastewater reuse was first mentioned in the Maltese regulations in 1992 with the establishment of the Water Services Corporation Act XXIII of 1991 (WSC 2011). This body was then in charge of managing potable and non-potable water, their treatment, disposal and reuse (Micallef et al. 2007). Since 2003, this body is also in charge of the collection and proper disposal of the sewage (UNEP et al. 2007).

In 2004, Malta joined the European Union and applied the European Water Framework Directive, WFD 91/271/CE, which has been successfully implemented since then (SEC 2009). Most of the Maltese population, at least in the south, is now connected to the sewerage system (Jagannathan et al. 2009), and with the recently built modern treatment facilities in Gozo (2008), Ic-Cumnija (2009) and Ta'Barkat (June 2011), Malta is the first island in the Mediterranean treating all its sewage before dumping it into the sea (Sansone 2011).

4.15 Monaco

All produced wastewater in Monaco is collected and treated, and the treated effluent is diverted to the sea for disposal. The existing treatment plant has been functional since 1990 and updated in 2008 in order to comply with the European Directive (PMDE 2009).

4.16 Montenegro

With abundant and good-quality surface and subsurface water resources, the state of Montenegro does not have shortage of water resources. Unfortunately, the country has one of the highest water consumption rates in Europe, possibly a consequence of the low water prices (MTEP 2007). The water distribution infrastructure is poor in the rural areas but covers most of the urban centres (MTEP 2007). The country is trying to adapt to the UN Water Framework Directive to protect, improve and prevent deterioration of its water resources quality (MTEP 2007).

4.17 Morocco

Morocco has an estimated 917 m^3 ARWR per capita (Aquastat 2011). Its water resources are mostly concentrated along its northern coastal regions, with the south-eastern region undergoing periodical water shortage during the year.

The first legislation regarding water in Morocco dates back to 1914, during the times of the French Protectorate. But, it was not until 1995 that the legislation was updated (Law No. 10-95) and a national water policy developed along with an institutional framework to regulate wastewater reuse (CIHEAM 2004). Since 2002, Morocco has specific wastewater reuse regulations, with the Ministerial Decree No. 1276-01, fixing norms for effluent quality for irrigation based on the WHO standards (MEDAWARE 2003). In 2005, a Master Sanitation Plan was launched by the Ministry of Interior and the Ministry of Water and Environment aiming at not only to increase the rate of wastewater collection and treatment but also to adopt an integrated water resources management approach (Mustapha 2009).

The reuse of untreated wastewater for irrigating vegetables is practised despite prohibition, with the consequent health impacts on the population (Melloul et al. 2002; Lamghari-Moubarrad and Assobhei 2005). Reuse is linked to agricultural irrigation, as the country devotes a large volume from its annual water extractions to this purpose, 84 % in 2011 (Aquastat). Estimates reveal that of the 600 Mm^3 wastewater produced, 42 % is discharged in wadis and rivers without treatment, 8 % undergoes treatment and the rest is discharged into the sea without treatment (Mustapha 2009).

4.18 Palestinian Territories

Due to freshwater scarcity and the availability of farmland, the potential for wastewater reuse in Palestinian territories is large and is considered a priority by the authorities (Zimmo and Imseih 2011). One of the major constraints is the low coverage of sewage collection. On average, only 33 % of the population is connected to sewer networks in the Palestinian territories, 46 % in Gaza Strip and 24 % in the West Bank, with most of the connections around major cities (Loizidou et al. 2004).

The Palestinian territories enacted an Environmental Law No. 7 (1999) regulating all environmental issues, but this law has yet to be enforced (Zimmo and Petta 2005) and, even though the territories do not have any specific standards for industrial or agricultural wastewater reuse, preparations of these policies by the Palestinian Water Authority are under way (Zimmo and Petta 2005).

4.19 Portugal

Portugal does not share Mediterranean coast but experiences a similar semi-arid climate as the rest of the MED countries. The country has 6,435 m^3 of ARWR per capita; unfortunately, these resources are not evenly distributed throughout the territory but concentrated in the north-west. Extractions are mostly used for agricultural purposes (69 %), followed by industrial use (18 %). Portugal treats most of its collected wastewater, and only 5 % of the generated wastewater is not properly collected. As much as 71 % of the generated wastewater is treated through secondary treatment process (SEC 2009).

There are several national legislations in regard to wastewater reuse. The national guidelines for reuse of reclaimed urban wastewater were published in 2006 (Portuguese Standard NP 4434). These guidelines recommended best irrigation practices to minimize environmental risks (Marecos do Monte 2007). The maximum recommended values were imported from the Portuguese Law No. 236/98. According to the national guidelines, vegetables are grouped into four classes depending on the level of risk of microbiological contamination after irrigation.

Following the publication of the Portuguese standards in 2006, the Instituto Regulador de Águas e Resíduos published the Law No.2/2007 for the general 'Use of Treated Wastewater', specifying the competent authorities responsible for quality control, production and distribution of wastewater. In 2010, the Entidade Reguladora dos Serviços de Águas e Resíduosissueda issued the Technical Guide No. 14 to promote water saving techniques and the reuse for agriculture and landscape irrigation, mostly on golf courses.

4.20 Slovenia

Slovenia is situated at the crossroads of Central Europe, the Mediterranean and the Balkans. It is a water-rich country with 16,000 m^3 ARWR per capita (Aquastat 2011). The major consumer of water is the industrial sector with over 82 % of all the extractions, followed by municipal use (Aquastat 2011). Irrigated land is just over 15,000 ha (Aquastat 2011) but is possibly underestimated as most of the irrigation facilities are very small and operate without authorization for water withdrawal (Aquastat 2011).

Wastewater treatment in Slovenia is endorsed by the Institute for Water of the Republic of Slovenia. The tasks of the institute were laid out in the Slovene Water Act of 2002 and comply mostly with water management plans, water rights and water protection and use. The Health Inspectorate of the Republic of Slovenia is in charge of monitoring the implementation of laws and regulations concerning water quality.

The country joined the European Union in 2004 and had to comply with the European Directive regarding wastewater collection and treatment. In 2007, Slovenia accounted for only one major city (agglomeration larger than 150,000 P.E.[4]), with secondary treatment available but with still 21 % of the wastewater produced in the city not collected (SEC 2009). Two years later, in 2009, the Office of Statistics of the Republic of Slovenia reported 168.5 Mm^3 of collected sewage, of which almost half (46 %) was coming from runoff. Almost 69 % of wastewater discharged from sewage systems was treated in treatment plants, and the rest remained untreated. The treated and untreated effluents were discharged mostly into surface water bodies (SORS 2009).

4.21 Spain

Spain treats more than the 90 % of the produced urban wastewater, but reuse of the treated wastewater is limited; for example, only 12 % of the treated wastewater was reused in 2008 (INE 2011a). This fraction is likely to increase in the near future; according to estimates from AQUAREC project, Spain has the highest water reuse potential in Europe, estimated to be 1,300 Mm^3/year by 2025 (Angelakis and Durham 2008; AQUAREC 2006b).

The first reuse guidelines were published as regional initiatives in Catalunya and Andalucía in 1994, based on the WHO approach, as a consequence of the expansion of the use of reclaimed water for golf courses irrigation (Calleja et al. 2000). But it was not until 2007 that Spain issued the Royal Decree RD 1620/2007, which not only established the quality standards of the treated wastewater for different uses (urban, industrial and agricultural uses) but also the quality control measures and analytical methods that might be followed for a proper and safe reuse at national level. This decree has been followed by the Water Quality National Plan: Sanitation and Reuse (2007–2015), which aims to fully comply with the EU Directive by 2015 at the regional level and achieve a reuse target of 1,200 Mm^3/year by 2015 (Melgarejo 2009).

The water regulation entities in Spain have been given authority to apply their own strategies to achieve the EU Directive and Water Quality National Plan in order to comply with the RD 1620/2007. In 2005, Catalunya region, guided by the European Directive 91/271/CE and a Royal Decree No. 11/1995, started what has been called *Sanitation Plan for Catalunya*. Under this plan, over 300 wastewater treatment plants were built, treating annually a volume of 665 Mm^3 of urban sewage. In 2008 and under the auspices of Royal Decree 1620/2007, 7.6 % of the annually treated wastewater was reused in Catalunya. The effluent that is not directly reused is disposed off into the river and indirectly reused downstream (ACA 2011).

With regard to water recycling, more than 150 reuse projects were implemented around the country in 2006, mostly for agricultural reuse (71 %) but also for environmental services (17 %) (Yagüe-Córdova 2011). Environmental applications include,

[4] P.E. refers to population equivalent, which means the biodegradable load having a 5-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day.

amongst others, artificial recharge of groundwater, irrigation of forests, maintaining environmental flows and preserving wetlands. Barcelona is home of probably one of the largest integrated water reuse projects in the world combining direct aquifer recharge for control of seawater intrusion (hydraulic barrier) and restoration of a wetland habitat, amongst others (Angelakis and Durham 2008; Ortuño et al. 2011). In the Comunitat Valenciana, the coastal region just south of Catalunya, the annual volume treated is around 503 Mm^3, and in 2009, 50 % of this volume was reused for agriculture (CMA 2011).

Reuse of reclaimed water is also devoted for recreational uses, irrigation of golf courses and landscape irrigation (Yagüe-Córdova 2011; Mujeriego 2007; Candela et al. 2007). The proliferation of golf courses along the touristic littoral of country has encouraged private investors and public regulations to promote recycling. There are already regional regulation policies in this regard in regions like Murcia and Andalucía (Yagüe-Córdova 2011).

4.22 Syrian Arab Republic

The reuse of wastewater is an ancient practice that supposedly started in the Middle East, particularly in Syria over 2,000 years ago (Kaisi 2005). In this semi-arid country, the use of wastewater for irrigation constitutes an invaluable source of water, capable of relaxing the existing stressed water resources. Syria has over 800 m^3 ARWR per capita (Aquastat 2011), most of them concentrated along the Euphrates River and the western region of the country. According to the Syrian Ministry of Irrigation, the country had a 14 % deficit in its average water resources availability during the period from 1992 to 2003 (UNEP et al. 2007). Pressure on its water resources has been increasing ever since. The high population growth, high rural-to-urban migration (Fernandez 2008) and rapid social and economic development has led to changes in land use accompanied by an increase in water use (UNEP et al. 2007).

Agriculture demands account for almost 88 % of all water extractions (Aquastat 2011). As the available water resources are not sufficient to satisfy the country's need, the volume of treated wastewater is fully recovered for irrigation. However, the treated volume is only a third of the collected wastewater. Another third is used for irrigation without treatment, and the remaining is lost either to the sea or towards inland sabkhas (Kaisi 2005). Large-scale irrigation with marginal-quality water (mixed treated and untreated effluents) occurs mostly around the most populated and main agricultural lands like the Ghouta region along the Barada valley around Damascus, the Orontes river valley and the Qwayq river valley south of Aleppo (Kaisi 2005).

One of the main health risks associated with the use of inadequately treated wastewater for agricultural purposes is the intestinal nematode infection amongst farmers and consumers (WHO 2006). The last and only published parasitology study in Aleppo (northern Syria) in 1981 showed that more than 60 % of the population was infected with intestinal parasites, associated with the reuse of wastewater for irrigation (Bradley and Hadidy 1981). In an effort to reduce disease occurrence in wastewater-irrigated areas and preventing infection through consumption of wastewater-irrigated crops, the Syrian Ministry of Agriculture and Agrarian Reform, in 1990, issued resolution No. 2823, preventing the raw-eaten vegetables to be irrigated with wastewater and allowing only fodder and industrial crops and fruit trees to be irrigated with wastewater. In 2003, the Syrian Standardization Commission issued the more specific Code of Practice No. 2752 on the use of treated wastewater for irrigation jointly with five ministries, the Atomic Energy Commission and the Centre of Scientific Studies and Research. In this Code of Practice, the permissible limits of treated wastewater use for different irrigation purposes were established.

Despite the Code of Practice forbidding the irrigation of the raw-eaten vegetables with untreated or inadequately treated wastewater, it is not uncommon to see parsley, mint and lettuce being irrigated with marginal-quality wastewater at the outskirts of the big cities. The Code of Practice is not aggressively enforced, and the lack of (affordable or available) alternative water resources encourages famers to use (and even prefer) wastewater over groundwater. The Water Master Plan, released in 2005, reported six operational wastewater treatment facilities in the country, four under construction and 15 being planned (Kaisi 2005). At least two out of four wastewater treatment plants under construction are not functional yet, and the operational ones are working at their potential capacity.

4.23 Tunisia

Reusing wastewater for agricultural irrigation formally started in Tunisia in 1975 with the publication of the Water Code (Code des Eaux) with a couple of articles regarding the use of wastewater for irrigation. The Water Code prohibits the use of raw wastewater for irrigation, unless it has been treated, and the farmer has notified the Ministry of Agriculture and Public Health of its use (Art. 105 and 106). Twenty years later, few modifications were added in an updated version of the Water Code, mostly regulating discharge of wastewater into natural zones (Decree 85-56). Four years later, in 1989, the Tunisian standards (NT 106.03) for wastewater reuse in agriculture were established, in order to preserve consumers' and environmental health. The Tunisian standards were developed based on WHO and FAO guidelines, adapted to relevant characteristics of the country (Zimmo and Imseih 2011; Chenini et al. 2003).

Despite the favourable legal settings for wastewater recycling, only 20–30 % of the treated wastewater is reused (Ayed et al. 2009). A major constraint for reuse in Tunisia is social acceptance. Recycled water is not free to farmers ($0.02/m^3 for the treated wastewater (Scheierling et al. 2010)), and moreover, it cannot be used to grow profitable vegetables (Zimmo and Imseih 2011; Kramer and Post 2006). Another possible reason for the low acceptance in reuse is the lack of confidence in the quality of the treated wastewater. In 2006–2007, all treated effluents in the country tested positive for *Giardia* sp., *E. coli* and *E. histolytica/dispar* cysts, suggesting endemic levels of these parasites in the Tunisian population (Ayed et al. 2009). The same study showed that over half of the plants irrigated with the treated effluent contained levels of helminth eggs (Ayed et al. 2009) above current standards, but no action has been taken by the government to address this pollution, adding to the reluctance of the farmers for recycling.

In any case, most of the current uses of recycled water are devoted to agriculture which includes irrigating trees, fodder crops, industrial crops and cereals (Bahri 2002). Recycling is currently popular in golf courses, which have the economic capabilities to further treat recycled water and comply with the national quality standards (Bahri 2002; Bahri et al. 2001). The government is also, through some pilot projects, promoting the use of treated wastewater for groundwater recharge, irrigation of forests and of vegetation along highways, wetland development and industrial use.

4.24 Turkey

Turkey is a water-rich country with almost 3,000 m^3 of ARWR per capita estimated in 2011 (Aquastat 2011). Direct reuse of the treated wastewater is not common. Untreated effluent is usually discharged into other receiving water bodies, such as creeks, rivers, lakes or the coastal shore. It is estimated that 35 % of the effluent produced is reused indirectly or partially directly, mostly in agriculture (Fatta et al. 2005).

Already in 1983, Turkey passed their 'Environmental Law' with the broad scope to prevent environmental pollution (Zimmo and Imseih 2011). But it was not until 1991 that the country published a technical bulletin to stipulate the standards for the reuse of waters in agriculture (Fatta et al. 2005). The number of treatment plants present in the country is rapidly growing (Turkstat 2008) as the country is undergoing fast economic growth. Already in 2005, 43 of its 81 provinces had urban wastewater treatment facilities (Fatta et al. 2005).

The environmental risk comes from industrial discharges. The current capability for industrial wastewater treatment cannot keep up with the current fast industrialization, and while in 2004 half of the industrial wastewater was treated, it was only 19.2 % in 2008 (Turkstat 2008).

5 Discussion and Conclusions

Countries around the Mediterranean are characterized by a large variation in their water resources. Even the most water-rich country, Croatia, suffers a remarkable seasonal and regional water disparity that it is currently addressing by transferring freshwater through submarine pipes to supply touristic resorts and inhabitants of the coastal islands (UNEP and MAP 2000). This situation would ease if a more integrated water resources management approach would be adopted and included the reuse of treated wastewater.

The EU Wastewater Directive has proven to be very effective in promoting the collection and treatment of wastewater, reaching unprecedented rates amongst EU-15 countries (collecting up to 95 % and treating 87 %) but also within the recently joined countries (Aquastat 2011). In 2011, Malta was declared the first island within the MED to treat all its collected effluent before discharging into the sea (Sansone 2011). The reuse of treated wastewater is not encouraged by the EU Wastewater Directive; therefore, the northern countries are reusing limited volumes.

There is no similar regional directive like the European Directive 91/271/CE for the African and Asian MED countries encouraging the collection, treatment or even reuse of treated wastewater. Treatment in south-eastern countries is low (55 % of the collected wastewater), and only economically strong countries treat most of their effluents. The intense water stress, along with high demand of water for agriculture (84 and 63 % for all southern and eastern countries, respectively), can easily justify the high fractions of wastewater reuse even in untreated or inadequately treated forms. The use of untreated wastewater is common in countries like Syria and, to a lower extent, in Morocco, Egypt and the Palestine territories.

The need for water, along with a favourable legislation, has made countries like Israel, Jordan and Cyprus to become leaders in water reuse. These countries have adopted effective water-recycling policies since the 1990s. Their legislation is not only based on the promotion of reuse but on measures for water saving and water quality protection. Cyprus and Jordan are currently leading greywater reuse legislations and guidelines and promoting double sewage systems to collect grey and black water separately.

Some of the northern MED countries already had early legislations for recycling water since early 1990s, like France (1991), or even earlier, like Italy (1977). In the case of Spain, only two coastal regions published guidelines for water reuse due to the increasing water demand for the irrigation of golf courses along the touristic MED coast (Calleja et al. 2000). It was not until well after the introduction of the European Directive 91/271/CE and the revision of the old legislations that water reuse has shown a rise. In 2006, Italy relaxed its technical standards, and Portugal published its standards encouraging irrigation with reclaimed water for farmlands and golf courses. France updated its guidelines the following year, the same year as Spain passed its national regulations for reuse.

Reuse seems to be gaining momentum amongst northern MED countries. However, the increasing trend might be overshadowed by the growing concerns from the new pharmaceutical products and chemicals found in treated effluent, with unknown consequences for public and environmental health.

Given the already scarce and the variation in water resources available within the Mediterranean region and the climate predictions anticipating further drier conditions, it is imperative to encourage integrated water resources management policies. It is crucial to promote water saving strategies to not only reduce the use of freshwater but to minimize the volume of water to be treated. Initiatives favouring this approach have been adopted by some countries like Jordan, Israel and Cyprus and should further be encouraged within the other countries in the region.

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Pollution and Measures Towards De-pollution of the Mediterranean Sea

Rasha El-Kholy, Aiman El-Saadi, and Alaa El-Din Abdin

Abstract Known as the cradle of civilization, the Mediterranean Sea was of a great strategic importance to all neighbouring countries since ancient times. Its water pollution history started quite early with substances and energy introduced to the marine environment resulting in such deleterious effects as harm to living resources, hazards to human health and hindrance to marine activities including fishing, impairment of quality for use of seawater and reduction of amenities.

The pollution of marine regions from land-based sources is a serious threat to the protection of the marine environment, including marine protected areas. It is difficult to tackle because of the diverse pressures and impacts that cause the pollution. Indeed, around 80 % of the pollution of the marine environment comes from land-based sources, mainly municipal, industrial and agricultural wastes and run-off. One may think of the discharge of synthetic substances, no synthetic substances and nutrient or organic matter enrichment in river basins1 and in the marine environment. Land-based pollution reaches the marine environment either from rivers or from direct discharges into coastal waters. The pollution of rivers and consequently of the sea affects both human health and ecosystems. Since these effects can be irreversible, prevention is all the more important.

Millions of tons of pollutants are being discharged into the Mediterranean Sea every year from industrial activities in the countries bordering the Mediterranean region. So, making these data public will help to sensitize national governments

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about the problem so that action will be taken to reduce and eliminate pollution from land-based sources. It will also alert public opinion which could influence national authorities to live up to their obligations under international conventions and protocols. The major sources of pollution are metal industries, oil refineries and industry, tanneries, organic and inorganic chemical industry and food processing industry. Another major source of pollution is the hydrocarbon inputs from point sources which could be added to the sea-based oil pollution from tankers (Colasimone 2006).

Recognizing the increasing adverse effects of human activities on the Mediterranean Sea, 16 Mediterranean countries and the European Union decided, under the auspices of the United Nations Environment Programme (UNEP), in 1975, to set up the Mediterranean Action Plan (MAP). The Barcelona Convention for the Protection of the Mediterranean Sea against Pollution, adopted 1 year later, aimed to support the collective efforts of Mediterranean States and the European Union against marine pollution (The Mediterranean Information Office for Environ-ment (MIO 2005)) . Based on the action plan, many measures followed targeting de-pollution of its waters.

This chapter highlights all possible pollution sources (according to the available information) degrading the Mediterranean Sea water and their relation towards threatening this shared Mediterranean Sea environment. Thereafter, certain specific soft and hard measures will be recommended for implementation for all Mediterranean countries towards the de-pollution of the sea.

Keywords De-pollution • Mediterranean • Environment • Mediterranean Action Plan

1 Introduction

The Mediterranean is the largest European sea, uniting the people of the countries that share its waters. Mediterranean countries must act now to safeguard their environment and properly manage their natural resources to the extent possible.

Quality of seawater is amongst the most important coastal resources, which is utilized as a primary resource by many coastal development sectors. Deterioration of coastal water quality has been amongst the earliest coastal concerns of the mankind. This concern has trigged the initiation of serious management efforts in many locations that have become early examples of coastal management programmes.

1.1 De-pollution of the Mediterranean by 2020

The third Euro-Mediterranean Ministerial Conference on the Environment took place in Cairo in November 2006. This was the first Euro-Med environment ministerial held outside the EU. The conference was dedicated to the Horizon 2020 Initiative for the de-pollution of the Mediterranean by the year 2020 that was endorsed by the leaders of Euro-Mediterranean (Euro-Med) countries at the *10th Anniversary Euro-Med Summit* in Barcelona last year. It was co-chaired by the Finnish Presidency of the EU and the government of Egypt. A ministerial declaration including the timetable of actions for Horizon 2020 was adopted by consensus. The commission is building a coalition of partners to implement the initiative. Its strategy key aims, as listed by Mediterranean Information Office (MIO 2006), are

- Reduce pollution levels across the region
- Promote sustainable use of the sea and its coastline
- Encourage neighbouring countries to cooperate on environmental issues
- Assist partner countries in developing effective institutions and policies to protect the environment
- Involve NGOs and the public in environmental decisions affecting them

The basic aims of the Commission's environment cooperation with the Mediterranean countries are

- To assist partner countries to develop functioning environment institutions and a sound, effectively enforced environment policy and legal framework that enables integration of environmental concerns into sectoral policies
- To achieve measurably reduced levels of pollution, consistently applied across the region, leading to corresponding health benefits and in addition to reduce the impacts of uncontrolled activity on our natural environment
- To promote preparedness of the environment administrations to address both emergency situations as well as punctual and long-term environment issues
- To promote a more sustainable use of the land and sea areas in the Mediterranean region
- To promote a strengthened civil society, in which the public has access to environmental information, participates in environmental decision making and environmental awareness is enhanced
- To encourage regional cooperation amongst partner countries to support these aims

2 The Mediterranean Action Plan

Following the United Nations Conference on the Human Environment in Stockholm in 1972, which had identified the Mediterranean as amongst the "particularly threatened bodies of water", six Mediterranean states requested the United Nations Environment Programme (UNEP) to set up an activity framework for environmental cooperation in the Mediterranean region. In 1975, the Mediterranean Action Plan (MAP) was approved by 16 Mediterranean states and the EU. In February 1976, at a conference in Barcelona, the Barcelona Convention was adopted, transferring the action plan into legally binding commitments (Ozhan 2003). Today, contracting parties of the Barcelona Convention are the EU and 20 Mediterranean states (Axel conrads et al. 2002).

2.1 The "New" Agenda: The Mediterranean Action Plan II

In 1994, MAP responded to the results of the 1992 Rio Conference on Environment and Development. Translating the requirements of the World Summit's Agenda 21 onto the regional Mediterranean level, MAP set up Agenda MED 21, which led to the adoption of MAP II on 10 June 1995 changing its classical pollutant-centred policy approach to an integrative strategy of environmental protection and sustainable development.

At the same time, with MAP II, it was recognized that lasting environmental protection needs to take into account all socio-economic policies. MAP therefore strives "to ensure sustainable management of natural marine and land resources and to integrate the environment in social and economic development, and land-use policies". A comprehensive list of socio-economic sectors to be targeted for integration was set up including

- Economic sector with agriculture, industry, energy, tourism, transport
- Urban development
- Management of natural resources

Further focal areas of the new agenda became:

- Integrated coastal area management
- Observation of trends and the formulation of sustainability strategies
- National and local capacity building
- Conservation and sustainable management of cultural heritage sites in the region

The old MAP focus of assessment, prevention and elimination of marine pollution thus became one objective amongst many others.

Policy goals of MAP II and its enclosed priority fields of activities can be attributed to the following four objectives of an integrated and sustainable policy:

- Enhancement of knowledge and research
- Assessment, prevention and reduction of pollution
- Integrated sustainable planning and policing
- Public information and participation

2.2 The Barcelona Declaration

The "general undertaking" of the 1976 Convention is "to prevent, abate and combat pollution of the Mediterranean Sea area and to protect and enhance the marine environment in that area".

It aimed in the first place at turning the Mediterranean basin into "an area of dialogue, exchange and co-operation" expected to guarantee "peace, stability and prosperity":

1. A political and security partnership for "establishing an area of peace and stability"
2. An economic and financial partnership for "creating an area of shared prosperity"
3. "A partnership in social, cultural and human affairs" for "developing human resources and promoting understanding"

The primary pathway to meet these ends is, along with increased financial assistance through the EU, the establishment of a Mediterranean free-trade area by 2010.

2.3 The Short and Medium-Term Priority Environmental Action Programme

Barcelona Declaration provided setting up a Short and Medium-Term Priority Environmental Action Programme (SMAP). With the Declaration of Helsinki, hosting the Euro-Mediterranean Conference on the Environment in 1997, the action programme was incorporated into the fundamental framework of the Barcelona process, providing a more precise definition of its environmental and sustainability objectives:

- "To help to change the current trend of environmental degradation"
- "To contribute to sustainable development" including "the protection of the environment" and "the improvement of health and living conditions"
- "To contribute to the further integration of environmental policies into all other policies"
- "To ensure that, with the building of a Free Trade area, steps are taken from the start to highlight trade and environment issues"

where efforts are to be focussed on the following five priority fields of action:

- Integrated water management
- Waste management
- Hot spots (pollution)
- Integrated coastal zone management
- Combating desertification

3 Countries' Pollution Issues

The European Environment Agency (EEA 2006) identifies the Mediterranean pollution hot spots and areas of major environmental concern based on UNEP/WHO data, country reports to UNEP/MAP and country National Action Plan. These hot spots are listed by country in the subsequent sections.

3.1 Albania

The main contamination problems are stockpiles of obsolete chemicals, untreated urban wastewater and solid wastes. Discharge of untreated urban wastewater, beach erosion and illegal construction on the coastline are witnessed at the bays. Most concerned areas are located in Durres district and Vlora district.

3.2 Algeria

Algeria's coast hosts 45 % of the country's population. Major pollution problems include untreated urban and industrial wastewater, petroleum hydrocarbon slicks and coastal erosion. Most of the urban wastewater is discharged untreated directly into the sea. Also, petroleum hydrocarbon pollution is very common along the Algerian coastline because of maritime oil-shipping lanes that pass close to the Algerian coast. Erosion is also a major issue. Out of 250–300 km of sandy beaches in Algeria, 85 % are retreating, losing sand at a rate ranging from 0.30 to 10.4 m/year. The areas of concern are the Bay of Algiers, Oran, Skikda, Annaba, Ghazaouet, Mostaganem, Arzew and Bejaia.

3.3 Bosnia and Herzegovina

The Mediterranean coast of Bosnia and Herzegovina on the Adriatic is 25 km long. The pollutants generated in the drainage basins of the major Bosnian rivers can be carried to the Adriatic Sea affecting its environment. The major pollution problems are untreated urban wastewater and occasional stockpiles of obsolete chemicals. The areas of concern are Mostar and Neum.

3.4 Croatia

Croatia has a permanent coastal population of 1,000,000 which increases considerably during the summer because of tourism. This has led to dumping and depositing of inert materials. Another threat to the coastline is fish farming, which has caused habitat degradation in the vicinity of the fish cages. Major pollution problems include urban wastewater, eutrophication of coastal waters and urbanization and destruction of the marine coastal habitat in Kastela Bay (Split); Rijeka, Zadar, Pula, Sibenik and Dubrovnik; Primorsko-Goranska.

3.5 Cyprus

The southern coastal zone of Cyprus is densely populated by about 370,000 permanent inhabitants. All coastal towns and tourist centres operate wastewater treatment plants. The major environmental problems are coastline alteration, industrial mining activities and urban wastewater in the Bay of Limassol, the Bay of Liopetri and Ayia Napa and the Bay of Vassilikos.

3.6 Egypt

The coastal area around Alexandria (Lake Manzala, Abu Qir Bay and Max Bay, Alexandrian coast) is the major area of concern in Egypt as is Port Said. Major environmental problems are caused by untreated urban and industrial wastewater, and intense urbanization has caused coastline degradation. Sensitive areas and pollution hot spots include the Alexandrian coast; Max Bay and Abu Qir Bay; Lake Maryut; Alexandria to Marsa Matruh coastline; Rosetta branch of the River Nile; and wetlands of lakes Manzala, Maryut, Burullus and Idku.

3.7 France

France's coastline in the Mediterranean extends for 1,960 km in the regions of Languedoc-Roussillon, Provence-Alpes-Côte d'Azur and Corsica. Major environmental problems are caused by river transported pollution and treated industrial and urban wastewater. In addition, intense urbanization along the densely populated coastline is also a major cause for concern. Areas of environmental concern and the major anthropogenic activities in them are Marseilles and Nice; river Rhône; Fos Etang de Berre; rivers Herault, Gard and Vaucluse and harbours of Marseilles, Sète, Port-la-Nouvelle, Port-Vendres, Toulon (French naval base), Nice, Bastia and Ajaccio.

3.8 Greece

The coastline of Greece has a length of approximately 15,000 km. It hosts 50 % of the country's population and the majority of the industrial activity. Most coastal cities operate wastewater treatment plants. Localized environmental problems are caused by poorly treated urban and industrial wastewater and run-off from agricultural areas. The major source of nitrogen to the marine coastal areas of Greece is run-off from agricultural land, which contributes from 45 % (in the Aegean Sea islands) to 70 % (in the eastern Peloponnesus) of the total load. The endangered marine coastal areas in Greece are Elefsis Bay, Saronikos Gulf (Athina), Thessaloniki Gulf, Pagasitikos Gulf (Volos), Amvrakikos Gulf (Preveza), Patra and Irakleio, Argolikos Gulf (Argos) and Lagoon of Messolongi.

3.9 Israel

Seventy percent of the population resides within 15 km of the Mediterranean coastline, where the major economic and commercial activities are concentrated. The main pollution sources include industrial and urban wastewater, although most of the urban wastewater is treated and recycled. The rivers are transporting nutrients from agricultural run-off. The areas of environmental concern are Haifa area, Hadera area and Tel Aviv—Jaffa area and Ashdod.

3.10 West Bank and Gaza

The Gaza Strip is 42 km long and 5.7–12 km wide. It hosts a one million population with strong growth potential as 50.2 % of the inhabitants are less than 15 years old. The area is highly urbanized. Poorly treated municipal wastewater is the main source of pollution of the coastal zone of Gaza Strip. Several small and medium industries also contribute to the pollution of the coastal area. More than 20 individual sewage drains end either on the beach or a short distance away in the surf zone. These drains carry mainly untreated wastewater. Furthermore, only 60 % of the population is served by sewerage systems. The major areas of concern are Gaza City, Khan Younis town, Rafah town and Dayr El-Balah town.

3.11 Italy

Italy's coastline stretches 7,500 km and the whole territory is located in drainage basins flowing into the Mediterranean Sea. Major environmental problems are caused by urban and industrial wastewater, agricultural run-off and shipping. Urbanization and concretization of the coastline is also occurring because of tourist infrastructure development. Most cities have wastewater treatment plants; however, only 63 % of the population is connected to them. Furthermore, 13 % of the existing plants have operational problems or need upgrading. The river pollution is a very important pollution vector in the area transporting urban and industrial wastewater as well as agricultural run-off from its drainage basin to the Adriatic Sea. Areas of environmental concern are Gulf of Trieste; lagoons of Venice, Comacchio and Orbetello; the coastal areas of Liguria, Lazio and Emilia-Romagna; the Tyrrhenian coast near the mouths of the rivers Arno and Tevere; harbours of Trieste, Venice, Genova, Livorno, Naples, Taranto, Brindisi, Ancona, Augusta-Priolo-Melilli, Milazzo, Ravenna and Gela.

3.12 Lebanon

It is estimated that 2.3 million people are resident in the Lebanese coastal zone. Major pollution problems are untreated urban wastewater, solid wastes and coastline urbanization. Urban wastewater is discharged into the sea untreated (44,000 tons of BOD5 per year) as no municipal WWTP is in operation in the country. Furthermore, beachfront dumping sites of municipal and industrial solid wastes constitute an important location-based service (LBS). Areas with major environmental problems are the Tripoli area, Beirut area, Mount Lebanon area and Sidon.

3.13 Libya

Libya's coastal zone hosts 85 % of the country's population and also most of its industrial, agricultural and tourist activity. There are no natural rivers in the area, only Wadis (temporary dry rivers) which transport sediment, litter and pollutants from inland to the sea during storms. Major environmental problems in Libya are oil pollution near terminal facilities as well as untreated urban and industrial wastewater from the bigger cities. Areas with major environmental problems are Tripoli and Benghazi, Az Zawiya, Zuwarah, Misratah, Al Khums and Sirt.

3.14 Malta

Malta has a coastline of 190 km, 43 % of which is heavily utilized. The built-up area comprises 24 % of the coast. This constitutes a very high population density (1,300 persons/km^2). The southern part of the island of Malta is the area with the majority of human activities and the major environmental problems, i.e. urban and industrial wastewater. On the island, 85 % of urban and industrial wastewater is disposed of untreated. Areas of major environmental concern are Southern Harbour District, Southern beaches in the vicinity of the Grand Harbour and Marsaxlokk Bay, the vicinity of the Grand Harbour and Msida Yacht Marine.

3.15 Monaco

Monaco has a population of 33,000 and a high population density (16,500 people per km^2). The city wastewater is discharged into the sea through submarine outfalls after treatment. Furthermore, there is also primary treatment of storm water before it is discharged into the marine environment. Solid wastes are recycled or incinerated, reducing their weight by 70 % before sanitary disposal. Special industrial wastes are also treated. The greater part of the coastline of Monaco is urbanized.

3.16 Morocco

The major urban centres, which are also the most polluted areas on the Mediterranean coast, are Tangiers, Tetouan, Nador and Al Hoceima. The main environmental problems are caused by urban and industrial wastewater, maritime traffic and coastal urbanization. For example, construction, sand extraction and erosion have resulted in serious stress on the beaches. The major beaches under stress are in Tetouan, Mdiq, Restinga Smir, Al Hoceima, Cala Iris, Nador and Essaidia. Major problems in the coastal areas which are also urban centres are Tetouan, Nador and Al Hoceima.

3.17 Serbia and Montenegro

The Mediterranean coast of Serbia and Montenegro has a population of 409,000. Four percent of the total population of the country resides in urban areas. The major towns are Bar, Herceg Novi, Kotor, Ulcinj, Budva and Tivat. Owing to the discharge of untreated urban wastewater, eutrophication problems and microbial pollution can be detected in the vicinity of coastal towns. The major pollution problems are untreated urban wastewater, eutrophication of coastal waters and uncollected solid wastes. The areas of concern are Bar, Herceg Novi, Kotor, Ulcinj, Budva and Tivat.

3.18 Slovenia

Slovenia possesses a short coastline on the Adriatic Sea (46.6 km) and hosts approximately 80,000 people. More than 80 % of the Slovenian coastline is urbanized and mostly within 1.5 km from the sea front. Major environmental problems are related to discharge of partly treated urban and industrial wastewater and run-off from agricultural land. The areas of the major environmental concern are Koper Bay and the Bay of Piran.

3.19 Spain

The Spanish Mediterranean coast has a population of 15.6 million, representing more than 39 % of the country's population. The major cities are Barcelona, Valencia, Malaga, Murcia, Palma de Mallorca, Granada, Cartagena, Benidorm, Tarragona and Algeciras. Urbanization affects the most valuable and fragile coastal biotopes. The building rate is especially high on the Mediterranean coast due to two major factors: tourist resorts and second homes development and growth of urban sprawl in metropolitan areas of the major cities. The rivers Ebro, Segura and Jucar are also important routes by which urban and industrial pollution are transported to the Mediterranean Sea. Although most of the coastal cities operate wastewater treatment plants, the major pollution problems include discharge of urban and industrial wastewater. The main pollution spots on the Mediterranean coast are Barcelona, Valencia, Cartagena, Tarragona, Algeciras and the mouth of the River Ebro (Aragosta).

3.20 Syria

The Syrian coastal area represents only 2 % of the country's surface but hosts 11 % of its population (i.e. 1.5 million). The major coastal cities are Lattakia, Jableh, Tartous and Banias. These problems are disposal of untreated urban and industrial wastewater, oil slicks from the oil refinery and the oil terminal and the management of solid wastes. The areas of concern are Lattakia area and Tartous-Banias area.

3.21 Tunisia

The coastal zone of Tunisia is densely populated, hosting 6.3 million. Tunis, Sfax, Sousse, Gabes and Bizerta are the most important cities. A major part of the cities' wastewater is treated. The major environmental problems are industrial and urban wastewater, industrial and urban solid wastes and coastal urbanization. The most endangered areas are the Gulf of Gabes, Sfax coastal zone, Lake of Bizerta and island of Djerba.

3.22 Turkey

The Turkish coast extends for 8,333 km and can be divided into the Aegean region and the eastern Mediterranean region. Urban and industrial centres, oil terminals, agricultural and recreational facilities on the coast are the major land-based pollution sources in both regions. Coastal erosion is also an important problem. Areas of concern include the Bay of Izmir, Buyuk Menderes River, Aliaga and Foca regions, Iskenderun Bay, Mersin and Bodrum.

4 Pollution Case Studies: Egypt

4.1 Water Quality of Abu Qir Bay Along the Mediterranean Coast of Egypt

As a component of Sustainable Management of Scarce Resources in the Mediterranean Coastal Zone Project (SMART 2005), the study was based on continuous monitoring of Abu Qir Bay along the Mediterranean coast of Egypt as shown in Fig. 1 for 5 years extending from 1998 up to 2002. Monitoring programme for Abu Qir Bay included bacteriological parameters (total coliform, *E. coli* and feacal streptococci), physical parameters (salinity, conductivity, pH, depth, temperature, dissolved oxygen and transparency) and chemical or eutrophication parameters (nitrite, nitrate, total phosphorus, total nitrogen, ammonium, reactive phosphate, reactive silicate, chlorophyll a and suspended particulate matter). The aim of the present investigation was to establish baseline knowledge of the water quality through continuous survey from which a database was built up and to assess the state of pollution in Abu Qir Bay. In general, gradual improvement for the water quality of Abu Qir Bay had been noticed during the period of the investigation (1998–2002) through continuous surveillance. The enforcement of the Egyptian environmental law (No. 4/1994) is one of the main reasons for this improvement.

4.1.1 Physical Parameters

- Monitoring of physical parameters revealed that salinity was generally low in front of fresh water outlets like Maadia and Rashid. With respect to pH values, slightly alkaline values were recorded for Abu Qir Bay. Low values of dissolved oxygen were observed sometimes in the Bay.
- Relatively high water temperature was observed most of the time in front of the electrical power station of Abu Qir Bay. This is due to the cooling water of the power station discharged into the bay. This phenomenon was continued during the monitoring years (from 1998 to 2002).
- High DO values were detected in surface water of the Maadia during May. This is due to the high rate of mixing and presence of strong surface currents. Sometimes, the presence of high amount of phytoplankton causes photosynthesis which lead to increase of DO, while the lower DO values were recorded in the deep water. This could be attributed to the discharge of untreated wastewater into the bay through Maadia outlet, Tabia outfall plus cooling water from the electrical power station.
- The investigation of seawater temperature during year 2000 revealed thermal pollution in Abu Qir Bay in front of the electrical power station especially in summer and autumn seasons. Relatively lower salinity values were observed at Rashid.

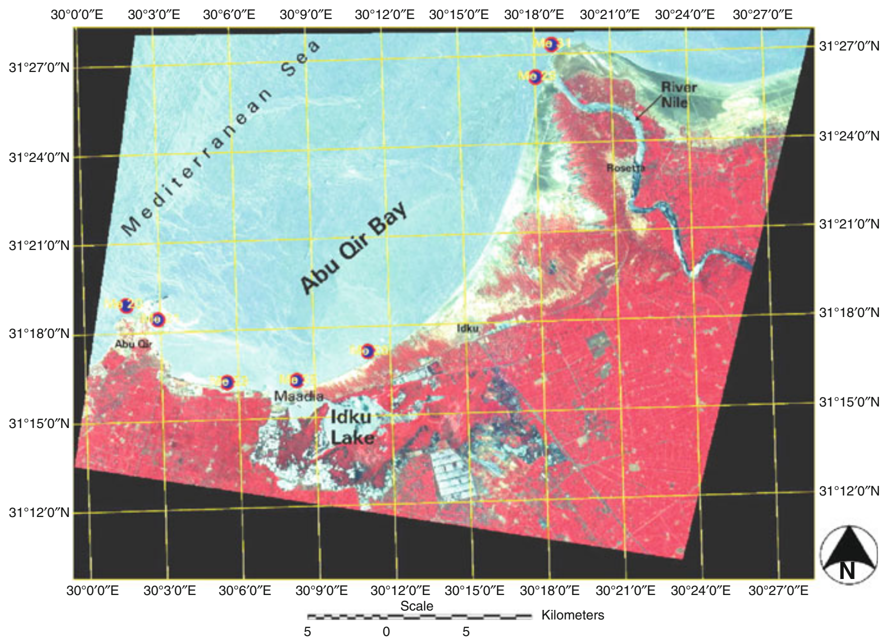

Fig. 1 Abu Qir Bay along the Mediterranean coast of Egypt

- Two cases of DO deficiency have been detected during year 2000: the first one was below the Egyptian guideline (4 mg/l) and the second was hypoxia (<3 mg/l). Deficiency of DO (<4 mg/l) has been detected during May 2000 at Abu Qir Bay, also during July 2000 at eastern of Abu Qir City and finally during November at Maadia. Hypoxia (<3 mg/l DO) has been detected in bottom water of Maadia during May 2000 and during September 2000 at the electrical power station and Maadia and finally during November at eastern Abu Qir City and the electrical power station.
- It is worthy to mention that the River Nile does not contribute to decrease salinity in front of Rashid during March and May. This is due to the change of seawater current being from sea towards Rashid estuary.

4.1.2 Bacteriological Parameters

Bacteriological investigation for pathogenic bacteria (total coliforms, *E. coli* and faecal streptococci) in Abu Qir Bay during the last 5 years (1998–2002) revealed the following:

- The sites especially in form of outlets like Maadia, Rosetta and outfalls were contaminated by faeces.

- Faecal contamination found in Abu Qir Bay is due to discharge of untreated sewage water.
- Eutrophication.
- Monitoring of eutrophication parameters, i.e. nitrite, nitrate, ammonia, phosphorous, silica, chlorophyll a and SPM, at Abu Qir during 1998 revealed high levels due to discharge of untreated wastewater into Abu Qir Bay.
- During year 2000, the regional and bimonthly variations of nitrate and nitrite along Abu Qir Bay showed relatively low levels.
- High levels of dissolved inorganic nitrogen (DIN) were detected in the bay due to the impact of discharge of domestic, industrial and agricultural run-off into the bay.
- High concentration of total nitrogen was observed to the east of Abu Qir City due to the impact of discharge of untreated wastewater into the bay.
- Relatively high levels of chlorophyll a and suspended matter were observed in front of outlets like El-Maadia and Rashid estuary.
- Maadia and Rashid sites were characterized by increasing primary production (relatively high levels of chlorophyll a). This may be related to the influence of drainage water brought by the River Nile or industrial wastewater.
- High concentrations of dissolved inorganic nitrogen (DIN) were recorded at the electrical power station and Maadia.
- In general, gradual improvement for water quality of Abu Qir Bay has been noticed during the period of the investigation (1998–2002). Continuous surveillance and enforcement of the Egyptian environmental law No. 4/94 are expected to be the main reasons for this improvement.

4.2 Improving Water Quality in Lake Manzala of Egypt

Located on the north-eastern edge of the Nile Delta in Egypt as shown in Fig. 2, close to Port Said, Lake Manzala once provided 30 % of all fish consumed in Egypt. Environmental and contaminant stresses have changed this. The public has become wary of eating Lake Manzala fish because they show a high frequency of organ malformation and discoloration. This situation has severely affected the fishing community, both socially and economically. In general, access to clean, reliable water is a primary concern for Egypt. Pollution from farms, cities and industrial centres flows through the Nile Delta, entering Lake Manzala and other large coastal lakes before pouring in the Mediterranean Sea. Traditionally, the wastewater has been left untreated, degrading the lake and sending pollution downstream into the Mediterranean (GEF 2006).

Lake Manzala Highlights:

- The lake is brackish and eutrophic.
- Land reclamation is a major development pressure.
- There is a net flow of water from the lake to the Mediterranean Sea. Changes in the lake's water budget will negatively affect the quality of the lake and the Mediterranean Sea.

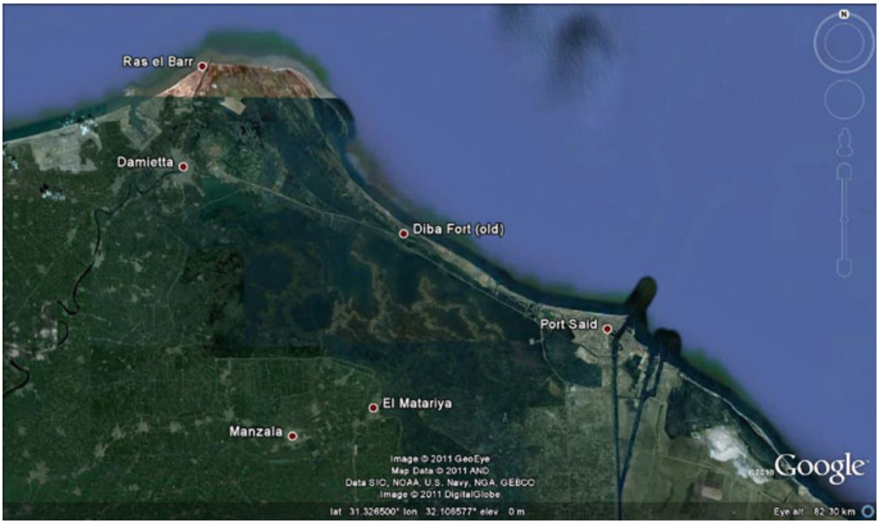

Fig. 2 Map of Manzala Lake

- Climate plays an important role in the lake's water budget and quality.
- Nine major drains are cited in literature as flowing into the lake transporting to large amounts of particulate matter, nutrients, bacteria, heavy metals and toxic organics.
- The lake turnover of 48 days is low. This has water quality implications.
- Aquatic vegetation is an important influencing factor for water quality.
- Typical water quality ranges
- Salinity 3,000–35,000 mg/l
- Temperature 11.3–30.50°C
- pH 7.8–9.0
- Chlorophyll 12.66–32.38 mg/l

A study suggested the use of engineered wetland for the lake. The successful operation of the engineered wetlands will encourage the government to replicate the technology in other parts of the lake, thus reducing the pollution load that reaches the Mediterranean Sea. Because they are the first of their type in Egypt and the Middle East, the wetlands should generate design criteria for new engineered wetlands in the region. Engineered wetlands also appear to be an appropriate decentralized wastewater treatment technique for remote communities in Egypt and the Middle East, especially with the availability of spacious desert lands. During operation, the project aims to engage members of the local community in economic activities related to the operation and maintenance of the facility to increase their awareness of the technology and cover some of the operational costs of the facility. Local residents will also be involved in harvesting and processing plants into marketable products. Meanwhile, the effluent will provide clean water for the aquaculture facility to produce fingerlings and juvenile fish for restocking the lake and for other aquaculture ventures.

5 The Mediterranean Pollution Maps

To conclude all the available pollution information towards de-pollution, details and analysis are presented in the following figures: Figure 3 presents the Mediterranean coastal areas with their population densities. Figure 4 indicates the distribution of the pollution sources by country, where most of the countries dump untreated urban and industrial wastes into the Mediterranean Sea. Types of pollution for each country are shown in Fig. 5. The percentages of countries sharing the same sources of pollution out of the total countries of the Mediterranean basin are highlighted in Fig. 6. Finally, Fig. 7 presents the hot spots scattered in the areas bordering the Mediterranean cost.

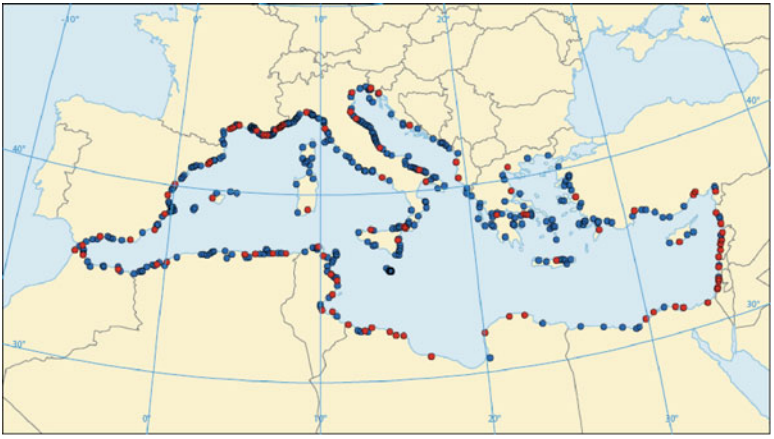

Fig. 3 Mediterranean coastal cities

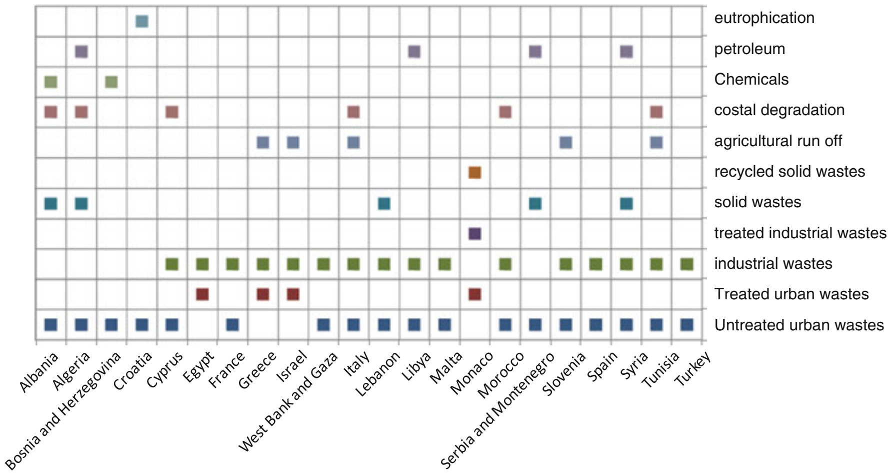

Fig. 4 Distribution of the pollution sources by countries

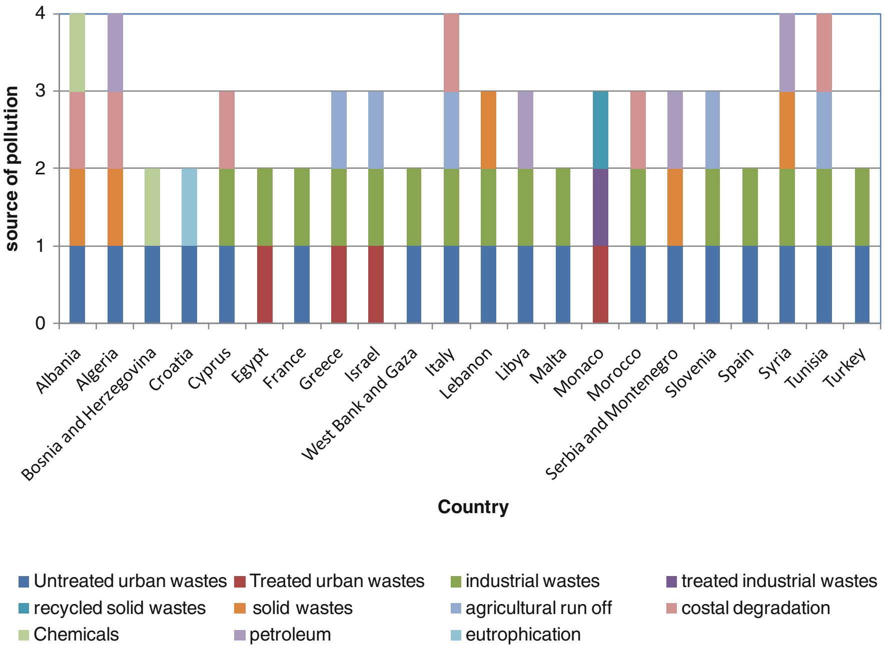

Fig. 5 Types of pollution for each country

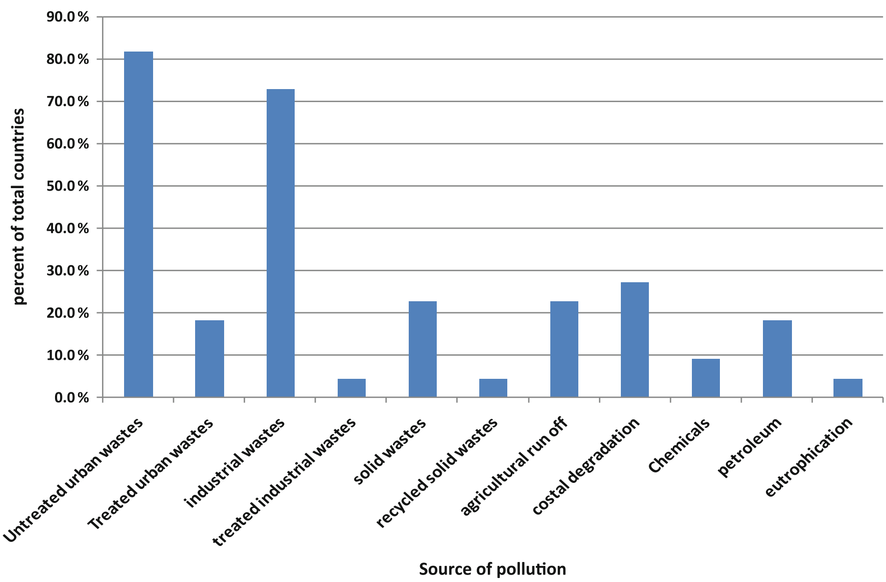

Fig. 6 Percentages of countries sharing the same sources of pollution to the total number of the Mediterranean basin countries

Fig. 7 pollution hot spot areas on the Mediterranean Sea

6 Towards De-pollution of the Mediterranean Sea

In 2009, Salim L. Sanin published a manuscript for the Components of Marine De-pollution in the Mediterranean Region. A separate section in Sanin's paper was dedicated to the activities towards de-pollution of the Mediterranean Sea. Sanin, 2009, stated that:

In a Mediterranean Hot Spot Investment Programme (MeHSIP) activity, coordinated by the European Investment Bank and the World Bank (finalized in 2008), projects that have the largest impact on Mediterranean pollution across the Mediterranean region was to be identified. This programme was initiated to support the non-EU member countries.

Many cooperation actions have been considered and activated for the de-pollution of the Mediterranean inspired by the Horizon 2020 initiative. In this chapter, only the Euro-Med programme which is exemplary of south Mediterranean joint forces programme is presented below.

6.1 Euro-Med Programme

This programme is funded by the European Union. Within this programme, the Sustainable Water Management and De-pollution of the Mediterranean, the project is activated. The project aims at enforcing sustainable water management policies, disseminating good practices in the region and supporting the initiative for the de-pollution of the Mediterranean. The project's timeframe is from 2009 to 2013 with a budget of 22 million euros, and the countries included are Algeria, Egypt, Israel, Jordan, Lebanon, Morocco, occupied Palestinian territory, Syria and Tunisia.

6.2 Euro-Med Objectives

The programme promotes the enforcement of sustainable water management policies and the dissemination of good practices in the region. This, in a context of increasing water scarcity and pressure on water resources from a wide range of users and desertification processes, directly linked to climate change.

It draws attention to threats to water resources and solutions that exist, as well as the need to adopt a more appropriate model of consumption, supporting partner countries in implementing sustainable water management policies.

It carries forward the results achieved by two earlier regional programmes, SMAP I, SMAP II and SMAP III and MEDA Water

6.3 Euro-Med Actions

- Conducts capacity building activities
- Supports the implementation of demonstration projects in integrated water management, coastal zone management and H2020
- Identifies good practices and success stories in the region and elsewhere
- Organizes events aiming to mobilize partner countries and donors, discuss thematic issues, harmonize policies and facilitate dialogue
- Mobilize finance to support infrastructure development
- Develops a communication and awareness-raising strategy targeting decision makers and stakeholders

Despite all carried out efforts and activities, there is still a threatening pollution from the Med-countries to the Med-basin despite all agreed upon action plans, declarations and international agreement programmes. Therefore, Med-countries need to cooperate even more and combine efforts at all levels (within each nation and across nations) trying to reduce this progressing pollution threat and work very hard towards meeting the agreed upon dated objectives within the various action plans and declarations. The levels of interventions and cooperation should include (but not limited to) public participation, public awareness and consensus, research, technology and its transfer across nations, decision makers will and support, financial support, private and government sectors sharing and support, international cooperation and coordination. If these interventions and more are given the nations' attention towards the issue of concern, pollution threat of the Med-basin is likely to be much reduced than what we witnessed throughout the current presented surveying research achieving an environmentally safe Med-basin that will, for sure, benefit and improve the quality of life of millions of Med-countries coastal populations.

7 Summary and Conclusions

This chapter highlights the Mediterranean countries' pollution issues, draws the Mediterranean pollution map and presents two case studies from Egypt.

In light of the above, it is clear that about three quarters of the Mediterranean countries dump domestic and industrial wastes into the sea; this is due to the fact that sanitation coverage in the southern and eastern Mediterranean countries remains inadequate.

More over than one fifth of the Mediterranean countries are considered responsible for inducing petroleum wastes to the sea (treated or untreated). One cannot refer to actions or plans undertaken at the regional level without seeing the Mediterranean Action Plan (MAP) as the most initiative framework for environmental cooperation in the Mediterranean region. Also the Euro-Med programme that promotes the enforcement of sustainable water management policies in the Mediterranean region inspired by the Horizon 2020 initiative is a modular example.

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Recycling and Reuse of Treated Wastewater: Challenges and Perspectives – The Example of the Júcar River Basin District and the Albufera Lake

Javier Ferrer Polo

Abstract The reuse of reclaimed water is a non-conventional hydrological resource that together with desalination constitutes an important pillar for the integrated water resources management in the Mediterranean, where climate change aggravates the stress on this already very vulnerable region.

The here presented work provides information about two recent documents elaborated in Spain to enforce an increasing use of reused water: the Royal Decree 1620/2007 and the draft National Water Reuse Plan. The first text gives the basic conditions, from a legal and a sanitary water quality point of view, to ensure a proper reuse, while the second presents a series of actions to be financed by the state that permit the incorporation of up to 249 hm^3 of additional water with an investment of 344 million euro in 2009–2015.

This document also describes the main reuse actions in the territory of the Júcar River Basin District with interesting characteristics and the corresponding strategies included in the Programme of Measures of the Júcar River Basin Management Plan. This Programme of Measures aims to satisfy water demands and at the same time to achieve the good status of water bodies, especially with regard to the good quantitative status of the groundwater bodies, which are jeopardized by an intensive use of resources. Therefore, reuse actions have been included in the Horizon 2010–2021 of the Programme of Measures that will contribute with an increase of 160 hm^3 of the reused water volume and a related investment of 431 million euro.

Those reuse actions, which are located in the vicinity of the Albufera wetland, are outstanding in this set of reuse actions. This wetland is characterized by an important availability of properly treated water resources, and a large irrigated area and was declared Ramsar wetland of international importance, but suffers from eutrophication problems. This set of features leads the Júcar River Basin Authority to propose an investment of 92 million euro in reuse actions that allow a volume increase for agricultural and environmental uses of 40 and 35 hm^3, respectively. The

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purpose of these activities is to improve the quality of certain direct effluents to the wetland and to ensure a contribution that is adequate and stable in time regarding quantity and quality, and that also includes an additional treatment with green filters. These actions are complemented with an intense quality and quantity modelling that ensures the environmental improvement of the wetland.

Keywords Wastewater treatment • Wastewater recycling • Wastewater reuse • Non-conventional water resources • Júcar river basin district • Green filter • National water reuse plan • Wetland

1 Introduction

The reuse of purified or reclaimed treated wastewater is a non-conventional water resource that jointly with desalination is a basic element for the integrated water resources management in the Mediterranean region, where climate change worsens the stress on this already vulnerable region.

Reclaiming treated wastewater allows its adaptation regarding quality to the different uses, especially from the sanitary and the agricultural point of views, and with respect to irrigation uses, a special focus can be put on the aspects related to effluent's salinity and its effects over soil permeability and drainage.

Direct reuse of this resource does, in general, not generate an additional resource. Usually, previously treated wastewater discharges into water courses have future uses and circulating flows might be reduced. Therefore, the possible effects of the reuse on them and on the environment must be carefully analyzed. However, in wastewater reuse may produce additional resources and result in a quality improvement in water bodies that previously received the discharges.

The traditional agricultural reuse of urban wastewater, with little disease controls, was converted into a controlled and programmed use and has become an important pillar of the integrated water resources management in the Mediterranean basins, being Spain and the Júcar River Basin District (RBD) typical examples.

A detailed description of the proposed activities regarding wastewater reuse both in Spain and the Júcar RBD is considered of interest, confirming the importance that such actions may have in meeting two objectives: demand satisfaction and the achievement of the good status of water bodies, all in accordance with the European Water Framework Directive 2000/60/CE.

2 Treated Wastewater Reuse in Spain

2.1 Background of Water Reuse in Spain

In Spain, conventional water resources have reached a very high degree of development. The increase of water demand is exacerbated by the effects of droughts, leading to the need for non-conventional resources.

The significant development of wastewater treatment techniques in Spain, in recent decades, favours the potential use of reclaimed water and increases the supply guarantee for urban and agricultural uses, especially in Mediterranean coastal areas, where the wastewater reuse means an increase in resources to face water scarcity, and insofar as possible, it contributes to the aim of zero waste dumping into the sea.

Wastewater reuse, as an alternative water source, generates water for activities that do not require drinking water quality, or can release natural water resources to destine them to preferential uses supply.

All these aspects are regulated by Royal Decree 1620/2007 of 7 December, establishing the legal framework for the reuse of treated wastewater. This Royal Decree addresses those aspects of the administrative processing of water rights that is necessary for its use as public water resource.

In addition, to achieve the good water status in 2015 as required by the EU Directive 2000/60/CE and to ensure the achievement of environmental goals or objectives, Spanish River Basin Authorities are developing the Programme of Measures (PoM) specified in the River Basin Management Plans (RBMP) – Article 11, EU Directive 2000/60/CE. These PoMs identify further measures for wastewater reuse, which in accordance to the updating process of the RBMPs need to be reviewed every 6 years.

In Spain, there are currently about 2,400 wastewater treatment plants (WWTP) and an approximate volume of 3,400 hm^3/year of treated wastewater, of which 368 hm^3/year is reused through approximately 320 wastewater recycling plants. This volume represents 10.8 % of the total volume of reused water and is mainly used for agricultural and environmental purposes, contributing the last to the maintenance of environmental flow regimes; 224 hm^3/year is reclaimed in operating wastewater regeneration plants, and 144 hm^3/year is currently reused without a regeneration treatment in plants under construction or planned.

As introduced, the volume of reused water in Spain in 2006 reached 368 hm^3/year (source: own elaboration based on NWRP 2010 data) being Júcar and Segura RBD those where this type of non-conventional resources was more widespread, with reused wastewater volumes considerably higher than in the rest of Spanish RBD as shows Fig. 1. Furthermore, the largest number of Spanish reuse systems are found on the Mediterranean coast, the Balearic and Canary Islands.

However, certain aspects that need improvement to develop more efficient reuse can be summarized in the following points:

- Weaknesses in the management and operation of wastewater treatment systems, e.g. by inadequate operation or lack of funding, control and resources
- Existence of uncontrolled spills into municipal collectors that hinder the treatment of wastewater and hence its regeneration in accordance with the quality standards prescribed by law
- Need to invest in existing reuse systems so as to suit the obligations under the existing Royal Decree
- Need to adapt the concession system to existing uses of reclaimed water

Fig. 1 Volume of water reused per RBD in Spain. Status in 2006 (Source: Ministry of Environment and Rural and Marine Affair (MARM 2009))

As a tool in order to solve these deficiencies, the National Water Reuse Plan (NWRP) is based on the following five main priorities:

- Development of the legal framework for water reuse through initiatives or plans of the public administrations
- Identification and implementation of the infrastructures needed to achieve the objectives set by the NWRP
- Implementation of the Best Practices for Water Reuse Guidance Document
- Promotion of wastewater reuse and desalination actions
- Dissemination, communication and public participation

2.2 *Royal Decree 1620/2007*

The Royal Decree 1620/2007, of 7 December (RD 2007), establishes the legal regime to rule the treated wastewater reuse (WWR) in Spain. It includes, amongst others, legal definitions and defines the allowed uses for reclaimed water, quality criteria, control parameters and procedures to get reuse permits. This text is a suitable legal frame for the incorporation of such resources in the water resources exploitation systems.

Table 1 Standards of targeted water quality (types from A to F) and regeneration treatments for purified waters according to the Royal Decree 1620/2007 (own elaboration – data source: RD 1620/2007)

Quality	Type	Treatment train (without desalination)
A	1	Chemical precipitation, filtration with membranes and disinfection (residual chlorine may be needed in distribution systems)
B	2	Chemical precipitation, depth filtration and disinfection (ultraviolet radiation + chlorination); (residual chlorine may be needed in distribution systems)
C D	3	Filtration and disinfection (trend of using ultraviolet radiation followed by a residual chlorine)
E	4	Filtration
F	–	Requires a case by case study
		Treatment train + desalination
A–F	5a	Chemical precipitation, filtration, filtration with membranes, RO desalination and residual chlorine
B, C, D, E	5b	Chemical precipitation, filtration, EDR desalination and disinfection (trend of using ultraviolet radiation followed by a residual chlorine)

Article 2 of RD 1620/2007 presents important definitions of legal aspects to be considered in the WWR process. Here, two concepts included in this policy are highlighted: Water Reuse and Regenerated or Reclaimed Water:

(a) Water Reuse: appliance on water, before it returns to Water Public Domain and to Maritime-Land Public Domain for a new privative water use, which having been used for the person who derived it, have received the treatments according to their discharge permit and those necessary to reach required quality according to the uses for which they will be assigned
(b) Regenerated or Reclaimed Water: treated or purified wastewater, which have received an additional or complementary treatment process to adequate their quality to that required for the assigned use

According to this Decree, Tables 1–4 show the different quality standards (categorized from A to F) and the necessary treatments to achieve them, depending on the final use of the purified/reclaimed wastewater. These specifications are covered in Royal Decree 1620/2007, which rules the reuse of purified waters after having received a previous depuration treatment in a wastewater treatment plant (WWTP).

As mentioned below, several quality types and categories define the treatments required to fulfil with these quality standards (described in the previous table) of the reclaimed water before being used. However, the different final uses considered in RD 1620/2007 define the quality standards of water reuse and consequently the required treatments and the parameters' thresholds of the control variables in order to ensure the achievement of the required quality.

These microbiological parameters whose thresholds are defined according to the final use of the reused water are *Escherichia coli, nematodes* and *Legionella.* Other parameters, for instance, solids in suspension and turbidity, are taken into account (Table 1).

Thus, Table 2 lists the different final uses (Applications row) which define at their right the required quality level and the microbiological parameters' thresholds to be respected for that purpose.

Once the necessary treatment types (from 1 to 4) are established in fulfilment of the quality types (from A to F) required by the final uses, the unit production costs (€/m^3) of these reclaimed waters can be assessed, distinguishing between implementation and operation costs. It has been differentiated between normal regenerating treatments and those which need an additional treatment of salts removal. These cost assessments are shown in Tables 3 and 4.

2.3 National Water Reuse Plan

The National Water Reuse Plan (NWRP 2010) aims at generating new water sources, setting aside the highest quality waters for the most demanding uses, and achieving an improved status of water bodies. This plan comes as a new management tool that intends to increase the supply guarantee for consolidated uses and to improve water use by replacing pre-potable water by reclaimed water. Additionally, in coastal areas, it will increase the net availability of water resources.

It ensures the water supply guarantee for irrigation during drought periods and releases natural resources in normal situations in many Spanish RBDs. It also covers the execution of the adapting works in existing WWTP to make the effluents fulfil with the quality requirements established in RD 1620/2007 and to make them profitable for a sustainable wastewater reuse.

Although NWRP was already developed and it passed the public consultation process in 2010, it has not yet been formally approved. Therefore, the forecasted volumes of wastewater reuse are provisional and may have changed in some RBD. Nevertheless, NWRP was a very useful background for the PoM's development in the RBMP's drafting process.

Some of the actions and measures included in the NWRP have been declared as works of general interest, and their financing is covered by the national government budget. So in the NWRP are included many of the actions or measures considered in the PoM of the RBMPs.

It establishes criteria for the General Interest Statement of the activities planned until 2015:

- Actions of wastewater reuse for environmental uses, according to the estimates of water resource plans and in fulfilment of the environmental objectives established by Article 92bis of the Revised Water Law Text, approved by Royal Legislative Decree 1/2001, of 20 July
- Actions of wastewater reuse for agricultural uses, leading to a replacement of water resources from conventional sources by reclaimed water
- Actions of wastewater reuse for urban uses, heading to the relief of resources, either raw water or drinking water resources

Table 2 Standards of targeted water quality (types from A to F) for purified waters according to the Royal Decree 1620/2007

Applications		Quality	Escherichia CFU/100 ml	Nematodes eggs/10 l	Legionella spp. 100 CFU/l
Industrial 3.2 a) y b)	Refrigeration towers and evaporation condensers	A	Absence	Absence	Absence
Residual 1.1 a) y b)	Private garden watering. Discharge of bathroom appliances		Absence	1	100
Direct recharge 5.2 a)	Recharge of aquifers by direct injection		Absence	1	No limit set
Urban 1.2 a), b), c), d)	Watering of urban green areas	B	<100–200	<1	<100
Agricultural 2.1 a)	Hosing down streets. Fire-fighting systems				
Recreational 4.1 a)	Industrial car wash. Irrigation with contact				
	Irrigation of golf courses				
Agricultural 2.2 a), b) y c)	Irrigation of crops for human consumption not avoiding direct contact of regenerated water with edible parts	C	<1.000	<1	No limit set
	Irrigation of pastureland for milk or meat producing animals.				
Industrial 3.1 c)	aquaculture				
	Process and cleaning water for use in food industry				
Environmental 5.1 a)	Recharge of aquifers by localized seepage through the soil		<1.000	No limited set	No limited set
Agricultural 2.3 a), b) y c)	Localized irrigation of ligneous crops impeding contact of regenerated water with food for human consumption	D	<10.000	<1	<100
Industrial 3.1 a) y b)	Irrigation of omamental flowers, greenhouses and nurseries with no direct contact of regenerated water with crops				
	Process and cleaning water except in food industry				
Environmental 4.2 a)	Ponds, bodies of water and running water with no public access		In this table dots are used as thousands separator		
Environmental 5.3 a) y b)	Irrigation of forests, green zones and similar areas with no public access	E	No limited set	No limited set	No limited set
Environmental 5.4 a)	Maintenance of wetlands, minimum flows and similar uses	F	The minimum quality required is studied on a case by case basis		

Source: RD 1620/2007
Uses allowed and controlled parameters

Table 3 Construction and maintenance costs – type of treatment, without salts removal, implementation and operating costs

		Costs	
Type of quality	Type of treatment	Implementation (€/m³ fed into the system/year)	Operation (€/m³ product)
A	1	0.82	0.14–0.20
B	2	0.12	0.06–0.09
C	3	0.05	0.04–0.07[a]
D			
E	4	0.03	0.04–0.07

[a]The influence of disinfection means a difference of 0.005 €/(m³product); it cannot be noticed with two decimals

Table 4 Construction and maintenance costs – type of treatment, without salts removal, implementation and operating costs

		Costs	
Type of quality	Type of treatment	Implementation (€/m³ fed into the system/day)	Operation (€/m³ product)
All	5a	259–458	0.35–0.45[a]
B, C, D, E	5b	248–405	0.35–0.45[b]

[a]In those cases where physicochemical and sand filtration treatments can be avoided, the range could be as low as 0.30–0.40 (€/m³ product)

[b]In those cases where physicochemical treatments can be avoided, the range could be as low as 0.30–0.40 (€/m³ product)

The scope of the plan covers all Spanish inter-regional river basin districts. However, reuse actions could be considered for intra-regional basins, in which case the request to involve agencies and the subsequent acceptance by the Directorate General for Water of the Ministry of Environment would be necessary.

The objectives of the National Water Reuse Plan (NWRP 2010) are:

- Contribute to achieve good water status under Article 92bis of the Revised Water Act, approved by Royal Decree 1/2001 of 20 July (in accordance with the Directive 2000/60/CE)
- Contribute to the establishment and maintenance of environmental flow regimes
- Reduce as far as possible direct wastewater discharges into the sea
- Establish an appropriate economic model to promote the sustainable reuse of wastewater
- Encourage the use of reclaimed water in accordance with best practices in wastewater reuse
- Informing, educating and increasing public awareness on the benefits of wastewater reuse
- Promote research, development and technological innovation regeneration systems

The NWRP is a coordination tool that will allow the orderly growth of water reuse and help achieve and ensure the objectives set by the Directive 2000/60/CE,

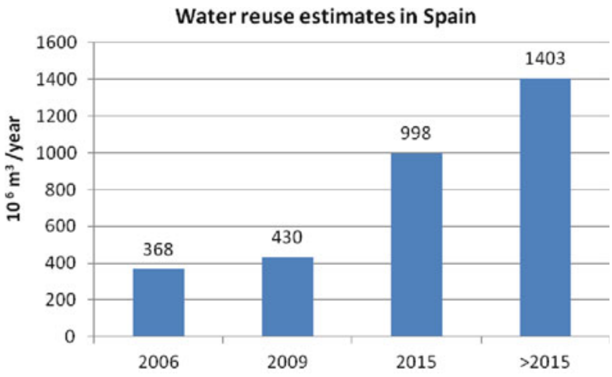


Fig. 2 Evolution of volumes of wastewater reuse in Spain (Source: Own elaboration based on NWRP 2010 data)

as it contributes indirectly to recovery, improvement and maintenance of the good status of surface water bodies and groundwater.

The NWRP aims to increase the volume of reclaimed water in the wastewater reuse from the mentioned 368 hm^3/year in 2006 up to over 1,400 hm^3/year after 2015 (Fig. 2). The estimated total activities of general interest in inter-regional RBD until 2015 are about 249 hm^3/year with an investment of 344 million euro.

According to the NWRP, the following actions will be considered of general interest: (a) the actions or works declared as not completed, (b) actions to reuse water for environmental purposes and (c) those for agricultural water reuse, involving the replacement of resources from conventional sources by reclaimed water.

The NWRP gathers many of the measures listed in the future PoM of the RBMPs in the several Spanish RBDs, specifically, those related to the improvement of wastewater treatment to adapt the WWTP effluents to the quality standards required for water reuse. In Table 5 are summarized the measures headed to increase this non-conventional resource for the next hydrological planning cycle that according to the Directive 2000/60/CE schedule would be by 2015 onwards (NWRP 2010).

3 Importance of Treated Wastewater Reuse in the Júcar River Basin District

3.1 Júcar River Basin District General Features

Many Spanish river basin districts (RBDs) suffer from water scarcity, persistent drought periods, land degradation and groundwater overexploitation, all of them exacerbated by the climate change process. For instance, the Júcar RBD, located at the Mediterranean shore, is one of those typical Spanish RBD suffering from the mentioned impacts. Furthermore, some other phenomena, for instance, floods and torrential

Table 5 Actions of the National Water Reuse Plan – Horizon 2015 (inter-regional RBDs)

Horizon 2015					
RBDs	Number of actions	Volume to reuse (hm^3/year)	Expected investment reclaim treatment (M €)	Expected investment transport (M €)	Expected total investment (M €)
Tajo	23	38	8	36	44
Júcar	55	53	15	54	69
Segura	32	90	99	36	135
Guadiana	15	21	8	30	38
Guadalquivir	1	7	7	2	9
Duero	2	3	0	1	1
Ebro	5	11	2	11	13
Cantábrico	7	20	18	12	30
Miño-Sil	4	6	1	3	4
Total	144	249	159	185	344

Source: NWRP (2010)

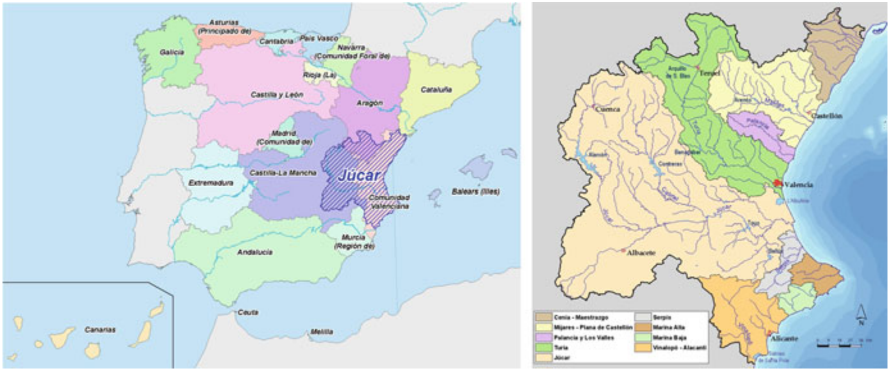


Fig. 3 *Left figure*: Map of autonomous regions' distribution in Spain and location of JRBD – *Right figure*: Map of the water exploitation systems and rivers network in the JRBD

rainfall episodes together with land-use changes and extensive water withdrawals, should also be considered while assessing the sources of land degradation and desertification.

The territory of the Júcar RB (CHJ 2009), with a surface of 42,851 km^2, is located geographically in the central eastern edge of the Iberian Peninsula. It is defined by Royal Decree 650/1987, of 8 May, indicating that it includes all watersheds draining into the Mediterranean Sea, between the Segura and Cenia river mouths, including also the latter. The set of catchment areas is structured in nine exploitation systems around the main rivers; amongst those, the Júcar is outstanding as it covers approximately 50 % of the total area, which is therefore named Júcar RBD (Fig. 3).

The Júcar RBD has a permanent population of 5,162,163 inhabitants, and its main economic sectors are tourism, with a population equivalent of 404,883 people concentrated mainly in the coast, and irrigated agriculture, with an irrigated surface of some 372,000 ha. Agricultural irrigation is the main water user in the JRBD with a 78 % of the total gross demand, representing urban and tourism use around 18 % and industrial use slightly less than 5 % of the total (CHJ 2009).

Groundwater resources are of particular importance as they represent the 51 % of the total water resource of the district in comparison with the 45 % from surface water. Resources from reuse represent 3 % of the total water resources. This information is shown in Fig. 4.

A typical Mediterranean climate with warm summers and mild winters is predominant in the JRBD. Maxim temperatures are normally registered in July and August, coinciding with the dry season. Average annual temperatures range from 14 to 16.5 °C. The average annual rainfall is about 500 mm; however, there is great spatial variability with values of 300 mm in the southern regions, while in other areas, reached values are higher than 750 mm, as shown in Fig. 5.

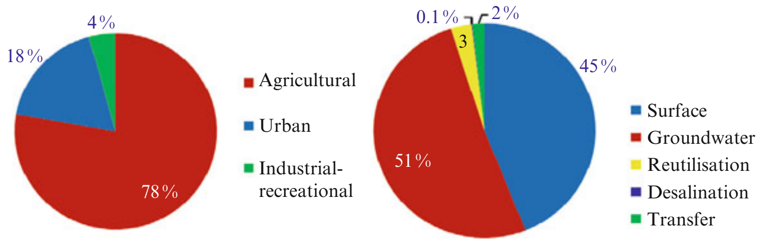


Fig. 4 *Left*: water demand in the Júcar River Basin District by different uses. *Right*: distribution of water resources in the JRBD

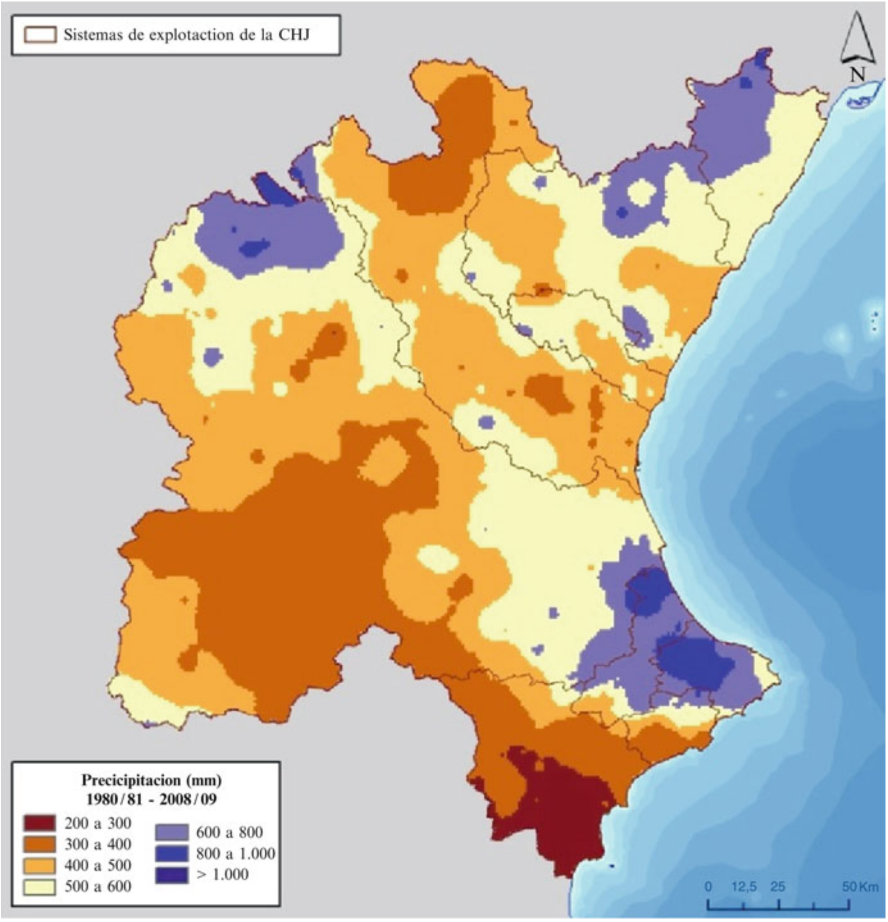


Fig. 5 Maps of the average annual precipitation ((mm) Júcar RBD). Period: 1980/1981–2008/2009 (Source: Júcar RBA)

Time or seasonal variability in the rainfall regime is of high importance, existing frequent torrential rainfall episodes (short time and high intensity rainfall episodes), a meteorological phenomenon commonly known as “gota fría” (cold drop in English), which are convective storms taking place mainly between October and November.

Most of the surface of the river basin territory is covered with permeable materials, which permit the infiltration of surface water from precipitation into underground strata.

3.2 Wastewater Reuse in the Programme of Measures of the Júcar River Basin Management Plan

Between all Spanish RBDs, the Júcar has the highest water reuse volumes. In 2006, Júcar RBD was already, jointly with Segura RBD, the river basin authority with the highest reuse volumes of 128.2 hm^3/year and 104.8 hm^3/year, respectively.

Total volume of treated wastewater in the Júcar RBD reaches 624.8 hm^3/year of which 145.8 hm^3/year are reclaimed (data from 2009) and includes the reused volumes for environmental purposes. The concentration in the coastal zone, of both major urban centres and major irrigation areas, favours the use of reused water and furthermore represents an additional water resource as urban discharges do not have any other posterior use.

The Programme of Measures (PoM) of the future Júcar River Basin Management Plan (RBMP), currently under development, must first collect those measures under way and planned in the various plans and programmes of several administrations, taking as its starting point the year 2010, regardless of the estimated ending date. This date is determined, amongst others, by the budgetary capacity of the various administrations, being 2015 or 2021 for those cases where a need of extension can be justified.

Within the frame of achieving the objectives/goals required by the Directive 2000/60/CE, the measures that help to achieve the good quantitative status in groundwater bodies are included, aimed at reducing withdrawals through demand management activities or replacing them supplying additional water resources: surface water surpluses and non-conventional resources. Here is where water reuse pays an essential role.

The demand management measures mainly include the irrigation modernization. A significant reduction regarding unitary allocations in urban supply is also being produced, although, given their lower importance, the expected volume of urban savings will not be globally important, but very significant in certain areas.

These water demand’s management measures are based on substitution of withdrawals providing other resources contributions.

According to the PoM, the main actions will mean an increase of water resources through surface water surpluses and non-conventional water resources: wastewater reuse and desalination.

The investment of the various administrations in the period 2010–2021 for all measures, both demand and resources availability management, is a total of 1,819 million € and allows a considerable increase in water resources, estimated at 387 hm^3/year and estimated savings of 118 hm^3/year due to modernization, with a significant dependence on the seasonality and on the growth of the water demand for reuse and desalination, and of the hydrologic variability in the case of surface surpluses. Specifically, the maximum capacity of desalination materializes only in part due to strong summer seasonality in demand and a lower growth of urban demand with respect to the original estimates. Table 6 summarizes the main features of the actions foreseen in the period 2010–2021 broken down by type of activity.

The annual equivalent cost (AEC) includes both the investment recovery costs (amortization) during its useful life and the operating costs; its value is given by the following expression:

$$\text{AEC} = \frac{r * (1+r)^n}{(1+r)^n - 1} * I + \text{AOC}$$

r: Discount rate (4 %)
I: Investment at constant prices 2009
AOC: Annual operating costs at constant prices 2009
n: Useful life of the works/infrastructures

In the case of the annual volume allocated to each type of measure, some considerations must be taken into account:

- In the case of the modernization, the gross savings have been considered as it is related to the improvement of the efficiency on resource management.
- In the case of wastewater reuse, desalination and increase of surface resources, the estimated production volume has been considered instead of the maximum capacity of the related measures.

Given these considerations, the cost per cubic metre shown in the table is an index for cost-effectiveness as to the improvement of the current resources' management. This ratio represents in no case the costs to be charged to the affected users since, on the one hand, the AEC includes the total investment cost including European funded parts and, on the other hand, regarding the modernization, the volume is not associated to the consumption, but to the savings.

Table 6 shows how the total costs of reuse are similar to those for more traditional actions taken to increase surface water resources; this is partly due to the necessary salt removal in some facilities, but they are in any case lower than costs for desalination for urban water supply in coastal zones.

Another consideration is the significant contribution of resources, where unconventional exceeds conventional resources, with the added advantage of having an almost complete warranty in drought situations, especially with regard to the urban water supply.

Table 6 Effectiveness and costs of measures based on demand and resources availability management from Programme of Measures of the Júcar RBMP (2010–2021)

Measures typology	Total investment mill €	Annual operating costs mill €/year	Annual equivalent cost mill €/year	Increase on water resources hm^3/year	Savings hm^3/year	Operating cost €/m^3	Total cost €/m^3
Modernization	549	7.9	43	–	118	0.07	0.36
Surface surpluses	579	41.0	78	189	–	0.22	0.41
Wastewater reuse	431	30.3	69	160	–	0.19	0.43
Desalination	261	55.5	79	72	–	0.77	1.09
Total	1.819	134.6	268	387	118	0.27	0.53

Amongst the actions planned, reuse plays an important role, not only due to the increase of non-conventional resources it provides to the basin, but also thanks to the improvement of surface water quality due to the reduction of discharges.

The programme of measures foresees a large number of reuse measures that include regeneration actions for treated wastewater as well as regulatory and distribution actions for the reclaimed water, mainly for agricultural purposes.

Below is a summary of the investment in reuse during the period 2010–2021 by operating system and the surroundings of the Albufera lake. The significant projected increase of reuse for the period 2010–2021 in the JRBD with agricultural and environmental purpose is estimated to be 125 and 35 hm^3/year, respectively. Also important is the relative weight of the Albufera wetland in this set, due to the magnitude of the discharge of Valencia and its metropolitan area, main urban centre in the territory and the interest for an environmental reuse in this important wetland, being foreseen an increase of agricultural reuse of 40 hm^3/year and of an environmental reuse of 35 hm^3/year. This importance gives reason for the detailed analysis of the situation in the Albufera wetland in the next chapter (Table 7).

4 Wastewater Reuse in the Surroundings of the Albufera Lake

4.1 Features and Problems of the Albufera Lake

The Albufera lake of Valencia, wetland included in the Ramsar Convention on Wetlands of International Importance, is perhaps the most emblematic environmental area within the territory of the Júcar RBD. Its operation is determined by human action, and it connects with the sea though five outlets or drainage channels, three of them directly communicated with the central lake. These outlets have sluice gates to regulate the levels and flows, operated by the “Junta de Desagüe” (Drainage Board) that allows the cultivation of rice in most of the 15,000 ha, forming the marsh area of which is predominant in the 21,000 ha of the natural park. This important anthropization characterizes the Albufera as a heavily modified water body.

Moreover, the Water Framework Directive (2000/CE/60) establishes that member states have to protect and enhance the status of surface water bodies, with the objective to achieve the good ecological status of those water bodies at the latest 15 years after the entry into force of the Directive that means in the year 2015. In the case of artificial or heavily modified water bodies, as the Albufera of Valencia is classified, the Directive provides that member states should *protect and improve with the objective of achieving the good ecological potential and a good chemical status*.

With this ambitious goal *began in 2002 a long process, promoted* by the then Ministry of Environment (MMA) in coordination with the other local and regional administrations, which began with a detailed analysis, through the study for the sustainable development of the Albufera of Valencia (MMA 2004).

Table 7 Wastewater reuse 2010–2021 in the operating systems of Júcar RBD

Wastewater reuse measures	Total investment (mill €) 2010–2021	Increase of reuse volume (hm^3) consumptive + environmental 2010–2021
Wastewater reuse measures for demand supply in Maestrazgo operating system	12	5
Wastewater reuse measures for demands supply in Mijares-Plana de Castellón operating system	30	13
Wastewater reuse measures for demands supply in Palancia-Los Valles operating system	17	4
Wastewater reuse measures for demands supply in Turia operating system	5	12
Wastewater reuse measures for demand supply in the Albufera lake's surroundings	92	40 + 35
Wastewater reuse measures for demands supply in Júcar operating system	2	3
Wastewater reuse measures for demands supply in Serpis operating system	39	10
Wastewater reuse measures for demands supply in Marina Alta operating system	52	6
Wastewater reuse measures for demands supply in Marina Baja operating system	101	2
Wastewater reuse measures for demands supply in L'Alacantí operating system	6	5
Wastewater reuse measures for demands supply in Vinalopó operating system	75	25
Total	431	125 + 35

The main purpose of this study, in addition to the improved knowledge of the system itself, was the development of the required methodological tools for the hydrologic and hydraulic analysis of the lake and its environment, analyzing the impact of the various planned actions of the different administrations.

Amongst the conclusions reached in this study was to define features that would characterize the sustainable scenario of the Albufera, assuming, in simple terms, as **key objective** *to reverse the current status with phytoplankton dominance to a status with dominance of submerged vegetation in the central lake, establishing as reference indicator the average chlorophyll a concentration in the lake.*

The parameters characterizing this current state of eutrophication have the values as shown in Table 8.

Table 8 Parameters for the characterization of eutrophication

Indicator		
Definition	UD	Characteristic range of the current situation (2006/2007–2010/11)
Nutrients – annual average concentration of total phosphorus in the lake	mg P/l	[0.17, 0.38] Average: 0.25
Phytoplankton – annual average concentration of chlorophyll a in lake	μg/l	[95,150] Average: 125

Additionally, the problems the Albufera faces as a result of the reduction of the effluent from the Júcar River due to the modernization of the irrigation systems should not be forgotten. In this sense, to ensure adequate water supply both in quantity and quality to the lake is basic, especially in drought situations.

In summary, in general, the problems of the wetland are characterized by eutrophication due to an excessive concentration of nutrients that leads to water quality problems, for the need to ensure adequate water supply both in quantity and in quality and for the existing risk of siltation in the lake.

In order to address this problem, currently four strategic lines are developed:

- Rehabilitation of the lake and the marsh
- Control of the siltation processes
- A system of interpretation natural trails
- Monitoring and evaluation

4.2 Wastewater Reuse Actions in the Surroundings of the Albufera Lake

Within the "Rehabilitation of the lake and the marsh" strategy, reuse actions, further detailed below, are included. They have a twofold objective:

- Improve the quality of determined direct inflows into the Albufera, reducing the nutrients input and consequently improving the eutrophication situation
- Ensure other inflows, regarding quantity and quality, adequate and stable in time that compensate the reduction of inflow as an effect of the undergoing irrigation modernization activities as well as the inflow reduction during drought periods

These actions, responsibility of the Ministry of Environment, currently undergoing or recently completed are:

1. Actions of wastewater reuse from the Pinedo wastewater treatment plant (WWTP)
2. Actions of Sueca WWTP's enlargement and improvement and reuse actions
3. Actions of wastewater reuse from the Albufera Sur WWTP
4. Redistribution of orchard's hydraulic infrastructure and sanitation network from Valencia City's metropolitan area (Fig. 6)

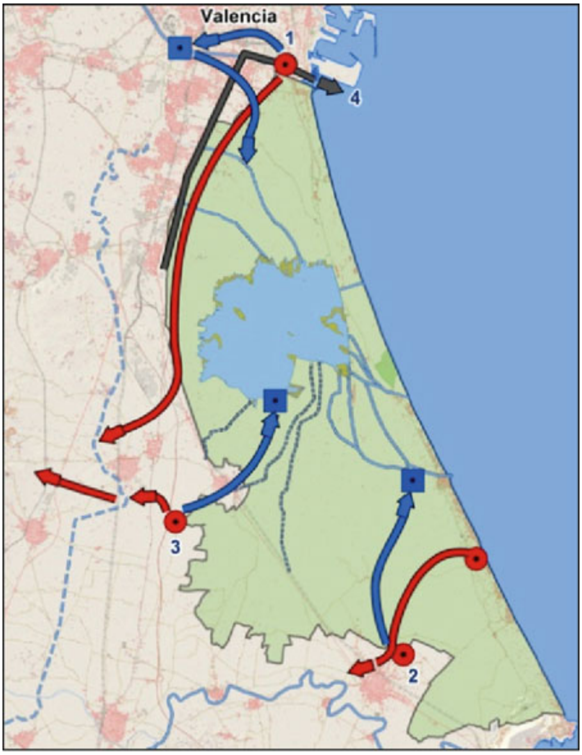


Fig. 6 Strategy of actions of wastewater reuse in the surroundings of Albufera lake

4.2.1 Actions of Wastewater Reuse from the Pinedo Wastewater Treatment Plant

The Pinedo treatment plants I and II carry out primary and secondary treatment, existing additionally in Pinedo II the possibility to reclaim water, with a sufficient capacity to reclaim the treated wastewater from Pinedo I and II. Currently, only Pinedo II uses the reclaim treatment to reuse water for the following users: *Acequia del Oro* and *Acequia del Favara* (rice fields in the north of the park). The unused surplus is discharged through a marine outfall sewer.

Within the actions of wastewater reuse from the Pinedo WWTP, several measures are being carried out in order to increase the reused volume and minimize the entrance of effluents with excess of nutrients into the Albufera. These measures will allow carrying reclaimed water to the *Acequia Real del Júcar* – ARJ (irrigation channel) through a pipe which connects from Pinedo WWTP till this irrigation channel (ARJ).

This pipe has been designed with several stretches being the Agriculture and Environment Department of the Regional Valencian Government, the authority in charge of the construction of the Pinedo–Catarroja Port stretch, and the Ministry of Environment, the one in charge of the Catarroja Port–ARJ stretch construction.

In addition to these actions, a pilot green filter with 0.1 m^3/s of capacity has been tested to assess its performance regarding nutrients removal and to determine if the treated water has the proper quality to be brought till Albufera lake respecting the strict environmental objectives. This green filter aims to achieve a total phosphorus concentration less than 0.1 mg/l, as it is necessary for a contribution from the Pinedo treatment plant to allow reversing the present eutrophication state in the Albufera.

In addition to these currently undergoing actions, the construction of another green filter to treat 1 m^3/s, which according to the estimates would allow treating the non-reused surplus from Pinedo before dumping it into the Albufera lake, is expected. The results analysis of the pilot green filter currently under construction will permit the study of the viability of this additional green filter to be possibly constructed in the future.

In summary, this action would increase the volume of agricultural and environmental reuse and substantially improve the quality of both.

The total investment for these running actions is estimated to be about 54 million euro, and they are expected to be completed during the year 2012. The total consumptive and environmental reused volume will then reach 126 hm^3/year, which means an increase of de 30 hm^3/year in consumptive and 26 hm^3/year in environmental, with respect to the current situation.

4.2.2 The Sueca Wastewater Treatment Plant: Enlargement, Improvement and Reuse Actions

In the case of Sueca, the first problem to be solved is the pollution in the irrigation channels inside the city and other places like Mareny de Barraquetes, El Perelló, and La Gola del Rei. The cause of these polluted channels is the direct dumping of untreated wastewater, which additionally means the discharge of untreated wastewater into the Albufera lake and the coastal waters and the use of untreated wastewater for irrigation according to RD 1620/2007 requirements for treated wastewater reuse.

The Júcar River Basin Authority (Júcar RBA) has foreseen a series of actions (nowadays finalized) to solve these problems, which consist in the connection of the wastewater dumping to the Sueca WWTP, enlargement of this plant and a wastewater pumping from Mareny de Barraquetes to the WWTP. To complement these actions, the construction of a reclaim treatment for treated wastewater and a green filter to additionally treat the waters not reused for irrigation purposes before their dumping has been put in place.

The total investment of all these actions was of 38 million euro. The water reuse is expected to be functioning in 2012. The total consumptive and environmental reused volume reaches up to 4 and 3 hm^3/year, respectively, even if in this case this does not mean a volume increase but an important improvement regarding quality.

4.2.3 Wastewater Reuse Actions at the Albufera Sur Wastewater Treatment Plant

The effluent from Albufera Sur WWTP dumps currently to the L'Alqueressia irrigation channel, which affects only a small area of the lake during summer months. The water quality did not allow its reuse because it did not fulfil the quality requirements of RD 1620/2007 for treated wastewater reuse.

For this reason, the works for a reclaim treatment of treated wastewater at the Albufera Sur WWTP have been carried out jointly with the construction of a green filter to ensure an additional treatment for the non-reused wastewater in irrigation before their dumping. These actions are already finalized.

The total investment was of 30 million euro, and the works are expected to start functioning in 2012. The total consumptive and environmental reused volume is 12 hm^3/year (half of it consumptive and the other half environmental), while, as in the anterior case, this does not mean a volume increase but an important improvement regarding quality.

4.2.4 Redistribution of Orchard's Hydraulic Infrastructure and Sanitation Network of the Valencian Metropolitan Area

One of the identified problems is the existence of irregular connections of the sanitation network in the municipalities from Valencia's metropolitan area, which means the existence of non-treated wastewater dumping into the irrigation channel network (e.g., Favara irrigation channel) which flows into the Albufera lake.

In addition, the water infrastructure of the *Colector Oeste* (sewage collector of the city of Valencia) is insufficient during the rainy season to alleviate the first heavily contaminated water run-off that overflow the collector and therefore flow directly into the Albufera lake.

A series of measures to mitigate these effects are being carried out which include the sanitation networks adaptation to make them dump into the West Collector, a new unit of the West Collector and retention tanks (storm tanks) to avoid first rain episodes' dumping and the modification of Favara's irrigation channel. This volume that will be collected in a controlled way will be let at the same time to the Pinedo treatment plant, increasing the effluent volumes and adapting it to the quality required for a discharge in the natural park. The expected total investment is about 60 million euro.

4.3 Effects of Wastewater Reuse in the Surroundings of the Albufera Lake

The effects of these actions regarding the status of the Albufera are difficult to assess before they are working long enough to have stable effects. However, currently mathematical modelling is used to estimate their effectiveness regarding the quality parameters and their compensatory effect on the reduction of effluents due to modernization and drought.

On the one hand, and with regard to the hydrological balance, using the hydraulic module AquatoolDMA (Andreu et al. 1996) and based on data provided by several flow control networks of the Júcar RBA, a water balance model was built to estimate inflows and outflows of the system and has been calibrated with the gauging records of the five goals (outlets into the sea) (CHJ 2012a). Additionally, different future scenarios have been studied, taking into account the coming into operation of Pinedo's green filter and the reduction of irrigation surpluses due to modernization actions, analyzing its impact and the water input into the system (CHJ 2012b).

The main conclusion is that reuse, along with an improved drought management of irrigation, ensures more regular and stable effluents to the Albufera, as it can be seen in Figs. 7 and 8.

On the other hand, the water quality model Sobek Rural-WQ of WL|Delft Hydraulic is used as a tool to simulate the water quality in the Albufera lake and its possible evolution, especially with reference to the chlorophyll a and total phosphorus concentration, in the context of different hypothetic scenarios the inflows into the lake. This model has been previously calibrated (CHJ 2012c) and used to obtain the chlorophyll a and phosphorus evolution (CHJ 2012d) in different reuse scenarios presented below.

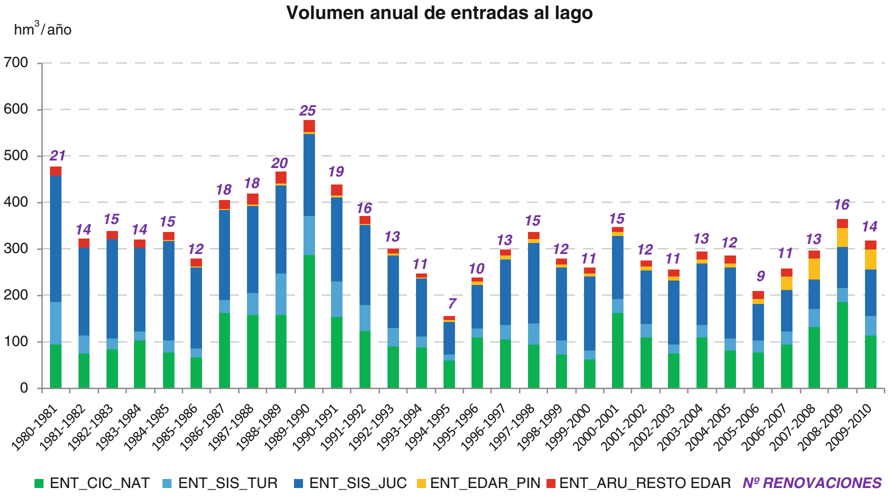
Table 9 shows the estimated improvements, provoked by those actions.

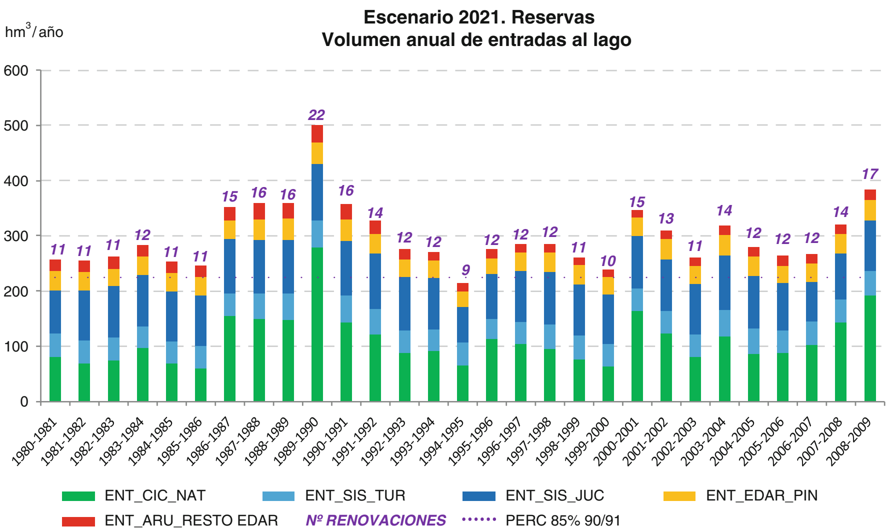
It can be seen that the reduction of nutrients in the effluents could lead to an estimated improvement of the lake with reduction values around 30 % for both chlorophyll a and total phosphorus.

5 Summary and Conclusions

The reuse of treated wastewater is an important non-conventional water resource with an important future in the Mediterranean basins that can help meeting certain demands, usually agricultural, and to improve the environmental status of affected water bodies. From the demand point of view, the increased guarantee, linking it to the urban water demands that are less sensitive to drought scarcity problems, and the continuous improvement of the quality control of reclaimed waters are the main factors that favour its use. From the environmental standpoint, the elimination of discharges or the substantial quality improvement of the returns to the natural environment contributes to achieve the objective of the good status of surface water bodies, and it is also improving the qualitative status of groundwater bodies by reducing necessary water withdrawals to satisfy the demands.

The recognition of this importance in Spain has led to the recent approval of the Royal Decree 1620/2007, of 7 December, that establishes the legal framework for the reuse and that determines the uses, necessary qualities and treatments for a proper use of the resources, ensuring this way the microbiological safety.





Figs. 7 and 8 Series of annual inflow into the lake (hm3) and number of renewals of the Albufera lake. *Upper figure*: current situation (CHJ 2012a) and *lower figure*: future scenario (CHJ 2012b)

Table 9 Improvement in chlorophyll and phosphorus concentrations after application of measures

	Average 2006/07–2010/11	Wastewater reuse running actions	Additional Pinedo green filter (1 m^3/s)
Estimated final cl-a concentration (μg/l)	125	109	88
Estimated final P concentration (mg/l)	0.25	0.21	0.16

The recent draft National Water Reuse Plan has updated the available information on water reuse in Spain and proposes various actions with a double objective: to increase the reuse volume and to improve the quality of reclaimed effluents with the aim to achieve a strict compliance of the Royal Decree mentioned above. This plan proposes at national scale the increase of the annual volume of reused wastewater from 369 hm^3 in 2006 to 430 hm^3 in 2009 and 998 hm^3 in 2015. Therefore, it proposes a set of actions to be financed by the state between 2009 and 2015 in those river basin districts with inter-regional basins and national competences. Once realized, these actions would permit the incorporation of additional 249 hm^3 with an investment of 344 million euro.

These reuse actions are particularly important in the Júcar RBD, where in the coastal area the geographical proximity of main urban centres to major irrigated areas is a clear positive factor. Also, the agricultural demand, which accounts for 78 % of the total demand, leads to an interesting field of implementation of reuse for irrigation, which is reflected in the Programme of Measures of the Júcar RBD.

This Programme of Measures aims to satisfy demands but also to achieve the good status of water bodies, particularly with regard to the good quantitative status of groundwater bodies, jeopardized by an intensive use of resources. To do this, between 2012 and 2021 in the Júcar RBD, several demand management actions and measures to offer additional resources, amongst those are found the increase of the used surface water, as new non-conventional resources from desalination and reuse, are foreseen. The increased volume provided by reuse in the Júcar RBD is 160 hm^3, which represents a 32 % of all actions, and requires an investment of 431 million euro, which is 24 % of the total investment and what sets the reuse as a strategic line of action in the Programme of Measures of the River Basin Management Plan. Further analysis shows a cost of 0.43 €/m^3, including the investment and operating costs, both of the treatment to reclaim water and the additional adjustment and distribution works; the latter are necessary to mitigate the high seasonal demand to be served, primarily agricultural.

In this set of reuse actions, those located in the vicinity of the Albufera wetland have an outstanding importance. In this area water resources from the Pinedo treatment plant, which purifies the discharge of Valencia and its metropolitan area, are available and important traditional irrigated areas that perform agricular water reuse are located. Also, the problems of this important wetland, declared a Ramsar site, are characterized by a situation of eutrophication and the need to ensure proper water effluents both regarding quality and quantity, so that the proposed reuse actions have a twofold objective:

- Improve the quality of determined direct effluents into the Albufera, reducing the nutrients input and consequently improving the eutrophication situation
- Ensure other effluents, regarding quantity and quality, adequate and stable in time that compensate the reduction of effluents as an effect of the undergoing irrigation modernization activities as well as the effluents reduction during drought periods

The objectives mentioned above are met in the planned actions for agricultural and environmental reuse of the effluents from the treatment plants in Pinedo, Albufera Sur and Sueca that suppose in total an investment of 92 million euro and an increase of agricultural and environmental reuse of 40 hm^3 and 35 hm^3, respectively. The effect of these actions, with an additional reduction of nutrients through the implementation of green filters, on the environmental status of the Albufera has been analyzed through intensive modelling of quality and quantity aspects. The obtained results allow us to ensure that the implemented actions will achieve more regular water effluents and a significant reduction of the chlorophyll and phosphorus in the water body, fact that will improve the eutrophication situation in this important wetland.

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Part IV
Water Polices, Governance and Social Issues

Mediterranean Water Outlook: Perspective on Policies and Water Management in Arab Countries

Khaled M. AbuZeid

Abstract The Mediterranean Region is usually characterized by its water stress situation. However, water availability is completely different between the North and the South (including the East) of the Mediterranean Sea. While the North may enjoy more than adequate amounts of rainfall, it is mostly the South that gives the Mediterranean Region the identity of water scarcity. The countries in the south and the east of the Mediterranean Sea include the eight Arab countries, Morocco, Algeria, Tunisia, Libya, Egypt, Palestine, Lebanon, and Syria.

This chapter gives an outlook on the water characteristics in the Mediterranean countries, in terms of per capita share of renewable water resources, as well as sectoral water uses by country. It highlights the different levels of dependencies between the North and the South, on the different forms of water, and in particular different dependencies on "green water" and "blue water" in sectoral uses. This chapter also reflects on the status of water supply and sanitation services coverage in the Mediterranean countries and the requirements to achieve the Millennium Development Goals in water supply and sanitation. Potential for sectoral water savings and wastewater reuse in the Mediterranean countries is presented.

The various regional strategies and legal frameworks that govern water management in the Mediterranean countries at the European, Mediterranean, and Arab Region levels are presented.

This chapter also presents a perspective on the required uniqueness in national policies and water management in the Arab countries in the Mediterranean due to water issues that characterize the Arab countries in the Mediterranean such as those related to nonrenewable groundwater management, transboundary water management, water scarcity, sea water intrusion, and wastewater reuse. The status of Integrated Water Resources Management (IWRM) plan development in the Arab countries in the Mediterranean is presented.

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Keywords Mediterranean • Water resources • IWRM • Green water • Blue water • Virtual water • Water demand management • Wastewater reuse • Transboundary waters • River basin approach • Nonrenewable groundwater • Water supply and sanitation

1 Introduction

Like most parts of the world facing increasing population and escalating water demands, the Mediterranean Region is not an exception. It is thus imperative for each country and for every region to assess the state of the water on a regular basis, to stand on the situation regarding water resources availability, sectoral uses, new infrastructure, physical changes, governance developments, and trends that provide interpretation of the past water sector evolution.

It is always important to take a pause, analyze changes, synthesize causes, evaluate impacts, identify cross-sectoral relations, and determine multidisciplinary linkages to be able to carefully project an outlook for the future. In the water sector, this is an important step that is always needed for efficient Integrated Water Resources Planning (IWRM).

2 Water Challenges in the Arab Mediterranean Region

The precipitation situation in the Mediterranean Region is different from the north to the south, and the region has a number of transboundary rivers and especially in the south Mediterranean, and this has its impact on the land use of the Mediterranean. This clearly can be observed from the increased green vegetation in the north of the Mediterranean Region, as compared to the south and east of the Mediterranean Region where countries' vegetation is restricted to river basins and the rainfall areas in the thin fringes of the northern coast of the south and east Mediterranean Region.

The water challenges in the Mediterranean Region especially in the Arab countries that are located in the drier areas in south and east Mediterranean are indicated by the following issues:

- Water scarcity and the growing supply/demand gap
- Coordination between different water sectors and stakeholders
- High dependency on transboundary waters
- Limited information on water resources
- Overlap of responsibilities
- Water quality degradation and water pollution
- Limited public awareness on water resources issues
- Lack of funds for water resources and services development

- Capacity building and institutional development
- Effective legislations and law enforcement

The current population in the Mediterranean Region in 2010 is about 445 million people, water used in irrigation is about 180 billion cubic meters (BCM) per year, domestic water use is about 40 BCM/year, and industrial water use is about 65 BCM/year, and it is expected that the population number will increase by 2050 to reach 600 million with an increase in water demand of about 25 %.

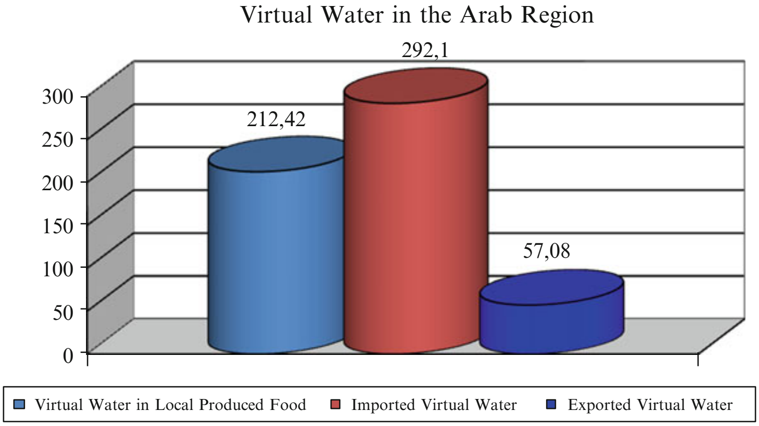
Most of the Arab countries in the south and east Mediterranean are below the water scarcity limit. There are two countries that fall above the water scarcity limit of 1,000 m^3/capita/year of renewable water resources, an internationally known standard number for the minimum amount of national per capita renewable water resources adequate enough for the different needs in the agriculture, industry, and domestic sectoral uses. In 2025, it is expected that all countries will be below that water scarcity limit for the south and east countries of the Mediterranean Region. All countries in the north of the Mediterranean Region are above the water scarcity limit, and the water situation is different from the north to the south.

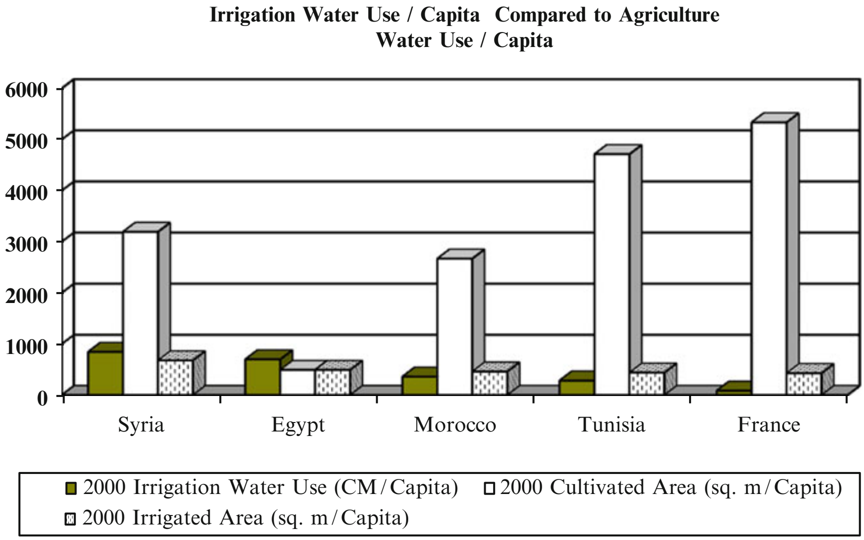
Cultivated areas, in France, are about 80 million acres, with 8 % in irrigated areas, and the remaining area is rain-fed agriculture and natural vegetation. The Rhone River, in France (north Mediterranean), discharges into the Mediterranean about 50 km^3/year. Whereas in Egypt, there are only 8 million acres of cultivated areas, and 100 % of this area is irrigated agriculture. On the other hand, the Nile River in Egypt (south Mediterranean) runs in the middle of the Deseret, and the only green areas exist in the thin strip around the Nile as irrigated agriculture. As Egypt does not receive that much rain, Egypt depends mainly on the Nile River and utilizes about 55.5 km^3/year for all its different uses without any freshwater flows into the Mediterranean, which is almost the same amount that the Rhone River discharges into the Mediterranean without use.

3 The Blue Water/Green Water Concept

The world receives about 110,000 km^3/year of precipitation, where about 60 % of which is considered as green water, and about 40 % is blue water. *Green water* is the water that is used directly from the rainfall for green vegetation whether it is rainfall agriculture, forests, or grazing land. *Blue water* is the surface water that runs into the rivers and all the water that can be abstracted from the ground water. Green water use for crop production, all over the globe, is more than blue water. However, in the Arab Region, the case is the opposite, which reflects rainfall scarcity and the external transboundary nature of its waters. In the Arab Region, there is about 170 km^3/year of blue water which contributes to food production, whereas there is about 45 km^3/year of green water that contributes to food production in the region. The Arab Region imports lots of virtual water because of water scarcity. In the Arab Region, about 215 km^3/year of virtual water is consumed locally for food production, and 57 km³/year of virtual water is exported in food products, while 295 km³/year of virtual water is imported as food products.

Several of the water assessments confuse irrigated areas with cultivated areas and ignore rain-fed agriculture areas. Irrigation water withdrawals are wrongly considered as the only agriculture consumption and are used for benchmarking countries and sometimes are wrongly used to assess countries' water use efficiency. However, as seen in the figure below, when properly assessed, agriculture water use should be divided into irrigated agriculture water use and rain-fed agriculture water use.

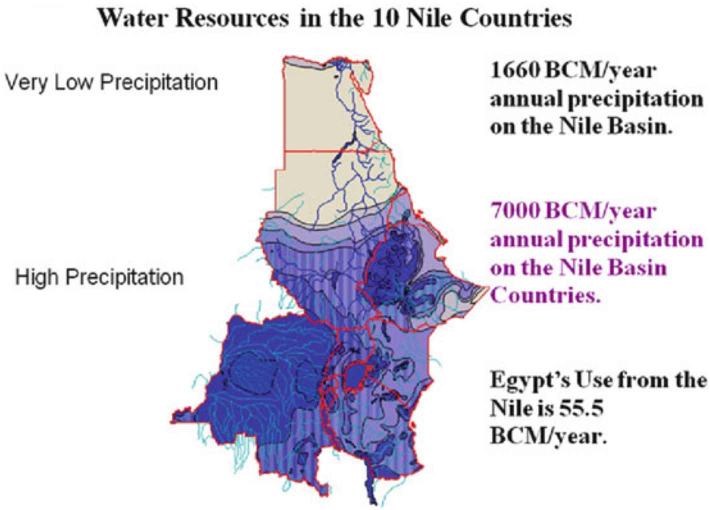


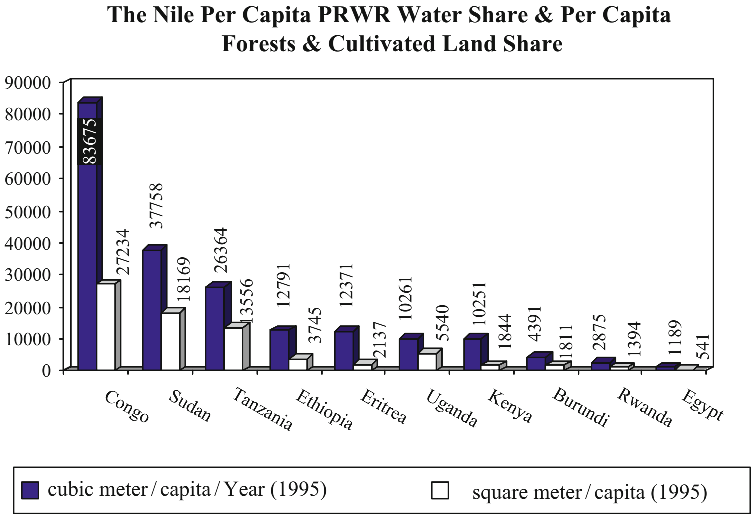


The per capita share of irrigated agriculture area in the north of the Mediterranean is small compared to the countries south of the Mediterranean; however, the per capita share of rain-fed agriculture in north Mediterranean countries is larger than that in southern Mediterranean countries. Oftentimes, it is wrongly perceived that southern Mediterranean countries are not efficiently using water or using too much water for agriculture, and that this water should be shifted to industry; however, this may not be the case as the dry nature of the region obligates the countries to use more irrigation than rain-fed agriculture, and irrigation water withdrawals are often assessed and computed while rain-fed water is not commonly assessed. The fact that a lot of water is directed to irrigation in the south part of the Mediterranean Region does not mean that water is used in agriculture rather than other uses, but it is because in the north, most of the agriculture area depends on rainfall rather than irrigation water, and nobody calculates how much rainfall or green water is being used for agriculture. CEDARE and the Arab Water Council were the first to assess green water uses in the Arab countries in the first Arab State of the Water Report in 2004.

4 The River Basin Versus the Watercourse Approach in Transboundary Waters

The importance of green water emphasizes the fact that in a transboundary river basin water sharing, the water resources in the whole river basin should be considered for reasonable and equitable utilization rather than just the waters in the river itself or the watercourse. For example, the Nile River basin shared by 11 countries, now after the separation of South Sudan, receives an average of about 1,660 BCM of annual precipitation on the Nile basin, and the Nile basin countries within their borders receive 7,000 BCM/year of average precipitation. Egypt use from the Nile is 55.5 BCM/year (AbuZeid 1997). When considering the green and blue waters within the river basins and within the borders of the riparian countries, the Nile per capita water share for each country may be presented, as shown below. This is also correlated with the per capita share of green cover “forests, cultivated, and pasture land” in the Nile countries. It is essential to differentiate between the water in the Nile River and water in Nile River “basin.” Especially for countries downstream that fall in arid zones such as south and east Mediterranean countries, it is important to clarify which waters are to be considered when applying the principle of equitable and reasonable utilization. It should be the waters of the river basin and not the waters of the watercourse itself on which downstream countries may be more dependent than upstream. It is also important to consider water resources beyond the basin and within the country borders to assess dependency on the waters of the transboundary river basin (AbuZeid 2008).





The 1997 UN convention on non-navigational uses of international watercourses requires 35 countries to ratify in order to be in effect. There are currently 24 countries that have ratified this convention. Six out of these countries are in the south and east of the Mediterranean Region including Lebanon, Tunisia, Syria, Morocco, Libya, and Jordan if considered as a Mediterranean country. Some of the countries have reservation on some of the articles and principles of the convention such as the notion of a "watercourse" rather than a "river basin." Some of the countries that ratified the conversion for transboundary waters do not have transboundary rivers, and some of the countries do not have rivers at all where these countries may not be affected one way or another by the ratification.

Helsinki rules, which used to govern the principles of transboundary water management, dealt with the "international drainage basin," as the "geographical area extending over two or more States determined by the watershed limits of the system of waters, including surface and underground waters, flowing into a common terminus." Equitable and reasonable utilization was based on water resources within the international drainage basin (AbuZeid 2001).

One can see the difference between adopting the watercourse approach rather than the river basin approach and the implications this may have especially on downstream countries that depend mainly on the blue water within the watercourse. This creates competition over the small portion of blue water that is often the main source for downstream countries, while ignoring green water that is the big share within a river basin and is often the main source for upstream countries. This is one of the reasons behind the reservation of some countries to ratify the convention.

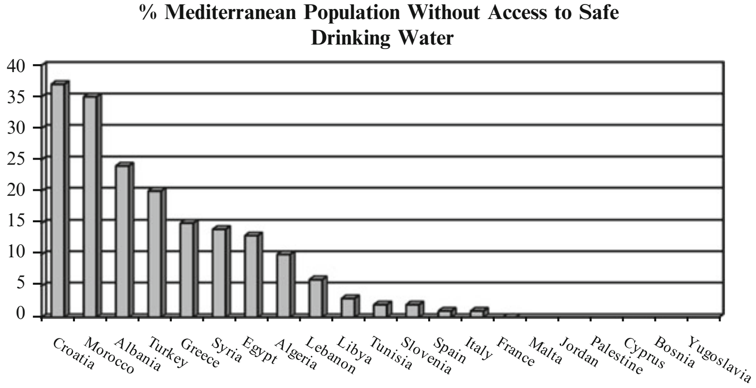
5 Transboundary and Nonrenewable Groundwater

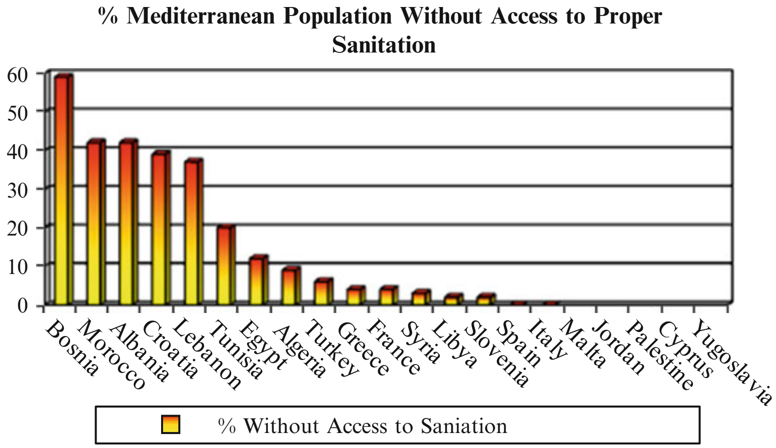
Most of the groundwater in southern part of the Mediterranean is nonrenewable, and in most cases, it is transboundary. Examples of this type of groundwater are found in the Nubian Sandstone Aquifers which are shared between Egypt, Libya, Sudan, and Chad. Petrified trees in the middle of the western desert in Egypt and isotope analysis indicate groundwater age of about 20,000 years which reflect that this groundwater is nonrenewable, and that the region used to receive rainfall in ancient times which resulted in the recharge of the Nubian Aquifer thousands of years ago (AbuZeid and ElRawady 2010). The south Mediterranean Region faces the double challenge of managing a groundwater resource that is transboundary and nonrenewable at the same time. This requires a future outlook that puts guidelines and policies for restricting use of this type of water to specific nonexploitable uses and regionally studied strategies whose implementation falls under continuous monitoring to avoid the rapid depletion of groundwater and negative developmental consequences.

6 Water Supply and Sanitation and the MDGs

One of the Millennium Development Goal targets is to reduce by half the percentage of people with no access to safe drinking water and improved sanitation by year 2015.

The graphs below show the year 2005 percentage of people without access to safe drinking water and improved sanitation in the Mediterranean. Rough estimates indicate the need for investment of at least 10 billion euros to achieve the water MDGs between year 2005 and 2015 in the Mediterranean. If achieved, this will still leave about 35 million people with no access to safe drinking water supply and improved sanitation (Arab Water Council and CEDARE 2007).

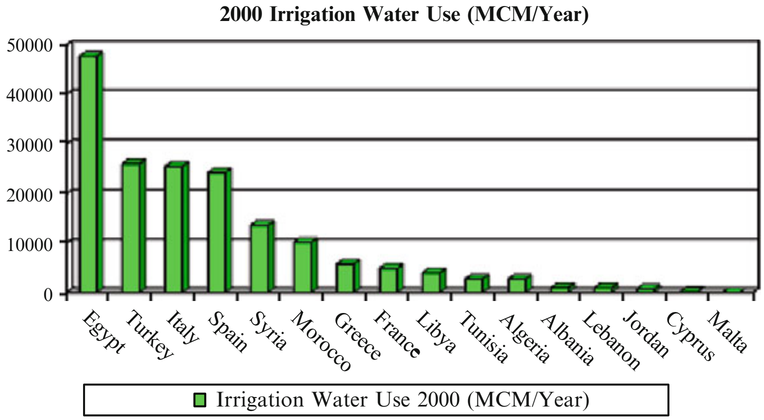


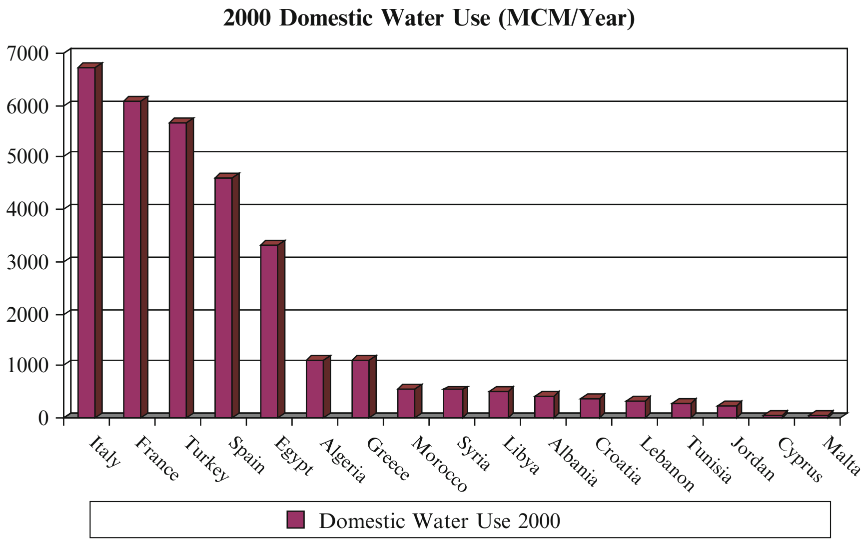


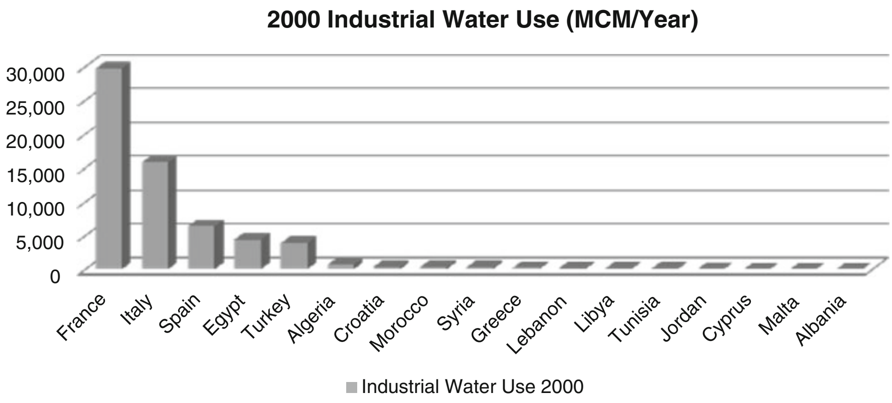
Even if the MDGs are achieved, the number of people without access to safe drinking water will increase. In the Arab Region which covers 22 countries including the 8 Arab Mediterranean countries, since 1990, 81 million people gained access to an improved drinking water source, but due to population growth, the number of people not using an improved source increased from 36 million in 1990 to 50 million in 2006. Since 1990, 89 million people in the 22 Arab States gained access to improved sanitation facilities; however, the number of people not using an improved facility increased from 90 million in 1990 to 96 million in 2006. Unless serious planning and investments are put in place, the outlook of water and sanitation services will be bleak for a large portion of the population.

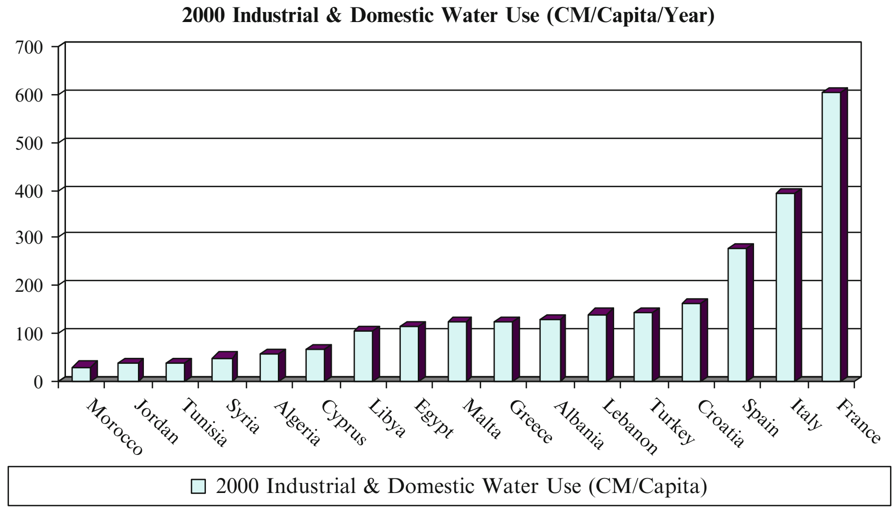
7 Water Demand Management Potential

The following graphs indicate the sectoral water withdrawals for irrigation, domestic, and industrial sectors in the Mediterranean countries as of year 2000. Although there is lack of updated data, however, the graphs indicate that demographics play an important role in assessing current and future outlooks of water at the national levels. Although a country may appear to be using large amount of waters, the per capita share of these water uses in that country may be at lower levels. The different indicators also show that water plays an important role in the development of a country and that developed countries often have larger per capita share of water withdrawals, especially for domestic and industrial sectors. The irrigation withdrawals by countries given below should not be used to reflect water consumption by the agriculture sector in those countries, because it only reflects blue water use in agriculture and not green water use, which may be larger, especially in north Mediterranean countries.









There is a potential for demand management and water savings in all withdrawal sectors, which will require certain interventions and investments. In the irrigation sector, indicated water demand management interventions may include land leveling, modern farm irrigation, canal lining, proper irrigation scheduling, low water consumption crops, improved drainage, and improved irrigation application efficiencies. These interventions through irrigation improvement projects may result in 10–15 % savings and sometimes even up to 30 % increased agricultural productivity.

There are 20–50 % losses in the water distribution systems in major Mediterranean cities. In the domestic sector, there are interventions to reduce consumption, some of which include installation of household water-saving devices which can save up to 15 % of domestic use, use of low-flow showerheads which can use less than 2.5 gallons per minute, installation of toilet displacement devices which can save 4.2 gallon per day per device, installation of faucet aerators which can save up to 1.5 gallon per day per device, installation of metering devices which actual have proved to save from 15 to 40 % of household consumption, installation of high-efficiency washing machines which can save up to 37 %, and implementation of landscape water conservation programs which can save up to 20 % including the installation of moisture sensors and rain shutoff switches.

There are some interventions to conserve water in industrial and commercial sectors which may include installation of self-closing faucets which can save up to 50 %, ultra low flush (ULF) which uses less than 1.6 gallons per flush, and installation of low-flow valve urinals which can save up to 33 %. In addition, measures of Clean Development Mechanisms (CDM) can also add to the industrial water savings.

If all of these potentials in the different water sectors are summed up and added to the potential of recycling and reuse, the potential for water savings in the Mediterranean will include:

- 10 % of the total irrigation water use
- 15 % of the total domestic water use household water-saving devices
- 20 % of the total domestic water use for metering
- 37 % of 2 % of domestic water use for high-efficiency washing machines
- 20 % of 5 % of domestic water use for landscape irrigation conservation programs
- 25 % of 5 % of the industrial and commercial water use (self-closing faucets, low-flush toilets, and low-flow urinals)
- Reuse of 80 % of domestic and industrial/commercial water use, after deducting their freshwater savings

The potential for water savings in the Mediterranean can reach up to 94 BCM/year, where Potential Irrigation Savings can reach up to 17 BCM/year, and Potential Domestic Water Savings can reach up to 10.25 billion cubic meters (BCM) divided as 3.3 BCM from household devices, 6.4 BCM from metering devices, 0.18 BCM from high-efficiency washing machines, and 0.3 BCM from landscape water conservation programs, whereas Potential Industrial and Commercial Water Savings can reach up to 0.8 BCM/year as minimum, since there could be other CDM interventions that can provide additional savings.

On the other hand, potential savings by using treated wastewater can reach up to 66 BCM/year.

There are costs associated with water demand management. In the irrigation sector, the irrigated land in the Mediterranean Region is about 42 million acres. The cost for implementing irrigation improvement programs is about 700 euros/acre. Investment cost for irrigation water savings of 17 BCM/year is about 29 billion euros. Investment costs for domestic water saving of 10 BCM/year will be about 27 billion euros. Investment costs for industrial and commercial savings of 0.8 BCM/year will be about 0.8 billion euros. Without accounting for the cost needed to fill the water supply and sanitation coverage gab, investment costs for treated wastewater of 66 BCM/year could reach up to 50 billion euros (AbuZeid 2003).

8 Regional Water Strategies Governing the Mediterranean Region

There are three main regional strategies that are governing water management in the Mediterranean: the *Arab Water Security Strategy* (for 22 Arab Countries under the League of Arab States), the *Mediterranean Water Strategy* (for member countries under the Union for the Mediterranean) which still needs to be approved, and the *European Water Framework Directive* (for European Union countries).

In addition, there are national plans, policies, and strategies in the Mediterranean Arab Countries which govern water management at the national level. Some of these frameworks may qualify to be considered as Integrated Water Resources Management (IWRM) plans. Integrated Water Resources Management (IWRM) is the systematic cross-sectoral process for the sustainable development of water resources to maximize the social, economic, and environmental benefits from its efficient use.

The Arab Water Council and CEDARE have compiled a list of these existing IWRM plans (Arab Water Council, CEDARE, and UNDP 2004).

9 Conclusions and Recommendations

Potential water savings in the Mediterranean Region is 94 BCM/year, 18 BCM of which are from savings in the southern and eastern Mediterranean countries, and 76 BCM could come from northern Mediterranean countries. These savings are 11 % domestic, 1 % industrial, 18 % irrigation, and 70 % from recycling and treated wastewater reuse. 94 BCM in the Mediterranean can contribute to annual wheat grain demand of 68 % of the Mediterranean population estimated at 280 million people.

Average water demand management investment cost is 1.7 euro/m^3 for savings in irrigation water, 2.7 euro/m^3 in domestic water use, 1.0 euro/m^3 for savings in industrial/ commercial, and 0.8 euro/m^3 for recycled and treated wastewater reuse.

Water demand management options should be embraced prior to desalination options. More investment should be directed to sewage collection, treatment, and reuse for environment and food security in the Mediterranean Region. Synergies are needed between regional water strategies covering the Arab Mediterranean countries.

Green water contributes more to food production in north Mediterranean while blue water contributes more to food production in south and east (Arab) Mediterranean countries. More attention needs to be given to green water in water resources assessment and in future planning. Amendment of the 1997 UN Convention on the Non-Navigational Transboundary Watercourses is needed to embrace the river basin approach rather than the watercourse approach to receive wider acceptance.

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Identifying Risks, Actions, and Opportunities for a Long-Term Water Strategy in the Mediterranean

Rafael Rodríguez-Clemente and Ana Hidalgo

Abstract As one of the world's driest regions, water scarcity critically affects the Mediterranean countries on their physical and socioeconomic conditions. The amount of water available per person is expected to fall by 2050 by more than half due to demographic growth and climate change trends. With agriculture accounting for using more than 80% of freshwater, a low water use efficiency, and the discharges of domestic, industrial, and agriculture wastewater leading to deterioration of water quality, together with the effects of the climate change, it is clear that more integrated approaches to water management are required. The Integrated Water Resources Management (IWRM) is the most promising perspective to cope with this intricate problem. But, as usual, a big problem is also a big opportunity to address fundamental changes in the human behavior and its societal model. The long-term strategy for water in the Mediterranean has to face the risks and to define the actions and opportunities for the water use in most of the human activities and, accordingly, its management in the area.

Keywords Water policy • Water management • Long-term water strategy • Mediterranean area • Public awareness program

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1 Introduction

Sustainability is a function of several goals with economic, environmental, ecological, social, and physical aims. The main objective of this chapter is to characterize the complex interlink between societal needs in the Mediterranean, water availability, and its threads and to extract and make concrete proposals for actions.

Several Mediterranean countries have to cope with aridity weather because there are arid areas inside their territory, or because they are connected with deserts for geographic or cultural reasons. Moreover, Mediterranean islands and peninsulas are almost lacking underground or groundwater. The social aspects related to water management are critical, as the technical proposals must be endorsed by the end users: the full society. Collaboration at different levels is crucial to achieve the mutually accepted goals of sustainable service delivery for all, targeting especially education (water in the school), public participation, public-private partnership, water prizing, safe drinking water, and adequate sanitation services for all.

Water is an essential issue for growth and prosperity in the Mediterranean Partner Countries (MPC), and knowledge and innovation in this area must be a priority to make the region a leader in research in water, energy, the environment, and the biology and biotechnology of arid-zone plant life.

2 The Socioeconomic Context in the Mediterranean

Over 500 million people are presently living in 25 countries of the Mediterranean region. The main features of the northern subregion are urbanized and industrialized societies with high-medium income levels; low population growth and predominance of private and communal forests; abandoning of large agricultural lands as a result of increased agricultural production and decreased rural population (offering large potential for afforestation, on one hand, and causing increased fire risk on the other); and pressures and disturbances from expanding urban concentration and increased tourism in forest areas (Laureano et al. 2008).

Common features of the southern/eastern subregion are low-medium income levels; high growth rates and population density in rural and forest areas; dominance of state ownership of forest resources; existence of rapid deforestation and natural resources degradation and their consequences (serious rates of soil erosion and desertification) due to destructive interventions of large rural populations (i.e., encroachment for croplands, overgrazing, overcutting of timber and fuel wood); populations heavily dependent on forests and natural resources for their livelihood; silvopastoral activities vital for rural inhabitants; and increasing urban expansion and tourism pressures especially in coastal zones (Laureano et al. 2008).

Although the Mediterranean has been a great trading region for centuries, at this moment, it has only occasionally succeeded in being competitive on international markets. Despite the success of some dynamic growth poles and clusters, all too often its enterprises, which are mostly small- and medium-sized, show lack of dynamism and competitiveness. They have not generally stood out in terms of innovation, as they were based for too long on a "rent economy," fostered by a mining-like exploitation of the region's geographical location and natural resources (Mediterranean Strategy for Sustainable Development 2006).

Most countries in the Mediterranean region are experiencing difficult employment situations, with unemployment rates ranging generally between 8 and 25 %, and Europe is not able to absorb the considerable pressure for emigration from Mediterranean countries. Young labor market entrants face strong difficulties with accessing employment after leaving school. Lack of investment in skills and technology may explain why agriculture is still important in the area (nearly 70 % of the available water resources are allocated to agriculture).

Poverty and education, especially in rural areas, are still dominant problems in many countries, although there is relatively little extreme poverty thanks to the area social cohesion fostered by religion or family values. Social policies for poverty reduction in rural areas need reevaluation to respond to these new challenges. Effective programs of poverty reduction require integrated rural development programs to be designed to improve the competitive position of rural producers, diversify the sources of income for rural workers, and expand the opportunities of rural residents with greater investment in social infrastructure, health, and education.

Considering, for instance, the tourism industry, the situation with regard to their cultural capacity is very uneven in the Mediterranean area, the development of creative industries and cultural resources could be effectively accomplished if more entrepreneurship and cultural capacities are developed, and cultural institutions, organizations, and networks are strengthened, helping to reaffirm natural and societal diversity in a context of globalization, but promoting the unique Mediterranean culture as a basic economic and social asset.

3 Political, Social, and Economic Aspects of Water Management in the Mediterranean Area

Sustainable development is an essential reference of any analysis of water management. The social, economic, environmental, and cultural dimensions are pillars of the sustainable development. Nowadays, the concept of human security on a global scale may be extended from its traditional meaning of worldwide political and military security, to also embrace the idea that every citizen should be able to benefit from sustainable socioeconomic development. Among different natural resources, water has been recognized as the key environmental resource for social and food security, economic growth, and prosperity. Human security can therefore be seen related to environmental preservation (water, ecosystems, and biodiversity) and to socioeconomic stability and sustainable development. The concept of sustainable management of water resources was first mentioned in Stockholm in 1972, during the United Nations World Conference, and then at the Rio summit in 1992 with Agenda 21.

Despite differences between Mediterranean countries in their societies, political systems, cultures, and economies, there are similarities in many aspects that influence the water situation (Hamdy and Lacirignola 1999):

- Poor management practices, inefficient water use, and failure to place a high economic value on water, which result in resource degradation from water logging, soil and water salinization, and pollution of aquifers.
- Few incentives for water conservation in agriculture and numerous disincentives.
- Irrigation developing faster than water-source mobilization (population growth and increasing demand for water for other uses are leading to rapid mining of aquifers, water shortages, competition, and conflict).
- An inadequate knowledge of the resources and the demand for water. It is thus essential to know not only the average values but also the spatial and temporal distributions of stochastic variables controlling the supply of water in the regions.
- Questionable outlook for developing new water supplies to meet increasing demands, given limited financial resources, escalating construction costs, and rising environmental opposition.

On the other hand, the policy and decision makers make policies or take decisions on water management that imply enormous investment without considering the long-term effects from technical, system maintenance, and socio-environmental point of view. In most of the cases, the decisions related to water management ignore the opinion of the end users and do not call for their commitment and participation.

Another general perception in the Mediterranean area is the lack of visibility of the important role that science and technology play in the sustainable development of the region. Parts of these problems are due to communication gaps between political bodies, administrative institutions, scientists, sociologists, lawyers, economists, end users, and citizens.

Water management approaches in the countries of the region are physically, socioeconomically, or environmentally unsuitable due to:

- Lack of public participation, inefficiency, and misallocation of water use. Low-value uses consuming a significant share of the resource and high-value uses suffering shortages.
- Unmonitored water quality and inappropriate use of low-quality water, without protection of the human health and the environment.
- Poor access to water and sanitation due to inadequate investment in safe water and sewerage services, especially for the poor.
- Cities are faced with mounting cost of new water sources development and water treatment.

The region has to identify the priority actions needed to improve water use efficiency. Nowadays, there is a structural imbalance between a constant increase of water demand and the available water resources (Fig. 1), being the water demand strongly higher than the water supply. Water uses must be reviewed as well as the tools to promote more desirable levels and patterns of use. They should incorporate aspects of conservation and efficient use, essential to achieving a reasonable balance between demand and supply.

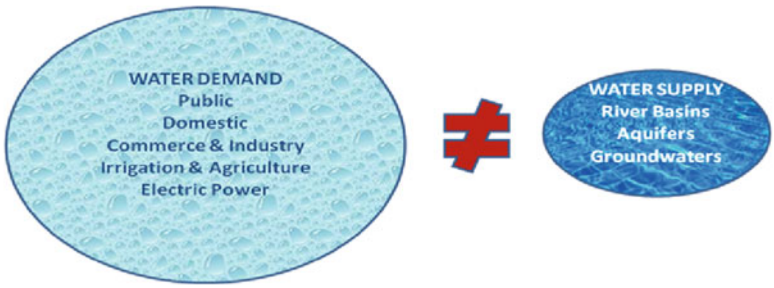

Fig. 1 Actual water demand and the different water uses versus water supply

Policies over water management should consider two different dimensions of the resource: its ethical value and its social and political value. Water has been described as a need, as a right, and as an economic good. Obviously, these characteristics imply social implications in terms of equity of distribution, policy-making, and inclusion-exclusion patterns in the decision-making process.

Which meaning should be given to natural resources is still an uncertain matter. Debates on social relations around water management and water uses are part of the building of a shared vision. However, power relationships are created, maintained, or challenged through resources management. Policies over water resources, water bodies, streams, rivers, and irrigation schemes affect the structure of social relationships and its reproduction. Water management has been historically the source of human culture and a means to maintain or transform the political frames.

4 Dimension of Water Conflicts and Water Security

Many of the factors relevant for human well-being and development are directly or indirectly linked to freshwater resources. Freshwater has always been scarce and local around the Mediterranean, but the encroaching desertification, increase of population, industrialization, and spread of tourism have made shortages acute. Not only is water scarce, its use is exclusive, and its sources may lie far from potential users. These three attributes mean that water has often been a source of conflict between individuals and countries. Families and clans have struggled for control of springs, and countries have sought to control watersheds and aquifers.

We can distinguish different dimensions of water security such as the demographic and the urban, the sanitary, the agricultural, and the climatic one (Houdret 2004). The depletion and degradation of the resource has therefore far-reaching consequences and an important impact on human development.

Direct Impacts of Water Scarcity:

- Increasing cost of water
- Lower quality of water and negative health outcomes (water-related diseases)
- Depressed agricultural yields and shortages of food

- Constraints on water-dependent industrial and energy activities
- Environmental damage

Indirect Impacts of Water Scarcity:

- Domestic social tensions over water distribution
- Geopolitical tensions over access to transborder water resources
- Economic and environmental costs of maintaining water supply
- Decreasing energy security through energy needs for maintaining water supply

The agricultural dimension of water security will move us toward the realization of a sustainable water use scenario by maximizing the efficiency of water use by farmers and rural and urbanizing communities, thus ensuring water volumes allocated for per capita domestic water consumption, ecosystem services, recreation, and aesthetics while meeting the needs of food production. The resulting sociopolitical consequences are very clear. Uncoordinated decision-making and divergent competences and interests of the key actors responsible for issues of water management and conservation often lead to competing claims of different sectors. The relevance of these implications for domestic security issues is reflected by the fact that in many countries the ministry of the interior possesses the largest competence regarding water issues.

Water conflict can not only be viewed as issues of misunderstanding between individuals, but it can occur between nations or among groups or public agencies and groups like farmers or NGOs. At the national level, water conflict arises in many different ways such as conflict on uses, conflict on controlling water resources, conflict between the state and the environment, and conflict among generation. Water can also lead to political hostilities, and many regions with political conflicts also share water resources. International organizations need to address conflict.

Most Mediterranean freshwater and groundwater resources are shared among countries (Wolfe 1999), being the Nile River a key global example. Within the countries, shared water among administrative units is also common in the Mediterranean. Disputes exist, especially during drought conditions, and potentially will increase due to the increasing water imbalances and increasing demands. Policies of a single government or basin unit cannot resolve issues over shared water bodies, and local interests are likely to diverge. International institutions play a key role as formal mechanisms to deal with water-related conflicts in the region.

In order to address the numerous factors related to the escalation or the cooperative resolution of water resource conflicts, indicators of water security and, finally, tools for preventing such conflicts have to be developed accordingly.

At least at local level, social participation in the water issues is an inclusive activity rooted in the early stages of civilization and agricultural and urban development, as everyone needs water. In a way, the open dialogue about water management is a primary form of democratic dialogue and handling of the conflicts, that is, a school for democratic organization, where the rule of the majority is established but respecting the rights of the minority. The unavoidable necessity of water makes negotiation and participation the unique way to handle the competing interest and avoid wars.

5 Long-Term Mediterranean Water Strategy

The European Neighborhood Policy (ENP), launched by the EU in 2003/2004, seeks to deepen political cooperation and economic integration between the EU and its immediate neighbors and to promote and support better governance and reform in Mediterranean countries. Through mutually agreed action plans, the EU and its ENP partners will share a common vision, will address a strategy to work in the common interest, and will devise measures beneficial to economic growth and social cohesion, raising living standards and protecting the environment, thereby contributing to the long-term goal of sustainable development in the Mediterranean region. The identification of water-related problems and the development of specific long-term visions for water resource development in the area determine the strategies and plans to attain that vision.

The decision to prepare a strategy for water in the Mediterranean (SWM) was among the key outcomes of the Euro-Mediterranean Ministerial Conference on Water (December 22, 2008, Dead Sea, Jordan). A Euro-Mediterranean water expert group (WEG), chaired by France and Egypt as UfM (Union for the Mediterranean) co-chairs, was entrusted to work on preparing the SWM, which has followed a structured, open, and inclusive regional preparatory process involving national governments, local authorities, and regional stakeholders. A reduced technical drafting group (TDG), chaired by Spain, prepared the draft SWM texts through an elaboration process. The intensive SWM preparatory process was administratively and technically assisted by the Mediterranean Component of the EU Water Initiative (MED EUWI is led by Greece and is serviced by the Global Water Partnership-Mediterranean) with the financial support of the European Commission and other partners.

The strategy for water in the Mediterranean (SWM) aims at providing a guiding document with orientations and objectives on water resources management and protection agreed by all countries in the Union for the Mediterranean (UfM), supported and enriched through inputs from stakeholder groups including civil society. The SWM was intended to be approved at the Euro-Mediterranean Ministerial Conference on Water (Barcelona, Spain, April 13, 2010), but it failed.

The long-term vision on water, life, and the environment envisages three global reference scenarios (Rosegrant et al. 2002):

1. The business-as-usual scenario (BAU) projects the likely water and food outcomes for a future trajectory based on the recent past, whereby current trends for water investments, water prices, and management are broadly maintained.
2. The water crisis scenario (CRI) projects deterioration of current trends and policies in the water sector.
3. The sustainable water use scenario (SUS) projects improvements in a wide range of water sector policies and trends. Below we will briefly describe the key elements of the dissemination strategy.

Then, the long-term SWM's objectives should be to conserve water quality and to balance quantity of used and available water to achieve regional sustainable economic growth, social prosperity, access to water for all, and environmental protection and rehabilitation. The SWM aims at stimulating the development of policy, cooperation, and technological tools; promoting the exchange of knowledge; and contributing to peace and stability.

The SWM is structured around four main thematic fields, that is, effective water governance, water and climate change adaptation, water demand management, and efficiency and nonconventional resources as well as water financing optimization and valuation.

Follow-up action-planning and concrete projects development with a focus on sustainability will be essential to the successful implementation of the SWM, addressing specific water challenges and helping to achieve solutions to problems of regional concern.

6 Some Proposals for Improving Integrated Water Resource and Water Demand Management

The objective of the SWM should be also the cooperation with the national and local authorities and institutions in strengthening the national and local capacities for planning and management of water. Concrete proposals extracted from the identification of risks in the area are:

- Use water issues as an opportunity to impulse democratic improvements by increasing public awareness and participation.
- Agriculture is at the heart of culture and society in SEMCs and is heavily interlinked with food and energy production, but is competing nowadays with other water demanding activities. One possible action could be moving agriculture into higher value-added product with lower water consumption. The good climate conditions and soil diversity must be fully exploited using the biodiversity and biotechnology knowledge.
- This region has very good solar resources for producing solar energy; any means to produce energy out of solar sources must be fully exploited for urban and agricultural use and, even, desalination of water from the sea. This action will be in line with the European prospect of zero-carbon energy consumption. In this sense, development of regionally focused infrastructures particularly for energy, water, agriculture, and transport and, if possible, their integration could create economies of scale and investment and increase the region's opportunities.
- Urban planning, securing water supply, and recycling of water used in industry and cities are critical issues and business opportunities in the coming years, as well as preservation of soil resources for addressing, among other environmental targets, the food supply security by 2050, when population is expected to reach the peak of 600 millions. Domestic supply of water in areas of water scarcity depends mainly on groundwater aquifers; however, rainwater and groundwater

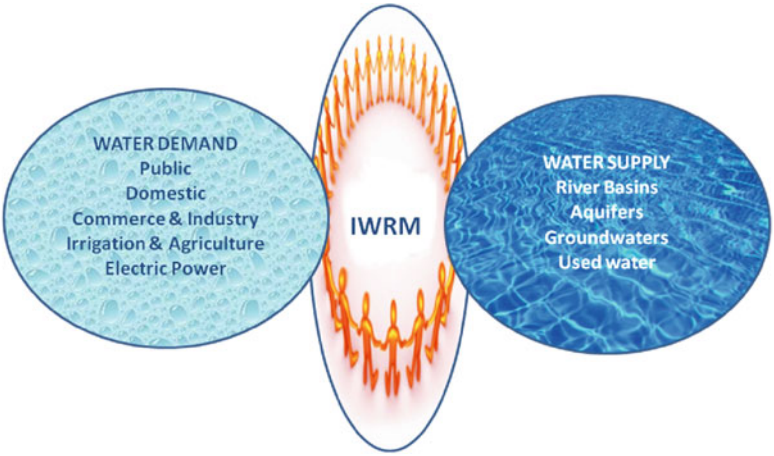

Fig. 2 Water demand and water supply balanced by an Integrated Water Resources Management approach

are rarely integrated into water management strategies, which usually focus exclusively on surface water. Countries need to integrate rainwater, groundwater, and reclaimed waters fully into their strategies to tackle water scarcity.

- A more sustainable decentralized water infrastructure could be developed instead of the current, highly centralized network of water, sewer lines, and treatment plants. Scattered communities facing water shortages and escalating costs of repairing the aging centralized infrastructure with water losses could use decentralized systems to reduce flows and thereby avoid big new water supply or wastewater treatment system costs.
- A broad challenge consists in the setup of common standards for all the Mediterranean countries and the harmonization of norms (equipments; prevention, information, and intervention systems; etc.) as well as more efficient monitoring of maritime pollution, which is a common issue that needs a common approach and join strategies and actions.
- In short, proposals for implementing IWRM in the MED countries taking into account the risks faced must, at least, focus in a political target, such as the increase of public participative mechanism and its comparison and mutual learning in the whole area, and, at least, the following three critical technologies:

  – Water-efficient technology
  – Rainwater storage, distribution, and use
  – Decentralized wastewater treatment, reuse, and resource recovery

IWRM is the instrument that could balance water demand and water supply in a sustainable way (Fig. 2).

7 Developing a Public Awareness Program

The social aspects related to water management are critical, as the technical proposals must be endorsed by the end users: the full society. Raising awareness about the importance of water issues is crucial to open a large societal debate. More emphasis should be put in engaging the media in this debate, up to now limited to some scientific and stakeholders groups protagonist. The lack of public perception of the importance of a proper water management and the ignorance of impacts of political and economic decision on the long-term guarantee of water supply are some of the biggest dangers of our current Mediterranean society. Collaboration at different levels is crucial to achieve the mutually accepted goals of sustainable service delivery for all. Education, outreach, and public awareness must all be a part of the water management strategies.

The purpose in preparing a communication program is to guide the stakeholders in overseeing public awareness activities and campaigns that promote more effective utilization and conservation of available water (Texas Water Development Board 2010). The strategy would be structured as follows:

1. One of the most important initial steps in preparing a communication strategy is to identify a set of goals, objectives, and updated knowledge material that should take into account an evaluation of communication gaps currently existing. This strategy should consider all the concurrent interests, not only those of the lobbies directly interested in water as an economic asset, as they pertain to the topical issues at hand. The main goal of the strategy is building human and institutional capacity, as these are the foundation of sustainable water resources management and service delivery.

The importance of capacity building was recognized during the Second World Water Forum and Ministerial Conference, The Hague, March 17–22, 2000. The Ministerial Declaration on Water Security in the twenty-first century included the following statement:

> "We will work together with other stakeholders to develop a stronger water culture through greater awareness. We will identify best practices based on enhanced research and knowledge generation capacities, knowledge dissemination through education and other channels and knowledge sharing between individuals, institutions and society at all appropriate levels. This will include co-ordination at regional and other levels, as appropriate, to promote arrangements for coping with water-related disasters and for sharing experience in water sector reform. It will also include international co-operation in technology transfers to, and capacity building in developing countries."

2. Target groups to which the strategy is addressed:

   - Policy makers, managers within and outside the water sector, professionals, technicians, and service personnel, whose decisions prepare the framework for the future
   - Users

- Educators and trainers that prepare people to adapt to and to shape the future
- The young generation who will live in and “implement” our future

The strategy should reflect the whole scope of education; education via distant learning, self-study, role play and simulation techniques, Internet knowledge transfer, and other forms of computer-aided learning are examples of this process supplementing the traditional classroom-based methods.

In order to match the demand for education with the supply of educators and trainers, the target groups need to interact with each other through networking and other forms of communication.

3. Working with local and mass media.

The local media will contribute at large in promoting the public awareness program in concrete locations. In order to plan effectively the program, the local scenario and the accurate profile of the target audience, understanding its interests, perceptions, and needs must be considered.

Social media are another resource that can be used to increase awareness and develop stronger customer relationships. A few examples of social media resources are blogs, e-mail, instant messaging, video, and podcasts.

Working with mass media is a fundamental activity in public awareness. However, the quality of the information must be contrasted and validated by a reliable source. In most of the Mediterranean countries, there exist observatories dealing with water issues that, unfortunately, are not well known by the public or by the communicators. This situation must change, and the observatories should incorporate a recurrent activity of dissemination of national and international information and news on water issues to mass media and the general public, as the water is a matter of regional importance not limited to a national dimension. Videos, articles, forecasts analysis, and other material should be continuously prepared or updated to catch the public interest. Capacity efforts can provide journalists with basic environmental information on a specific topic or general environmental information. Information centers that are accessible to the media and to the public may constitute one approach. Therefore, specific capacity-building activities directed to journalists and other communicators should be foreseen.

Educational and awareness efforts must target practically any sector of society.

Environmental education and awareness rising can include any of the following types of activities:

- Reorienting current education and awareness programs, at different education levels, to include water environmental dimensions
- Basic education and awareness programs (e.g., in schools)
- Adult and community education and awareness programs, in close relation with the media
- Education, training, and awareness programs for professional, technical, and vocational personnel

Other approaches to promoting education and public awareness in water issues include, for example, guiding frameworks for sustainable environmental education, information centers, and environmental "holidays."

Experts everywhere feel that "the hook is education." In other words, the solution to the problem is not that we invest more money and effort purely into science communication itself but that we should consolidate first of all formal learning environments.

In connection with that, some other questions emerge, such as: Is it possible to merge science communication and formal learning environments? In what aspects can they support each other? What are the weaknesses of formal learning environments that science communication could compensate (for instance, new or innovative science teaching methods and strategies, special training for science teachers, guidelines to elaborate school books or school syllabus, etc.)? What should be the role of science festivals and other science promotion events?

7.1 Indicators of Success

The continuing interest from the local actors in the field of water management and the willingness of citizens to coorganize events and maintain and make evolve the exchanges are a proof of success. Expected impact on the target groups are:

- Qualitative indicators: Improvement in awareness, behavior, and attitude of water users, policy makers, and professionals, as obtained by periodic public opinion polls
- Quantitative indicators:
  - Water conservation strategies taught during the campaign
  - Reduction in water pollution
  - Reduced consumption of water
  - Number of persons trained in capacity-building tutorials
  - Number of secondary schools units and universities covered
  - Numbers and dates of awareness campaigns on media
  - Number of training programs initiated
  - Number of workshops/seminars/conferences during each campaign

As conclusion, we underline the importance of using the threats related to water scarcity, floods, and droughts, as a driver to support IWRM strategies, as well as the need to promote water efficiency and water demand management through a combination of different tools, such as water pricing; better irrigation technologies and techniques; water efficiency in buildings, industry, tourism, and distribution networks; wastewater reuse; awareness-raising campaigns; and educational measures. Sustainable and integrated water management, on the other hand, is a school of participative democracy.

8 Concluding Remarks

MELIA project (Mediterranean Dialogue on Integrated Water Management), a FP6 EU Project, has been completed in August 2011 after 5 years of activity that is being followed by the itinerant exhibition: Water, Domination and Myth that started in Agadir (Morocco) and will move during 2011 and 2012 to many Mediterranean and European countries. The closing conference represented a milestone and a starting point. The recommendations produced at the end of the conference contained a synthesis of the work of 5 years of dialogue and mark the rationale of new activities based in a better mutual understanding and a pragmatic approach for cooperation. The project started with the usual enthusiasm provoked by the success of an ambitious and complex proposal (45 partners…) that was prepared over a very long discussion period. The management of the project has been a very difficult task, due to the issues provoked by the heterogeneity of the partners, which ranged from ministries of water and research institutions to farmer's associations; however, despite these contradicting issues, the project has been a great success. MELIA has been a school, not only because of the mutual learning on integrated water management between experienced partners coming from most of the countries bordering the Mediterranean and beyond but also, perhaps more importantly, because the MELIA project has shown us which are the common interests in the water issues in the whole Mediterranean area. The presentations and results of the four workshops organized covering most of the aspects dealing with water, its culture, its perception, and water management provided excellent material to facilitate open discussion and the proposals of some recommendations that are listed below. MELIA has also been a very clear showcase of organizing the scientific cooperation between the EU and the Mediterranean partner countries (MPC).

Water is a common issue in all the countries surrounding our "Mare Nostrum," and this is being recognized in the ministerial declarations issued either in the Barcelona Process or under the umbrella of the Union for the Mediterranean. A proper handling of water is fundamental to promote agriculture, industry, tourism, and urban development, as water is a scarce resource and most of the countries suffer an enormous water stress. Tight political decisions must be taken to avoid an improper use of the scarce resource, promote a fair share of water for the concerned stakeholders, avoid contamination of water, and promote the use of recovered waters. The European Neighbourhood and Partnership Instrument (ENPI) Program Horizon 2020 offers a unique opportunity to join efforts of all riparian countries to improve the quality of the Mediterranean Sea. Actions must be taken to treat waters before they reach the sea and to find uses and/or markets for the treated waters. This is not only an economic issue but a cultural one. The MELIA project has analyzed these problems and proposed actions to recover a sustainable water culture. An important outcome of MELIA has been the interaction with the Steering Group of Horizon 2020, and the project MIRA of political dialogue between EU and the MPC on scientific cooperation, to define a research agenda to support the Horizon 2020 objectives. MELIA definitely has been a project with a tough development but where we have learned a lot from each other, and we have planted the seed for future cooperation in a frame of mutual personal and scientific cooperation.

The participants in the MELIA closing conference agreed on the fact that Mediterranean countries are facing acute water challenges due to the high demographic growth; the displacement of populations to the urban areas; the unsustainability of the traditional agricultural models, which consume most of the available water resources; and the threat to the region by the climate change. All these circumstances can have detrimental consequences on development and political stability of the region at large. Therefore, the countries have no other choice but to embrace an integrated water management process that is economically sound, socially acceptable, and environmentally viable. These unprecedented challenges in the Mediterranean, compounded by climate change, require unprecedented solutions as well as a nonconventional way of thinking.

The main recommendations of the MELIA project presented and discussed in the closing conference can be summarized as follows:

1. All Mediterranean countries, north and south, should consider transforming their current socioeconomic model toward a more socially equitable and more environmentally sustainable economic model. Mediterranean countries, however, should be prepared for the transition period between the different models, especially they should strengthen the institutional setup and enhance the existing governance and provide for multistakeholder dialogue.
2. There is a need to customize the adaptation of European Water Framework Directive (WFD) in the southern part of the Mediterranean Basin, taking into account their specific characteristics and challenges such as drought, water scarcity, etc. This, however, should be done in full participation with all the stakeholders.
3. Water authorities should be politically independent to ensure more independent, sustainable, and appropriate water management decisions.
4. A balanced approach in addressing water problems must consider both supply and demand management options.
5. It is imperative to develop the culture of living with less water and improve the resilience of systems and people toward the climate as well as global changes.
6. Public concern on water challenges in the Basin must be promoted at large and develop an appropriate mechanism for stakeholder participation, consultation, and collective reflection. In this regard, it is important to develop a clear communication strategy to address and involve the media in this issue, particularly targeting the awareness of various groups (children, women, farmers, decision makers, etc.) on the water challenges in the Mediterranean Basin.
7. Appropriate technologies that meet the economic, social, environmental, and cultural consideration in each country should be adapted. In this context, it is necessary to import/adapt innovative techniques and technologies on reducing losses and improving farm water management. Techniques should also include the optimization of using the green water within the overall management.
8. The Mediterranean countries must implement policies for preserving ecosystem services as a fundamental component in attaining their food and water securities.
9. Cooperation among the Mediterranean countries, especially in the South and East Mediterranean, is needed more than ever to overcome the escalating water

scarcity challenges, which is a regional problem that exceeds the capabilities of the national strategies to cope with. In this regard, the countries should start identifying policy gaps and move toward harmonizing these policies.

10. The use of nonconventional water resources (especially treated wastewater) as part of the water budget in the Basin must be a common target. This resource must no longer be considered as a waste. Moreover, it is very crucial to promote the use of treated effluent through raising the awareness and providing various incentives and subsidies to users. Trust building of the public on the safety and usefulness of this resource must be supported by good practices and transparency.
11. All water polices and institutions in the Basin need to be directed to include social and gender perspectives in their organizational culture and practice. At the same time, they need to address the strategic need to mainstream gender through capacity building and creating positive attitude and behavior within their structures.
12. Performance indicators that allow the comparison and identification of high performance and good water practices are needed. The good practice results can be considered as the bench marks for improved water management in the Basin.

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Mediterranean Water Policies Conceptual Framework

Gaëlle Nion

Abstract The WP5 MELIA project aimed to collect and analyze information on existing water policies in the Mediterranean area. The partners have disclosed all information available to them to feed the analysis conducted.

After consultation with all partners, the work of WP5 allowed the construction of a conceptual framework on water policies issues. The analysis shows that the legislative and regulatory framework for water management in the Mediterranean countries is multifaceted.

The first step was to identify common key issues to the countries. These issues are grouped under the following names:

– National strategies, institutional, and legal framework system
– Participatory approach and governance
– Water scarcity
– Water sector, cost recovery, and tariff policy
– Groundwater
– Nonconventional waters
– Control and monitoring of water resources

The second step allowed the identification of gaps for each of these issues.

The project is now at the last step – to present the solutions (institutional, planning, integrated management, etc.) existing in the Mediterranean area.

It shows that there are a number of tools for better water management either by example on issues of coordination, sharing of water, demand, or pollution management. These levers have been identified through the examples provided by the partners. They have varying levels of portability. The purpose of this document is not to assess the level of transferability of these tools but to provide a brief overview. One objective of MELIA is to promote dialogue across the Mediterranean through

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the conceptual framework, from which actors can have an overview of existing levers. This overview promotes the linking of different actors: advice on existing levers is the first step toward integrating new tools into public policy.

Keywords Water policy • National strategies • Institutional, and legal framework • Participatory approach • Governance • Water scarcity • Water sector • Cost recovery • Tariff policy • Groundwater • Nonconventional waters • Control and monitoring of water resources

1 Introduction

A policy is a plan or a course of actions selected from among alternatives and in light of given conditions (impacts of chosen options, cost, social acceptability, water availability, etc.) to guide decisions and measures to be implemented in order to achieve quantitative/qualitative objectives.

The notion of water policy obviously has two interdependent sides, from a sustainable and integrated management point of view. On the one hand, water policies have a distributive justice dimension, that is to say, they must organize water uses depending on the resource's availability and its different users' demand. On the other hand, water policies must guarantee human health and environmental protection as far as such protection is related to the state of water resources.

However, water policies have many facets other than these two main elements. Water resources are of strategic importance as regards states' development: food production (agriculture, fisheries, etc.), cutting of energy dependence (hydroelectricity), creation of employments in new economic sectors (tourism, outdoor activities, etc.), and so on depend on water resources. The definition of a water policy is thus closely linked to strategic choices and political and economic constraints which exceed "mere" available resources' allocation or the fight against pollution and the deterioration of ecosystems.

The WP5 team has collected information about water policies and water management in the Mediterranean countries. This work is presented in the first version of "Mediterranean Water Policies" (D37). This document has been built with the participation of several partners who made a feedback about water policies in their countries. IOW has made a supplementary research work.

The analysis of the information contained in "Mediterranean Water Policies" allows us to identify the main water policy issues in the Mediterranean area. We can name as main issues water tariff policies, groundwater management, scarcity management, or the development of nonconventional water resources.

The conceptual framework focuses on the best practices, experiences, or principles of water policy identified in the several Mediterranean countries. These elements are synthesized below per principal issue.

These elements will be the support of recommendations to promote the application of the Water Framework Directive principles in EU and non-EU countries of the Mediterranean area.

2 Water Management: Main Water Issues in Mediterranean Countries

Following the analysis of the main water policies in some Mediterranean countries, we can bring to light principal issues in water management.

2.1 National Strategies, Institutional System, and Legal Framework

- Overlapping of responsibilities between institutional stakeholders (short-term planning, fragmented short-term policy): Conflicting resolutions that do not contribute to water management efficiency
- Legal framework outdated
- No implementation of legal texts and no decrees
- Delay in text promulgation
- No specific "organism" per water issue or per territory (basin) and no national and regional coordination
- Difficulties of EU directives translation into national laws and EU objectives not reached
- Legal framework does not respond to general issues of sustainable development and preservation of economical and social equilibrium
- No public status of water
- Centralization of the decision-making process: No implementation of the subsidiarity principle
- National strategies not defined for each water issue and stakeholders not identified in the master plans
- No long-term vision in water management, no planning, no national water plan, and no basin management plan

2.2 Participatory Approach and Governance

- Absence of water users associations (gaps in water management at local scales) or wrong functioning of existing associations (economic, financial, and institutional reasons)
- Misunderstanding of the concept of operational partnership among stakeholders in the water sector
- No full definition of the role and the responsibilities of each water stakeholder
- Insufficiency of the contribution of the civil corporation and no awareness for water resource preservation
- Institutional framework not adapted to participatory approach

2.3 Water Scarcity

- Scarcity tends to become a structural phenomenon.
- Scarcity is a limited factor of the agricultural development; agriculture, in some countries, is totally dependant on irrigation.
- Scarcity will intensify with the climate change.
- Scarcity implicates difficulties to satisfy all uses.
- Lack of dissemination of knowledge to private stakeholders (e.g., farmers).
- Lack of incentives to farmers and high costs of new irrigation methods (pumps, maintenance, material, etc.).
- Existence of ancestral water rights.

2.4 Water Sector, Cost Recovery, and Tariff Policy

- Connection to the networks not completed in all countries (urban vs. rural).
- Difficulties to recover costs more particularly in rural areas (too expansive charges of exploitation).
- Inadequate tariff policy, increase of tariffs not accepted by populations, ancestral water rights, systematic nonpayment, and existence of graduated tariffs.
- Absence of long-term technical or financial plans for preventive maintenance, high losses in networks, and nonoptimization of the urban supply networks.
- Misuse of cleaning water by industry, shops, car-washing, irrigating backyards, and public gardens.
- Nonexistence of a national “agency” or “office” in charge of drinking water management.
- Nonprotection of the withdrawal areas for drinking water (illegal wells, notably) and pollution risk.
- Lack of purification stations (lack of technical, financial, and human resources) and discharge of wastewaters in the environment without any treatment (generally more affected in coastal zones, water diseases).
- Overlapping of responsibilities between institutional stakeholders (short-term planning, fragmented short-term policy).
- Silting of dams reduces their useful storage capacities.

Particular Case: Costs Recovery and Agriculture

- Absence of water pricing for individual irrigation users.
- Absence of water meters.
- For collective infrastructures, payment is done on the basis of subscribed area, more rarely on the flow and the number of points.

2.5 Groundwater

- Unsustainable use of groundwater: Demand and uses exceed renewable supply and overexploitation of the majority of groundwater resources
- Innumerable private wells (no control of abstraction, pollution, etc.)
- Very high economic value of new mobilization projects and bad quality of groundwater not yet mobilized
- Pollution of groundwater due to intensive use of fertilizers
- Gradual deterioration due to overestimation of agricultural inputs
- Industrial pollution
- Bad geographic distribution of underground resources
- Implementation of management plans difficult because of naturals and economics factors and related to existing hydraulic infrastructures

2.6 Nonconventional Waters

- No reuse of treated wastewater and agriculture drainage water and no desalinization of marine and brackish waters
- High cost of mobilization
- Low rate of mobilization of the existing nonconventional water resources
- Reuse of marginal water in agriculture: Research is insufficient

2.7 Control and Monitoring of Water Resources

- Lack of measure networks and observation to follow water quality (surface and groundwaters)
- Approximative data, not based on measurement

3 Water Policy: A Diversity of Levers to Act

By analyzing the water policies and water management strategies in the Mediterranean area, we can highlight examples of policies and management in the Mediterranean countries. These examples, according to different contexts, could be read as "good practices" and recommendations for water management and all linked to the formulation of water policies in the Mediterranean countries.

3.1 Defining and Implementing National Water Strategies: The Central Role of Institutional Systems and Legal Frameworks

- Examples of National Strategies
  - Implementation of a research project on irrigation and agriculture executed by the National Water Research Center (Egypt)
  - Reorganization plan of water management sector (irrigation, drinking, and wastewaters) and organization of 22 boards for 4 regional water authorities working under the auspices of the Ministry of Energy and Water; regional authorities take part in the water policy planning at national level (Lebanon)
  - Development of policies and strategies of demand management in addition to water supply strategies (Jordan, Morocco, Egypt, Tunisia, France)
  - Establishment of a drinking water corporation in charge of use, purification, distribution, and sale of water (Jordan)
- National Framework and Institutional System
  - The Ministry of Water and Irrigation is responsible of water resources; two agencies are executing bodies (WAJ for drinking and wastewater, JVA for the development of the Jordan Rift Valley): No overlapping of responsibilities (Jordan).
  - Urgent need of reforms that reflect the government intentions toward water sector (careful planning based on long-term data availability, taking into consideration various water rights, priority for reasonable domestic use, socioeconomical development, water allocation among sectors); water policy issues are institutional development, private water participation, water pricing and costs recovery, human resources development, water resources management, service level, water quality and environment, public awareness, efficiency measures, and investment (Jordan).
  - Concentration of the responsibilities for water issues in the Ministry of Agriculture, Natural Resources and Environment visible through the promulgation law (Cyprus).
  - Creation of a National Water Authority to accelerate the implementation of EU Directives (Cyprus).
  - Promulgation of a law on water to adapt water management to social and economical development in a long-term view (federal principles: Public status of water, unity of water resources management, recognition of the economical value of water, adoption of the polluter-pays principle, and creation of basin agencies promote national and regional solidarity with mechanisms of solidarity concerning transfers between basins) (Morocco).
  - Project of water resources management (elaboration of a national plan, elaboration of a master plan for each basin agency) (Morocco).
  - 1964 law: Basis of a decentralized management at level of large hydrographic basins, a concerted management leads by local assemblies of elected

representative water stakeholders, and incentive financial tools for a good qualitative and quantitative management (France).

– Water agency roles: To facilitate the different actions with common interest for the basin, with the view of ensuring the balance between the water resources and the water needs, to achieve the quality objectives set by the regulations and to improve and increase the resource; field of intervention covers the surface waters, the groundwaters, and the marine coastal waters; means of intervention through an intervention program: financial participations for the execution of all types of works, construction and exploitation of the structures that meet the needs set by the Basin Committee, studies and research on water that the agencies can carry out or have performed on its behalf, and application of the "user-polluter-pays" principle (France).
– 1992 Water Law: Principles of the heritage character of water; the global and interlinking management of the water resource in all its forms, surface waters, groundwaters, coastal marine water between all the users; the conservation of the aquatic ecosystems and of the wetlands; the valorization of water viewed as an economic resource for the different uses. The main tool for management is the Master Plan for Water Development and Management (or SDAGE in French) that, at the basin level, constitutes the framework and specifies the orientations for management and planning over a period ranging from 10 to 15 years. In sub-basins, it is the Plan for Water Development and Management (or SAGE in French) backed by the local structures (France).
– 2006 LEMA (law for water and aquatic environments): Provides the administration, the territorial communities, and the water stakeholders in general with the tools for recapturing water quality and provides the territorial communities with the means to adapt the public services of potable water and sanitation to the new stakes in terms of transparency vis-à-vis the users, of solidarity toward the destitute, and of environmental efficiency (France).

3.2 Participatory Approach and Governance: Role and Responsibilities of the Stakeholders

Water shortage in the Mediterranean area also results from a crisis of governance which must be solved by the definition of new roles and responsibilities at the same time for private and public stakeholders. The adoption of new methods of governance should guarantee the respect and the trust of private stakeholders in the institutions, to increase the capacity of these institutions to answer to evolutions and to obtain a social consensus and solve conflicts.

• 10-year plan: Innovative aspects of this action plan are interfacing managers and farmers through a combination of advice and incentives. The plan also should be based on the interaction between the farmer water need and the service allocation that requires an innovative cycle of analysis for the determination of the best feasible water allocation, which requires expertise in the technology and management of

irrigation system. On the other hand, farmer response to financial and nonfinancial incentives is an uncharted area of research, which needs exploring to improve effectively water use efficiency through consensus and participation (Lebanon).
- Water policy defined on a partnership basis between the state, all the territorial communities, and the users – manufacturers, large regional developers, fishermen and fish farmers, and conservation associations – associated at each level. Dialogue is institutionalized at three levels (France):
  - At the national level.
  - Governance and basin districts (the Basin Committee, which brings together the different public or private stakeholders acting in the water field, is designed to discuss and define in a concerted way the broad lines of the policy for the management of the water resource and the protection of the natural aquatic environments; the water agencies play also a role in guaranteeing information and awareness of the general public).
  - At the level of the affluents and the sub-basins corresponding to an hydrographic unit or an aquifer (a local water commission made up for half by the representatives from the territorial communities, for one quarter of the users representatives and for another quarter of the state representatives, can be created to elaborate and follow the application of the Plan for Water Development and Management (SAGE); the interested territorial communities can also join forces within a local water community to facilitate the realization of the objectives set under the Master Plan for the Development and Management of Water).
  - The "local water community" can be responsible to undertake the study, the execution, and the exploitation of all the works, structures, or installations that have a character of general interest or emergency.
- Experiences of concerted management between the agricultural users: The mission CGGREF 2005 has indeed "reported, concerning irrigation, the virtues of collective discipline, the virtues of collective structures, or concerning the individual irrigation users, the virtues of the mandatory procedure. These are the local approaches that area adapted to the crops of the territories concerned which scale varies from the small catchment to one department or even a region. These collective approaches are recommended by the mission, if necessary." This mission also recommends setting up a legal tool used for controlling, even prohibiting, and the utilization of resources privately in the perimeters supplied by a collective installation. These initiative of collective concerted management can lead to a sharp reduction in the water consumptions for irrigation at the level of the catchment point (France).

3.3 Manage Shortage and Drought Periods

Focusing on the elements produced on water policies by the MELIA partners, irrigated agriculture seems to be the main issue when talking about water scarcity.

Drought periods are becoming more and more frequent, and studies about the effects of climate change are still not in favor of a water resource increase in the Mediterranean area, particularly in the south.

However, droughts and scarcity have also an impact on water supply for drinking water, industrial water, and ecosystems. Scarcity increases locally with tourism consumption.

The following actions and recommendations aim at promoting a better scarcity management in the Mediterranean countries.

Short-Term Actions

- Crisis management: Restriction of water demand for irrigated areas by decree, for example, (France) with different thresholds and appropriated measures

Mid- and Long-Term Recommendations

- Study to evaluate and quantify the available resources in order to compare it with the water demand (Tunisia) and control withdrawals by water meters (France)
- Policy of reinforcement of connection between reservoirs and regional transfers (Tunisia)
- Improve the farm management practices: Creation of collective interest groups (associations of owners and end users) or development of sustainable participatory management associations (improve local water allocation), reduction of the irrigation time (decrease evaporation), creation of federations that take part in operation and maintenance of branch canals (decrease losses), and development of modern irrigation or appropriate irrigation methods (decrease wasting by studying water use efficiency) (Morocco, Egypt, Tunisia)
- Cultivation of new varieties with a shorter growth duration and lower water consumption (decrease consumption by crops) (Egypt)
- Maximize the drainage water reuse (Egypt)
- Develop participatory approach with an operational partnership between managers and farmers (promote implementation of management plans and dissemination of good practices in water management)
- Drought plan: Develop by basin and include drought thresholds and protocols of actions (Spain, France)
- Institutional framework: Creation of a “drought observatory” made up of administrations with competences in water issues to form a center of knowledge, anticipation, mitigation, and follow-up of the effects of droughts in the territory (Spain)

3.4 Manage Water Sector and Define an Adequate Tariff Policy

- Tariff policy founded on the progressivity of tariffs for incitation to water saving (France), existence of a social tariff for poor people, and existence of low tariff for first cubic meters consumed (Tunisia). Subscription fees for domestic water supply vary and differences are partly due to water availability and distribution

costs (gravity vs. pumping) (Lebanon, France); in order to avoid too sudden raise in the water price, different mechanisms for public aid are accessible to the municipalities (from water agencies, departments, and regions) (France).
- Payment system concerning water pollution: The study aims the conception of a payment system able to be applied by the “water” agency (Morocco); user-polluter-pays principle (EU countries); and sanitation charges, charge for storage of water during low waters period, and charge for modernizing the collection network (France).
- Government subsidies to ensure costs recovery in rural areas (Tunisia).
- Priority for reasonable domestic use.
- Water supply: Limitation of well construction in areas of groundwater deterioration (Cyprus).
- Optimization of water urban distribution networks: Improve control of the water generated and supply; adapt facilities; reform and improve the water network, consumption, and management; and incorporate technology into the process (Spain).
- Water policy to define the characteristics of water for human consumption.
- Water transfer systems.
- Management of water services
  - Regional water authorities have to set and collect water tariff for domestic and agricultural use (Lebanon).
  - Establishment of a drinking water corporation (planning, designing, operating, and maintaining water projects for domestic purposes) responsible of use, purification, supply, and sale of water (Jordan).
  - Creation of a National Office of Drinkable Water (ONEP, Morocco) – production and distribution in the cities – and private organizations for big cities.
  - National program for drinkable water (PAGER, Morocco): Generalize access to drinkable water for rural populations.
  - Creation of a higher water consul to endow the country with a national water strategy: Coordination between different departments intervening in water sector, definition of national orientations, and studies of master plans (Morocco).
  - Intervention programs of water agencies (France) funded by water taxation based on the water pays for water.
  - Organization of the services of adduction of drinking water and of collection and treatment of wastewaters are placed under the supervision of the communes and their groups of communes (France): Control exercised a posteriori by territorial administration of the state (legality of contracts, technical standards, budgets) and management of water services can be delegated to private companies.
  - Wastewater is vested to the government, and the written permission of the district officer is required before any such water may be taken or used (Cyprus).
  - National plan on water quality: Reach the objectives of the urban wastewater treatment directive and of the WFD for sanitation and purification, duration: 2007–2015 (Spain).

3.5 *Managing and Protecting Groundwater Resources*

- Development of new irrigation methods for water saving (Tunisia, Egypt).
- Improvement of water management techniques and practices for saving water (Tunisia).
- Use of nonconventional waters (Tunisia, Egypt).
- Optimize use of rainfall (Egypt).
- Cultivation of new crop varieties with lower water consumption (Egypt).
- Reduce abstractions for each renewable aquifer to the sustainable rate (Jordan).
- Water pumps ordinance: To control better the use of water pumps and involved the registration of all water pumps and the setting up of an inventory of all pumps used for groundwater abstraction (Malta).
- Specific policy statements address resource exploitation, monitoring, resource protection and sustainability resource development, priority of allocation, regulation and control, and private sector participation (Jordan).
- A resource authority has the role to investigate the disposal or discharge of dangerous substances and thus maintains the right to prohibit or grant authorization of its disposal once it ensures that all the necessary technical precautions are respected, and no harm is being done to the groundwater (Malta).
- Groundwater is vested to the government, and the written permission of the district officer is required before any water may be taken or use (Cyprus).
- Authorization of abstraction: Decentralized regional authorities or department services of the state conduct the application dossiers according to their competencies. The administration can take "drought decrees" for the restriction of the withdrawals during a water scarcity period (France).
- Aquifer's contracts: The strategy of safeguarding the groundwater resources is based on the setup of a new way of governance taking in account the participation of the stakeholders in the management of this resource by the promotion of an aquifer's contract linking the different actors (river basin agency, administrations, elected officials, associations of users of agricultural water, association of the producers and exporters of agricultural produce, chamber of agriculture, agricultural credit bank, etc.) and engaging them more in the decision-making process.
- This contract constitutes a tool to facilitate the realization of the operations on which all the partners are engaged (Morocco).
- Monitoring of groundwater pollution (pollution state description in irrigated perimeters, collection of data about the intensive agricultural sector, delimitation of areas and zones affected by agricultural pollution, instauration of a control system in order to use the fertilizers in a rational way) (Morocco).
- Study aquifer recharge especially since the knowledge improves the understanding of the role of groundwater in the hydrological resource as a whole (Spain).
- Integration of surface and groundwater in schemes of joint exploitation (Spain, France).

3.6 Nonconventional Waters: Local Resources to Solve Local Problems

- Economic support to a new sector: Credit and subsidies to relative investment expenses to the realization of private projects (Tunisia)
- National strategy for the reuse of treated wastewater (mobilization for golf, green spaces) and collection of rain water (individual basin construction encouraged by government credits) and desalinization of brackish waters in extension in some touristic urban areas and south agglomerations (Tunisia)
- Coordination of research: Reuse of marginal water in agriculture and reform of the agricultural research in order to avoid the disparity of research actions (Tunisia)
- Development of nonconventional water resources as a measure of development of irrigated agriculture and not as a substitute to conventional resources (Egypt)
- Development of marine water desalinization for coastal cities (Morocco)

3.7 Networks for Monitoring of Water Resources

- Development of measure networks to follow water quality within the framework of water resources mobilization programs (Tunisia).
- Generalization of meters for domestics and industrial and agricultural uses.
- Interest in a common regulation: Implementation of EU Directives on IPPC and nitrates OK or ongoing in EU countries.
- Monitoring for irrigation: Pollution state in irrigated perimeters, collection of data about intensive agricultural sector, and control of the use of fertilizers (Morocco).
- System of evaluation of water quality: General state of water courses quality and aquifers can be assessed through observations made regularly during the year by the networks of general knowledge (mainly the national network of basin and the national network of groundwaters). Quality is assessed on the basis of standardized grids (SEQ-Water) (France).
- Water Information System (WIS) has the following missions: Production of all types of data on water, management and conservation of these sets of data, and easy access to data. SIW concerns all data useful for the general knowledge of the water resources and the aquatic environments – quality, quantity, uses, regulatory data, etc. (France).

4 Conclusions

The definition of public policy as presented in the introduction of this document may not itself reflect the needs of management and the interactions between society and impacts on water resources.

The implementation of a public policy is not simply limited to the application of regulations and directives but also requires the integration of new concepts taking into account the specificities of each society.

We know that there are difficulties in terms of water management in the north and the south of the Mediterranean Sea. The feedback from the water management in Europe combined with the one on national actions in the southern Mediterranean found the basis of a collective awareness of issues related to water availability.

In the North area, strongly guided by the Water Framework Directive and its daughter directives, public policy in the field of water and the resulting measures show effectiveness by a gradual improvement of the water quality, but this effectiveness is not uniform across geographic areas, economical sectors, and types of water bodies.

In the southern area, the different countries have all set up targeted actions to address their key challenges, some managing to integrate Integrated Water Resource Management (IWRM) principles.

But beyond these actions that (based on the descriptions and effective results) could be adapted and applied to other countries and contexts, this analysis shows the existence of essential principles: innovative and founder principles of a balanced and shared water resource management.

This is because they incorporate the specificities of each society that participation and consultation between the various stakeholders seem to be two of these founder principles. How to manage water without involving all stakeholders, including the end users of this resource? How without involving them, ensure the effectiveness of public policies and measures?

These questions on participation and consultation open doors for a wider concept: the governance. Definitions given by Rogers and Hall (2003) show the different key concepts of good governance. "Distributed water governance is a mix of formal and informal institutions that are in place for managing water resources emphasizing the link between communities and local government entities. The effective water governance is a structure of governance that is open and transparent, inclusive and communicative, consistent and unifying, fair and ethic."

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Effective Water Governance and How to Achieve

A. Hamdy and Redouane Choukr-Allah

Abstract In most countries of the Mediterranean, the importance of governance of water resources for sustainable development is well recognized politically, but, within the water community, there is little recognition of its centrality.

The acute water crisis widely impeding the sustainable development for most of the arid and semiarid countries of the region brought conclusively that it is often a crisis of water governance and signed out making water governance effective as a priority of action.

Nowadays, it is increasingly realized that neither the traditional public sector nor the illusive market can resolve all challenges in water resources management; complementarities and coordination and the creation of accountable but dynamic relationships between different players and stakeholders are required. In the region, if we secure access to water for all, maintain vital ecosystem and produce economic development out of water management, the only option we have is the effective water resources governance fundamentally based on harnessing and increasing the availability of water resources, more efficient water use, producing more with less water and appropriate recycling and reuse.

Governments, civil societies and private sector are the main water governance systems; there is a great need to an appropriate setting of the enabling conditions, those facilitating dynamic interactions dialogues; participation and partnerships, amongst them, are the decisive key elements leading to govern satisfactorily the water resources in the Mediterranean region.

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1 Introduction

In contrast to most other resources, there is no substitute for water, and the basic challenge is therefore to improve its governance, that is, to have a clear strategy and policy for how to develop, conserve and utilize the resources to ensure that the necessary institutional and technical arrangements are in place to implement the policy. In many developing countries including those of the Mediterranean, socio-economic advances and demographic changes, such as increasing urbanization, are imposing enormous pressure of the freshwater resources.

Politically and socially, the challenge most countries are now facing is how to meet the increasing water scarcities seriously affecting the running development plans.

The emerging questions are: How we, as individuals, and as parts of collective society, govern the access to and control over water resources and their benefits? How can the increased competition in water demand amongst the water user sectors be handled through institutional and other arrangements? What roles do authorities, donors and users play in this regard? Lessons learned and experiences show that water scarcity and competition will force or stimulate people to develop new practices and partnerships or to look for substitutes to improve water governance.

Nowadays, many countries are currently in the process of changing the ways of how water is being governed. From a practical point of view, this means formulating, setting in place and implementing water policies, legislation and regulations. What is to be emphasized is that for improving water governance, it is necessary to facilitate dynamic interaction dialogues and partnerships amongst governments, civil societies and private sector. In this context, there is no simple governance formula which can be applied. Indeed, governing mechanisms vary considerably across countries due to the variations of water resources characteristics and socio-economic and political frameworks. However successful models exhibit a good "fit" between local hydrological, environmental, cultural, economic and political factors. Given that no optimal governance model exists – since it has to adapt to local and national specificities – it is while actually confronting national experiences that good governance practices can emerge.

Achieving effective water governance cannot be undertaken using blueprints imported from overseas; it needs to be developed to suit local conditions with the benefit of lessons learned around the world. Unfortunately, water reviews and water reports regarding several arid and semiarid countries all give the impression that there is failure rather than success in governing water resources.

The reasons behind are numerous but, primarily, attributed to the absence of the enabling conditions required to govern the water resources effectively. For those countries, complementarities and coordination and the creation of accountable but dynamic relationships between different players and stakeholders are required. Equally, it is needed that the entire water resource – literally from drops of rain to discarded drains – has to be included in a strategy that deals with multiple objectives including more crop per drop, more care per drop and less wastage per drop. Those are the water governance challenges.

2 Water Governance: The Four Dimensions

The social, economic, environmental and political are the four dimensions of water governance (Fig. 1) (Tropp 2005). The social dimension points to the equitable use of water resources. The economic one draws the attention to the efficient use of water and the role of water in overall economic growth. Studies have illustrated that per capita incomes and the quality of governance are strongly positively correlated.

The political dimension is mainly directed at granting water stakeholders and citizens at large equal democratic opportunities to influence and monitor political processes and outcomes. It points to ensure greater water equity for women as well as other socially, economically and politically weak groups.

The environmental dimension of water governance is the one regarding sustainable water use and ecosystem integrity, emphasizing the essential role for maintaining a healthy environment.

Water quality degradation is consequently a serious threat to environmental sustainability and public health, and it will also reduce the use options of the water that is available. This brings us to the questions: What kinds of governance options are possible and effective to cope with this largely invisible threat? How can this new task be combined with the tremendous challenges to insure food security and completion over water quantity?

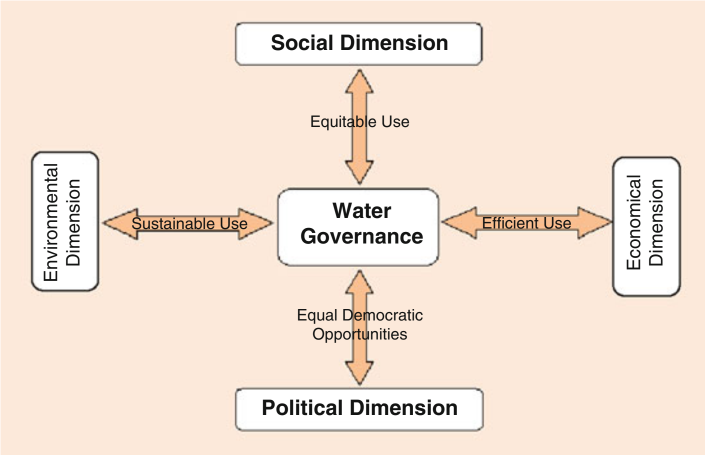

Fig. 1 Water governance dimensions (Source: Tropp 2005)

3 Water Governance: Major Coordination Gaps

A typology of the major coordination gaps in water governance is given in Table 1.

In practice, many of these gaps overlap as do the solution intended to address them. This can be clearly observed from the definition of each of the presented gaps.

Such gaps proceed mainly from the multiplicity of actors in the water sector that demonstrate clearly the interaction between territorial and central level of government is not always coherent. The learned lessons indicate that such coordinated gaps are widely spread and particularly acute and diverse in the centralized political. This is to be attributed to the lake in sufficient interest and expertise in sub-national and national government and thereby creating both administrative and capacity coordination gaps as well as the information one.

Concerning water governance, it is quite evident that there are many different sources of gaps (Fig. 2).

Table 1 Water governance: Majorgaps

Administrative gap	Geographical "mismatch" between hydrological boundaries and administrative ones
Information gap	Asymmetries of information between various authorities in charge of policymaking or implementation of water (and between public and non-governmental actors)
Policy gap	Sectoral fragmentation of water-related tasks amongst government ministries and agencies which hinders integrated policy development
Capacity gap	"Local" water management actors have insufficient capacity to effectively apply water policy in terms of scientific and technical competences, size and quality of infrastructure etc.
Funding gap	Unstable or insufficient revenues undermine effective implementation of water responsibilities at sub-national levels of government

Source: OECD (2009)

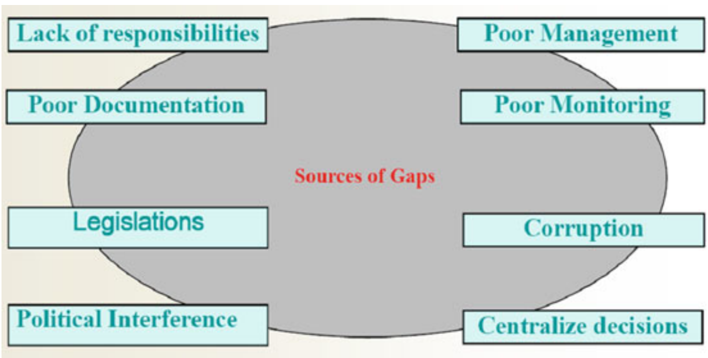

Fig. 2 Governance/management challenges (Source: El-Kassar 2009)

The presence of such numerous sources of gaps evidently indicates that improved governance and impacts on water resources management and related services are both complex and dynamic. Furthermore, it demonstrates that water governance cannot be achieved unless there are overall changes in how societies and private and political system function (GWP 2003).

In order to fulfil such existing gaps, it is needed to find reasonable answers to the following critical questions:

- To what extent do the different gaps identified as challenges for governance characterized the water sector in the different arid and semiarid countries?
- How might these gaps hinder integrated water resources management?
- What mechanisms have been used for addressing these gaps? What are their pros and cons?

Those are nowadays the major questions challenging our goal towards an effective water governance.

4 Water Governance: The Challenges

The detailed reports and cited review presented by GWP (2000, 2001, 2002, 2003), the case studies presented by Tendler (1997) and the empirical examples of water governance in several countries (Keohane and Ostrom 1995) all indicate clearly that water improved governance is not an easy issue, but it is a complex one that involves a wide range of skills, institutions and actors. Responsibilities are often unclear, with several government agencies responsible for water supply without any of them fully dictated to water resources governance.

To meet the water governance challenges, many countries have embarked upon institutional reforms, decentralizing and tasking local authorities with service provision. Other countries have turned to privatization in an attempt to use the skills and resources of contracts. However, for both approaches, several countries are still far away from having a reliable progress in governing their water resources. This could be the result of several reasons, the major amongst them being weak local capacity, unclear responsibilities for water resources management, corruption, ineffective regulation and above all weak institutions, public awareness and the absence of champions/leaders and updated skilled managers.

5 Water Governance Responses

The ways societies govern their water resources impact profoundly on urban and rural peoples' livelihood opportunities and environmental sustainability. In most countries, issues of power and politics are decisive for governance of water. They play an important role in shaping governance and involve the characteristics of actors and policy processes. Politics can both hinder and facilitate water policy reform and implementation. The representation of various interests in water decision-making and the role of politics are important components in addressing governance dynamics.

Here it is worth noting that water decisions are anchored in governance systems across three levels: government, civil society and the private sector. Facilitating dynamic interactions – dialogues and partnerships – amongst them is critical for improving water governance reform and implementation (Rogers and Hall 2003; UNDP 2006a, b).

As part of national and international water agendas, many countries are currently responding to water governance challenges by developing and implementing national integrated water resources management (IWRM) plans and strategies. The content of such plans and strategies varies, but some common features can be traced: they typically include reform of decentralization (including setting in place new administrative water units – river basin organizations), privatization of water services, multi-stakeholder participation and water rights. Many developing countries are currently in the phase of formulating such strategies or are in the process of implementation (GWP 2003; CEDARE and AWC 2007).

6 Water Governance: Tools and Approaches

6.1 Dialoguing and Networking

Dialoguing and networking are important to the formulation and implementation of water reform. Both tools must be understood as being a long-term partnership and commitment towards reforming the water sector. It is not a "one-off" event. It must be perceived as a long-term process that is attempting to change the relationships between government and other stakeholders and to form a basis for an ongoing, effective and fruitful dialogue and networking at local and national levels.

National and local dialogue and network processes can thus catalyze broad support for water reform, its financing and effective coordination of implementation. Experience suggests that reform that is anchored within society renders implementation much easier. Various forms of dialogue and inclusive network processes are useful tools to build support, common understanding and trust amongst key players and to get broad buy-in and ownership by the public and stakeholders of required reforms (UNDP-GWF 2011).

6.2 Financing and Investment: Water Pricing in the Wider Context of Governance and Technology

Experiences suggest that the introduction of pricing regimes for improved irrigation efficiency must go hand in hand with wider application of water saving technology and improvements of water governance.

Water and water services have traditionally been underpriced, resulting in inefficient use by those who have had access to cheap water, for instance, in agriculture, households and industries. It has also led to a dearth of financial resources where the water sector has not been self-financing but has lived from subsidies. Therefore, more investment in the water sector, be it from public or private sources, must go hand in hand with the recognition that water pricing is an essential instrument to enhance the sustainability of the resource, expand services, including operation and maintenance of water resources management functions, etc. Most improvements in the water-related sectors will not occur if governments do not consider developing socially acceptable pricing and tariff policies (Abu-Zeid and Hamdy 2010).

Clearly, the water sector in many countries is underfinanced. Currently, government taxation funds the management of water resources and services in many developing countries. Most developing country governments have far not been able to raise adequate funds through taxation or the application of water tariffs for cost recovery.

In this context, the government has an important role to play in providing incentives through clear regulatory and institutional frameworks for increased finance and for various partnerships arrangements with clearly defined roles for all parties.

It is well recognized that improved governance will lower transaction costs and make a significant combination to create a favourable environment to increase water investment and to ensure that investment is used correctly and efficiently. The introduction of an effective autonomous regulatory authority and transparent and accountable processes will provide better and more opportunities to attract new financing. However, for an increasing number of countries, there is a growing need to adequately reflect the use of water and other natural income and put in place policies and market failures and the economic and social undervaluation of water resources.

6.3 Building Knowledge and Capacity Development

Despite the increasing interest on water management over the past decade and the many and diverse activities to develop skills, the growing challenges require a much greater volume of more structured and better targeted capacity building, supported by related materials and follow on actions. Such activity should tackle all possible issues, address all stakeholder groups and at all levels (national, local and regional) (Hamdy 2010a).

Technical skills and knowledge will continue to be important for the water sector. The successful implementation of water governance reform will require even more emphasis on skills and capacities related to the management of dialogue and network processes. It is important to develop knowledge and capacities that effectively can respond to situations characterized by complexity, uncertainties, change and trade-offs.

Some of the areas that require enhanced capacity include, for example, integrated water resources management, transboundary waters, gender mainstreaming and institutional/technical innovations and adaptability.

More attention therefore needs to be given to knowledge and capacities that are critical to develop inclusive and flexible water governance systems that can respond to changing social and hydrological conditions. However, it is important that efforts to build capacities also focus on going from increased knowledge to its application, that is, action.

For the new institutions created by decentralization and their newly assigned roles and tasks, effective implementation of water strategies and assigned programmes requires improving local authorities and user groups. Thus, attention has to shift to capacity building of the decentralized agencies in their new institutional context; this is what we have to focus on so that they can work effectively in a participatory, people- and service-oriented approach with water groups, communities and households. This requires that central agencies also have to be transformed, so that they can take up their new roles and responsibilities.

Indeed in the local level, there is serious shortage of capacities, knowledge, know-how and other capabilities needed to participate in and implement water polices and projects. Thus, they can be attributed to the centralized approach (i.e. top-down approach) of water policy development and shortage of advanced training and capacity building campaigns on the new emerging IWRM issues and approaches (Abu-Zeid & Hamdy 2010).

6.4 Adequate Legal and Regulatory Framework

In many countries, in the water sector, enforcement of legislations is weak and judicial systems are inadequate. When both are combined with low wages, huge income disparities and accountability and transparency shortcomings, corruption dominates. Furthermore, opaque power structure can breed corruption.

Corruption reduces economic growth, discourages investment, violates human dignity, increase health risks and *robs* poor people of their livelihoods and their access to water. New research case studies increasingly show how corrupt practices are determinable to sustainable water use and service provision. Yet the systematic means to prevent and punish corruption in the governance of water are often absent.

Fighting corruption require the presence of anti-corruption measures such as legal, financial, public service delivery system and private sector reforms. Indeed anti-corruption measures are now perceived as central to equitable and sustainable water governance.

Getting to good water governance, further effort is needed to combat corruption through awareness raising, decentralization, inclusion of transparency and programmes on water integrity and accountability.

6.5 *Reforming Institutional Settings*

Water institutions take several forms: the ones that manage the quantity and quality of water resources and promote inter-sectorial planning, those that proved service or regulate service provider and those that manage the financing of water investment. For clarifying the role of those water institutions emerges the following questions:

- What are the roles and responsibilities of various water-related institutions? Who decides who will get what water, when and how?
- How are property rights defined, who benefits from these rights and how are they enforced? These are all central issues that many times need further clarification in current water policies and legislations.

Insecurity of water rights, mismatches between formal legislation and informal customary water rights and an unequal distribution of water rights are frequent sources of conflict. Improving them can lead to better water decision-making.

Case studies regarding greater number of countries clearly indicate that the establishment of well-defined and coherent roles and responsibilities, such as through legislation of formal and informal water rights, leads to a number of social, economic and environmental benefits; those are effectively improving the governance of water resources; some of those benefits could be outline in:

- The promotion of equitable water use between existing user groups besides improving access to water amongst them
- Improving the efficiency of existing water supply allocation as well as providing bases for hydrological data and information to manage the resource more effectively

Nowadays major efforts are carried out for improving the capability of the institution in governing successfully the available water resources. Considerable progresses have been made in reforming institutional setting particularly as regards consolidating responsibilities on water planning and legalizations. However, in many countries, authorities reasonable for the wider water sector (supply, irrigation, environment, sanitation, etc.) are characterized by overlapping and conflicting function. This constitutes a major impediment in achieving appropriate balance between the water supplies and demand and thereby a poorly water governance.

Countries need institutional, educational and financial support to ensure effective operation of institutions. The institutional objectives have to cover the strengthening of water management and regulation functions, the improvement of information and the assessment of water resources systems, the promotion of the participatory management approach and to provide the water sectors with needed investment. Those are the key pillars enabling countries to actively tackle their water governance challenges (Chiccioli et al. 2010).

6.6 Creation of an Enabling Environment for Action Implementation

It is the key element towards more effective water governance. However, the creation of an enabling environment requires a coherent legal framework with a strong and autonomous regulatory regime. Clear transaction between stakeholders is needed in a climate of trust with shared responsibility for safeguarding water resources.

Nowadays, there are many actions working towards more effective water governance, amongst them: revised laws, institutional reforms, the introduction of economic instruments and social reforms such as gender mainstreaming, participation and decentralization.

However, the crucial point is not in identifying the actions and tools for achieving an effective water governance but in how to implement successfully such approaches. This is an important part of the work of bilateral and multilateral organizations to support the enhancement of capacities to strengthen national and local water agenda and policies, investments priorities and scaling up the activities for improving water governance through an appropriate sound governance practices.

6.7 Well-Defined Coherent Water Rights

Ambiguous water rights are a frequent source of local tension and conflict. It ultimately results in poor decision-making on water use efficiency and equitable water use. In most developing countries, water rights are placed within a legal context strongly characterized by pluralism. Most governments' legislation and regulatory authority powers largely ignore customary water rights.

In most developing countries, specialized government agencies are in charge of large-scale irrigation networks and the distribution of water permits. Unclear water rights and management of related infrastructure can lead to confusing and conflicting situations of roles and responsibilities amongst government agencies and water users of who is entitled to what water, when and how, as well as unclear guidelines on operation and maintenance of infrastructure (Tropp et al. 2006).

Despite progresses in water rights reform during the past decades, the legal development is still lagging behind that of land, forest and energy resources. There are, however, increasing pressures from local to international levels to continue reform in water rights and a need to further clarify its content.

Setting in place well-defined and coherent water rights is fundamental to deal with increasing competition between water users (Hamdy 2010b):

- It can promote improved access to water by groups that previously have been denied formal or informal water rights and equitable water use between existing user groups.

- It can improve the efficiency of existing water supply allocations.
- It promotes the willingness of farmers and urban water users to take economic risks to make necessary investments in improved water management and practices.
- It can render other governance measures more effective, such as the application of pricing mechanisms.

6.8 National Water Governance Indicators

For any water reform, it is vitally important to consider carefully social, economic and political conditions, both drivers and policies inside and outside the water sector; those could have direct or indirect impacts on how water is being used and governed. In this regard though efforts in most countries are going, yet monitoring achievement is still limited, and there is lacking robust indicators that can monitor and assess trends for national water governance reform.

Water governance indicator is intended to be useful to national stakeholder as a tool for priority setting and for strengthening the responsiveness of institutions and processes to the water needs of water users.

The development and application of a propriety water governance will make major contribution to the type of water policy intervention that is required by government and the whole development community. This is a primary challenging task. Each country has to develop its own indicators in its own realities to monitor the enabling environment, the institutional framework and the management instruments to evaluate the progress as well as the drawbacks encountered in water governance running programme.

6.9 Developing Optimum Involvement of Water Professionals: Public-Private Partnership

Many communities are now reaching socio-politically sensitive limits of water availability, where the cost of managing shortages of water is becoming a constraint on the lives of individuals and on economy. Averting a full scale crisis will require changing attitude at all levels and making the mental shift from asking how much more water is needed in deciding what activities can be best afforded with the water available. That shift in thinking will result in water development being tackled in a coherent integrated manner, by a combination of strong public and private sector institutions, and with vision that looks beyond the boundaries of individual activities. Both private and public professionals can be appealed to rational management and increased funding required to improve water resources governance.

6.10 Building a Partnership Approach

For most developing countries, it is needed to establish practical rules for local partnership amongst the various stakeholders active in the development and management of the water sector (local authorities, operators, communities and NGOs).

Experience evidently shows that a single entity cannot be entrusted with the full burden of responsibility; partnership between operators and partners possessing immediate knowledge of local circumstances and able to maintain relationship with members of the community is therefore fundamental. Such partnership must become more flexible and be combined with public-private partnership in order to be able to govern efficiently the available water resources.

6.11 Promotion of Central Policymaking and Decentralized Management

An integrated strategy for managing water as a common resource ensuring its rational use is urgently needed. Traditionally, for most countries, water sector institutions have overlapping tasks; and competing users in agriculture, municipalities and industry fragment the sector further, making the coordination of resource planning and management by a central institution critical. Some form of national water body should be responsible for designing and implementing the national water strategy. The mandate of this body, and the sector's organization as a whole, should be described in a water law that defines water as a public good, recognizes water rights and creates autonomous and decentralized managerial units, as well as setting water quality standards, pollution control and conservation guidelines. Water delivery, by contrast, should be decentralized, to be the responsibility of local irrigation authorities, water and sewage utilities, and rural communities. Following such institutions, arrangements will definitely enable in achieving a better water resources governance.

6.12 Promoting Gender Equity in Water Decision-Making

Integrating gender concerns in water decision-making is important not to greater equity but also for greater efficiency. Accelerating poverty alleviation and socio-economic development in the developing countries depends on mobilizing every available skill, thereby, increasing natural resilience and empowering people to improve their own lives. In the Arab countries, the will to change is growing, and there are some replicable examples of successful measures for promoting gender equity in decision-making. However, skill needed is a better understanding of what has to be done, what can be done and how to do it. Practical methods such as budgeting and gender analysis of programmes and projects need further development being appropriate tools for a better water governance.

6.13 Raising Awareness

Awareness is the foundation of water governance as it is the first step for sensitization, participation and action. Nowadays the existing climatic changes on one hand & the water scarcity on the other hand are driving most countries ranking water awareness on the top of the water governance issues. Indeed, awareness-raising activities are ongoing in many countries, but their coverage is still limited amongst the users as they have not been approached in an organized way and with a long-term plan. This is reflected on the efficient water use in irrigation being with very poor values, around 40 %, and with water losses exceeding 50 %, which clearly indicates weakness of water awareness in this sector, and that majority of farmers are not practising any water-saving measures.

Here comes the important role the NGOs could play as key actors in raising awareness. They have to be further supported to effectively deliver that role. This is also the case of the media. Its role should be activated on both national and local levels through well-tailored and easy to understand programmes, dialogue and frequent meeting.

7 The Way Forward: Some Further Considerations Towards Effective Water Governance

7.1 Essential Efforts

For many countries, and in particular the arid and semiarid ones, to be able to govern the water resources effectively and to achieve better distributed governance, efforts should focus on:

- Improving regulation, clearer definition of roles and relations, better allocation mechanisms to bring water distribution in line with society's changing needs, capacity building to prepare individuals and institutions and improving financing, including better use of existing budgets.
- Water governance must be seen within border governance systems in society and must account for social changes.
- Moving towards more effective water governance will require several changes but the process of change should be principally based on:
  - Building as much as possible on existing arrangements
  - Capitalizing on opportunities and being realistic
  - Opening processes and policymaking with all stakeholders as far as practical
  - Establishing effective sociopolitical and administrative systems and adopting an IWRM approach with transparent and participation processes that address ecological and human needs

7.2 Partnership Choices

In many parts of the world, there is a huge distrust between the state civil society and the market keeping one another at arm's length. This does not render partnership formation any easier. Despite of such unreasonable situation, it is a must to improve water resources governances by creating a strong partnership between the involved government, civil society and private sector. In this regard, the questions to be asked are:

- To what extent and in what ways those players could be involved?
- What needs to be done by different players? What should the different players do?

Answering the above raised questions implies that role responsibilities and the role of each partner to be well defined and accordingly:

7.2.1 Governments

The prime responsibilities rest on governments. They should:

- Establish an effective governance framework although care is needed to account for external influences such as international agreements. Government should not abdicate responsibility but nor can the state act alone, and achieving good water governance will require action through partnership.
- Strengthen their capacities for sustainable management of water resources and, as appropriate, decentralize operational and service delivery functions to municipalities, local governments, communities and private operators. Water services should be paid for by consumers and/or through transparent, targeted and funded subsidies so that all water service delivery systems are financially and managerially sustainable.
- Commit to institutional development and prepare simple but clear legal and regulatory frameworks that avoid jurisdictional overlaps and conflict between sectors and fill administrative gaps.

7.2.2 Donors

The donor community should commit an increased percentage of their funds for water and for establishing better water governance systems. Extra support should be given to countries with sensible socio-economic policies to help implementing laws and building administrative capacity for efficient public institutions at different levels of authority as well as providing seed money for infrastructure development for the poor. Experience suggests that to make private sector engagement work, effective government regulatory power is required.

7.2.3 Stakeholders and Civil Society

Better communications and access to information sharing should be promoted to help establishing accountable and transparent systems and reducing corruption. Civil society and the local media should act as watchdogs to help ensuring compliance within a monopoly situation. Stakeholders should secure legitimacy and “ownership” of policies by society through social mobilization and participation.

NGOs and community-based organizations can act as links between the state and community directly responsible for natural resources management and service delivery: they can also counterbalance the overwhelming governmental and economic powers. Civil society organizations are particularly strong in their knowledge of and links to the local context. Such links and knowledge can form a basis for flexible, innovative and dynamic institutional framework for sustainable water governance.

Monitoring and evaluating several water governance case studies clearly demonstrate that several visions compatibility, equitable presentation, legitimacy, communication and mutual trust and understanding are some key elements in successful partnership amongst the different players involved in the water resources governance.

7.3 Introducing Effective Mechanisms for Coordination and Cooperation

Different types of mechanisms can address vertical and horizontal coordination challenges. For instance, different types of contracts can be established between local and national levels or between municipalities in order to optimize the scale of implementation of water policies.

Other complementary strategies should also be considered such as delegated water governance partnerships involve delegation by government or the relevant authority of water governance to a lower level. The one where involvement of a large numbers of stakeholders who represent diverse interests and who treat each other more or less as equals is to be recommended.

However, such approach to be successful requires sustainable funding, effective leadership and management, interpersonal trust amongst participants and committed, cooperative participants. In addition for better governance of the water resources, some horizontal and vertical coordination tools are required in tandem with alternative service delivery approaches.

Those tools are listed in:

– The geographically based tools: those are particularly important for limiting jurisdictional overlaps and gaps and encouraging collaboration between different policymakers. These approaches tend to integrate a wide range of water functions across a geographical area. The most obvious example is that of *watershed agencies, partnerships or committees*.

– The functionally based tools: those tend to be used for ensuring effective and harmonized policy implementation, monitoring, and enforcement. These might include cooperation agreements and power-sharing instruments, which tend to be used at the national level for inter-ministerial coordination.

A good governance strategy implies the prior adoption of a "vision" (or a set of prioritized principles for decision-making about water) which should help frame decision-making. Ideally, this good governance model would be adopted prior to business model restructuring.

8 Concluding Remarks

- The concept of water governance has gained a lot of ground and evolved over the past decade and will continue to be an international priority through 2015 within the Decade on Water for Life and is now having a wider acceptance as a critical issue at both regional and national levels.
- Identifying the action is easy to do, but the difficulty is how to implement it properly on the ground.
- Governance depends to a large extent on the underlying political and cultural conditions as well as economic factors. Because of the varying characteristics of water resources and the myriad socio-economic and political frameworks, governing mechanisms vary considerably across countries, including differences such as the pace at which countries are moving towards implementing water policy reforms, the level of the reform and the degree of targeting environmental and social objectives.
- There is no blueprint to improved governance. With social, political and economic preconditions as a base, any society must find its own way of improving governance. Despite the variety in design and implementation of improved governance, there are also certain characteristics of the water sector that must be taken into account.
- More decentralization is needed in water governance along with a stronger central role in IWRM. This must be accompanied by the necessary financial resources and human capacity development at the local level. Often, local governments do not have the capacity to do what is required. Local groups and individuals are hampered by lack of access to key information and, frequently, by exclusion from participating in water decision-making. There should also be a more sober view on decentralization itself and what types of decentralization are useful for improved water resources management to achieve an effective water governance.
- Most developing countries are suffering shortages in financial capital to enhance efforts to improve water governance. Business, as usual, is no longer a viable option. If investment levels and reform speed are not steeped up, countries' abilities in achieving water security and food security will be seriously compromised.

- Besides those valuable remarks and observations, focus should be given:
  – To move beyond what has become a state and polarized debate on public or private management. The debate should be about sustainable access to safe water supply. Only by concerted action on the part of all parties can improvement be made.
  – To stimulate each country to plan policy reform dialogue, capacity building, actual reform and development of infrastructure in an integrated, timely and in a sequential manner.

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Water and Food Security in the Arab Region

Safwat Abdel-Dayem and Rachael McDonnell

Abstract The Arab region is characterized by high population growth rate, large and rapidly increasing food deficits, limited water resources, and highly variable income levels both within and between countries. Although crop yield values have gradually increased over the last few decades, the Arab countries are still unable to feed themselves using their limited water resources, and they are net importers of food supplies. The situation is likely to deteriorate with increasing water shortages which threaten the locally produced food supply due to, among others, aquifer depletion, salinization of soils, climate change, and reallocation of agricultural water to other sectors and users.

The most viable option is to increase agricultural water productivity of the arid Arab region, not the agricultural land productivity. Cropping pattern shift policy could be adjusted through applying a system for financial incentives to encourage the farmers to cultivate less water-consumption crops. A resilient agriculture requires higher effectiveness with respect to increasing the use efficiency of natural resources and agricultural outputs. Agricultural trade liberalization could have an important role to help achieve the important objective of food security in some countries.

Keywords Food deficits • Water scarcity • Water productivity • Trade • Food security

1 Introduction

By 2050, the world's population is expected to reach 9.1 billion, a 50% increase compared to 2000. Nearly all of this population increase will occur in developing countries. Urbanization will continue at an accelerated pace, and about 70% of the

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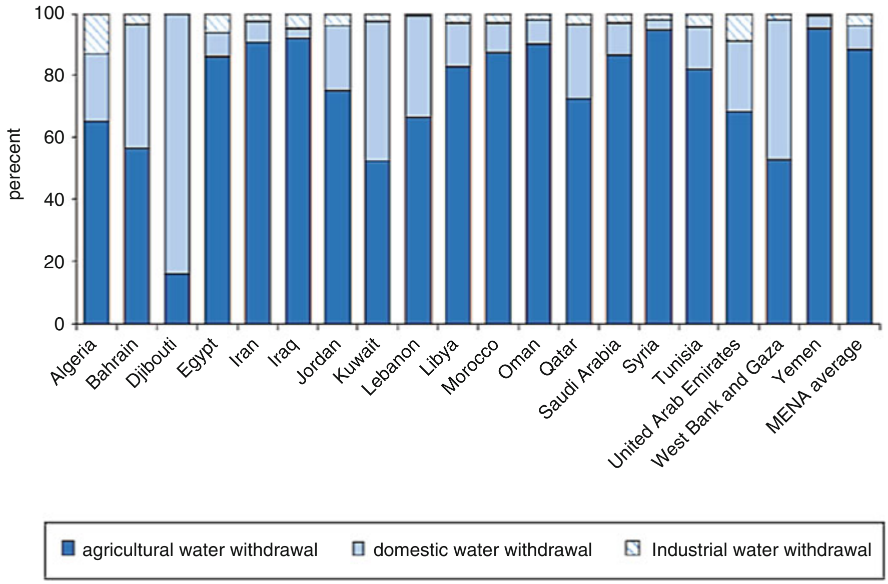


Fig. 1 Water withdrawal per sector in the MENA countries

world's population will be living in towns and cities. In order to feed this larger, more urban, and partially richer population, it is estimated that food production (net of food used for biofuels) must increase by 70–110 % at the global level and at least doubling in the developing countries. The estimate of 110% for future food requirement assumes changes in dietary adjustment of food demand (WWF6 2011). A major concern that currently dominates the political, economic, and social life in many countries is how to continue securing food supplies. "'Food security' exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." The current global food security situation is highly unstable, driven by dynamics in energy prices, poor harvests, rising demand from a growing population, use of biofuels, and producer-country export bans. These factors, individually and combined, result in sharp price increases and disruption to world grain markets, the brunt of which are felt by the world's poorest nations.

Meanwhile, water use has been growing globally at more than twice the rate of population increase in the last century, and an increasing number of regions are reaching the limit at which reliable water services can be delivered. Essentially, demographic growth and economic development are putting unprecedented pressures on renewable, but finite, water resources, particularly in arid regions. Water shortages make the problem of food security even worst as it reduces global food supply through reductions in irrigated agricultural production. Unfortunately, while agriculture consumes large amounts of water, its use is characterized by low efficiency. Globally, about 65% of water abstractions go to agriculture, while this percent rises up to 90% in many Arab countries (Fig. 1). Exactly how much water will be needed to meet projected food demand is not well understood, but studies suggest that at least 20% more irrigation water will be needed by 2025 (FAO 2006). This represents a great challenge for water-scarce countries with limited surface water resources and nonrenewable groundwater aquifers depleted at unsustainable rates. Water demand competition is also growing among other stakeholders, including those of expanding urban centers, industry, and aquatic ecosystems. These all leave nations with serious water security challenges. Balancing "water security" and "food security" is a big challenge, particularly in countries with limited water resources and fast-growing populations. In this sense, water security means a sustainable water use scenario that maximizes the efficiency of water use by different users, thus ensuring water volumes are allocated for per capita domestic water consumption, ecosystem services, recreation, and aesthetics while meeting the needs of food and fiber production.

Countries in the Arab region face complex and serious challenges. The region is characterized by high population growth rates, large and rapidly increasing food deficits, highly variable income levels both within and between countries, and limited natural resources, particularly arable land and water. Most of the region falls within the arid and semiarid rainfall zones, where 60 % of the total population lives. Therefore, it is a must that countries in the region address and tackle these issues at national, regional, and international levels. This chapter draws largely from the regional report prepared by the Arab Water Council for the 5th World Water Forum held in Istanbul during March 2009. The chapter also benefits from the analyses presented in the background note prepared by the informal consortium of the 6th World Water Forum for the thematic priority "Contribute to Food Security by Optimal Use of Water."

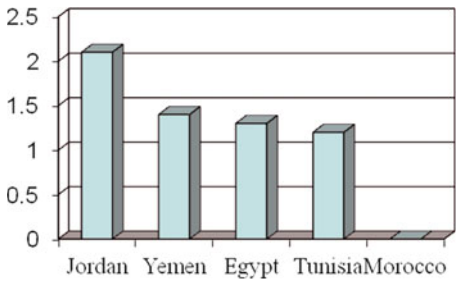
2 Water Security

The Arab region, being one of the most dry and water-scarce regions in the world, has a regional annual average of 1,200 m^3 per capita per year compared to a world average that is close to 7,000 m^3 (Shetty 2006). The most water-scarce countries in the region, such as Saudi Arabia and Jordan, have per capita annual water resources less than 200 m^3. Overall, it is also expected that by 2025, due to population increase, the regional average water availability is projected to be just over 500 m^3 per person per year.

Not only is water scarce, but river flows are highly variable and difficult to manage. Many countries in the region are mining groundwater, a temporary and risky expedient (Fig. 2). Saudi Arabia has paid a heavy price to build up its grain reserves, where 85% of the kingdom's current water use was directed toward agricultural production.[1]

[1] New policy was recently adopted in Saudi Arabia preventing use of groundwater resources in irrigating grains and fodder crops.

Fig. 2 Value (% of GDP) of groundwater depletion



This water came from nonreplenishable fossil aquifers, which are being sucked dry by the use of 1,000 ton of water to produce every single ton of grain. These challenges are further exacerbated as many of the major water resources in the region are shared between countries lying both within and outside the region. The most significant basins are those of the Jordan, Nile, and Euphrates/Tigris, all of which are subject to contentious riparian issues. Large aquifers underlie North Africa and the Arabian Peninsula but are costly to develop and pose potential problems as agreement on abstractions by several countries is difficult to achieve. One solution adopted by mostly the oil-exporting countries of the region is to desalinate with the Arab world, accounting for about 60% of total global desalination capacity. But this option is still restricted to the major oil-exporting countries.

Deteriorating water quality is also an increasingly serious issue in many areas due to a combination of low river flows, inadequate treatment, agricultural runoffs, and uncontrolled effluent from industry. Seawater intrusion into coastal aquifers is a critical issue in most locations, and water logging and salinization affect several of the major irrigated areas.

Due to its arid climate, most parts of the region experience frequent droughts, and the FAO identified Iraq, Jordan, Morocco, and Syria as the most affected (FAO 2002). Droughts cause a major reduction in agricultural output mainly in rainfed areas but also in irrigated areas where inflow into reservoir will be reduced. Dramatic changes in climatic and hydrologic features in recent years have affected the economies of the region and specifically those of the dry areas where rainfed agriculture is the dominant activity and the only source of income for a majority of the rural population. Droughts of higher frequency and longer duration have had a serious impact on development in several countries of the region, with severe repercussions for economic growth, food security, and poverty alleviation. Droughts affect the lives of the rural poor through decreased agricultural production, death of livestock, and endangered environment, as seen in the loss of soil fertility, loss of species, and the threat of extinction. In the 1994/1995 crop season, a drought season in Morocco, agricultural output of 1995 was 45% lower than the previous year, a non-drought year (ICARDA 2007). Rural landless or small landholders lost 100 million work days in agricultural employment.

Most of the drought-coping strategies implemented by governments of the region have focused on mitigation measures and emergency plans. Governments need to address the issue as a structural phenomenon, inextricably linked with the

Table 1 Annual renewable water resources (RWR)

Source	Unit	Northeast Africa	West Asia	North Africa	Arabian Peninsula	Total region
Precipitation	mm	308	225	102	78	177
Internal RWR	km^3	37.8	176.2	48.1	6.5	268.5
Net incoming flows	km^3	108.7	28.3	11	0	148
Total RWR	km^3	146.5	204.5	59.1	6.5	416.5

Sources: FAO (2008)

Table 2 Expected evolution of irrigation water withdrawals

	Unit	Northeast Africa	West Asia	North Africa	Arabian Peninsula	Total region
2003/2005						
Water requirement ratio	%	57	48	55	50	52
Irrigation water withdrawal	km^3	98.4	126.2	22.2	21.7	268.5
idem as percent of RWR	%	67	62	38	334	64
2030						
Water requirement ratio	%	62	57	60	58	59
Irrigation water withdrawal	km^3	125.1	160.1	29.1	21.5	338.6
Idem as percent of RWR	%	85	78	49	331	81
2050						
Water requirement ratio	%	69	65	64	64	66
Irrigation water withdrawal	km^3	130.2	164.7	30.1	21.7	346.2
Idem as percent of RWR	%	89	81	51	334	83

Sources: FAO (2008)

socioeconomic production system and within the context of scarce, declining, and degraded water resources.

Water needed for agricultural sector to ensure the food needs of the people is diminishing and constitutes the main challenge facing the farming sector. The fast-growing population and rising rates of development make the demands of other water use sectors expand at the cost of water available for agriculture. Addressing the crop production challenge requires to improve water access and therefore increase water storages where needed, as well as expanding irrigated areas and the wider use of management practices that will improve the efficiency of water use, e.g., water-"harvesting" techniques and conservation of soil moisture. In severe water-scarce regions, the effort would have to focus on getting "more crops per drop." This shows the strong relationship between food security and water security as they have become two sides of one coin.

3 Water Productivity

Irrigation water withdrawals in the Arab region are likely to increase by some 29%, from the current 269 to 346 km^3/year in 2050 (Table 1). This increase is modest compared to the more than 50% increase projected in the harvested irrigated area.

Most of this difference will result from the expected improvement in the water requirement ratio (Table 2), leading to a reduction in irrigation water withdrawal per irrigated ha. On average, it is estimated that this ratio for the region was a high 52 % in 2003/2005 and could increase to 66% by 2050.

The problems of agricultural production sustainability may be most acute in some regional countries. For example, in Yemen, the area irrigated by wells rose from 37,000 ha in 1970 to 368,000 in 1996. Government policy strongly encouraged this development with subsidies on fuel and the low interest rates on loans for digging new water wells. Consequently, the extraction from groundwater exceeded recharge by 400% which led to a dramatic fall in water tables. The very significant growth of Yemeni agriculture during the past decade (5.0 % per year) is clearly unsustainable, and this has serious negative implications for the welfare of the country, where roughly 75% of the labor force works in agriculture. In Yemen, and throughout the region, a viable food security strategy will have to pay more attention to using natural resources sustainably.

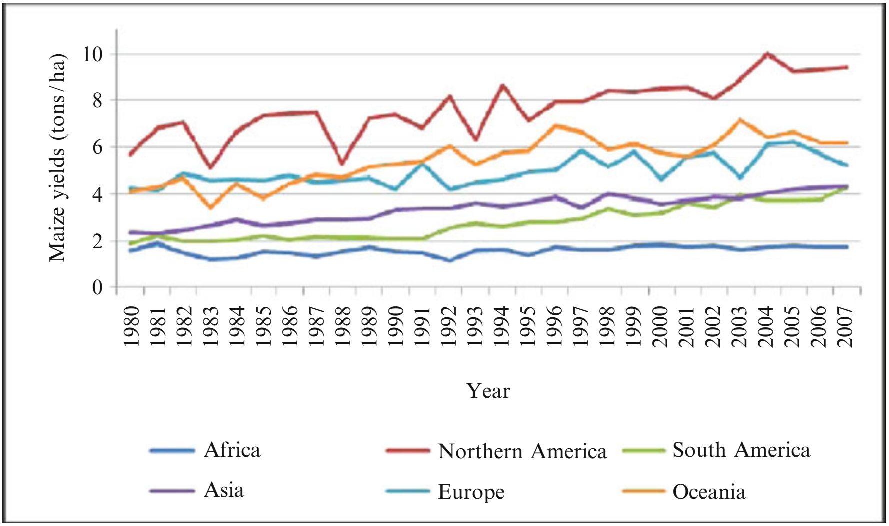
Policies to improve the agricultural production are to maximize the water productivity and are more likely to bring long-term sustainability. Two strategies can be followed to increase the water productivity: (1) increasing crop yield while maintaining constant water use level (dealing with other agricultural inputs) and (2) reducing water consumption and maintaining the yield level. Following these strategies for the water-scarce situation of the arid Arab region, offer the most viable options to increase the agricultural water productivity not the agricultural land productivity.

An example for maximizing the water productivity is the Egyptian policy for cropping pattern shift from high water-consumption crops. This policy is aiming at limiting the area cultivated by rice and sugarcane, the two high water-consumption crops, and encourages the cultivation of alternative crops that have less water consumption. Yet, this policy is not well implemented on rice-cultivation areas due to the high market price of rice comparing to the other crops. The cropping pattern shift policy could be adjusted through applying a system for financial incentives to encourage the farmers to cultivate less water-consumption crops.

Agriculture in the GCC is challenging and in recent years has reoriented itself away from water-intensive crops like wheat to more value-added crops like fruits and vegetables, leaving cereal production to foreign countries and importing stocks to meet demands. Developments in protected agriculture and in the use of marginal waters, such as treated wastewater and saline water, are bringing benefits to present and future possibilities of agricultural production

4 Agricultural Production

A measure of the overall performance of the agricultural sector in the Arab region is how well local yields compare with similar countries and with global averages. As Fig. 3 for productivity highlights, there is a significant gap in crop productivity among the different regions of the world. There are several reasons why yield gaps



Source: FAOSTAT

Fig. 3 Progress in maize yields, 1980–2007 (FAO)

exist. Farmers often do not have sufficient economic means or incentives to adopt yield-enhancing seeds or cropping techniques; they may lack access to information, extension services, and technical skills, and sometimes available technologies have not been adapted to local conditions. Poor infrastructure, weak institutions, and discouraging farm policies can also create obstacles to the adoption of improved technologies at farm level. Solutions lie with public sector investments in infrastructure and institutions and sound policies to stimulate adoption of technologies that reduce costs as well as improving productivity, thus increasing agricultural incomes. Changes in crop management techniques can also help in closing yield gaps.

If the required increase in crop production is compared with the speed of increase over the past period at the global level, it can be observed that the speed of increasing food production has to be significantly faster to cope with the expected need (Schultz et al. 2009). There is a common understanding that 80–90 % of the necessary production increases would have to come from increases in yields and cropping intensity and only 10–20 % from expansion of arable land. It will therefore be of importance to analyze which part of this increase can be achieved by improvements or expansion of rainfed agriculture and which part by irrigated agriculture. This increase in food production will have to be achieved at affordable costs and at affordable prices, especially for the urban poor.

Actions in response to food security may encompass four major *constituents* of the food pathway: (1) increase the supply (productivity enhancement), (2) improve the efficiency of the value chain from producer to consumer, (3) reduce unnecessary demand (excessive consumption and waste) and avoidable degradation (natural resource losses), and (4) enhance the capacity to manage risks and uncertainties derived from crises (environmental, financial, etc.). When investigating the water

Table 3 Production indices and growth rates

	Index (2003/2005 = 100)				Growth rate, % p.a.			
	1991–1993	2003–2005	2030	2050	1990–2005	2005–2030	2030–2050	2005–2050
Total agriculture	69	100	165	216	3.1	1.9	1.4	1.7
All crops	72	100	154	192				
Livestock	65	100	182	254				
Share livestock (%)	36	39	43	45				

Source: FAO: FAOSTAT

implication for these food security actions, one may find an analogous approach: (1) increase the supply (through wastewater reuse, rainfall harvesting, storage, etc.); (2) increase efficiency and productivity of water use; (3) reduce demand (e.g., cropping allocations); (4) enhance capacity of especially rainfed agriculture to cope with climate variability and change; (5) importance of use of facilitation and conflict resolution techniques in discussions among stakeholders.

Intensification of agricultural production to reduce yield gap implies increasing land and water productivity in all agricultural systems (mainly rainfed, rangeland, and irrigated partially or fully). In most countries with agriculture-based economies where rural population is more than 40 % of total population and agriculture has a predominant economical, social, and ecological role, increasing productivity to achieve food security is clearly a priority. The suite of technological options available to producers needs to be as broad as possible, ranging from new plant varieties and animal breeds better adapted to changing conditions to farming systems with improved water-saving technologies, reduction of losses and waste, and natural resource management. New or tailored technologies will be needed to address the problem of rapidly increasing water scarcity and also to reduce postharvest losses.

Agricultural production in Arab countries is projected to grow by more than 60 % between 2001/2003 and 2030 and to more than double by 2050 (Table 3). In spite of this noticeable increase in the volume of production in terms of annual growth rates, this would imply a considerable slowdown from the 3.1 % growth of the period 1990–2005 to 1.9 and 1.4 % over the periods 2005–2030 and 2030–2050, respectively.

The FAO/IIASA3 2002 Global Agro-Ecological Zone (GAEZ) study finds that there is still land with rainfed and irrigated agricultural production potential not yet in use in the region (Table 4). During the next 50 years, arable land could expand by some 11 % (from 76 to 83 million ha), of which some 28 % (from 24 to 29 million ha) would be irrigated. The latter, however, would mean that, by 2050, many of the countries in the region would have exhausted the potential for irrigated land expansion (or exceeded this potential in the case of fossil water use).

Global crises (financial, energy, soaring food prices, trade distortion and speculations, possible impacts of climate change, etc.) make the least developed countries most vulnerable and exposed to high risk of food insecurity. For food supply to be sustainable, action must be taken to arrest the destruction and degradation of the natural resource base. This requires investments to manage the resource base,

Table 4 Crop production and land use in the region

	Rainfed land (mln ha)			Irrigated land (mln ha)			Total land (mln ha)		
	2003/ 2005	2030	2050	2003/ 2005	2030	2050	2003/ 2005	2030	2050
Total harvested land	33.8	40.6	44.7	22.4	30.3	34.3	56.2	70.8	79.0
Arable land	51.9	52.6	53.4	24.2	25.8	28.6	76.1	78.7	82.6
Potential land	152			35			171**		
idem excl. Sudan	59			33			77**		
Arable land as % of potential	34	35	35	64	73	81	43	46	48

Source: FAO: FAOSTAT; AT2050

** total potential land is not equal to the sum of rainfed and irrigable potential land since part of the latter is on rainfed land

improve technical production efficiency (yields), and develop practices that foster sustainable and intensified food production. It implies promoting a sustainable and adaptive way to intensify agriculture production and invest in agricultural water, for small holders. Particular efforts should be made in least developed countries most vulnerable to changes.

Given the suite of currently recognized challenges to achieving food security, it is important to develop strategies to improve the resilience of agriculture to meet the world's needs. Especially in case of rainfed agriculture, climate change may have a significant impact on agricultural production; a goal would have to be to develop strategies to improve the resilience of agriculture to these changes. In the Arab countries, yields of rainfed agriculture could decline between 20 and 40% if no effective adaptation measures are taken. Even if climate change is expected to increase crop productivity of rainfed agriculture in certain areas (thanks to an extended growing season), it is generally agreed among the research community that climate variability and the frequency of extreme weather events will increase even in the near term in all regions. Also, an increasing demand for biofuel feedstock may put additional pressures on global agricultural production. More productive and resilient agriculture requires higher effectiveness with respect to food security goals and increased efficiency, substantial increases in irrigated agriculture, as well as in the use of natural resources and inputs for production.

5 Food Consumption

Between 2002 and 2006, demand for food in the Arab world grew by around 4%, while production rose by 2.6%, leading to an increase in imports to meet domestic consumption. The shortage persisted despite an expansion in the cultivated areas in some Arab countries as a result of reforms aimed at increasing crop.

Food consumption, in terms of kcal/person/day, is the key variable used for measuring and evaluating the evolution of the world food situation. Table 5 shows

Table 5 Per capita food consumption (kcal/person/day)

Region	1969/1971	1979/1981	1989/1991	1999/2001
World	2,411	2,549	2,704	2,789
Developing countries	2,111	2,308	2,520	2,654
Sub-Saharan Africa	2,100	2,078	2,106	2,194
Near East/North Africa	2,382	2,834	3,011	2,974
Latin America and Caribbean	2,465	2,698	2,689	2,836
South Asia	2,066	2,084	2,329	2,392
East Asia	2,012	2,317	2,625	2,872
Industrial countries	3,046	3,133	3,292	3,446
Transition countries	3,323	3,389	3,280	2,900

Source: FAO (2006)

that the world, in general, and the Arab region, in particular (highlighted in green), have made significant progress in raising food consumption per person. In the past three decades to 1999/2001, the Near East/North African countries increased from an average of approximately 2,400 kcal/person/day to almost 3,000 kcal/person/day.

FAO statistics also shows that the percentage of undernourishment of the population in the Arab region is 10%, corresponding to 22 and 33% in south Asia and sub-Saharan Africa, respectively. That might show that the overall present situation in the Arab region is prosperous. However, it has to be noted that countries in the Arab region are the largest grain importers in the world with widening food gaps as a result of high population growth and modest technology adoption rates in cereal. Over the last two decades, net agricultural imports have ranged between US$ 16 and 20 billion. This clearly highlights the high dependency on food imports.

6 Agriculture Trade

Many countries have a high dependence on food imports because they are resource constrained, as the case in the Arab countries. Many countries will continue, depending on international trade, to ensure their food security (Fig. 4). The volume of food exported (green) or imported (yellow-red) is expressed as a percentage of total consumption in each country and represents, for the food-importing country, their relative dependence on external sources of food (WWF6 2011).

While it is a long way for Arab countries to reach high levels of food security, there is an indication that agricultural trade liberalization could have an important role to play to achieve this important objective sought in the region. Both the domestically implemented structural reforms currently conducted in the field of agriculture and the WTO negotiations under way aim at substantial improvements in the environment in which farmers and consumers of agricultural and food products operate by reducing the trade-distorting mechanisms currently in place. The outcome of domestic reforms, the free trade agreements with the EU and other partners, and the WTO negotiations will effectively form the boundaries within

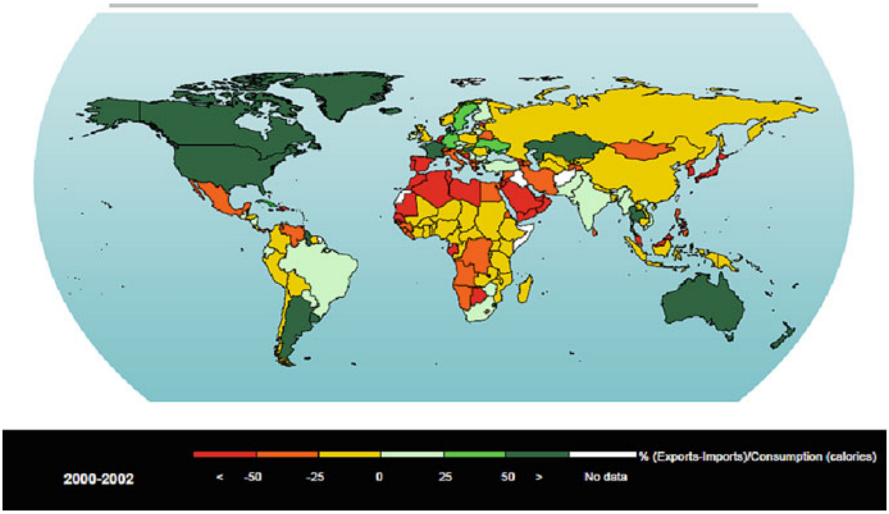


Fig. 4 Average net trade in food in the years 2000–2002

which agricultural and trade policies for Arab countries and their major trading partners can develop for the next few decades.

Unilateral decisions by countries to restrict exports tend to aggravate the situation and result in increased speculation. Several factors point to the risk of growing price volatility. Low-income food deficit countries need to reduce their vulnerability to international market shocks. Price volatility issues and the need for a better governance of global commodity markets and food security system have attracted recent attention. Steps to prevent future food crises include establishing effective social safety nets, measures to tackle price volatility including appropriate use of food reserves, significant investments in modernization of irrigation and drainage systems (including both technology and management techniques aiming fair sharing between users), as well as the installation of new systems, anticipation of possible impacts of climate change, especially with respect to rainfed agriculture, productivity-enhancing and fair-sharing governance mechanisms for small-holder farmers, and new institutional arrangements.

7 Agricultural Socioeconomic Dimension in Rural Economy

While agriculture and the rural economy are important elements in the Arab region, their contribution to the general domestic product (GDP) is low and has been declining in the recent years. Table 6 shows that agriculture, even in Syria, which has the highest share of contribution to GDP in the region, contributes only 24%. For instance, agriculture in Jordan contributes a mere 2% to GDP. Despite that, agriculture is by

Table 6 Water use and GDP contribution of agriculture and industry

Country	Agriculture share		Industry share	
	Water use (%)	GDP (%)	Water use (%)	GDP (%)
Algeria	69	12	15	60
Egypt	88	14	8	34
Iran	92	19	2	22
Jordan	75	2	3	n/a
Lebanon	72	12	4	22
Morocco	93	16	3	32
Saudi Arabia	90	7	1	n/a
Syria	96	24	2	30
Tunisia	87	12	3	29
Yemen	96	15	1	48

Source: AWC (2009)

far the dominant user of water, where in some countries like Morocco, Syria, and Yemen, agriculture consumes close to 100% of all available water resources. The wide gap between water use and GDP contribution for agriculture is highlighted even more when contrasted to the industrial sector (Table 6). For example, Algeria uses 69 and 15% of its water in agriculture and industry, but their contributions are 12 and 60% of GDP, respectively. This is the case in each country; the contribution of GDP is always less from agriculture when compared with the industrial sector contribution.

Therefore, from a narrow macroeconomic perspective, rationale of justifying the allocation of water to agriculture over industrial and other sectors is weak. Thus, as countries confront the water crisis situation, there will no doubt be increasing pressure to allocate water away from agricultural to industrial and municipal uses as well as to increase water efficiency within the agricultural sector. Some countries in the region such as Tunisia, Morocco, and Jordan have already begun addressing the issue of water reallocation where others have not.

However, from a broader development point, it is important to note that agriculture claims the largest share of the work force in the region with a high proportion of the poor depending on the sector for the livelihoods. Region-wide, 88% of economically active population works in the agriculture sector. In some countries such as Egypt and Morocco, more than 90% of the economically active population is agricultural workers. Thus, despite the small contribution to GDP, agriculture is still the key to development in many developing regions including the region. Based upon that and to solve this paradox, since water will still be the main input in agriculture, the focus has to be on how to improve efficiencies and reduce overall usage through new technologies and research.

After the deep recession faced by the region in the 1980s, wide-ranging economic reforms have been implemented in the 1990s, aimed at tightening demand, liberalizing trade, and improving the regulatory framework in which the process of development was being implemented. Those reforms gave a significant boost to growth with an average annual GDP growth estimated at around 3% (Shetty 2006) and have started putting the foundations of a market-based economy where the private sector is encouraged to play a more prominent role. Despite these signs of economic recovery, the region still suffers from the burden of an inefficient public sector, high levels of unemployment, substantial poverty, slow steps in global and regional integration, and a mounting pressure on its natural resources as a result of population growth, urbanization, and demand changes. All these challenges are related in one way or another to the performance of agriculture, a sector still contributing to growth and employment. While some of these challenges have directly or indirectly hindered the development of the sector, others are the result of its inability to achieve substantial jumps in productivity hampered by limited extension services and poor investment climate to support the adoption of new technologies. The limited progress achieved in the agricultural sector has important implications with respect to the fight against poverty which has to be considered as an important dimension of the development agenda in the region.

8 Water Pricing Policy

Overall mismanagement of various policies dealing with both input and output prices in agriculture contribute to rural poverty in a substantial way. When prices do not reflect the actual scarcity and are artificially set, overconsumption and undersupply tend to occur. Heavy subsidies for producers of "strategic crops" such as wheat, sugar, oilseeds, beef, and dairy products, as well as on irrigation water are common pricing policies in the region. Producer subsidies for these "strategic crops" are often justified by a policy of promoting self-sufficiency but by encouraging the production of crops which has little comparative advantage; public support is used inefficiently. Furthermore, targeting mechanisms are generally weak, and therefore, subsidies tend to benefit middle- and high-income producers rather than poor ones who have limited access to markets or state purchases.

Agriculture might have needed subsidies and protection to attain some economies of scale in production and marketing, but it has now become a more mature sector that needs to improve efficiency further, become more competitive in a more open trade environment, and less reliant on subsidies. Reduction of some subsidies, and possibly phasing out other subsidies, such as for irrigation, would reduce the rate of depletion of aquifers to a more sustainable level and encourage efficiency gains in the sector by promoting a shift toward higher value-added crops.

When the price paid for a commodity reasonably reflects the true market price, this forces efficient distribution. In other words, subsidized water leads to a waste in agricultural water. The primary alternative to quantity-based allocation of water is incentive-based allocation, either through volumetric water prices or through markets in transferable water rights. The latter is not a popular policy in most of the Arab countries, although informal water markets exist as in the case in Yemen. Volumetric water pricing is more acceptable in the countries of the region rather than from a cost recovery perspective. Empirical evidence shows that farmers are price responsive in their use of irrigation water. The four main types of responses to higher water prices are use of less water on a given crop, adoption of water-conserving

Table 7 Per capita food consumption (kcal/person/day) (FAO 2006)

Region	2015	2030	2050
World	2,950	3,040	3,130
Developing countries	2,860	2,960	3,070
Sub-Saharan Africa	2,420	2,600	2,830
Near East/North Africa	3,080	3,130	3,190
Latin America and Caribbean	2,990	3,120	3,200
South Asia	2,660	2,790	2,980
East Asia	3,110	3,190	3,230
Industrial countries	3,480	3,520	3,540
Transition countries	3,030	3,150	3,270

Source: AWC (2009)

irrigation technology, shifting of water applications to more water-efficient crops, and change in crop mix to higher-value crops. However, this has to be balanced against the fact that for most countries in the world, water price acceptability in agriculture is very low, and the Arab region is no exception.

9 Future Expectations

Table 7 shows the estimated per capita food consumption up to 2050. Again, it shows that countries in the Arab region will maintain the progress that they already made in the last decades and will reach almost 3,200 kcal/person/day, which is a good progress compared to other similar regions of the world.

In terms of water, withdrawals could increase from the current 269 to 346 km^3/year in 2050. This increase is the modest compared to the more than 50 % increase projected in the harvested irrigated area. Most of this difference will result from the expected improvement in the water requirement ratio, leading to a reduction in irrigation water withdrawal per irrigated ha. On average, it is estimated that this ratio for the region was a high 52 % in 2003/2005 and could increase to 66 % by 2050.

Taking into account the expected impacts of climate change by 2050 (through the combined effect of changes in precipitation and in evapotranspiration), the availability of renewable water resources will decrease while, at the same time, irrigation water withdrawals would need to increase, thus severely worsening the situation of water scarcity in the region.

10 Concluding Remarks and Recommendations

- Food security is high on the political agenda of the last few years in Arab countries.
- Countries in the region have made a great progress in increasing the per capita food consumption to almost 3,000 kcal/person/day. It is expected to reach 3,200 kcal/person/day by 2050. However, there is clearly a high dependency on food imports.

- Agriculture's contribution to the GDP is low and has been declining in the recent years; however, agriculture claims the largest share of the work force in the region with a high proportion of the poor depending on the sector for the livelihoods.
- For years, finding enough water for people meant finding more water to use. Today, and into the future, the way forward is to find ways to use water in a more sustainable manner across all sectors to meet the growing demands.
- Reforms in agricultural policy and drought management are critical especially with respect to the rural poor. Countries have to review their approach to drought management because of a higher degree of vulnerability to drought in the region. The careful management of water resources will become increasingly important in mitigating the impact of drought on the economies of the region in the future.
- Technical innovations and water sector reforms need to be accompanied by agricultural sector reforms. Empirical evidence indicates that water sector reforms in the absence of associated reforms in the agricultural sector will be unproductive and unsustainable.
- Significant investments in modernization of irrigation and drainage systems and enhancing rainfed agriculture (including both technology and management techniques) contribute to future food crises.
- Subsidies and incentives played a critical role in leading agricultural development and growth in the region, but they have also resulted in environmentally unsustainable and inefficient uses of a scarce resource. They have led to market distortions, excessive use of groundwater for irrigation, and a high fiscal burden. The primary alternative to quantity-based allocation of water is incentive-based allocation, either through volumetric water prices or through markets in transferable water rights.
- Greater integration with world markets will become essential; likewise will investments in human capital, natural resource management, and research and technological development. Countries in the region should also have more integration and complement each other to reach self-sufficiency and minimize food imports from outside the region and maximize the use of their resources.
- There seems to be a convergence of actions in the response to food security needs. The enabling environment to make these changes happen needs to be provided through policy, institutions (capacity building), private partnerships, fare trades, and other measures.

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Analysis of Gender Roles Related to Water Resources Management in the Case of APP Fruit Tree Planting Project in the Béni Mellal Area

Fatema Mosseddaq, D.J. Mulla, and Viviane Ndamba Faye

Abstract Agriculture uses 86% of water resources and plays a major economic and social role in Morocco. Women play a key role in agriculture in general, and in the collection and safeguarding of water for domestic and agricultural use. However, women's participation in agriculture and in water management is ignored or even impeded: women have a much less influential role than men in management, in problem analysis, and in related decision-making processes. There is a need to explore different mechanisms for increasing women's access to decision-making in agriculture and Integrated Water Resources Management (IWRM). The APP Fruit Tree Arboriculture project (PAF) was implemented in compliance with the "MCC Gender Policy," and "gender issue assessments and plans" are required. PAF perimeters are subject to a detailed study of the population socioeconomic characteristics, as well as gender roles relative to agricultural and environmental management, illiteracy, and land ownership patterns by gender. The objective of the present work is to analyze information about gender roles and attitudes in some of the PAF perimeters in the Beni Mellal region. This chapter will document role distribution and production factors ownership and access by gender and will make recommendations of gender-specific training programs designed to increase the capacity and involvement of women and their access to decision-making in agriculture and IWRM.

Keywords Gender • Irrigation • Water resources • Olive tree • Rural development

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1 Introduction

Water is a critical resource, whether for human consumption, agricultural use, or sanitation, and one that is in increasingly short supply in the MENA region. In Morocco, water resources are characterized by their scarcity, spatial and temporal irregularity, and an increasing pressure due to demographic thrust, irrigated agriculture, and urban development. In most parts of rural areas, groundwater is overexploited and its replenishment is limited by poor rainfall and ecological degradation. Since mid-century, Morocco has known a fairly rapid increase in population that has not been associated with sufficient socioeconomic development. Overall annual rainfall is estimated to about 150 billion cubic meters (m^3); as a result of inefficient management practices, 80 % of the 150 billion m^3 of precipitation is lost each year through evaporation or discharge into the sea. Only 14 % (21 billion m^3) of the total rainfall is presently believed to be usable by acceptable economic and technical means. Currently, 11.7 billion m^3 are used, of which 75 % is surface water and 25 % is subterranean water. Water management in Morocco, like everywhere else, is tied to the management of other natural resources and must address the needs of its three major users: agriculture, industry, and the household sector.

- Agriculture: 86 %, permitting year-round irrigation of about 1.004 of a potential 1.364 million ha;
- Industry: 5.5 % especially concentrated in the northwest zone of the country and in the Casablanca-Mohammedia agglomeration; and
- Potable water: 8.5 %, i.e., an annual average of 38 m^3 per capita, or over 100 l per day, for each of the 30 million inhabitants.

Irrigated agriculture accounts for:

- 45 % of agricultural added value;
- 75 % of agricultural exports; and
- 40 % of total employment.

However, agriculture, which consumes more than 85 % of the region's water, is using water and capital investment inefficiently: irrigated agriculture does not generate the potential yields yet with an under-valorization and overexploitation of water resources (Mosseddaq 2009, 2010). These problems pose challenges everywhere in the world, but in the case of the shortages being experienced in Morocco, the consequences are more severe. Morocco faces a serious challenge in terms of water resources management over the near and medium terms, both in terms of quantity and quality. Considering the importance of water to the economy and social and environmental conditions of the country, it is absolutely critical that its water resources be managed efficiently and equitably for both the current and the future generations. Following this perspective, the new strategy of integrated development of Moroccan agriculture (MAPM 2008) and some other development programs, emphasizing safeguarding of natural resources for a sustainable agriculture, were designed and implemented lately (MCC 2007).

1.1 The Morocco Green Plan (PMV)

The PMV, the new development strategy of Moroccan agriculture, meets a real need for a strategic vision and opens new horizons with the Moroccan agriculture of tomorrow. Through this strategy, Morocco clearly establishes the importance attached to agriculture as a lever of the national economy and the need for the development of this sector in a context of globalization. The objectives of this strategy include improving rural economy and conserving natural resources such as soil and water.

1.2 Morocco Fruit Tree Project (PAF)

In August 2007, the MCC signed a 5-year compact with the Kingdom of Morocco. The project is designed to stimulate growth in the agricultural sector through transformation from extensive cropping of annuals, notably cereals, to more productive market-oriented cultivation of perennial tree crops (olives, almonds, figs, dates), based on sustainable management of soil and water resources and improved links to national and international markets. MCC is providing $300 million to plant olive trees on 90,000 ha of rain-fed and 16,000 ha of irrigated regions in Morocco. Olive trees have higher water use efficiencies than annual crops that are facing high risk of failure due to decreased rainfall and diminishing supplies of irrigation water. The project also involves measures to conserve soil and water resources through reduction of erosion rates and improvements in water harvesting and irrigation efficiencies. The overall objectives of this project are to improve the rural economy of small-scale farmers in Morocco while conserving soil and water resources. The number of direct beneficiaries in this project is estimated at 60,000 people in rain-fed areas and 14,000 people in irrigated areas.

The PMV made no mention of the female population which represents about 32 % of active rural population. On the contrary, the PAF was implemented in compliance with the "MCC Gender Policy," and "gender issue assessments and plans" are required. An interesting aspect of the Fruit Tree project is to increase participation of rural women in management of fruit trees and conservation of soil and water resources. Toward this aim, each perimeter where project activities take place is subject to a detailed study of socioeconomic characteristics of the population, as well as gender roles relative to agricultural and environmental management. Other features of the project consist of strengthening capacity of producers and associations and strengthening marketing capacity through, mainly, pilot projects for value-added products produced by women.

The objective of the present work is to analyze information about gender roles and attitudes in the PAF Perimeters in the Beni Mellal region, summarize these data, and develop gender-specific training programs designed to increase the capacity and involvement of women in agricultural and environmental management activities. With gender analysis, we will gain a more accurate picture of communities, natural resource uses, households, and water users. Understanding gender roles, relations, and inequalities which can help explain the choices people make and their different options.

2 Material and Methods

The study was conducted by compiling Agency for Partnership and Progress (APP) reports in the framework of the Fruit Tree project (APP 2010a, b, c, d) as well as field investigations in the "petite et moyenne hydraulique" (PMH) irrigated perimeters in the Béni Mellal region: Foum Al Ansar, Tanougha, Ait Ouirrah, and Zaouiat Cheikh. The methodology we used includes:

- Feasibility studies from the MCC project were analyzed to document the age distribution of participants, as well as rates of illiteracy and land ownership patterns by gender. Specific roles of women were tabulated for all aspects of agricultural and environmental management.
- Information about the roles of women was extracted from the feasibility studies.
- Two field trips were conducted in the Béni Mellal region to confirm this information and fill knowledge gaps.
- Data were summarized using standard gender analysis tools developed by Buisset (2001).

3 Results and Discussions

3.1 Integrated Water Resources Management (IWRM) in the Fruit Tree Project (PAF)

Several authors agree that IWRM is a process which promotes the coordinated development and the management of water, the grounds, and the related resources, in order to maximize the economic welfare and social in an equitable way without compromising the durability of vital ecosystems (Grigg 1999; Global Water Partnership 2000; Mitchell 2005; Mulla 2009).

In compliance with the Global Water Partnership (2000) orientations, the PAF-ZI (zones irriguées) uses an integrated and a participative approach which involves all the institutional speakers and recipients concerned. A participative process implies the participation of the recipients top-down and bottom-up at the national level, at the level of the village and the basin of the river with the small water user. Participation also implies governments, companies, citizens, groups, ONG, women, and underprivileged groups in an open and transparent way. However, in order to make this development sustainable, it is necessary that durability is translated in terms of safeguarding of the environment and positive social effects, necessarily including gender equality. The women and the young people are thus considered as much as the men as actresses and actors of the awaited development of the targeted perimeters and will be able to take part equitably for the discounted benefits of the project. The process assumes also an effective communication, data, and information exchange and compromises for replacement plans management.

Within the framework of the PAF-ZI, there is for each perimeter a "feasibility study, conception, and the environmental evaluations." The objective of this study is

Table 1 Profile of men activities/women on the level of the PAF, perimeter of Ait Ouirrah

Type of activity	Activity	Women/girls (%)	Men/boys (%)
Productive	Arboriculture	60	40
	Creation of income	0	100
Reproductive tasks	Water collection	80	20
	Wood collection	80	20
	Food preparation	100	0
	Care of children	100	0
	Health care	50	50
	Household	100	0
Total		71%	29%

to provide to the MAPM with the engineering actions and supervision services necessary for the execution of the various components of the project relating to the irrigation, the rehabilitation, and the intensification of the plantations of olive tree. The study is devoted to the description of the perimeter characteristics, by stressing those of the plantations of olive trees, using a participative diagnosis carried out with the farmers of the perimeter in the presence of the local persons in charge for the Ministry of Agriculture and the local authorities. After the feasibility study, there are two other parts of the project. The first part comprises the action plans for the rehabilitation and the intensification of the plantations of olive trees. It consists of the detailed planning of the coatings and rehabilitation of the seguias and irrigation canals, adjustment of Khéttara and sources, construction and/or rehabilitation of derivation dams, construction of pumping stations and basins of accumulation, and the rehabilitation of the existing irrigated olive-growing orchards. Another component deals with actions toward strengthening capacity of producers and associations through education and technical assistance centered on the improved techniques of orchards production and harvests and on the management and the maintenance of the system of irrigation water distribution. The second comprises recommendations of the Strategic Environmental Evaluation, which relates to the environmental protection plan in relation to crop integrated production and the study relating to the equality between women and men.

3.2 Gender Analysis in the PAF-Irrigated Perimeters

The division of work in the PMH-irrigated perimeters is characterized by the fact that women, like men, have well-determined roles and undertake tasks distributed according to their labor force and defined according to their respective roles assigned by society (Table 1).

Men play a dominant part in maintenance operations, irrigation, harvest, and olive processing; they have access to the benefits of the marketing of the olive produce. While women continue to be responsible for their traditional reproductive roles, they are in charge of the household chores (food processing, meal preparation, house cleaning, laundry, wood and water collection), care for the family, and children's

Table 2 Profile of access and control, perimeter of Ait Ouirrah

Resources	Access		Control	
	Women	Men	Women	Men
Land	X	X		X
Irrigation water		X		X
Equipment	X	X		X
Labor		X		X
Money/cash	X	X		X
Benefit				
External income	X	X		X
Possession of goods	X	X	X	X
Essential needs	X	X	X	
Health	X	X		X
Education	X	X	X	X

education. In addition, they are also responsible for productive activities; 60–80 % of the women (depending on the zones) are involved in all the farming activities related to the olive tree, except for their maintenance operations and irrigation. Women participate in the harvest, the processing, and the transport and storage of olives. Unfortunately, very few take part in the marketing of products and thus do not have direct access to the incomes which result from this. However, they manage financially and market the derived products. They are also in charge of the task of collecting and transporting olive tree waste products, including branches of the olive tree to be used for cooking and heating. Besides some other cultural practices (fodder, leguminous crops, livestock, etc.), women also take part in the productive process while devoting themselves to weaving and carpet production.

In general, women constitute the main source of free, permanent, or occasional labor, employed by small farms or as agriculture workers for lower incomes than paid to men. They are thus contributing, like the men, to the generation of a good part of the family income and are, thus, as much responsible as the men for the family food security. However, they have little or no access to all the benefits of the marketing of the olive products.

Moreover, when men emigrate toward the cities or abroad for employment, their absence increases women's participation in productive activities. They become head of the household, like divorced or widowed women with all the responsibilities for care and management of the family goods and farm. Few women have access to land ownership or the right to use agricultural water. Besides, having access is being able to utilize a particular resource, facility, etc.; it is not having control, which is being able to exert power or authority to decide about the acquisition, use, allocation, or disposal of a resource, facility, or opportunity (Table 2).

In addition, on the community level, few women are actively involved in associations, particularly membership in the farm water users association (AUEA), whereas men's participation in AUEA is dominant. Indeed, one of the dysfunctions of local development associations is the fact that they do not take into account the gender dimensions in their organization. Women do not participate in the top level of management; they are excluded from participation in the decision-making process at the collective level, and actions are usually oriented mainly toward practical

Table 3 Practical needs and strategic interests of the women, perimeter of Ait Ouirrah

Practical needs	Strategic interests
Installation of water source in the center of the douar	Control of water management
Elimination of illiteracy	Increase in the decision-making power of the women within the household
	Free time for other activities
Establishment of preschool	Valorization of the work of the woman
Improvement of access to health care	Female secondary schooling
Creation of opportunities for improving household incomes	Marketing control
	Creation of opportunities for collective organization
Introduction of improved cookstoves/easy fuel supply	Access to education
Access to the souk	Access to the decision-making process in mixed gender associations

needs rather than toward strategies required to bring about structural changes and empowerment of women (Table 3).

3.3 Constraints to Women Participation and to Their Access to the Project Benefits

There are several constraints and limits to a correct and generalized application of gender mainstreaming such as the absence of a strong mandate for the mechanisms representing women, lack of autonomy, limited financial and human resources, lack of expertise in "gender mainstreaming," lack of will and of political engagement, and bureaucratic résistance to gender issues.

The individual's position in society can limit the access and the control of resources and benefits. It is possible to have access to resources, without having control of them (Table 2). This reality limits the capacity of the women to take part and profit from the project activities, particularly at the decisional level. Consequently, it is advisable to describe the constraints which can block women's participation and their access to the project benefits in order for the project to address these constraints and fulfill strategic needs of the women.

There are differences in the levels of awareness at the national, regional, and local level policies; in level of engagement; and in the awareness of benefits of greater equality between men and women. There is also a low representation of women in the spheres and the bodies of the local and regional authority, as well as in the public institutions (external services, local communities) and in professional organizations such as the AUEA.

Reluctance to female participation comes as much from the men as from the women themselves. In addition, few women are arable land owners; when they are, they do not have the right to use agricultural water.

Existing professional organizations and local development associations are not really functional or have limited possibilities to be dynamic and obtain funding. Furthermore, for the AUEA, there is also the complexity of application of water rights law and conflicts between the various irrigation water users. Another constraint consists in the lack of basic social services (electricity, drinking water, etc.) in rural areas. Since women are in charge of water collection chores, they are burdened with extra work. This situation is all the more problematic in zones where males emigrate, adding productive work to the house work for already overloaded women. On the environmental level, when water resources are reduced, the women and girls suffer from it first. In addition, the women are also in charge of used water and domestic waste management. In spite of that, the women are not at all involved in the environmental protection extension programs; they even are responsible themselves for the degradation of the natural resources and are excluded from awareness campaigns for protection techniques against waterborne diseases, the use of fertilizers, and cultural practices for improvement of the olive production. On the socioeconomic level, in spite of women's substantial contribution to various components of the olive value chain, it is the men who are in charge of the task of sales and marketing. In certain situations, the women can take part in it, but overall, the benefits are quasi exclusively used by the men who can be opposed to their equitable distribution. In other situations, the women are weakened by the burden of house work and other less remunerating activities in terms of incomes.

In the zones targeted by the PAF, the problem of labor is not a question of availability but rather a question of professionalism, quality of the investment, and motivation of the agricultural workers. Therefore, since the girls emigrate less than the young men for cultural reasons, targeting this labor force constitutes an opportunity to instigate the olive value chain. On the cultural level, women are more prone than the men to undergo the consequences of illiteracy and the risks of leaving school during the primary education. The lack of literacy and of mastering life skills blocks the women and the girls from becoming self-reliant and explains their acceptance of social restrictions that hinders their mobility and their contribution to the decision-making process in farm management.

3.4 Opportunities of Women Participation in the Project

In spite of the constraints arising in the project sites, the PMH perimeters offer great opportunities at the strategic, institutional, socioeconomic, or environmental level. The project could build its actions and its activities on these grounds for improved effectiveness and with the intention of offering equal opportunities in the framework of the PAF to women and men. The first strength relates to the existence of a certain number of institutional mechanisms facilitating the promotion of equal opportunity for men and women. Also, the partners involved in the PAF, the APP, and the MAPM are conscious of the need for taking into account the gender dimension and share a common vision on this subject. The MAPM is particularly involved in the implementation of the gender strategy within the department in its agricultural policies and is engaged in a series of actions which integrate the gender approach. On the level of the perimeters targeted by the PAF, the project can be based on a series of opportunities, the most important of which is female participation in agricultural work in a general way as well as components of the olive value chain in particular. Furthermore, women have the knowhow and the will to participate more fully in the decision-making process at the family, the farm, and the community levels.

4 Concluding Remarks

Because of social and cultural circumstances, there is a need to explore different mechanisms for increasing women's access to decision-making and widening the spectrum of activities through which women can fully participate and profit from the project. Involvement of women in decision-making is interwoven with gender hierarchies and roles leading to situations where women's participation in agriculture and water management is ignored or even impeded. Although "gender issues" have been reflected in all statements of the PAF, there is still a long way to go before rhetoric is replaced by operational mechanisms and actions to ensure an equitable participation of women. Therefore, special efforts must be made to ensure women's participation at all organizational levels. In developing the full and effective participation of women at all levels of decision-making, consideration has to be given to the way society assigns particular social, economic, and cultural roles to men and women (Table 3). There is a need to ensure that agriculture and the water sector as a whole is gender aware, a process which should begin by the implementation of training programs for water professionals and community on gender approaches and methodologies. Also, reforms must be introduced at various levels of local communities for an effective integration of gender and participative approaches into the management of local and regional businesses, in accordance with what currently occurs at the national level.

Based on the collected information, the following recommendations were made in order to improve the living conditions of the local population, men, women, and children:

- Promote the construction and/or renovation of schools, clinics, and roads.
- Lighten the burden of women: supply of drinking water, electrification, preschool, modern ovens.
- Expand the institutional mechanisms to facilitate the promotion of equal opportunities for men and women: reforms must be introduced at various levels of local communities for an effective integration of gender and participative approaches into the management of local and regional businesses, in accordance with what currently occurs at the national level.
- Emphasize actions and strategies required to bring about structural changes and empowerment of women (Table 3).

In addition, gender-specific training programs, designed to increase the capacity and involvement of women in agricultural and environmental management activities (Table 4), were developed. Lessons learned in this study could be used to improve approaches for increasing opportunities for women in the Moroccan Green Plan.

Table 4 Gender-specific training programs

Identification	Justification	Objectives	Expected results
Contribute to capacity building on gender approach			
Expand public outreach efforts to educate agriculture and water professionals of the perimeters about the importance of women's involvement and the abilities of women to participate in decision-making	It will take a long time to change the attitudes toward women's involvement in these communities, so education and outreach efforts must be ongoing A gender perspective is necessary to ensure both women's and men's participation for improved management practices. Involving both women and men enhances the results and improves the likelihood of their sustainability with an eye on environmental conservation	Increase awareness of women's rights, abilities, and opportunities	A gradual shift in the expectations about women's participation and acceptance of women as decision makers
Help the AUEA move toward gender equality training at the association level			
Ensure that any official or unofficial criteria for participation in meetings of the farmer's associations do not disenfranchise women	Support capacity development of the research and policy communities in the region to undertake social and gender analyses and to look beyond the technical aspects of agriculture and water resources management toward a greater understanding of the social and gender issues and power relations	Make it easier for the women to participate in the association	The removal of all discriminatory constraints and believes

Help the AUEA move toward gender equality training for women			
A scholarship program for women that would require them to participate in meetings, trainings, and workshops associated with the project and include basic literacy courses to help them participate more effectively	This would not only remedy their fear of losing out on wages to attend meetings but would serve to validate their presence at the meetings. It could also help women develop the necessary skills for creating and sustaining an entrepreneurial association	Improve the basic literacy skills of female participants, improve the status of women in the farmer's association, and promote women's involvement in decision-making within the community	Women's empowerment and promotion of women's rights, an increase in the number of women participating in meetings of the association
Contribute to environmental protection and preservation of natural resources			
Water management and irrigation water economy			
Recycling of the olive by-products			
Natural resources management is the main axis of the PAF; it did receive already a great deal of attention, and several training programs are focusing on such critical issues as:			
Sustainable management of soil and water resources and improved links to national and international markets			
Measures to conserve soil and water resources through reduction of erosion rates and improvements in water harvesting and irrigation efficiencies			
Following this perspective, recycling of the olive by-products constitutes an important topic too in the framework of the PAF education component			

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Integrated Participatory Water Resources Management and Water Governance

Doris Schnepf and Stephan Lutter

Abstract MELIA, the Mediterranean Dialogue on Integrated Water Management, aims at the integration of several aspects of water management with sustainable development, as this is the most effective way to contribute and to properly address integrated water management. To achieve this objective, the project concept foresees the establishment of a space of dialogue between actors dealing with the different issues linked to water management in the Mediterranean countries. This dialogue leads to the provision of a consensual framework integrating best practices, opinions, assessment of options and actions, etc., for the development of an integrated and sustainable water policy and management in the Mediterranean. This is done by taking into account relevant EU Mediterranean policies and initiatives as tools to support the cultural, commercial, industrial and human exchanges between the EU and the Mediterranean countries.

This chapter is the conceptual framework for Integrated Water Resources Management (IWRM) and Water Governance (WGOV), a cogwheel in a big clockwork providing the Mediterranean countries with an instrument for the integration of the positions and interests of different stakeholders at local and regional scale as well as with a knowledge base to discuss issues and conflicts within the country among different economic and social actors and with the neighbouring countries in issues related to water. Such integration is an essential precondition to anticipate impacts and effects of different water policies on a specific country or region.

The conceptual framework has been designed as dynamic, comprehensive and shared framework which builds on an ample dialogue, debate and consensus within the project team. Thereby, a broad and comprehensive picture is painted. After a short introduction into the topic, the history of IWRM is outlined, followed by a description of the water problem specific for the Mediterranean region. In the following

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chapters, the solutions provided by IWRM are presented; additionally, the differences and connections between water management and water governance are explained. Participation as a key element of IWRM is highlighted in the next chapter. Other key issues are different gender aspects which have to be taken into account when designing adequate management and governance tools. The chapter ends with identifying the main topics to be addressed in the process of elaborating a Mediterranean-wide approach as well as with presenting best practice examples.

Keywords Integrated participatory water resources management • Water governance • Mediterranean • MELIA

1 Introduction

Water is one of the most essential resources for the existence of life on earth. Thus, water is a priority in major policies on development, also because almost one third of the regions of the world have been defined as water-stressed regions (UNDP 2006; Rees 2002).

Scarcity and depletion have become its defining features. While water resources in general are distributed very unevenly all over the world, the Mediterranean region is particularly affected.

To deal with the growing problems of water scarcity and water depletion, the concept of IWRM has risen in the international arena as one core concept (Global Water Partnership TEC 2004; Barlebo 2007; MED EUWI and GEF SPM 2007). IWRM is a participatory planning and implementation process that brings stakeholders together to determine how to meet society's long-term needs for water resources while maintaining essential ecological services and economic benefits. There is still a long way to go. However, many walkers all over the world contribute essential pieces to create knowledge on how to reach this goal.

The aim of this chapter is to share experiences and innovations to be found in dialogues, platforms and publications in order to create a discussion base for a common framework adaptable for integrated and participatory water management in the Mediterranean region.

2 History

Water management issues are on the international agenda since many years. Since the 1970s, the international community has started important and far-reaching policies. These include tackling desertification, controlling water pollution, developing conflict prevention measures in the light of ongoing and potential water conflicts, monitoring and preventing water-related threats and hazards (Castro 2007) and overcoming the deficiencies and inequalities in the allocation and distribution of water for essential human use in developing countries. An overview and synthesis of the international activities “MILESTONES 1972–2006: from Stockholm to Mexico” can be found at the UNESCO Water Portal (http://www.unesco.org/water/wwap/milestones/index.shtml).

However, as Castro (2007) points out very clearly, the international political efforts have not been successful yet. The contrary is the case, as can be shown by the goal on guaranteeing universal access to essential water and sanitation services which was restated in the late 1970s by the United Nations endorsing the provision of essential volumes of safe water to every human being on earth by 1990. Unfortunately, this goal has not been achieved. Moreover, the current targets as expressed in the UN Millennium Development Goals (MDGs) adopted in 2000–2002 are limited to halving the proportion of the world population without access to these services by 2015. A recent evaluation of the progress made in relation to the MDGs shows that even these limited objectives will not be achieved in many of the countries, which are characterized by “fragile states with weak governance and institutions” (WHO 2005).

3 The Mediterranean Water Problem

In the Mediterranean, water resources are limited, fragile and very unevenly distributed over space and time. During the second half of the twentieth century, water demand has increased twofold, reaching 280 km^3/year in all rim countries in 2005. Agriculture is the main water-consuming sector and accounts for 64 % of total water demand: 45 % in the North and 82 % in the South and East. In numerous Mediterranean countries, water use is reaching the limit level of available resources. Temporary or structural water shortages have been observed. The number of *water-poor* Mediterranean populations living in countries with less than 1,000 m^3/capita/year reaches 180 million inhabitants, 60 million of whom face shortage conditions with less than 500 m^3/capita/year. Twenty million Mediterranean people are still deprived of access to drinking water, particularly in the South and East. Water supply in several Mediterranean countries is endangered by both the over-exploitation of a part of the renewable groundwater (generating salt-water intrusion, which makes the water unusable) and the exploitation of nonrenewable resources (e.g. fossil groundwater). Thus, “unsustainable” water production is estimated at 16 km^3/year, of which 66 % comes from fossil water withdrawals and 34 % from over-exploitation of renewable water.

In addition to the stress on natural water resources, man-induced degradations and pollution also impact the water regime and quality, thus further limiting the possibilities of use. The consequence is an increase in:

- The vulnerability of supply due to rising costs (notably for water treatment)
- Health risks
- Conflicts of use between users, major sectors, regions or countries

Pressures on water resources will thus increase significantly in the South and East, and it is expected that, by 2025, 80 million Mediterranean people will face shortage conditions (with less than 500 m^3/capita/year). The increase in water demand for agriculture and for urban use and the scarcity of resources signify that one out of every three Mediterranean countries will withdraw over 50 % of the annual volume of its renewable natural resources. The changes in temperature and rainfall described by the climatic models will further aggravate these trends, and the Mediterranean regions will find themselves particularly exposed to a reduction in their water resources. Development along these lines could give rise to acute crisis situations in some countries. In the southern and eastern Mediterranean, given the demographic growth, the population of the countries which would face water shortage in 2050 has been estimated at 290 million people.

The percentage of unsustainable water supplies derived from fossil sources or from over-exploitation will grow. The rise in the demand for water will be steepest in the least water-rich countries, which will then be exposed to structural shortages. Under these circumstances, some fossil resources will rapidly be depleted and coastal aquifers further destroyed by salt-water intrusion. Moreover, the silting up of water retained in dams limits their lifespan (e.g. dams in Algeria have lost a quarter of their original capacity), and there are fewer and fewer sites on which to build new dams. Growing quantities of industrial and urban waste and reduced run-off resulting from increased extractions will also affect the quality of water and aquatic systems. It is likely that wetlands will continue to retract. These elements further aggravate the factors leading to increasing water vulnerability (costs, health and conflicts).

An alternative may be the management of water demand, and not only the supply. Observations have shown that increasing the supply, which has been the traditional response in Mediterranean water policies, is now reaching its limits. In response to this situation, water demand management can lead to major progress by limiting losses and inappropriate use (waste, leaks exceeding 50 % in some towns, etc.) and by ensuring more efficient use of the resource. There is considerable room for progress since improved water demand management (WDM) would allow saving up to 25 % of water demand, i.e. approximately 85 km^3/year in 2025. Irrigated agriculture represents the largest potential for volume savings, with nearly 65 % of total water potential savings identified in the Mediterranean (transport losses reduced by 50 %, down to 10 %, irrigation water efficiency increased from 60 to 80 %). A further 22 % in water savings potential can be expected from industry (recycling rate up to 50 %), and another 13 % from drinking water supply (transport losses and household leaks reduced by 50 %, respectively, down to 15 and 10 %). According to this optimistic view, assumed to be generalized throughout the Mediterranean countries, total water demand would level off at 102 km^3/year in the North and at 144 km^3/year in the South and Middle East, globally equivalent to the drop in total current demand of approximately 40 km^3/year. The benefits could also be seen in energy savings. These objectives are "win-win", when compared with traditional supply-side approaches. They limit environmental impacts, risks of conflicts and the costs of access to water and generate regional potential for economic growth and stability (UNEP and Plan Bleu 2006a, b).

4 Integrated Water Resource Management

Integrated Water Resource Management (IWRM) and development is defined by the Global Water Partnership as a "process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (Agarwal et al. 2000). The principle of IWRM was formed with the objectives of coordinating policymaking, planning and implementation in an integrated manner across sectors, institutions and professions to take into account the complex coordination issues arising over the management of international watercourses. It explicitly challenges conventional, fractional water development and management systems and puts emphasis on an integrated approach with more coordinated decision-making across sectors and scales.

Thus, it stands for creating new approaches to tackle the water crises through common principles (United Nations Conference on Environment and Development 1992).

These are:

- Water as a finite and vulnerable resource
- The importance of a participatory approach involving users, planners and policymakers
- Recognition of the special role of women as water users
- Water as an economic good with economic value in competing uses and as having key social and environmental roles

The potential for IWRM to help overcome the problems and inefficiencies inherent in uncoordinated, sector-dominated and competitive water management approaches was clearly recognized at the World Summit on Sustainable Development 2002 in Johannesburg. All countries were called upon to develop IWRM and water efficiency plans by 2005 which inter alia should:

- Employ the full range of policy instruments to improve the efficient use of water resources and promote their allocation among competing uses in ways that give priority to basic human needs and balances human development requirements with the need to preserve or restore ecosystems and their functions
- Include actions at all levels and adopt an integrated water basin approach
- Support the diffusion of technology and capacity building for non-conventional water resources development and conservation approaches
- Facilitate the establishment of partnerships, the involvement of all concerned stakeholders and, while respecting local conditions, provide stable and transparent regulatory frameworks, monitoring systems and measures to improve public accountability (Rees 2006)

Although the principles on IWRM are generally agreed upon in the international arena, there is arising warning too, when only the normative way of thinking is taking into account. Saravana (2006) thus calls for enlightening and strengthening also the informal way of interaction and thus allowing for ends, not yet defined by international principles. He argues that water resources are integrated at various levels by diverse actors in space and time. In a diagnosis of its integration, he reveals various problem areas:

1. There is no linear relation between policy and implementation; rather they are in ebb and flow, with policies contested, multiple and overlaid.
2. The management region is socially constructed and dynamic; the river basin is not necessarily the appropriate scale for management (Lane et al. 2004).
3. Participation of actors is diverse, not necessarily communicative and collective.
4. Knowledge of water resource management emerges through constant interaction among actors as part of their daily struggle with the environment and the prevailing rules.
5. Functional attributes that determine integration are diverse in the social realm of resource management.

In this complexity, the normative and idealistic concept of "IWRM package" that focuses on promoting collective and consensual management of natural resources by bringing stakeholders to participate within a watershed is prone to potential pitfalls. One way to move forward is to understand the process of integration of both *formal and informal* mechanisms of the water economy.

Saravana (2006) further argues that not one of these two mechanisms is superior to the other. In fact, each of them has advantages and disadvantages. For instance, formal mechanisms are better positioned to bring in macro, social and physical changes and values; they are rigid, have high transaction cost and low pay-offs and bring in commonly prevailing rules in a particular jurisdiction. The informal mechanisms are better positioned to reflect social values that cut across administrative jurisdictions, have less transaction cost and high pay-off and are easily adaptable to growing uncertainty in water economies.

5 From Management to Governance

Water resources in the countries around the Mediterranean Sea are limited and unequally distributed in both space and time – the countries of the South account for about 13 % of the total. The Mediterranean region is home to 60 % of the world's "water poor", and today, 20 million Mediterranean have no access to drinking water, particularly in the countries to the South and East of the region (Thivet and Blinda 2008).

The World Bank was the first international organization which used the term governance and defined it as follows (Singh et al. 2009): "The manner in which power is exercised in the management of a country's economic and social resources by government". With water crises recognized primarily as a crisis of governance, effective water governance in an IWRM context is a critically important prerequisite for meeting current and future water challenges.

The idea of water governance was put forth in the World Water Vision (2002), which argued for a holistic approach that linked socio-economic development and environmental protection.

The Global Water Partnership (Rogers and Hall 2003) defines Water Governance as: *Water governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources and the delivery of water services, at different levels of society.*

Governance, in general, has three distinct aspects (Singh 2009):

1. The form of a political regime (parliamentary or presidential, military or civilian, and authoritarian or democratic).
2. The processes by which authority is exercised in the management of a country's economic and social resources.
3. The capacity of governments to design, formulate and implement policies and, in general, to discharge governmental functions. The terms usually describe conditions in a country as a whole.

Different initiatives have been taken by various countries to model the national policies on this framework, but given the prescriptive nature of the IWRM, which fell short of evolving a robust implementation technique, there is a need to move away from the normative framework to a substantive framework, from management orientation to a substantive idea of governance (Singh et al. 2009).

For examples of governance initiatives and implementation efforts divided by subregions (El Kharraz 2008), please refer to the review report D46–48.

6 Participation

IWRM is an approach that not only promotes the coordination of the main users but seeks the participation of all the main stakeholders in all the decision-making processes. In this sense, the Participatory Irrigation Management (PIM) approach is also an integral part of IWRM as any other approach that promotes the participation of the interested parties.

The framework proposed by the IWRM initiated a bottom-up approach in the discourse around water but which remained top-down in content (Jansky and Uitto 2005). Various devolution strategies saw the target group (farmers, the poor, women) mainly as beneficiaries and less as participants. Second, since water was seen as a basic human necessity, the issue of its sustainability was not harmonized with the demand structure of the resource.

Public participation involves the rights of persons to take part in decision-making that affects them and gives concrete benefits to decision-making. It does so through the guarantee of rights on access to information, public participation in decision-making and access to justice in environmental matters. This improves decision-making through greater information and enhances respect for decisions and assists in the development of democracy, civil society and the rule of law. Public participation contributes to the endeavours of public authorities to protect the environment, to learn about the concerns of the public, including the various users of the water resources, and to take due account of such concerns. Public participation in the field of water management should lead to an improvement in the quality and implementation of, and commitment to, decisions, as well as increased accountability, transparency and public awareness of water management issues. This in turn will help to achieve water management goals and improve the environment.

Principle 10 of the Rio Declaration on Environment and Development (United Nations Conference on Environment and Development, Rio de Janeiro 1992) emphasizes that environmental issues are best handled with the participation of all concerned citizens, at the relevant level.

Other widely recognized international policy documents emphasize the need for an adequate role of the public, including non-governmental organizations (NGOs), in environmental and water management. Examples are the Dublin Statement on Water and Sustainable Development (International Conference on Water and the Environment, Dublin, 1992), Agenda 21 (United Nations Conference on Environment and Development, Rio de Janeiro, 1992), the Noordwijk Political Statement and Action Plan (Ministerial Conference on Drinking-Water and Environmental Sanitation, Noordwijk, 1994) and the Guidelines on Access to Environmental Information and Public Participation in Environmental Decision-Making (Environment for Europe Conference, Sofia, 1995).

In the pan-European region, there are a number of international legal documents which are important for public participation in water management. The Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters (Aarhus, 25 June 1998; Aarhus Convention) guarantees the rights of access to information, public participation in decision-making and access to justice in environmental matters. The Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 17 March 1992; UNECE Water Convention) and the Protocol on Water and Health to the 1992 Convention on the Protection and Use of Transboundary Watercourses and International Lakes (London, 17 June 1999; Protocol on Water and Health) form a legal framework for the pan-European region in the field of water management and the protection of human health and safety.

Public participation in the field of water management should take place in a manner that takes full account of the rights and responsibilities of the public and the public authorities. At the national level, states are encouraged to guarantee legal rights for the public on access to information, public participation in decision-making and access to justice in environmental matters, so that the public may enjoy these rights during decision-making processes relating to water management. For that purpose, states should adapt their national legal systems, as necessary.

7 Gender Aspects

One of the Millennium Development Goals is to improve the gender equality and empowerment of women. Although some actions are being already taken, there is a certain degree of uncertainty about what are the main needs that should be tackled in this sector. Participatory processes have been promoted in the water sector during the last two decades and they have achieved a remarkable success. However, it has to be recognized that such processes have been largely dominated by a male participation, and it is precisely here where new spaces have to be provided for women participation, as they are main actors in the use of water. Attention to gender roles can reduce the risks that gender biases and stereotypes lead to women being ignored, disadvantaged or marginalized. It is of paramount importance that IWRM approaches promote the use of gender analysis tools to investigate how planned developments will affect local women but also to involve them in the decision-making processes.

Sargadoy (2005) defines in a conference paper which is based on several meetings and conferences, such as the Integration of Gender Dimension in Water Management in the Mediterranean Region (INGEDI) workshop, nine problem areas affecting the conditions of women in the water sector or better said in the context of Integrated Water Resources Management (IWRM). These are discussed below.

7.1 Limited Access to Land and Water Resources

It is well demonstrated that women's access to land as well as to water is limited and generally insecure. Women's rights are determined by the lines of authority and subordinated within the household and the community in specific cultural settings. Often customary laws are the bases for decisions because formal laws do not cover sufficiently the aspects related to the access of women to land and water. But even when such formal legislation exists, rural women are not aware of their rights. Hence, there is a problem of unsatisfactory legislation covering these rights but also one of information dissemination.

The restricted access to land and water resources is not only a restrictive condition in itself but has also important external consequences as in its absence the access to credit and to agricultural inputs is also restricted as most of the suppliers and banks will ask for a guarantee that cannot be provided.

7.2 Restricted Use of Gender Analysis Tools

Many tools already exist for the analysis of gender problems within the water sector and within development programmes concerning water development (see e.g. the FAO Socio-Economic and Gender Analysis Programme (SEAGA) Irrigation guide

(FAO 2001) and the World Bank's GenderNet page (http://www.worldbank.org/gender/). Checklists and guidelines as e.g. Swedish International Development Cooperation Agency (SIDA) can also be mentioned.

However, it is a matter of fact that such tools are not being used adequately. Several reasons can be identified for the scarce use of such tools. Among them, it can be mentioned that many water specialist are unfamiliar with such tools and retract from their application, multidisciplinary teams rarely include gender specialist, and some of the tools are not very specific in how to quantify the actions that are needed to ensure a greater participation of women in the development process and others. At the basis of this problem, there is a capacity building shortage and an unsatisfactory dissemination system of these tools. Surely, there is also a need for preparing new material and guidelines that are more adapted to local needs. International lending institutions should be strict in the application of such guidelines.

7.3 Scarce Women Participation in Water Governance

It is important to distinguish here what type of management is predominant in the management of the water resources. If the management corresponds essentially to the "public management model", whereby public institutions carry out most of the functions, than the opportunity for women to participate in the planning, development and management of the resources is limited, as the number of women working in such public institutions remain low although considerable progress is being made in several countries of the Mediterranean Region. The problem here is not only of ensuring an equal opportunity for women to work in such institutions but ensuring that universities and related scientific institutions generate enough of critical mass of women graduates to have a considerable number of women applying for the vacancies.

If the management is oriented towards participatory models, like the PIM, the situation is even worse as very few women are active in Water Users Associations, Water Cooperatives and other types of groups and associations. The extent to which women are included in community meetings and decision-making expands or diminishes women's opportunities. Such participation is affected by general cultural norms and stereotypes and by specific matters such as whether meetings are held at times and places convenient for women. One area where women participation in governance has considerably increased is the domestic supply and sanitation. There is a wider acceptance that this specific use concerns women in a very direct way and its management becomes more effective when they are directly involved in it.

7.4 Insufficient Understanding of Local Gender Problems

The "Public Management Model" of water resources tends to centralize decisions at ministerial level. In this system, it is difficult to channel the local problems to higher hierarchical levels, and this often results in the fact that field needs are neglected, ignored or poorly attended.

A direct consequence of this lack of understanding of local problems is that extension services directed towards women are generally unsatisfactory. There are few female extension officers that are gender specialists. In Morocco, the number of women working in the extension services is about 9 %, while the percentage of work carried out by women is 50 %. Similarly in Tunisia, the female's extension workers are 3 % while the work carried out by women is 23 % (FAO 2003). Related training material is rarely gender sensitive.

7.5 Unequal Distribution of the Benefits Arising from Water Development Projects

Water development projects and in particular irrigation projects brings improved conditions of life to the benefiting farmers, but it is not so evident to what extend this reflects in a better life for women. There are quite a number of examples that illustrate that often they result in more work but few benefits. Cultural aspects, distributions of labour in the household and other limitations can make this desirable equity difficult to attain. Surveys documenting the gender distribution of work in irrigation projects are very much needed. The reasons for such inequities often are the result of insufficient analysis of the availability of labour at family level and lack of understanding of the local rules governing it when projects are designed and implemented.

Irrigation projects generate new employment. The figures of the employment generation capacity of irrigation depend of many local conditions, but in general, it is estimated that 1 ha under labour-intensive cultivation methods (no machinery) and horticultural production may generate as much as 150–200 days/year. The total number of days generated by irrigation hides the common problem that at certain critical times (harvesting, weeding and others), the male availability of work is not sufficient to cover the needs, and contributions from all members of family are needed and sometimes external labourers have to be hired. However, these contributions are rarely compensated financially or with other contributions.

Women are well suited for most of the work generated by irrigation, but their access to these new job opportunities is often restricted due to cultural reasons and limited know-how to undertake the required activities. This is very unfortunate, as often landless women are the poorest sector of the society and they are often deprived from this important opportunity.

Additionally, women have a difficult access to formal employment. The Africa region has the lowest proportion of women employed in formal sector, while they are very active in the informal sector. To understand these differences, it is necessary to find the roots of this marginalization in the work. Often they have their origin in the restricted access to knowledge and the different workloads of women and men in the family and farm context.

7.6 Women Are Called to New Roles for Which They Are Not Prepared

The migration of male workers from the less developed countries of the Mediterranean basin to the more industrialized ones has become a phenomenon of large proportions that is producing a strong change in the rural areas of the developing countries. Next to this external migration, there is also an internal migration from rural areas to urban ones where the labour opportunities appear greater. The result of such migrations is that an increased number of household are headed by women on temporal bases and, in some cases, in nearly permanent bases. Often women become responsible for the management of all house affairs but also of the land (irrigated or not) of the family, and they are not prepared for this new role. Cultural roles and lack of knowledge may limit their capacity to assume this new role of managers of family farms resulting in misuse of available family resources.

Also, a contributing factor is that many of the women head of households are such due to major events (death of husband, separation, etc.) that have upset their lives finding themselves with little preparation to deal with this new dramatic situation.

Globalization is also affecting social roles in rural communities and agricultural management, including irrigation. Many women are changing their attitude towards agricultural work. Younger female generations are becoming very reluctant to accept physical agricultural work without specific payment. Domestic water supply programmes often make women's groups responsible for the operation and maintenance of new devices (pumps generally). While some of the programmes include proper training programmes for new responsibilities, many also do not, with the consequence that after some time the new facilities remain unusable.

7.7 Lack of Institutional Coordination Among Water Programmes Focusing on Gender

The fragmented approach of water resources management has many shortcomings, but one of the most limiting ones is the difficulty for achieving effective coordination of their action. Women have attracted the attention of many donors, and many programmes have been developed to support their empowerment and elimination of inequalities. However, often such programmes are uncoordinated at national level resulting in duplication of efforts or missing opportunities where they could have provided more effective assistance (Hamdy 2005).

The replacement of the fragmented approach by the integrated one should improve the coordination among concerned stakeholders, but in the case of gender, this may not be sufficient and special gender coordination committees or other similar arrangements may be needed.

7.8 Limited Access to Information and Technology

Illiteracy is more extended among women than men. The same applies to attendance to primary and secondary schools where women still have lower rates than men. These are basic problems that have to be improved regardless of their implication in water resources. The fact remains that a literate person with some basic school formation will have greater chances to access to information and technical know-how that will provide her or him with better opportunities in life.

The other side of the knowledge equation is whether the necessary information arrives at the people requiring it. This is a complex question because first it has to be determined what kind of information or knowledge may be required at local level. Gender analysis tools are very appropriate for identifying such needs. In general, the present communication systems have great capabilities to address some of the underlying problems but few are addressed to improve the conditions of women in rural areas. As a case in point, the lack of information campaigns illustrating the risk of using/drinking unsafe water has been the cause for many illness and deaths of children. The cost of such campaigns is certainly much lower than the cost for the society of human lives and illnesses.

7.9 Limited Gender-Disaggregated Statistical Information

Many of the observations are based on common knowledge available among the participants of conferences and workshops, but it is hard to document it with figures. Unfortunately, there is a limited availability of statistics disaggregated following a gender perspective, and therefore it becomes difficult to quantify the gravity of situations related to the access of women and men to land and water resources.

Once more gender-disaggregated information is available, it will be possible to develop appropriate indicators that permit to follow more closely the advancements made in the gender issues mentioned here and others that may be relevant within specific contexts.

8 Best Practice Examples

8.1 Tunisia

Tunisia was one of the first countries to adopt a national water-saving strategy for both urban and agricultural demand. By doing this, it confirmed a cultural "oasis" tradition of a frugal and patrimonial management of water, such a rare resource in Tunisia. Thanks to this policy, water demand for irrigation has stabilized in spite of increasing agricultural development, the size of peak demands and the unfavourable climatic conditions (droughts). The water demands of both tourism (a source of foreign currency) and cities (a source of social stability) have been assured. The underlying principles of the Tunisian WDM strategy are:

- Moving from isolated technical measures to an integrated approach
- A participatory approach, which makes the users more responsible (960 water user associations were created covering 60 % of the public irrigated area)
- A gradual introduction of reforms and adaptation to local situations
- Introduction of financial incentive systems aiming at promoting water conservation-based equipment and technologies (60 % grant for purchasing such equipment)
- Support to farmers' income, allowing them to plan for and secure agricultural investment and labour
- A pricing system that combines transparency with flexibility, compatible with the national goals of food security and allowing a gradual recovery of costs

8.2 Morocco

In Morocco, a methodology of economic approach to agricultural water demand has been developed based on comparing the cost of one cubic metre saved with the cost of development of new water resources. It emerges from this study that the cost of one cubic metre of water saved, via adoption of spot irrigation, is lower than that of mobilized soft water; thus, the saved water volumes have been optimized through improving the yields of market gardening and tree growing. The productivity gains expected have been profitable, thus generating an extra added value. The evaluation of the cost/benefit ratio has revealed, on the whole, a return of over 30 % of the capital costs. Accordingly, the benefits of a WDM are not only economic but also social (increase in farmers' income) and environmental (reduction of water abstraction) (GWP-Med et al. 2006).

8.3 Turkey

"Turkey has a number of laws and plans though there is no evidence of an IWRM plan in place. Turkey is an EU Candidate Country and gradually tries to abide to principles and conditions of the EU Water Framework Directive" (Bilen 2009).

Starting in the 1950s, Turkey has planned and developed water resources on the hydrological basin scale. State Water Works (DSİ) established regional directorates accordingly. Hydropower production, domestic and industrial water supply and the development of irrigated land have been planned for each river basin. However, these are not counted as IWRM due to the neglection of the environment totally or partially. It was not until the late 1970s that environmental consideration exercises were made. The first environmental law was established in 1983. The Environmental Impact Assessment regulation which is based on this law was established in 1993. Since Turkey is an EU candidate country, several laws and by-laws have been introduced on the way of completely assuming the EU Water Framework Directive (WFD). A project called MATRA was executed together with the Dutch government, in order to prepare a guide for the implementation of the WFD in Turkey.

8.3.1 Participatory Irrigation Management

The World Bank has supported the participatory irrigation water management in Turkey through the Participatory Privatization of Irrigation Management and Investment Project (PPIMIP). This project was started in 1998 for the duration of 5 years. Today 96 % of the irrigation systems are operated by irrigation associations (Özlu 2004).

8.4 France

In France, a basin committee, which brings together the different public or private stakeholders acting in the water field, is designed to discuss and define in a concerted way the broad lines of the policy for the water resources management and the natural aquatic environments protection. It is made up by 40 % of the representatives of the local communities, 40 % of the representatives from socio-professional organizations and of the users' representatives and 20 % of the state representatives. It is within this committee that the dialogue must be forged; the water governance effectively depends upon how this assembly operates. The state outlines the orientations of the action of the water agencies and participates in the elaboration of the financial decisions of these ones. Since 1992, the basin committee is responsible for the elaboration of the Master Plan for Water Development and Management (French acronym SDAGE), before it is submitted to the state for its approval. The state follows the execution and gives its opinion regarding the perimeters of the Plan for Water Development and Management (French acronym SAGE). Pursuant to the terms of the law of 21 April 2004, annexed to the article L 212-1 of the Environment Code, "Each basin or group of hydrographic basins has one or more Master Plan which sets the fundamental orientations of a balanced management of the water resource (…) and the water quantity and quality objectives". These SDAGE must be handed in every 6 years, and they are juridically opposable to any administrative decision in the area of water. The town planning documents must therefore be compatible with their orientations. To achieve the objectives of the European Water Framework Directive (WFD) (European Commission 2000), in parallel with the elaboration of a new SDAGE, a programme of measures describes the means and the actions to be implemented. Each programme lasts on average five (5) years.

The water agencies play the role of booster of the actions at the level of the hydrographic basin through financial incentives granted to the local owners for the realization of the actions that are matching the objectives set by the programme of measures.

9 Conclusions

The conceptual framework for Integrated Water Resources Management (IWRM) and Water Governance (WGOV) is a cogwheel in a big clockwork providing the Mediterranean countries with an instrument for the integration of the positions and interests of different stakeholders at local and regional scale as well as with a knowledge base to discuss issues and conflicts within the country among different economic and social actors and with the neighbouring countries in issues related to water. This is of special importance, as in the Mediterranean region, water is a crucial resource which is limited, fragile and very unevenly distributed over space and time. Under such preconditions, participatory IWRM is key to find sustainable solutions, as integrating all relevant stakeholders is essential to anticipate impacts and effects of different water policies on a specific country or region.

The conceptual framework has been designed as dynamic, comprehensive and shared framework which builds on an ample dialogue, debate and consensus within the project team. Thereby, a broad and comprehensive picture is painted, as the bow is drawn starting from IWRM as general approach and covering gender aspects as well as the main topics to be addressed in the process of elaborating a Mediterranean-wide approach as well as with presenting best practice examples. In its application, new insights shall be gained for ensuring an adequate and sustainable management of the precious resource water.

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Violence, the Bitit Canal and the Nile Basin: An Asymmetric Comparison

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Abstract This chapter uses a comparative case study methodology to compare very different hydrological systems: the Nile and the Bitit canal. While at first the two systems appear vastly different, they share several features. First, they are both inhabited by diverse communities. Second, they are both subject to partial and unclear legal regimes. Third, they are both located in environments where natural resources are under severe strain. The chapter addresses the question of violence in the two systems and finds that the best solution to issues related to water distribution is shared and participatory management of the water.

Keywords Water management • Climate change • Aquifer depletion • North Africa • Violence

1 Introduction

Scholarship concerning water-based conflict has bloomed since the publication of Thomas Homer-Dixon's works on the environment and conflict. While Thomas Homer-Dixon's work did not discuss water issues alone, his work highlighted the role of resource shortages in creating conflicts. Water was viewed as an object of conflict for a long time; more recent approaches to it have been haunted by this legacy. The gist of the argument is that the wars of the future will not be about oil but about water and other environmental resources. This argument has a long history. Unfortunately, it is also the result of a myth. First, there is a serious flaw in assuming that water is a resource like gold or oil, which are embedded into land and have to be retrieved artificially. Such a condition applies only to fossil water, which

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is not considered a sustainable water resource. After explaining how water differs from other resources, this chapter will outline the contending literatures connected with water and conflict. Second, the chapter will outline the role played by adaptation in response to water shortages and explain the appeal of the "resource wars hypothesis." Using both international and domestic case studies, the chapter contends that the idea of water wars is a myth constructed to veil deeper and more profound resentment toward the other.

2 Why Is Water Different?

Water is one of the most heavily regulated natural resources, and social norms, religious ideas, custom, and formal law have nearly always regulated consumptive use, even before the emergence of state systems. Attempts to create water markets have never worked except in a very limited sense, in terms of bottled water, and even where municipal water supplies are in private hands, the firms are subject to regulation by state entities; states and societies are not ready to treat water like other commodities due to its life-giving and life-sustaining aspects. They are willing to tolerate only limited markets in water and have postponed international trade in water indefinitely (Lopes 2008).

Unlike most other natural resources, water is also renewable. A vast natural hydraulic cycle operates globally, and all areas receive some measure of an annual water endowment, although its level varies greatly from region to region and year to year. It is possible to plan water use and to ensure that there is water available for long periods of time through storage, regulated use, and water recycling. Consequently, water losses to other communities or states do not necessarily translate into a permanent or complete loss akin to losing control of an oil well or a gold mine. In these two examples, the global resources are set at a set sum. Distribution of oil and gold is almost always a zero sum game – one country's loss is another's gain. In terms of water, factors such as the river's slope and the pressure the water places at dams render absolute stoppage of rivers a rare event, and controlling the flow of water is never absolute because of seepage, evaporation, and even outright water theft.

Unlike other resources that need infrastructure that can be isolated from populations, water tends to flow through human farming communities or just below them. It is not possible to divorce the human settlements from water because of issues related to prior use and outright presence on the land. The same cannot be said about gold and oil whose extraction can often lead to the expulsion of any resident populations, without affecting operations. While other resources have seen a dramatic shift in terms of the questions facing sourcing, process, and using, with water, the challenge has always been the same – using amounts below the renewable annual/ endowment and significantly reducing use during droughts. It is impossible to regulate water exploitation and use without the cooperation of those who live on the lands it traverses – in sharp contrast to oil or gold. Any use that is not consented to locally can be subverts through extralegal extraction.

Within societies, access to water has been the object of political conflict and even violence – in contrast to minerals which have always belongs to the state, unless landowners were assigned the rights explicitly. Given that the state often makes for a poor farmer, farming has been left to individuals, families, communities, and firms, and this means that water use rights could not be maintained strictly in the hands of the state. While the state has historically rejected the commoditization of water, it has also rejected ideas that gave it sole monopoly of over the resource due to the needs of farmers whose products are essential to the survival of the state and its well-being. While in many locales farmers have come to blows over water rights, water has rarely caused wars, because conflicts took place in the presence of many factors, of which water disputes were only one. In general, societies have known that water is a resource whose nature enjoins cooperation.

3 Two Levels of Analysis

Rather than mandating conflict between stakeholders, the natural water cycle enjoins cooperation as a rational response to climate change, drought, and other pressures like water quality degradation and salinity; this is particularly important in internationally shared river basins and aquifers, where the stakeholders are sovereign and acknowledge no higher authority – especially in arid areas. Internally, disputes leading to violent conflict between actors are not caused by water but rather a failure of the social structure to negotiate in response to new circumstances. A social actor, such as a rebel movement or an ethnic minority, may reject a state-imposed "solution" because it was devised in a nonparticipatory way. The rejection may lead to actions like destroying waterworks. Even the norms that lead to interpersonal violence related to water disputes are really about a party's refusal to abide by preexisting rules rather than a dispute over the water itself. No dead body or broken jaw has generated water in the quantities being disputed upon.

This chapter examines water disputes at two levels of analysis: at the level of states sharing a river basin (the Nile) and at the level of communities sharing a canal (the Bitit irrigation canal in the Sais basin of Morocco). There are some similarities in terms of the regimes that govern each system as well as differences. The chapter argues that water disputes in local areas can turn violent under some circumstances, and that this in turn feeds the mistaken perception that states fight wars for water.

4 The Literature on Water

There is a nearly universal model used to study transboundary water issues, authors include Nurit Kliot, Thomas Naff, Bourahma, Lowi, Gleick, and many others – from nearly all nationalities and intellectual commitments. The basic elements of the model include:

- The natural context: The geography of the river or aquifer being studied. Who owns land and where is it owned? What is the annual water endowment available in the basin?
- The legal context: In international cases, have the participants accepted the commonly referred to international rules on water (the Helsinki rules) or not? Are there any other treaties? In internal cases, the question of the legal framework and water rights is critical.
- Cooperative arrangements and lack thereof: Is there a history of conflict between the areas? Are there any conflicts involving nothing other than water? Is water a critical issue in conflict or are there unrelated problems at the root of the conflict?
- Use by the participating countries and communities: Who uses the water and under what conditions and circumstances?
- Disputes over use: Are the rights of any users, whether countries, communities, or individuals, in dispute? What is the nature of the disputes?
- Historical and identity factors: How do the people of the area define themselves and others in terms of identity and how were these identities formed? Is there a role for water itself in the formation of identity? In the cases of Egypt, Southern Sudan, Israel, and Uruguay, the country is often defined in relation to a water source.

The usual methodological approach has been the case study. During the last decade, a new methodological approach appeared – intensive quantitative methods paralleling the Correlates of War project. This method sought to bring mathematical rigor to the study of conflicts in international river systems and to the issue of water and conflict generally. Examples of this work include the Toset and Gleditsch study (1999) and the Bronchmann and Gleditsch paper (2006) that found only a slight relationship between the existence of an international river system and additional propensity toward war between states.

More innovative methods include participant observation, where the scholar spends time in the river basin studied and develops relationships of significance with its inhabitants. These newer methods have tended to provide a great deal of additional information about the river basins as well as aquifers. This work is an attempt to bridge the case study tradition with the newer participatory approaches to the question.

4.1 The Central Dispute in the Literature

Aside from general consensus on methods, with some complementary variations, scholarship in the field has generally been gravely concerned with the relationship between warfare and water. In general, there are two camps on this issue and there is an emergent middle field that posits that interaction should be used to replace both conflict and cooperation over water resources (Zeitoun 2008). The general trends to be detected are often related to the scholar's background. Scholars from national security studies and traditional environmental studies backgrounds contend that water disputes cause war and often attribute solutions to a hegemon's ability to impose them or an epistemic community's ability to transcend them. Thomas Naff, Peter Gleick, Adel Darwish, and others have argued that water disputes can cause war. Scholars with perspectives that are linked to human security studies, conflict resolution, or participatory approaches to the environment, often in alliance with historians, tend to argue that the disputes over water are not a cause of war but an opportunity for peaceful interaction. Such scholars include Meriam Lowi and others. In general, this camp argues that water is a transnational challenge that cannot be addressed by a state alone. It needs to be addressed within a basin- or aquifer-wide community. In internal situations, a similar pattern emerges between those who view water as a basis for disputes and those who see it as enjoining more cooperative relations between communities and farmers. Unlike the international system, norms and laws govern water use, so at least in theory; disputes can be resolved through legal means.

4.2 The Politics of the Literature

As with all fields in the social sciences, there is a long and unfortunate tradition of supporting friends in literature and attacking one's enemies – Williams, Mitchell, and Kolars made themselves advocates for the Southeast Anatolia project in Turkey and interpreted the history of its construction from the perspective of the benefits it accrues to the Turkish states. It is important to remember that the problem is present in nearly all regions, including the Arab world; unlike the works of Williams, Kolars, and Mitchell, examples of Arab scholarship, such as works by Walid Radwan and Hamad Bu-rahamah, are explicitly partial. That Arab scholars use the same methods and models as their Western counterparts indicates that the traditional model has transcultural applicability. The main difference lies in Radwan and Bu-rahamah being open about their identity and political commitment to the Arab states.

4.3 Literature Dealing with Internal Water Issues

One of the distinctive traits of social studies in water issues is the ability of the field to duplicate nearly the whole scope of social science approaches into the field. There is a political economy approach that examines the relationship between power and water distribution. There are bureaucratic process approaches to water that examines government regulatory procedures and their influence on water issues and power relationships between people (Selby 2004). Other scholars examine the lawmaking process to see whose interests were served by the construction of the status quo legal framework; associated with this approach is a method that examines the laws governing water directly and subjects them to deconstruction. Finally, there is a water and gender approach used by many development agencies both domestically and internationally. The work conducted by the IDRC of Canada tends to include a significant element of gender studies. Gender in this context refers to the power relationship between men and women and the assignment of roles by sex and their association with valued and marginalized positions in society. In this segment of literature, the main focus is who gets water, why, and in return for what? There is also interest and concern for water dispute settlement, particularly through conflict resolution, especially if extralegal violence was used in the dispute.

4.4 Resource War and Its Appeal

"Resource war" refers to violent conflict over natural resources like water, fish stocks, and forests. It was first articulated by Thomas Homer-Dixon and popularized by Robert Kaplan. The idea quickly gained support because analysts wanted to understand war in rational terms. The possession of materials is regarded by many as a rational reason for going to war, and this calculus is very appealing to many scholars and policy makers. There are several reasons for this.

First, this perspective is fed by statements of some political leaders who have argued that they would go to war "only for water." This position has been argued by the late President Anwar El Sadat and King Hussein of Jordan. In the case of Egypt, members of parliament have supported bombing Ethiopia in response to a small dam being built on the Blue Nile in the latter part of the twentieth century, so it has been easy to find cause in water as a result. This perspective finds support among those who interpret the 1967 Arab-Israeli war as a water war (Bulloch and Darwish 1993).

Second, neorealist thinkers like Thomas Naff inadvertently brought concepts used to study the security dilemma such as power, location, and population into the study of water issue. And while these are relevant topics, they do not cover the complexity of water issues which fall at place that sees the interaction of the social and natural worlds. To be fair, they do not conclude that war over water is inevitable, but they bring the language of war into water studies, and this leads to scholarship that views the problem from a securitized perspective.

Third, there is a confusion of the levels of analysis – there are fights and even murders between farmers and local communities related to water, on the surface, wars over water appear very reasonable. Of course, there is the whole question of whether it is possible to anthropomorphize the state (Wendt 1999), but there is a further problem of associating the passions related to private violence to the structured, bureaucratic violence of states. Farmers exchanging blows in a water dispute may have had a long history of personal problems, intraclan and intratribal disputes that revolve around many other factors such as politics, marriage prospects, business ventures, and unfulfilled contracts in addition to the water dispute itself. Consequently, without careful observation and immersion into their society, it is impossible to simply assign causation to water disputes in this case. Finally, the idea of resource war satisfies a very reasonable desire for a parsimonious, rational explanation for war. As humans, we try to understand the terrible process of war in terms that appeal to reason, and the idea that war is fought over resources have tremendous appeal and in some cases, such as oil or gold, it sometimes is the case. “Resource war” entailing transferring the old arguments concerning gold and war to natural resources like forests, water, and food.

5 The Nile

Egypt has been a country that linked war and water, but its stance has changed dramatically as the realities imposed by the very nature of the water cycle became more deeply understood. Egypt asserted that it owned all Nile waters. Late President Sadat in his own words: “If Ethiopia takes any action to block our right to the Nile Waters, there will be no alternative for us but to use force” (Krishna 1988). Egypt rejected shared management of Nile waters in the 1950s, preferring to build the Aswan High Dam unilaterally. It also rejected cooperation with any Nile co-riparian except the Sudan, with which it shared a language and a dominant religion.

5.1 Egyptian Policy

When the democratically elected Sudanese government of Ismail al-Azhari proposed an integrated Nile waters management plan and asked for the renegotiation of the British-imposed 1929 Sudanese-Egyptian Nile waters agreement between 1956 and 1958, Egypt imposed economic sanctions and invited a *coup d'etat* in Sudan – which materialized in 1958 (Kalpakian 2004). Bulloch and Darwish describe Egypt as the “Oliver Twist” of the Nile because the country seems to always want more and has never acknowledged the right of any other country to use the Nile, except for Sudan (1993). Given that three quarters of the water originates in Ethiopia and an additional fifth originates in the Great Lakes states of Central Africa, the Egyptian position is under increasing criticism from countries in sub-Saharan Africa.

The Aswan High Dam is the centerpiece of Egypt's Nile policy. It is meant to store enough water to last Egypt at least a year. In reality, the Aswan High Dam represents an ecological and water management disaster. It wastes 10–13 km^3 of water a year through seepage and evaporation – the same amount used by Morocco for all urban and agricultural needs and two thirds of Sudan's Nile water's allocation (Chesworth 1994). In order to secure Egyptian control over water, a great deal of water is wasted through the inappropriate location of the Aswan High Dam. Egypt appears to be making policy not on the basis of maximizing water for all in the basin but rather in response to its Fashoda complex – fear of a powerful upstream state that can dictate policy to Egypt. Fashoda, Sudan, was the site of a confrontation between France and the Anglo-Egyptian forces reoccupying the Mahdist Sudan. Egypt's alarm at the prospect of a French-controlled upper Nile was barely contained by the British, who acted in a manner that protected their Egyptian clients throughout their stay in the Nile Basin at the expense of the peoples of Great Lakes states, the Sudan, and Ethiopia. Egypt objected to the British-led Gezira scheme in 1925 in Sudan and had to be reassured that the relatively small dams the British were constructing in Sudan were to provide "timely water" to Egypt and for power generation. Egyptian troops were also sent to garrison these dams, in addition to the Owens Falls dam in Uganda, and some remain (Waterbury 1979).

5.2 *The Failure of Nile Policy*

If Egypt's policy was intended to secure water for agriculture and urban use, then it can be judged a total failure. The policy of noncooperation with Ethiopia and limited cooperation with Sudan, through the 1959 Nile Waters Agreement, failed to ensure Egyptian water security due to population growth as well as the waste inherent in both the Aswan High Dam and in the Egyptian water distribution systems. Securing more and better quality water entails water demand management in Egypt as well as partnerships with upstream states where storage is more efficient with regard to seepage and evaporation. Between 1990 and 2010, Egypt's population grew from 52 million people to 82 million people, and Egyptian birth rates remain relatively high. This led to increasing urbanization and the loss of great tracts of agricultural land. There was also a decrease in the area available for cultivation per Egyptian resident. Egypt has about 3 million ha of farmland, so it has less than half a hectare to produce food for each single Egyptian citizen, and while there have been improvements in production. Egypt remains gravely dependent on food sales by the United States, Australia, Europe, and Malaysia:

Egypt depends on several sources for supplying agricultural and food imports. However, there has been some concentration in terms of the origins of each food commodity. The origin of Egyptian imports of cereals in particular is almost exclusively the United States, which supplied Egypt with 65 % of wheat and 77 % of maize (yellow corn for poultry feed) in the pre-agreement period (1993–1994) and 67.7 % of wheat and 81.7 % of maize in the post-agreement period (1995–2001). Australia is the second supplier but with a smaller share in the second period. Malaysia is the main origin of Egypt's imports of edible oil: 49 % in the first period and 44.8 % (albeit with a greater volume) in the second period. As for sugar, Cuba has been overtaken by Brazil as the main supplier of Egypt's sugar imports. In the second period, Brazil supplied Egypt with more than half of sugar imports, compared with only 24.4 % in the first period (Siam 2003).

Since 2005, the situation has actually deteriorated. According to the Egyptian Minister of Agriculture, Amin Abaza, Egypt imports about 40 % of its food and about 60 % of its wheat (Salem and Yassin 2010). The weakness of Egyptian agriculture, coupled with the dramatic increase in the country's population has led it to reconsider some aspects of its Nile policy. First, Ethiopia's population growth is even faster and by the middle of this century, Ethiopia could well have twice as many people as Egypt; at present, Ethiopia does not use irrigated agriculture to any significant extent. Second, it is now obvious that monopolizing the Nile is not likely to provide Egypt with food security. To its credit, Egyptian policy responded well to the changes in the world and sought a new approach to Ethiopia.

5.3 Attempts to Break Out of the Fashoda Complex

The new approach included Egyptian outreach through the Nile Basin Initiative and through dialogue and discourses with the co-riparian states. In 1999, Egypt helped form the Nile Basin Initiative (NBI) to cooperate with its Nile river neighbors concerning the inevitable issues of mutual concern. The officially stated goals of the organization include:

To develop the Nile Basin water resources in a sustainable and equitable way to ensure prosperity, security, and peace for all its peoples
To ensure efficient water management and the optimal use of the resources
To ensure cooperation and joint action between the riparian countries, seeking win-win gains
To target poverty eradication and promote economic integration
To ensure that the program results in a move from planning to action

The NBI quickly developed into a full-fledged organization with a secretariat and a headquarters as well as a structure. At least on the level of discourse, Egypt committed itself to sharing the Nile with the remaining states. This represented a further development of Egypt's suggestions during the 1980s and 1990s to allow Nile co-riparians "emergency" use rights to 2 km^3 of water during droughts (Shahin 1986). Unfortunately, despite more than a decade of meetings, dialogue, and interaction, the organization is facing a crisis at this stage because of developments that took place in 2010. Ethiopia and the five states in the Great Lakes region have banded together to codevelop the Nile without regard to the Sudanese and Egyptian Nile waters agreements of 1929 and 1959. Ethiopia and its allies are almost certainly likely to be joined by the nascent government in Southern Sudan. Egypt and Sudan have indicated their opposition to the plans of the other co-riparians, and Egypt has returned to threaten war, thereby feeding the perception that war disputes cause war (McConnell 2010). With the emergence of an independent state in South Sudan, Egypt and Sudan are not likely to be able to reach Uganda, Rwanda, Kenya, Tanzania, and Burundi. While the Sudan borders Ethiopia, the rump Northern Sudan has its share of separatist regions – the Blue Nile State, the Nuba Hills, Darfur, and the Red Sea Hills, so it cannot assist Egypt in any intervention in Ethiopia.

Ultimately, the question of the efficiency of the Aswan High Dam needs to be asked. At their most demanding, Ethiopia's plans call for utilizing 6 km^3 of water; this is less than half the quantity wasted every year at Aswan. Storing the water in Ethiopia and Uganda would make more water available for all co-riparians. Egypt's inefficient distribution system could be updated and the country could actually be in a situation where it actually enjoys more water use with less gross water consumption through the elimination of waste. About half of the water released by the Aswan High Dam is lost in Egypt's inefficient irrigation canals and urban water distribution systems. At the end, Egypt is frightened of the other and is not necessarily interested in pursuing relationships of equality, interdependence, and regional integration with the peoples living south of it, except – and then only in a limited sense – the Sudanese. To solve its problems in the Nile, Egypt needs to return to the table and join the rest of the states in the Nile Community. There are hopeful signs that indicate this. At an Arab Water Council meeting in 2006, the Egyptian Minister of Irrigation openly stated that Egypt must face a nonagricultural future because to feed Egypt, he would need a second Nile. Given the vast dependency on imported food, it is also difficult to see those supplying the food approving of Egyptian invasions above the submerged Second Cataract – the traditional border of Egypt. Also, Egypt's military record in the Nile Basin is mixed. It defeated the Sultanates of the Sudan in 1825 and created the country but was soundly defeated by Ethiopia in 1875.

6 The Bitit Canal

The canal carries water from a natural spring in the Saiss sub-basin of Morocco through the Hajeb district of the same area to Aïn Cheggag – a plain outside Fes. At the source itself, half the water is reserved for the City of Meknes. RADEEM (*Régie Autonome de Distribution Eau et Electricité Meknès*), a private monopoly water company, controls the site itself and there is a representative of the Sebou Basin Hydrological Agency (ABHS) permanently dwelling at point where the canal exists the RADEM facility. About half of the spring's 1,000 $\mathrm{l\,s^{-1}}$ output is reserved for the city of Meknes according to an agreement between the state and the stakeholders. The spring's average output has been declining over the years, and during droughts, it is significantly below its 1,000 $\mathrm{l\,s^{-1}}$ level. Once the canal leaves the RADEM facility, it carries water into an area inhabited by the Regrara community, traditionally a branch of the Aït Oualal tribe. The canal's infrastructure transfers water to the Regrara, enabling their farmers to water their crops daily. These arrangements date to the time of the French protectorate, which is accused by other members of the Aït Oualal tribe of favoring the Regrara as a part of a colonial divide-and-rule policy. The Regrara dispute this and claim to have been present at the site before the arrival of the French. The canal's waters are supposed to be shared by two tribal communities as per an independence era agreement. Water not used for Meknes is to be divided according to a 51–49 % ration between the upland Aït Oualal in Hajeb and the lowland Aït Oualal in Aïn Cheggag (Fig. 1).

6.1 Problems

The colonial era law created with consultations with both tribes, called the Official Bulletin of 1940 (OB 1940 hereafter), divides the waters between the two tribes, and the city of Meknes' water company is not being applied literally with resulting

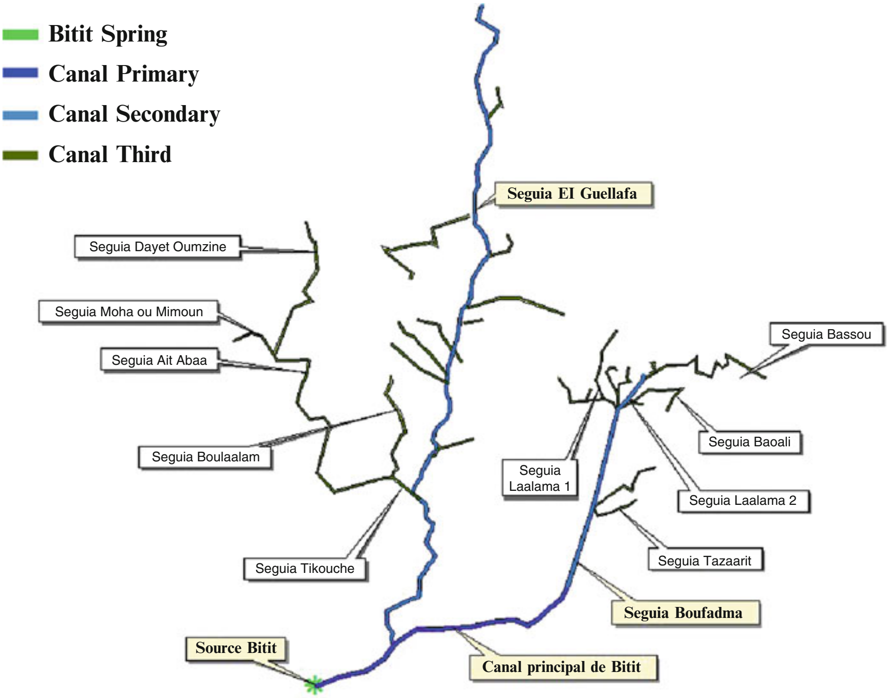

Fig. 1 The Bitit canal system

Table 1 OB 1040 water allocations and actual use

Shares	RADEEM (%)	Aït Oualal (%)	Aït Ayyach (%)
OB 1940	60	24	16
Actual use	60	Unknown	Less than 16

water stress and aquifer depletion as lowland communities dig wells to compensate for their water shortages. The city of Meknes' water company overdraws its allotment in order to compensate for reduced flows, and this has a dramatic effect on water available particularly downstream (Table 1).

Given the urban share and the use of the water both by the upstream tribe and Regrara, the canal rarely delivers water below, and the farmers in Aïn Cheggag are forced into additional well digging, which further depletes the aquifer that feeds the spring providing water to the canal. In many cases in Aïn Cheggag, farmers get canal water once every 12 days and should they lack the financial wherewithal to store water and to use drip irrigation. The farmers of the regions literally live under the tyranny of the irrigation turn and their ability to store water is limited. As upstream farmers began using storage systems, they were able to free themselves partially from dependence on the turn and to plant more useful crops. In one case, farmers accepted half the water every 7 days instead of every fortnight, and the results were

Table 2 Water users associations in the Bitit canal system and their shares

WUA	Water share fissane	Predominant crops	Turn and notes
Boufadma	9	Onions, potatoes, vegetables	Shifted from 14-day turn to a 7-day turn, got rid of tobacco
Tichniwin	5	Onions, potatoes, vegetables	Shifted from 30 days to 14-day turn and then to a 7-day turn, got rid of tobacco
Khrichfa	3	Onions, potatoes, vegetables	5-day turn allowed move away from tobacco
Malouiya	5	Onions, potatoes, vegetables	7-day turn, has a well that is unused due to lack of electricity
Guellafa	9	Onions, potatoes, vegetables	7-day turn, WUA is against wells
Al Wahda Aït Ayyach	Up to 30 never realized	Tobacco is dominant, some olives	12 days leading to tobacco's popularity. The longer turn suggests that the water actually reaching the region falls far short of the allotment

very good. We held meetings with the presidents of the water users associations, and we were able to see a clear pattern in the relationship between the turn and the nature of the crop farmed. Downstream farmers feel compelled to plant tobacco, because it is one of the few crops that can withstand a 12-day watering cycle. Each water users' association (WUA) is allocated a share of the canal water measured in units corresponding to a block of 336 h of canal water flow, a *fasse*, plural *fissane*.

We observed that farmers in their 60s to 80s note that there has been climate change during their lifetimes. Since 1980, the region saw more droughts due to the decline in rainfall. The farmers also confirmed that natural springs and rivers used for irrigation were depleted; for instance, the Aïn Chegag and Ain Taoujdat springs. The WUA presidents confirmed that the output of a *fasse* was about 22 $l\,s^{-1}$ but currently stands at 16 $l\,s^{-1}$ except for years where there was enough rain such as 2008–2010. As a result, farmers were obliged to dig wells looking for underground water, often without authorization to avoid renting which is more expensive.

Renting 1 h of canal water costs 800–1,400 dirhams (80–140 €) per hour per year. Due to those successive years of drought, there was water theft as well as some fighting between individuals belonging to the two tribes. During the drought of 1980–2008, the water disputes took a legal turn with the tribes going to court over water rights. Since 2008, the situation improved, the dispute is reduced. The canal's output increased, and the cost or renting water decreased. The Agamgam Spring's revival yielded 260 $l\,s^{-1}$, which allowed the two tribes to farm with a good margin of comfort. Farmers with access to the Agamgam spring's water were able to water their fields once every 4 days instead of the usual 7 (Table 2).

While there has been no mobilized conflict between the two large tribes and no emergence of a permanent protracted conflict dynamic, there has been violence over farm and water-related issues, and in one case, the victim was a government's representative was apparently assaulted in a dispute over road construction. According to local Ministry of Agriculture officials, there have been cases of assault and battery over the years, demands for separate canals, as well as sabotage of the canal and associated water works. An examination of the canal reveled leaks, poor maintenance, and what appears to be intentional holes at various locations. The canal is poorly maintained because all work on it needs the approval of all three recognized stakeholders – the state and the two tribal communities.

The canal is also in desperate need of repairs. The IDRC-AUI research team took photographs of the canal that documented damage, overgrown weeds and trees in the pathway of the water, and even deliberate and clearly unauthorized diversions of water through punctures and holes are common. The state has decided to repair the canal and to do so unilaterally because reaching an agreement with the two tribes proved very difficult. The decision did not reflect any change in the allotment regime.

6.2 Exploring Solutions

At the very short term, the repair of the canal is a very important step. Repairing the canal and perhaps enclosing it could lead to an increase in the water available to all. This will require mediation between the state, RADEEM, and the three farming communities affected by the canal. It may also help if the status of OB 1040 is legally clarified because as it stands it is an unclear piece of law. Since the 1960 constitution abolished tribalism, the legal force of an agreement between two tribes and the state is naturally unclear. It may also be wise to help in installing water saving technologies which at present farmers do not have an incentive to install. While there are some slight shifts toward commercial farming in all three communities, the land ownership rights in the three areas are different, so it is very likely that the three communities will continue to exist as economic zones regardless of the levels of intermarriage and the arrival of new farmers from other regions of Morocco.

It is noteworthy that the violence did not take place between the communities as identity communities. It occurred between individuals, and no one seriously anticipates tribal mobilization against the other communities or against the state. It also remains to be seen if water issues were critical or if there were other issues that had fed the conflict. And while there have been intertribal lawsuits particularly during droughts, with the tribes acting as collective bodies, the critical issue is that these were lawsuits not battles. Violence has also taken place within the tribal communities themselves due to issues that stem from politics, wealth, land rights, differing educational attainment, and disappointed marriage proposals; these events are both rare and personal. They rarely involve water rights, unless the local norm was broken by a party, which is an offense against the community as well as one's neighbors.

A closer look suggests that that the analogy used by those arguing that water causes war is not applicable. States may have economic, political, religious, and other problems with each other and may choose to use water issues as a part of their overall conflict with each other. Rural farmers worldwide often dwell on the margins of society and live lives marked with stress and extraordinary responsibility. They often cannot find solutions to the problems that face them, because they do not have the education to try and find alternatives to conflict with a neighbor or perceived opponent. Even so, violence is rare even in times of severe stress. The Saiss basin's record suggests that even under stress, tribal communities have attempted to use the law and not the fist.

7 Emergent Themes

Despite the vast differences in scale, there are some commonalities between the Bitit canal and the Nile. First, in both cases, the water artery is shared by different communities who do not see each other as partners but rather as rivals. In both cases, the colonial power selected a primary beneficiary and marginalized other communities. Egypt was granted the lion's share of the water by Britain, and the development of the upstream states and the Sudan was stymied. In the case of the Bitit canal, the French protectorate built the canal to accommodate the upland communities first. The main difference lies in Egypt being a downstream actor while the Regrara are as upstream as possible.

Second, in both cases, organized violence over water is not likely. Despite Egypt's angry discourse, it is hard to see how the country could mount an invasion of Ethiopia when it would have to fight through Ethiopia's Northern Sudanese clients – the rebel movements that oppose Khartoum in Eastern Sudan and in the Blue Nile State. Ethiopia is also the sort of opponent that is not likely to be cowed by airpower alone. For all the talk of war over water, there is little evidence that states prefer it over negotiated outcomes. The occasional conflict between individual farmers does not translate to warfare at the communal or state level.

Third, in both cases, the actual solutions lie in cooperative use of resources as well as more efficient utilization of the resources available. It took Egypt's population reaching a level that makes the Nile incapable of providing enough water to feed the population for the Egyptian government to consider working with its co-riparians. In the case of the Saiss basin, the decline of the aquifer is increasingly forcing downstream communities to look at alternatives to agriculture. There has already been a sharp increase in the use of drip irrigation. There is a slower but ongoing shift to more water efficient crops as well.

8 Conclusion

Because we regard ourselves as a rational species, we tend to try rationalizing and finding causes for the most irrational of all social interactions – violent conflict and war. We tend to fear those on whom we have to depend for resources, so we threaten, we cajole. Yet the economic and water interests that divide the areas within a water basin are present whether the basin is inhabited by a single collective or several, but it is rare to find conflict that exists only for economic reasons. Conflict, when it occurs, tends to take place in areas that are shared by many identity communities, and it tends to occur when they have had a record of structured relationships of power and domination – which inevitably collapse into demands of equality. "Resource war" or the idea that people would rather kill for water when they can cooperate it for is very popular, because it gives a logical veneer to what is not rationalizable. Sadly, it also serves to let people avoid the implications of relationships of power between groups and the need to question them – water is much easier to blame in contrast.

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General Conclusions

Redouane Choukr-Allah, Ragab Ragab, and Rafael Rodriguez-Clemente

This book included four parts with 18 contributions. The first part of this book dealt with the Integrated Water Resources Management (IWRM) in the Mediterranean region. This part covered the following issues: the prospect of IWRM in the Mediterranean region, the conceptual framework, and the possible increase of water productivity.

The second part dealt with the water resources management under climate and land use changes. This part covered the following issues: the quantification of water resources under different scenarios of possible climate and land use changes, projection of the gap between the water supply and demand, the new water policies required in the light of possible climate and land use changes including the drought events, the challenges in quantifying water resources, and models (e.g., IHMS and SALTMED) as useful tools to predict the impact of climate and land use change on water resources and to study the impact of irrigation water management on yield and water productivity.

The third part dealt with the nonconventional water resources management and pollution control. This part covered the following issues: prospective of wastewater use as additional water resource, wastewater treatment technologies and its reuse, and safe use and pollution control when using wastewater.

The fourth part dealt with water governance, policies, and the social aspect of water resources management. This part covered the following issues: the governance and water policies models in the regions, the varying social issues across the basin, the drought risks and food insecurity, the gender role, the conflicts, and the participatory aspect.

In general, the book highlighted the following important issues:

- As one of the world's driest regions, the limited water resources in the Mediterranean area critically affect the socioeconomic development and the GDP of the Mediterranean countries. The activities are centered on agriculture and tourism. Both require a significant amount of water during summer, when water is in short supply. The amount of water available per person is expected to fall by

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2050 by more than half due to demographic growth and climate change trends. With agriculture accounting for using more than 80% of freshwater, a low water use efficiency, and the discharges of domestic, industrial, and agriculture wastewater leading to deterioration of water quality, together with the effects of the climate change, it is clear that more integrated approaches to water management are required.

- The combination of possible impacts of climate change and land use requires a proper plan for water resources management and mitigation strategies. There is a delicate balance between food security and energy security when changing the land use from arable crops to biofuel crops. Land use changes, if coinciding with droughts, could lead to desertification. Water resources management needs to be handled with an integrated approach that takes into account the water resources availability (quantity and quality), the land use, the water demand, and the climate change.
- Models, when calibrated and independently tested, can be useful tools for Integrated Water Resources Management. The Integrated Hydrological Modelling System (IHMS) and SALTMED can be used to quantify water resources; investigate the impact of land use and climate changes on water resources, plant biomass, harvest, and sowing dates; and quantify the gap between water supply and demand. These models are good alternatives to the usual 3-year experiments and costly experiments.
- Climate change adds to current challenges in the Mediterranean region, as precipitation is expected to decline and drought to intensify. Agriculture, as a result, must cope with meeting the increasing demand for food, fodder, and fiber, but with less water. The logical response is to produce more crops with less water, that is, to improve water productivity (WP) which is the return per unit of water consumed by the plants. WP in the region is generally low and there is a great potential for its improvement.
- Green Water contributes more to food production in north Mediterranean EU countries while Blue Water contributes more to food production in south and east Mediterranean countries. More attention needs to be given to improve the use of the Green Water in the region and to include it in future planning.
- More decentralization is needed in water. This must be accompanied by the necessary financial resources and human capacity development at the local level. Often, local governments do not have the capacity to do what is required. Local groups and individuals are hampered by lack of access to key information and by exclusion from participating in water decision making.
- Reforms in agricultural policy and drought management are critical, especially with respect to the rural poor. Countries have to review their approach to drought management because of a higher degree of vulnerability to drought in the region. The careful management of water resources will become increasingly important in mitigating the impact of drought on the economies of the region in the future.
- Technical innovations and water sector reforms need to be accompanied by agricultural sector reforms. Current evidence indicates that water sector reforms in the absence of associated reforms in the agricultural sector are unproductive and unsustainable.

- Significant investments in modernization of irrigation and drainage systems and enhancing rainfed agriculture, including both technology and management techniques, could improve the level of food security.
- Integrated water management policy is necessary. It should account for climate change, extreme events, and population growth. The policy should foresee the importance of stakeholders' and local community's participation and the role of the capacity building at all levels, especially for the farmer groups. The policy should adopt more decentralized and autonomous water resources management as a crucial precondition to meet the future's challenges. The future options need to focus on the productivity enhancement and the water cost effective recovery.
- Water valuation is required to truly reflect its value. More investment in rainfed agriculture is required and more work is needed to enhance on farm water use efficiency.
- Improve knowledge sharing among practitioners. Promote broad dissemination of successful scientific results to the public, end users, and all concerned agents (translate scientific outputs into simple common language). Increase of training opportunities for technical and non-technical staff.
- The use of treated wastewater should be regarded as a means of increasing water resources availability in the Mediterranean region and should therefore be considered as an option in the national water strategy plans. Wastewater reuse needs to be perceived as a measure towards three fundamental objectives within Integrated Water Resources Management: assuring environmental sustainability, economic viability, and a contribution to food security. Uses of wastewater in activities other than agricultural might be economically interesting and ecologically sustainable. In fact, the reuse of wastewater in industry, recreational areas, forestry, and on golf courses seems to be more economical and could also increase the percentage of reused wastewater. This would contribute to increasing the efficiency of the Mediterranean region's overall water use. Water Demand Management options should be embraced prior to the relatively costly desalination options. More investment should be directed to sewage collection, treatment, and reuse for environment and food security in the Mediterranean region. Synergies are needed between the different water strategies of the Mediterranean countries.
- The Mediterranean countries must implement policies for preserving ecosystem services as a fundamental component in attaining their food and water securities.
- Sustainable use of water resources. Water resources management is always associated with the word "sustainability." Sustainability is a difficult term to apply and is difficult to estimate, and its forecast over a long period of time is a challenge. Sustainability is not for eternity; it should be associated with a time span. The majority of the scientists like the time span to be rather short, with a maximum of 50 years. Enough attention should be paid to the sustainability in relation to "water security," defined as the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems, and production coupled with an acceptable level of water-related risks to people, environments, and economies.
- There is also a need to adopt the concept of the "Green Economy" in water management, where growth in income and employment is driven by investment that

reduces carbon emissions and pollution, enhances energy and resource efficiency, and prevents loss of ecosystem services.

- Supply-led management is unsustainable. A sustainable demand-led approach is required to manage the water resources with focus on conserving water and using it more efficiently and accounting for the need for a healthy freshwater ecosystem.
- Water resources need to be used more efficiently. There is a critical need to improve the water use efficiency, especially in agriculture. Technical and management options to improve productivity include developing new crop varieties with higher yields per unit of water, for example, crops with comparable yields but shorter growth periods; switching to crops that consume less water or use water more efficiently; improving soil management, fertilization, pest, and weed control; and improving the reliability of water supplies at critical crop growth periods. This would encourage farmers to invest more in other inputs and would lead to higher output per unit of water; promoting deficit irrigation, which can increase productivity per unit of water by providing less-than-full irrigation requirements; promoting supplemental irrigation, which uses limited irrigation at critical periods to supplement rainfall, use of nonconventional water resources such as agriculture drainage water, seawater, brackish groundwater, and domestic wastewater; use new crops that are drought and salinity tolerant such as quinoa and amaranth; and allocate water to the more water-efficient land use.
- Substantial and sustainable improvements in agricultural water productivity can be achieved through integrated management at all scales. On-farm water-productive techniques include deficit irrigation, supplemental irrigation, water harvesting, and precision irrigation. Improved techniques if coupled with improved irrigation management, better crop selection and appropriate cultural practices, and improved drought and salt tolerance levels plants will help to achieve this objective.
- New water policies are required. Water resources management requires sound water policies and legislation. The current policies need to have links between water quality, land use, and water resources; a link between water scarcity issues and agricultural policies; a policy with regard to biofuel/energy crops and their impact on water availability and food security; a policy on the use of wastewater at the times of shortages; a policy on the use of less water-demanding and drought-tolerant crops to cope with drought periods; and above all, a proactive management of drought, which so far was reactive. Demand management strategies should be promoted as obligatory measures in the water policy, assessing the risks and impacts of alternative water supply options such as desalination and brackish water and wastewater reuse. A forecast of water scarcity and drought events for the year ahead should be made, water use efficiency among all users should be improved, and effective and harmonized/unified transboundary monitoring systems for data comparability should be put in place. The region should adopt a joint policy on water security, food security, energy security, and environment security. Stakeholders (water users, polluters, scientists, government, and private sectors) should have a shared vision and make collective informed decisions. Stakeholders should collectively manage the water resources, raise the awareness of consumers on the value of water, and introduce an Eco-Label

regulation which will help in choosing products with lower water consumption or water footprint, the total volume of freshwater that is used to produce the goods and services expressed as m^3.

This book puts great emphasis on the importance of Integrated Water Resources Management IWRM as the way forward towards food, water, and energy security. The book offered ways and means to better manage the limited water resources; to use the water more efficiently; to adopt new policies in order to cope with climate change and the drought events; to increase water supply through the use of nonconventional water resources, especially wastewater; to adopt stakeholder participation and information exchange; and to raise the of public awareness to the value of water. It is very useful book for all those involved in all aspects of water resources and it has valuable information to scientists, researchers, farmers, extension services, students, and the public at large.

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Abbreviations

AfWA	African Water Association
APP	Agence du Partenariat pour le Progrès
AUEA	Association des Usagers des Eaux Agricoles
AWN	Africa Water Network
BOT	Board of Trustees (of ERF)
DPPBV	Département de Production, Protection et Biotechnologies Végétales
ERF	Economic Research Forum
EUROMED	Euro-Mediterranean Partnership
EuroMeSCo	Euro-Mediterranean Study Commission
EWF	European Water Forum
EWN	Ecumenical Water Network
EWP	European Water Partnership
FIDA	Fonds International pour le Développement Agricole
GERM	Groupement d'Etudes et de Recherches sur la Méditerranée
GWP	Global Water Partnership
GWRC	Global Water Research Coalition
IAI	Istituto Affari Internazionali
IAV	Institut Agronomique et Vétérinaire
ICLEI	International Council for Local Environmental Initiatives
IEEI	Instituto de Estudos Estratégicos e Internacionais
INGEDI	Integration of Gender Dimension in Water Management in the Mediterranean Region
IPEMED	Institut de Prospective Economique du Monde Méditerranéen
IPWM	Integrated Participatory Water Management
IWA	International Water Association
IWRM	Integrated Water Resources Management
JMP	The WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation
MAPM	Ministère de l'Agriculture et de la Pêche Maritimes
MCA	Millennium Challenge Account

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MCC	Millennium Challenge Corporation
MDGs	UN Millennium Development Goals
MEDCOAST	Network for coastal and marine conservation in the Mediterranean and the Black Sea
MELIA	Mediterranean Dialogue on Integrated Water Management
MeSCo	Mediterranean Study Commission
MFAA	Moroccan Fulbright Alumni Association
NGOs	Non-government organizations
PAF	Projet d'Arboriculture Fruitière
PIM	Participatory Irrigation Management
PMV	Plan Maroc Vert
PPIMIP	Participatory Privatization of Irrigation Management and Investment Project
SAGE	Water Development and Management Plan (French acronym)
SDAGE	Water Development and Management Master Plan (French Schéma Directeur des Aménagements et Développement de l' Eau)
SEAGAFAO	Socio-Economic and Gender Analysis Programme
SIDA	Swedish International Development Cooperation Agency (Swedish acronym)
TNAV	Vlaams Netwerk Watertechnologie
UGP	Unité de Gestion des Projets
UNEP/MAP	United Nations Environment Programme's Mediterranean Action Plan
UNOPS	United Nations Office for Project Services
UNW-DPAC	The UN-Water Decade Programme on Advocacy and Communication
UNW-DPC	UN-Water Decade Programme on Capacity Development
WDM	Water Demand Management
WEF	Water Environment Federation
WFD	Water Framework Directive (2000/60/EC)
WGOV	Water Governance
WIN	Water Integrity Network
WRM	Water Resources Management
WWAP	World Water Assessment Programme

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