

# ARAB ENVIRONMENT WATER

*Sustainable Management of a Scarce Resource*

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المنتدى العربي للبيئة والتنمية  
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## Preface

*Water: Sustainable Management of a Scarce Resource* is the third of a series of annual reports on the state of Arab environment, produced by the Arab Forum for Environment and Development (AFED). The first AFED report, published in 2008 under the title Arab Environment: Future Challenges, covered the most pressing environmental issues in the region. The second report, Impact of Climate Change on Arab Countries, was published in 2009 and addressed the vulnerabilities to climate change facing Arab countries. This report covers water issues in the driest region of the world.

Water is the major challenge facing the Arab region. Arab countries are already in the midst of a water crisis. As early as 2015, almost all Arab countries will be below the level of severe water scarcity at less than 500 cubic meters per capita per year; nine countries will be below 200 cubic meters, six of which below 100 cubic meters. Climate change will worsen the situation. Water flow in the Euphrates may decrease by 30% and in the Jordan River by 80%. An average increase in temperature of 2°C may decrease the flow in the Nile by 50%. Over 85% of fresh water is used for agriculture, with more than half wasted due to unsustainable practices. Efficiency levels of water for human use are low, even in countries depending almost entirely on desalination. Although the region produces more than half of the world's desalinated water, it depends entirely on imported technologies and equipment.

In addition to documenting the latest data on the state of water in the Arab countries, the report is designed to contribute to the discourse on the sustainable management of water resources. The treatment of the subject is both broad and multidisciplinary, thus providing the public, experts and decision makers with critical understanding, without being overly technical or academic in nature. The report combines in one volume a large amount of critical material on water from a variety of sources, analyzes them, discusses success stories as well as shortcomings, and proposes policy measures. While contributing to the dissemination of knowledge and information sharing, the report ultimately aims at inciting action for sustainable water policies.

The Arab water sector has been the subject of numerous studies by government agencies, development banks, and aid organizations. Therefore, critical issues in the Arab water sector have been researched and documented. The World Bank 2009 report, *Water in the Arab World: Management Perspectives and Innovations*, is but one example. This AFED report does not duplicate work already done, but rather builds on it to propose specific reforms and action plan.

Despite investments in Arab water infrastructure, the benefits of a sustainable, secure, and equitable management of water resources continue to elude the region

with serious ramifications on public health and well-being. The report sets the context by laying down why these benefits have been slow to come by and what challenges need to be addressed to attain water sustainability in the region.

The report also describes new trends and the prospects for reforms affecting the future of water in Arab countries. It addresses water governance, management of shared water resources, the role of laws and customary arrangements, the sustainability of desalination, constraints in water reuse, water pricing, use of analytical tools such as remote sensing, and the management of agricultural, municipal, and industrial water resources, among others.

AFED Secretariat wishes to thank all those who supported this initiative, specifically the report's main editor Dr. Mohamed El-Ashry, Dr. Mostafa Kamal Tolba and Dr. Mohamed Kassas who helped in laying down the methodology and appraising of the outcome, and Dr. Shawki Barghouti who put at our disposal the resources of the International Center for Biosaline Agriculture (ICBA). AFED's special thanks go to the OPEC Fund for International Development (OFID) for its continuous genuine support to the Forum's program, the Islamic Development Bank (IDB), and all corporate and media partners who made this endeavor possible. Thanks are also due to the authors and the many experts who contributed to the contents, and the editorial and production team of *Al-Bia Wal-Tanmia* (Environment & Development) magazine for their dedication to produce this report and book up to the highest standards and in record time.

AFED hopes this report will contribute to the ongoing dialogue on the future of water in Arab countries and catalyze institutional reforms. If this report can inform and help shape public policy for sustainable water management in the Arab world, then it would have served its purpose.

**Najib Saab**  
*Secretary General*  
*Arab Forum for Environment and Development*

## EXECUTIVE SUMMARY

**ARAB ENVIRONMENT  
WATER****2010 Report of the Arab Forum for Environment and Development (AFED)**

The Arab world is facing the prospect of severe water and food shortages unless rapid and effective measures are taken to address the region's water scarcity dilemma. Even if all available fresh water resources in the region were utilized, Arab countries on the whole would still find themselves below the water scarcity level. Alarmingly, the 2010 report of the Arab Forum for Environment and Development (AFED) has found that Arabs will face, as early as 2015, the condition of severe water scarcity, at which the annual per capita share will be less than 500 cubic meters. This is below one-tenth of the world's average, currently estimated at over 6,000 cubic meters. Water scarcity is a limitation to economic development, food production, and human health and well being.

Why does an allocation that is below 500 cubic meters (500,000 liters) per capita represent severe water scarcity? Some figures can serve as a useful illustration: it takes 150 liters of water to make a quarter liter cup of coffee; one kilogram of wheat needs 1,300 liters, while one kilogram of beef takes 15,000 liters of water to be produced. The larger the difference between a region's water resources and its water needs, the higher its degree of water (and food) insecurity.

Water supply sources in the Arab world, two-thirds of which originate outside the region, are being stretched to their limits. Thirteen Arab countries are among the world's nineteen most water-scarce nations, and per capita water availability in eight countries is already below 200 cubic meters, less than half the amount designated as severe water scarcity. The figure drops to below 100 cubic meters in six countries. By 2015, the only countries in the region which will still pass the water scarcity test, at above 1,000 cubic meters per capita, will be Iraq and Sudan – and even that assumes that water supplies from Turkey and Ethiopia will continue to be sustained at their present levels. Without fundamental changes in policies and practices, the situation will get worse, with drastic social, political and economic ramifications.

The Arab region is one of the driest in the world. More than 70% of the land is dry and rainfall is sparse and poorly distributed; climate change will exacerbate the situation. By the end of the 21<sup>st</sup> century, Arab countries are predicted to experience an alarming 25% decrease in precipitation and a 25% increase in evaporation rates, according to climate change models. As a result, rain-fed agriculture will be threatened, with average yields estimated to decline by 20%.

Water use in the Arab region is dominated by agriculture, which utilizes about 85% of the water resources, against a world average of 70%. Irrigation efficiency is very low in most countries, at 30% against a world average of about 45%.

Agricultural productivity is still measured by tons produced per hectare of land regardless of water wasted, while it should be measured by tons produced per cubic meter of water so that water usage can be captured as part of the cost of production.

Since surface water supplies do not meet growing demand due to population growth and economic development, groundwater resources have been over-exploited beyond safe yield levels. This has resulted in significant declines in water tables and in the pollution of aquifers. Water pollution is a major challenge in the region due to increasing discharges into water bodies of domestic and industrial waste water, as well as agricultural chemicals, which raises serious health risks, especially among children. Over 43% of waste water in the region is discharged without treatment, while a small fraction not exceeding 20% is reused. Furthermore, overexploitation of groundwater along coastal areas is resulting in salt water intrusion.

Water shortages have compelled a number of Arab countries to rely heavily on desalination for the bulk of their municipal and industrial water needs. With 5% of the world population, Arab countries are endowed with just 1% of the world's renewable fresh water resources, while they have over 50% of the world's desalination capacity. At the projected rate of annual increases, current desalination capacity will be doubled by 2016, using expensive, fully imported and polluting technologies. In some countries part of the expensive desalinated water is being used to irrigate low-value crops, or even golf courses. The discharge from desalination stations contributes heavily to increased salinity and higher temperatures of seawater in coastal areas. Sustainability of desalination to meet increasing demand depends on technological breakthrough and developing local capacity, which make the technology more affordable and environmentally friendly. This might be achieved mainly by introducing new desalination methods using solar energy.

This AFED report has found that most public organizations in the Arab world, serving both irrigation and urban water needs, do not function properly and have not served their clients effectively. Responsibility for managing water and water services is dispersed across multiple institutions which rarely coordinate among themselves. Moreover, decision making is top-down with no, or ineffective, stakeholder participation.

The report argues that free water is wasted water. Artificially low prices and heavy subsidies to water services are at the root of inefficiency, overuse, excessive pollution, and environmental degradation. For example, the average price charged for water in the region is about 35% of the cost of production, and in the case of desalinated water it is only 10%. While water pricing has been advocated for a long time, especially in irrigation, it is seldom enacted, even though it is central to attracting increased investment in the sector. Nevertheless, finance alone will not address the water challenges, because no technological or engineering solutions will be effective without the necessary policy, institutional, and legal reforms.

Proper management of municipal and industrial water supplies requires the introduction of water pricing schemes. When assessing water rates for municipal and industrial users, policy-makers should seek pricing structures that meet the goals of local acceptability, economic efficiency, cost recovery, and equity. Flat fees should be replaced by a two-tier tariff structure: a fixed charge for individual



basic needs and for ensuring cash flow to providers, and a variable charge based on level of usage to encourage changed use patterns and enhance efficiency.

The problems plaguing water management in the region are daunting, and a sole focus on developing new supplies is no longer viable. There is an urgent need for a strategic shift from a culture of water development to one of improving water management, rationalizing water consumption, encouraging reuse and protecting water supplies from overuse and pollution.

A core recommendation of this AFED report is that before investing large capital into increasing supplies, less expensive investments that reduce water losses and enhance efficiency should be implemented. This means a reorientation in government's role, from being focused exclusively on being a provider to that of becoming an effective regulator and planner.

Arabs cannot afford to waste a single drop of water. Governments should urgently implement sustainable water management policies which rationalize demand to ensure more efficient use. This can be achieved by attaching an economic value to water, measured by the value of the end product from each drop. Governments should implement water efficiency measures, shift from irrigation by flooding to more efficient irrigation systems including drip irrigation, introduce crop varieties that are resilient to salinity and aridity, recycle and reuse wastewater, and develop affordable technologies for water desalination. More research is needed to address the challenges of food security and adaptation to climate change.

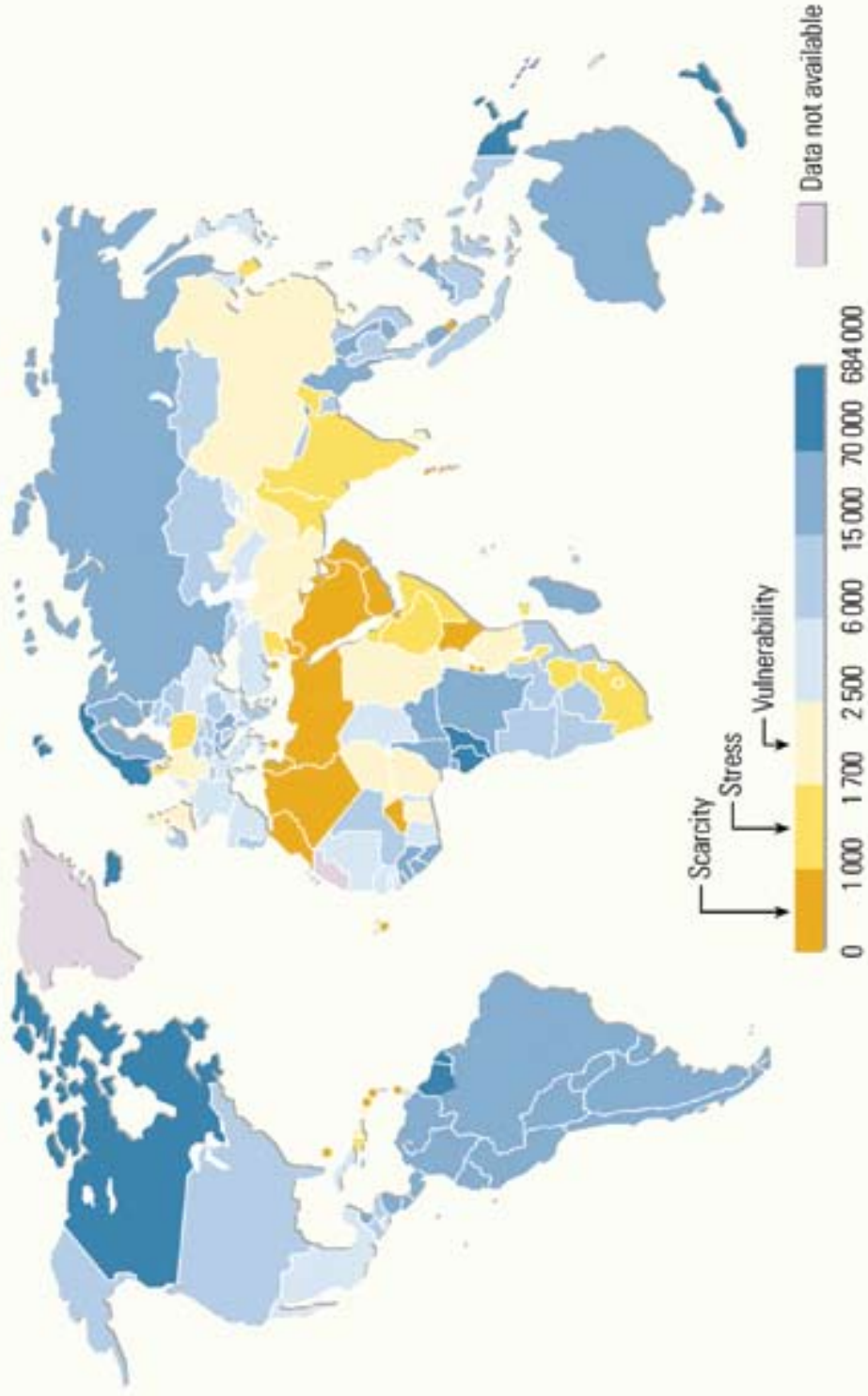
The main message of this report is threefold: First, the Arab world is already living a water crisis that will only get worse with inaction. Second, the water crisis, though serious and multi-dimensional, can be addressed through policy and institutional reforms as well as education, research, and public awareness campaigns. Third, averting a water crisis and suffering in the Arab world is only possible if Arab heads of state and governments make a strategic political decision to take up the recommendations for reforms seriously and urgently.

The state of water resources in the Arab world is precarious and worsening. It is perhaps the most serious challenge facing the region in the coming decades, and without concerted efforts at improving water management and institutions, the situation will only deteriorate further.

The water crisis is knocking on Arab doors; the time to act is now.

# Fresh Water availability

cubic meters per person per year



Source: FAO, UN, World Resources Institute, 2007

## INTRODUCTION

# ARAB WATER: Sustainable Management of a Scarce Resource

## 2010 Report of the Arab Forum for Environment and Development (AFED)

Since the beginning of time, water has been shaping the face of the Earth, not only as a geologic agent, cutting valleys and canyons and sculpting rock formations, but also as a major factor in the rise and fall of great civilizations and a source of conflict and tension between nations. The first great civilizations arose on the banks of great rivers – the Nile in Egypt, the Tigris and Euphrates of Mesopotamia, the Indus in Pakistan, and the Hwang Ho of China. All of these civilizations built large irrigation systems and made the land productive. By the same token, civilizations collapsed when water supplies failed or were improperly managed. The decline of the Sumerian civilization of Mesopotamia, for example, is believed to have been due to prolonged droughts and poor irrigation practices resulting in salt build-up in the soil. Similarly, the abandonment of Roman aqueducts, canals, and reservoirs in North Africa caused the return of the region to desert condition.

Water sustains life, it sustains the environment, and it sustains development. The global water crisis relates to both quantity and quality and is closely linked to the global environmental crisis and the degradation of life-supporting ecosystems. It is a crisis of management: fragmented institutions, inadequate policies and deficient legal systems, insufficient funding for water supply and pollution control, and shortage of political will.

Rapid population growth in developing countries contributes to environmental degradation, and this degradation, along with inadequate water supply and sanitation services, imposes large health problems and burdensome economic costs. Water supply sources are being stretched to their limits, and many parts of the world are facing water scarcity. Sanitation facilities are either lacking or are being overloaded, and surface and groundwater pollution is increasing rapidly. In the 20<sup>th</sup> century, the world's population tripled and the use of water grew sixfold. By 2050 an additional 3 billion people will be born mostly in countries already suffering from water shortages.

It is the poor in rural and peri-urban areas that suffer the most. 1.2 billion people are without access to safe water and 2.6 billion are without basic sanitation. The annual total number of people dying because of unsafe water amounts to 1.8 million and the number of people suffering from hunger and malnutrition exceeds one billion. By 2025, more than half the people on our planet will be living with water scarcity. The 2007 assessment by the Intergovernmental Panel on Climate Change (IPCC) notes that, because of climate change, water availability will decrease by 10-30% in arid regions, some of which are presently water stressed. Similarly, water supplies stored in glaciers are projected to decline, reducing water availability in regions where more than one-sixth of the world population currently resides. In Asia, for

example, crop yields are expected to decline by 2.5-10% by 2020 and 132 million people in the region could be at risk of extreme hunger by 2050.

If “water is life” and adequate clean water is a “fundamental human right” as argued in international forums, why is the progress in dealing with the water crisis ever so slow? One reason is inadequate finance. The funding in most national and international assistance budgets is surprisingly low. There is a disconnect between commitments and actions, between needs and what many governments and aid agencies are actually spending.

A combination of national government budgets, international and bilateral funding, debt relief, private sector investments and community-level resources are required. Governments must also establish the enabling framework for encouraging private investments and public-private partnerships for clean water and sanitation. Another key source of funding is revenues from water pricing.

Artificially low prices for water services (and sometimes no pricing at all) are at the root of inefficiency, overuse, excessive pollution releases and environmental degradation. Simply put, free water is wasted water. While water pricing has been advocated for a long time, particularly in irrigation, it is seldom enacted even though it is central to increased investment in the sector. Governments in developing countries cannot meet the investment demands for water services now, let alone in the future. And the private sector will not invest unless it can be assured a reasonable return. Yet developing country governments continue to resist water pricing and the phase-out of subsidies, arguing that the poor cannot afford to pay. The fact is that middle class areas pay low prices for networked services, while the poor pay much higher prices for poorer quality water from street vendors.

While substantial financial resources are needed, finance alone will not solve the global water crisis. Experience shows that technological or engineering solutions by themselves will not be effective without the necessary policy, institutional and legal reforms. Land tenure reforms, improved pricing policies, transparent water rights and allocation systems, economic incentives, improved legal and regulatory frameworks, creation of basin management authorities, and public participation are all necessary pieces of the policy reform. Empowering women’s groups, the poor, youth, and community-based groups to have an adequate voice in participatory decision-making is also essential.

Ultimately, the water crisis cannot be addressed in isolation from other crises such as land degradation, deforestation and ecosystem loss. Taking an integrated approach that considers the links between water, land and people, and making the necessary reforms and investments in all these areas can go a long way towards sustainable water management. Deforestation and degradation of watersheds mean that less fresh water is available. Conserving fresh water ecosystems through better management would not only help maintain the quantity of available water, but its quality as well.

In water management, the task sometimes seems overwhelming. How to coordinate services, industry, trade, transport, agriculture, fisheries, science, environment, development goals, waste management and diverse populations?

How to involve various international agencies, levels of government, the private sector and NGOs? How to forge international action when upstream nations see little direct benefit in stopping pollution that affects downstream users; when coastal nations see little incentive for protecting wetlands that sustain fisheries used by other nations; when countries with trans-boundary groundwater aquifers feel no obligation to protect recharge zones from degradation that affects the wells of their neighbors?

These are not insignificant questions since 43% of the world's population lives in international river basins, which cover almost half the planet's land surface and contain over 80% of the fresh water river flow. There are also countless aquifers that cross political boundaries. Water scarcity has the potential to increase tensions among nations that share water resources. The water crisis, however, has many dimensions and varies across regions. Water supplies are scarce in some regions and relatively abundant in others. And the effects of long-term climate change are also likely to vary across regions.

## **WATER IN THE ARAB REGION**

All these features of the global water crisis manifest themselves in the Arab region. The state of water resources and management in most Arab countries is precarious. Population growth and associated demand for water in the region have reduced per capita supply to one-fourth of its 1960 levels. Without fundamental change in policies and practices the situation will get worse with both political and economic ramifications.

The 2010 Annual Report of the Arab Forum for Environment and Development (AFED) on water in Arab countries highlights the state of water management and use in the region and the need for more sustainable management of this scarce and valuable resource. The report is designed to contribute to the discourse on the sustainable management of water resources in the Arab world. The treatment of the subject is both broad and multidisciplinary, thus providing critical understanding without being overly technical or academic. The goal of publishing this report is to make the case for water reforms in Arab countries and advance policy recommendations for rational management and use of water, and for laws and institutions.

The following is a summary of findings and suggested recommendations.

## **WATER SECTOR OVERVIEW**

The water sector in Arab countries suffers from multiple strains. Arab countries rank last in renewable freshwater availability per capita compared to other regions of the world. Currently, 13 Arab countries are among the world's 19 most water-scarce countries. Per capita water availability in 8 Arab countries is below 200 m<sup>3</sup> per year. By 2015, it is expected that average annual freshwater availability in Arab countries will be below 500 m<sup>3</sup> per capita, designated the severe water scarcity mark. In 2025, only Sudan and Iraq are expected to be above the water scarcity level. In some Arab countries, total water withdrawals already exceed available renewable water resources. In fact, internal renewable freshwater resources per capita in most Arab countries are already below the

water scarcity level of 1,000 m<sup>3</sup>, compared to a world average over 6,000 m<sup>3</sup>. More than 45 million people in the Arab world still lack access to clean water or safe sanitation. The growth in population in the coming two decades, 90 percent of which will occur in urban areas, will increase the political pressure to meet these demands especially for domestic and industrial use.

However, public budgets are already constrained and can hardly sustain efficient levels of water services to current populations, which are growing at 2-3% annually. Most of this growth is adding pressure on already crowded and inadequately serviced cities and towns. Ambitious plans for rapid economic growth and increased pace of industrialization will further add to water shortages.

The political economy of low water tariffs and high fuel and water subsidies in Arab countries has contributed to overuse of scarce water resources and has deprived providers of desperately needed revenues to maintain the financial health and physical condition of urban and rural water supply networks. The price charged for water is estimated to cover only about 35 percent of the average cost of supply, and charges in many irrigation systems are much less.

Because renewable water resources cannot meet growing demand, governments have often encouraged the over-exploitation of groundwater resources. For example, the average annual abstraction from groundwater in all sub-basins in Jordan is about 160% of the annual renewable average of recharge. In Yemen, groundwater is being pumped at a rate that is four times greater than natural recharge, forcing farmers to abandon once productive valleys. The over-extraction of groundwater beyond safe yield levels has resulted not only in dramatic declines in the water table, but also in the pollution of groundwater aquifers in coastal areas by saline seawater. Some countries are expanding investment in desalination of seawater and in wastewater treatment and reuse. Proper treatment of wastewater and controlled reuse, however, continue to be of high concern posing serious risks to public health and the environment.

Water pollution is also a serious challenge in the region, attributed to the use of high levels of chemicals in agriculture as well as to increasing inflows of domestic and industrial wastewater into water bodies. The lack of sanitation facilities for large segments of the population contributes to water pollution by raw sewage. The discharge of brine effluents from seawater desalination plants causes degradation to coastal marine areas. The Gulf countries flush about 24 tons of chlorine, 65 tons of pipe-cleaning anti-scaling agents, and about 300 kg of copper into the Gulf daily.

Quick fixes and short-term solutions are not adequate to address the challenges of the water sector in Arab countries. Policy-makers need to change course and adopt policy reforms that address key strategic issues. They need to make a strategic shift away from investing in the development of water supplies to efficiently managing the available supply of water resources. Water demand management has proved to yield significant benefits and may often be more cost-effective than traditional supply management measures. Managing demand will provide policy-makers with the opportunity to create mechanisms to adjust water allocation more equitably, rationally, and sustainably. The water needs of the municipal, industrial, and agricultural sectors are legitimate, but so are the priorities to maintain water flows to wetlands, aquifers, river basins, and other ecosystems.

When introducing new policy frameworks, a high priority should be given to articulating and measuring reliable performance indicators to monitor the effects of policy reforms. Reliable accounting of the economic, social, and environmental effects of new policies provides useful guideposts for navigating a transition to a sustainable water future.

## **WATER RESOURCES AND CLIMATE CHANGE**

As a result of climate change, the atmospheric processes responsible for the aridity of the Arab region are projected to intensify. By the end of the 21st century, Arab countries are predicted to experience an alarming 25% decrease in precipitation and a 25% increase in evaporation rates, according to climate change models. As a result, rain-fed agriculture will be threatened, with average yields declining by 20% in Arab countries overall, and by 40% in Algeria and Morocco. Water deficits, already a fact driven by natural water scarcity and unrelenting rising demand in the region, will be exacerbated. Failing to develop adaptation strategies now will contribute to greater suffering in the future.

In addition to climate disruption, water resources in Arab countries are vulnerable to other stresses such as population growth, changing land use patterns, variable rainfall, and natural water scarcity. Vulnerabilities to these stresses are not unlike those to climate change. Therefore, a vulnerability-based approach would be most effective in advancing targeted intervention policies to address existing vulnerabilities (e.g., inherent aridity) as well as future ones (e.g., climate change). It would also permit policy-makers to formulate strategies based on accumulated knowledge of the region's resiliency factors and adaptive capacity.

## **STATE OF FRESHWATER ECOSYSTEMS**

Freshwater ecosystems supply the Arab region with water and provide critical habitats for aquatic biodiversity. Therefore, information about the condition of freshwater ecosystems matters. Arab countries for the most part have been unable to provide systematic, reliable, and up-to-date information on the state of wetlands, marshes, lakes, river basins, oases, and their biological endowments. Arab governments are thus urged to provide support and to commit resources to establish an evaluation, monitoring, and reporting mechanism for conducting assessment studies about the state of freshwater ecosystems. To ensure their effectiveness, the assessment studies have to be scientifically credible and relevant to decision-makers' needs.

As human interactions with freshwater ecosystems accelerate in Arab countries, assessment studies will be needed to address how freshwater ecosystems are changing, whether they are thriving or diminishing, what new challenges they are facing, and whether policy-makers are addressing these ecosystem challenges effectively. They should also highlight the threats to biodiversity and ecosystem sustainability.

Arab governments are also urged to increase their capacity to utilize that knowledge and muster the political will to transform this knowledge into

action. This will enhance the ability of water resources professionals to design, implement, and evaluate effective interventions for the sustainable management of freshwater ecosystems.

### **AGRICULTURAL WATER MANAGEMENT**

Agriculture accounts for over 83% of water use in the Arab region, reaching 90% in some countries, against a world average of 70%. Despite serious water shortages, irrigation efficiencies remain at 30-40%, low water prices are still common, groundwater reserves are fast depleting, and incentives for irrigation improvement are lacking. The demands placed on the agricultural sector are plenty, almost unrealistic. Arab agriculture is expected to contribute to food security, reduce the Arab world's food import bill, provide rural employment, redirect some of its share of fresh water to municipal and industrial use, acclimatize to marginal-quality water for irrigation, and adapt to climate change. Agricultural practices are also blamed for increased soil and water salinity, toxic pollution from use of agro-chemicals, damming of rivers, and the loss of biodiversity associated with wetlands destruction.

These concerns, though serious and multi-dimensional, can be addressed through a mix of institutional reforms, changes in incentive structures, and technical innovations. A mix of economic mechanisms such as rebates, reduced taxes, targeted subsidies, price signals, access to water rights, tradable water permits, and other economic incentives should be considered by policy-makers to persuade farmers to adopt irrigation-efficient technologies, change cropping patterns, improve irrigation scheduling, reduce over-abstraction, and in general shift agricultural activities towards higher-value crops.

Arab governments should also provide financial support to research efforts focused on developing new local crop varieties tolerant to aridity and salinity conditions. For countries that rely on rain-fed agriculture, a new drive to improve and invest in rainwater harvesting systems is highly recommended.

In effect, these policy reforms would result in a new political economy of water. This change requires Arab governments to consider the wisdom of acquiring water 'virtually' through the import of, say grains, from water-rich countries, while allocating scarce water resources to low-water consuming, high value-adding crops that can generate foreign exchange. It is more realistic to attain food security through trade policies.

### **WASTEWATER TREATMENT AND REUSE**

The volume of wastewater generated by the domestic and industrial sectors in Arab countries is approximately 10 km<sup>3</sup>/year, of which 5.7 km<sup>3</sup> undergoes treatment. These figures suggest that on average 43% of annually generated wastewater is discharged in untreated form. Of the volume of wastewater that is treated, only one third is reused. The volume of generated wastewater in Arab countries is expected to grow quickly due to increased utilization of water by rising populations, industrialization, and higher standards of living. The quality of treated wastewater in Arab countries must also be questioned. Wastewater treatment plants in Arab countries have highly variable efficiency.



They are allowed to handle waste loads that exceed their capacity limits, hampering their effectiveness. The practice of combining domestic and industrial wastewater for treatment imposes limitations on the ability of plants to operate satisfactorily. In some Arab countries, crop irrigation by untreated wastewater is practiced due to the unavailability of fresh water.

The untapped potential of wastewater treatment and reuse for augmenting Arab countries' water supplies requires appropriate policy interventions. Policy-makers need to demonstrate a long-term political commitment to a national strategy for the utilization of wastewater treatment and reuse and to establishing proper institutional structures and water reuse policies. The development of appropriate policies for promoting reuse should include economic analysis of treatment and reuse options, dissemination of practical knowledge, development of best practices, cost recovery mechanisms, professional training, public awareness campaigns, and the adoption of adapted standards and guidelines that take into consideration reuse schemes and technical and financial resources.

Because reclaimed wastewater represents a valuable resource in a water-scarce region, it is desirable to treat all generated wastewater and to reuse all treated water. Beyond meeting quantitative goals, however, judicious planning calls for wastewater to be properly treated and suitably reused according to requirements of protecting health and the environment.

Viable options based on different treatment levels and different end-uses of wastewater (including food and non-food crops, landscaping, or groundwater recharge) should be assessed. Treatment options should consider the ease of replication and up-grading as well as the availability of a local trained workforce to operate, monitor, and maintain plant facilities. For reuse in agriculture, selection criteria for crops, irrigation methods, and application periods should be considered. Wastewater treatment technologies should be suitable to local conditions, acceptable to users, and affordable to those who will pay for them. Finally, reuse must be part of a larger water strategy that manages and regulates demand effectively.

## **DESALINATION**

Shortages in renewable and non-renewable water sources have compelled a number of Arab countries to rely on desalination for supplying the bulk of their municipal and industrial water needs. Arab countries, with 5% of the world population, have a 50% share of all cumulative desalination capacity contracted for in the world since 1944. The high rate of annual increase in contracted capacity will be maintained over the next decade, doubling current capacity by the year 2016. This comes at a high cost. Annual investments to produce, manage, and operate seawater desalination plants in the Arab world are predicted to reach \$15 to \$20 billion in the next decade. At present, 25% of Saudi oil and gas production is used locally to generate electricity and produce water. With present growth rates for demand, this fraction will be 50% by 2030, according to Saudi officials. Despite the high cost incurred in producing desalinated water, there is no relief from the demand side. Water tariffs cover on average 10% of cost. Water subsidies, if they continue to be unchallenged, could consume up to 10% of oil revenues in some GCC countries by 2025. Water leakage rates in the distribution network are estimated to be 20-40%. In countries of the GCC, average daily water consumption per capita has reached 300-750 liters, the highest in the world.

These high costs are untenable in the long term, necessitating bold reforms to allay concerns about the sustainability of the desalination sector. Before sinking large capital in desalination plants, managing costs by reducing distribution water losses and promoting efficiency in water production and use should be given a high priority by water governing institutions. This is the least expensive option for meeting rising demand. Governments should re-think their pricing strategies by charging tariffs that recover costs while offering rebates to consumers as incentives for efficient water use.

Taking a longer-term perspective, governments are urged to divest from plant ownership and operation and assume the role of a regulator. This shift would automatically provide opportunities for the private sector to develop, with government incentives, a more competitive locally- and regionally-based desalination industry encompassing design, manufacturing, construction, operation, and research and development (R&D). Given the large market size and the strategic role of desalination in some Arab countries, the economic benefits cannot be overestimated. To address concerns about carbon emissions, Arab governments should link any future expansion in desalination capacity to heavy investments in abundantly available renewable sources of energy.

### **WATER LAWS AND CUSTOMARY WATER ARRANGEMENTS**

With very few exceptions, Arab states do not yet have well-defined water legislation. Different water-related legislations have been drawn up over time to address different or specific water issues. Still, the substance and scope of most of their respective mandates tend to be limited and fragmented. The result has been either only minimal legislation dealing with water resources, or overlapping laws that are outdated and do not satisfy current requirements. Institutionally, water management is still highly centralized in many Arab countries with responsibilities scattered among many ministries and water authorities, leading to inefficiencies and mismanagement. Control of water pumping is mostly absent and enforcement of water legislation is limited.

Although diverse customary arrangements have been demonstrated to effectively complement formal legal arrangements for utilizing water resources in some Arab countries (e.g., Oman), several Arab states continue to focus on the use of statutory arrangements. Many Arab countries seem not to appreciate the relevance of their societies' rich tradition of customary arrangements to provide guidance to today's issues of water governance, regulation of services, management of water resources, water allocation, conflict mediation, infractions and sanctions, and conservation and protection of water resources and ecosystems.

Arab governments should enact comprehensive national water legislation that can facilitate institutional reforms and provide legal protection for more bottom-up forms of participatory water governance. In doing so, legal experts and water managers need to heed the living legacy of customary water arrangements and institutions and identify possibilities for incorporating this tradition into water legislation in harmony with statutory water laws.

Responsive water legislation in Arab states must address existing gaps in

current laws. Water laws should establish mechanisms to control and regulate water access, promote water use efficiency through a system of economic instruments and incentives, enable pollution control and environmental impact assessment enforcement, facilitate institutional arrangements, establish protected areas vital to water resources, provide for land use planning, and set enforceable penalties for violations that cause damage to water resources. Finally, the realities of climate change dictate that provisions in water laws not be set in stone. Because water availability and quality will be more subject to climate-induced variations that cannot be predicted with confidence, water legislation needs to cater for these uncertainties.

### **TRANS-BOUNDARY WATER RESOURCES**

Most Arab states depend for their water supply on rivers and/or aquifers that are shared with neighboring countries. Of all renewable water resources in Arab countries, two thirds originate from sources outside the region. And yet not a single formal agreement for joint management of shared water resources exists in the region. Only seven Arab states have ratified the UN Convention on the Non-Navigational Uses of International Watercourses, which codifies the core principles of International Water Law and is often used to conclude joint management and water sharing agreements.

To foster joint management of shared water basins or aquifers, Arab countries should pursue cooperative agreements drawing on principles of the UN Convention on the Law of Non-Navigational Uses of International Watercourses. It is prudent to move beyond data sharing and basic consultations and take bold steps to identify a sustainable formula for sharing waters guided by legal principles of equitable and reasonable use and the obligation not to cause harm, rather than relying on existing power imbalances. Arab countries which are not parties to said UN Convention should sign and ratify the Convention.

Managing shared water resources should not be left within the domain of only water resources professionals, but should also be placed on the agenda of the country's top diplomats and foreign affairs specialists. Decision-makers at the highest levels in Arab countries should review the constraints to concluding effective and fair agreements on sharing and managing trans-boundary water resources and take steps to provide the country's water professionals the mandate as well as the administrative and financial resources needed to draft and execute such agreements.

### **WATER GOVERNANCE**

The development of the water sector in Arab countries has been associated with a weak water governance structure. Large public water sectors, subsidies, and unhelpful political economies have conspired to limit public voice, accountability, and participation. This is reflected in inequitable allocation, wasteful use, increasing pollution trends, lack of transparency, and inefficient water services. Although water user associations (WUA) have been established in a number of countries as a form of participatory irrigation management, adequate legal mandates to support and empower their mission are still

lacking or slow in the making. This despite the evidence that WUAs do contribute to a more efficient sector including improved collection of charges for infrastructure, operation, maintenance, and use.

Most public sector organizations in Arab countries (serving both irrigation and urban water supply needs) do not function properly and have been unable to serve their customers efficiently. Responsibility for managing water and water services is dispersed across multiple institutions, which rarely coordinate among themselves. Decision-making processes take top-down direction with absent or ineffective stakeholders' participation. Information is hardly shared between policy makers and authorities charged with implementation or between governmental and non-governmental actors. Apart from efficiency concerns, there are serious equity problems with current water practices, with the poor, women, and children suffering the most. Moreover, the water sector in the region has not recognized that many of the decisions governing its performance are made outside the sector.

Good governance should be seen as a vehicle to improve water resources management. Arab policy-makers should put in place institutional processes to permit all communities of water users and beneficiaries to participate in water decision-making as well as management. Public sector reforms need to be introduced to increase decentralization and promote the transfer of responsibility and authority to local user groups. More effective institution-strengthening measures and legal frameworks are needed to expand public-private partnership (PPP) capacity, while managing risks and social equity.

### **REMOTE SENSING: GENERATING KNOWLEDGE ABOUT GROUNDWATER**

Most Arab countries rely significantly on groundwater to meet human consumption needs and irrigation water demand. And yet, groundwater resources have not been fully mapped across the Arab world. Where productive aquifers are known to exist, over-drilling and over-pumping threaten the sustainability of the resource. Improving knowledge about groundwater resources is a necessary pre-condition for determining safe extraction rates, establishing equitable shares among competing users, and managing them sustainably, as well as for locating new water accumulation below the surface.

Arab governments should undertake studies to explore new groundwater basins and to monitor the condition of actively mined aquifers. Various remote sensing technologies via satellite imaging and analysis can provide investigators with valuable information about potential groundwater formations. Arab policy-makers should increase their capacity to utilize this knowledge to answer questions about the boundaries of each groundwater basin, the depth of aquifers, levels of salinity, the quantity of water stored, and sustainable pumping rates. Changes in these parameters over time and space should be monitored and updated using database systems that can be shared with water users.

Proper management of groundwater resources is data intensive. Acquired knowledge via remote sensing can significantly assist water planners identify potentially new groundwater basins as well as develop policies for their wise use and sustainable management.

## CONCLUDING REMARKS

The Arab world is already witnessing a water crisis. Comprehensive and sustained water policy reforms are still lacking. Can the trend in deteriorating water quantity and quality be stopped or better yet reversed? Can an impending, or rather present water crisis be averted?

Contributors to this report have pointed to policy and institutional reforms underway in some Arab countries. These reforms, however, are in their infancy and it will take a number of years before their outcomes materialize. Abu Dhabi has recently commissioned the preparation of a Water Resources Master Plan to introduce reforms and guide a strategy for integrated management of the Emirate's water resources. The Dubai-based Arab Water Academy is leading inspiring efforts to redefine the development of human capital and institutional capacity in Arab countries. Morocco and Yemen are the first countries in the Arab world to prepare comprehensive water laws. Water user associations are now established in Egypt, Jordan, Libya, Morocco, Oman, Tunisia, and Yemen. In some countries, the private sector is making strident contributions in water services provision. Tunisia and Jordan have made remarkable progress in wastewater treatment and reuse. Traditional water management systems, such as the Aflaj in Oman, have been uniquely successful in instituting effective water governance systems based on customary arrangements. Universities and regional water research centers are becoming more committed to conducting high quality research to develop and strengthen the region's adaptive capacity.

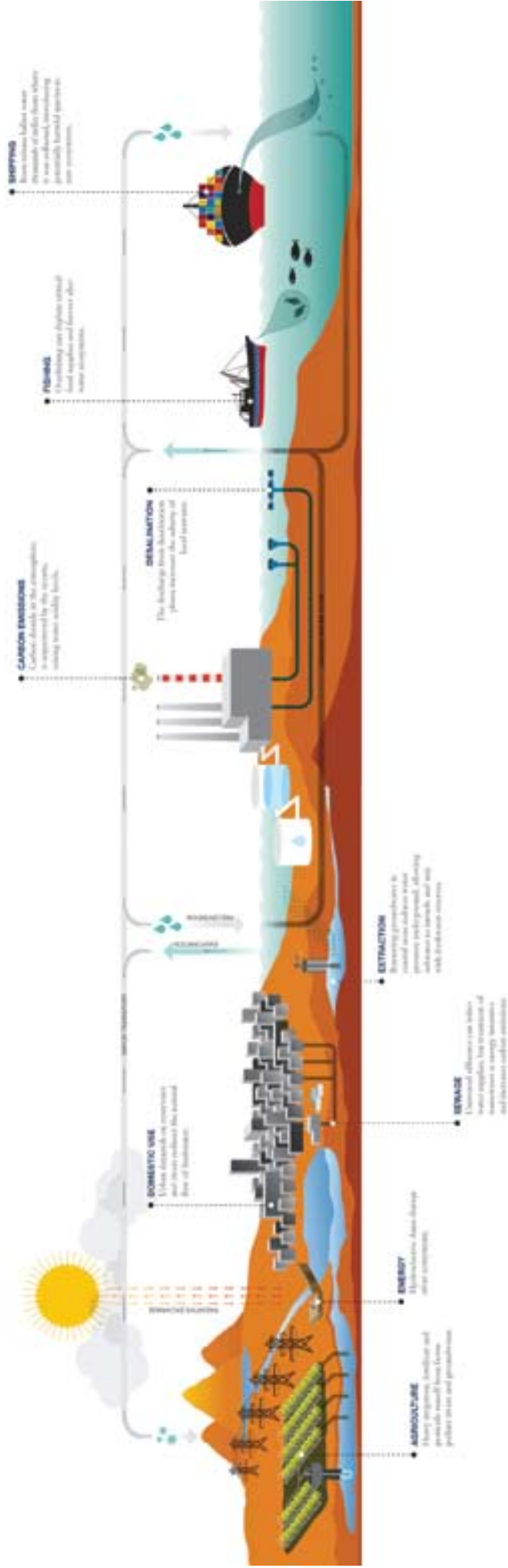
Despite these positive efforts, Arab countries are slow in adopting more far-reaching water reforms. Water tariffs remain below cost and irrigation efficiency is stubbornly low. Underground water aquifers are being over-exploited and freshwater ecosystems are being destroyed. Pollution of water calls for serious remedies. Some Arab countries still boast the highest annual per capita water consumption rates in the world. Arab governments' growing investments in tourism, raw materials extraction, and power, to name a few sectors, do not bode well for the future of water in the region.

Given the severity of water strains, it is difficult to pin hopes on partial solutions. Public-private partnerships cannot succeed if current water pricing structures remain unaltered. Water user associations cannot succeed if legal protection is not accorded. Water use efficiency will not improve if across-the-board subsidies are not removed or significantly reduced. Wastewater treatment plants cannot be effective if industries continue to discharge their waste streams untreated. Are these reform efforts then a case of too little, too late? It does not have to be so if Arab leaders make a commitment to launching and sustaining a genuine and comprehensive policy reform effort. The starting point for transformation rests with commitment and action at the highest political level.

This report makes the case for reforms in the water sector and suggests specific recommendations for changing water policies and practices, together with sustained education and public awareness programs. It is no secret that change is not easy and entails taking risks. Political pressure will ensue by those with entrenched interests who stand to be affected by removing subsidies and charging rational water tariffs. Water reforms require bold leadership and firm action for the sake of a sustainable water future filled with hope for current and future generations.

### 6.5 Billion Drops in the Bucket

The hydrologic cycle has moved water around the world for thousands of years. But man's increasing interaction with that cycle has added several layers of complexity and consequence. Though the total amount of water on the planet will never change, each interaction with it potentially changes its direction, chemistry, usefulness or availability for some amount of time. All 6.5 billion people on Earth contribute to those changes.



Source: WATER, IBM, 2009

# Water Sector Overview

SHAWKI BARGHOUTI



## I. INTRODUCTION

The water sector in the Arab countries is facing several challenges. This sector is receiving increasing attention among policy makers and development agencies in the region. For example, the World Bank devoted its regional development report of the Middle East in 2007 to the water sector (World Bank, 2007). The Islamic Development Bank (IDB) commissioned a special report on water in the member countries to mark its 30th anniversary (IDB, 2005). The United Nations Development Program (UNDP) Arab Human Development Report for 2009 devoted a special chapter to issues related to water and environmental security in the region (UNDP, 2009). This chapter draws substantially on issues and data presented in these three reports.

Available renewable water resources per capita in the Arab world are among the lowest in the world. Expanding economic growth and burgeoning populations in the region will intensify the effects of water scarcity. To meet increasing demands for domestic, agricultural, and industrial water uses, underground water aquifers are being pumped at rates exceeding their replenishment limits. This raises serious questions about the future viability and integrity of these renewable water systems. Compounding these issues, millions in the Arab world still lack access to clean water and safe sanitation. The severity of water shortages is forcing many countries in the region to augment conventional surface and sub-surface water resources by investing in more expensive, less favorable water

systems and non-conventional water sources. These sources include seawater desalination, wastewater treatment for reuse, and tapping non-renewable water supplies from deep aquifers.

Water policies and strategies promoted by government programs as well as by international and bilateral development agencies have focused on the following issues: options for comprehensive management of water as an integrated ecological resource; policies, rules, and regulations to address the public good dimension of water particularly as resources are declining in both quantity and quality; the institutional framework for efficient implementation and monitoring of these policies and regulations; the economic role of water in increasing agricultural productivity and food security; impact on the poor; management of water supplies, demands, and allocation among various users within an integrated and participatory approach; water pricing and financing; sustainable management of water utilities; water rights; river basin planning; and international cooperation.

This chapter will address a selection of these issues and their implications on the performance of the water sector in the Arab world. Furthermore, the chapter will discuss the multi-dimensional role of water in economic development, protecting the environment, driving social development, and safeguarding health and hygiene. The chapter will also highlight factors affecting the provision of water services to millions of households, especially the poor, to improve their quality of life.

FIGURE 1 ACTUAL RENEWABLE FRESHWATER RESOURCES PER CAPITA, BY REGION

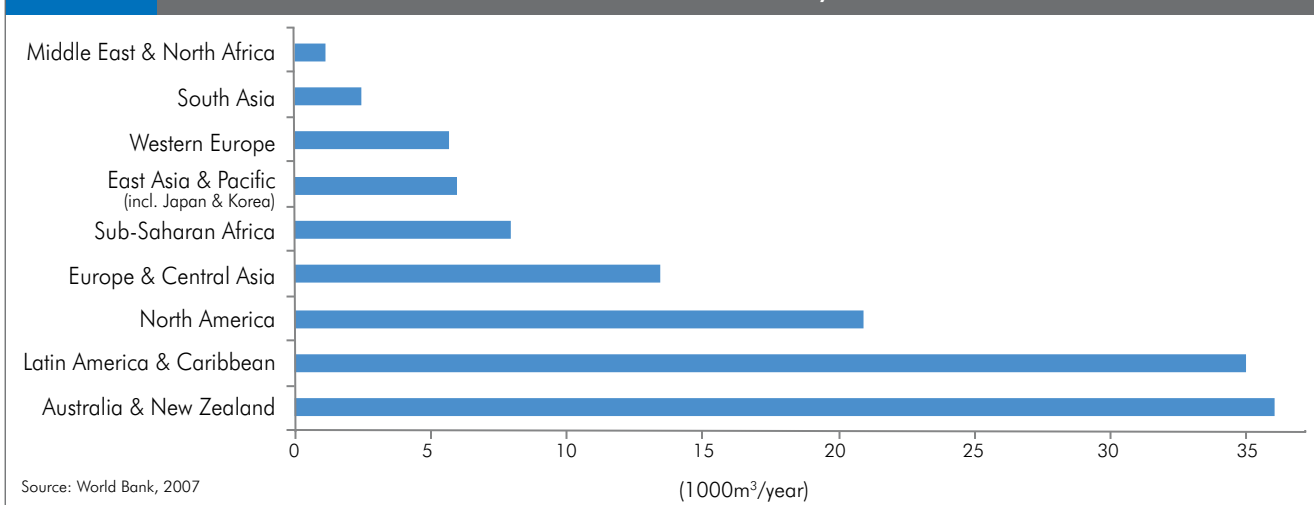




TABLE 1 WATER AVAILABILITY AND USAGE IN ARAB COUNTRIES

Country	Annual Availability					Annual Water Usage		% Use by Sector			
	Natural Renewable Resource Bm <sup>3</sup> /year	Desalinated End Water Bm <sup>3</sup> /year	Wastewater Reuse Bm <sup>3</sup> /year	Per Capita Renewable Availability m <sup>3</sup> (2006)*	2015** (AFED) m <sup>3</sup>	2025** (AFED) m <sup>3</sup>	Bm <sup>3</sup>	As a % of Total Water Resources	Domestic	Industry	Agriculture
Algeria	11.50	0.07	Neg.	350	297	261	4.59	40	25	15	60
Bahrain	0.11	0.14	Neg.	157	125	106	0.25	170	26	3	71
Djibouti	0.02	0.00	Neg.	367	306	260	0.02	113	88	0	12
Egypt	61.90	0.06	5.90	773	641	552	73.10	108	6	8	86
Iraq	80.00	0.03	n.a.	2652	1989	1551	42.80	48	3	5	92
Jordan	0.87	0.00	0.07	164	114	98	0.98	104	26	7	68
Kuwait	0.11	0.65	0.12	7	5	4	0.76	87	37	2	60
Lebanon	3.20	0.00	n.a.	1110	999	919	1.29	40	28	4	68
Libya	0.80	0.03	n.a.	99	80	67	3.89	469	9	4	87
Morocco	20.00	0.02	0.07	940	620	558	16.84	84	5	-	95
Oman	1.60	0.12	0.02	550	440	365	1.22	74	9	1	93
Qatar	0.05	0.12	n.a.	71	50	40	0.28	n.a.	23	3	74
Saudi Arabia	2.50	2.28	0.15	96	77	64	17.00	506	15	1	84
Sudan	24.00	0.00	0.00	1711	1369	1122	19.00	5	6	5	89
Syria	18.70	0.00	0.26	865	650	550	14.70	78	9	1	87
Tunisia	3.35	0.00	0.14	450	405	373	2.53	72	12	4	84
UAE	0.20	0.95	0.14	35	26	20	1.60	180	24	10	67
West Bank & Gaza	0.76	0.00	0.01	215	160	120	0.44	57	51	49	58
Yemen	2.50	0.02	0.03	97	70	50	3.20	126	5	2	93

Source: World Bank, 2003  
(Figures collected in 2002-2003)

Neg: negligible volume of used water  
n.a.: Not available

\* Total Actual Renewable Water Resources (TARWR) per capita figures from World Water Development Reports 2 (2006) and 3 (2009), UNESCO. TARWR tables are based on AQUASTAT FAO. Index web-update site accessed on 19 July 2010. [http://www.unesco.org/water/wwap/wwdr/indicators/pdf/Table\\_4.3\\_Updated.pdf](http://www.unesco.org/water/wwap/wwdr/indicators/pdf/Table_4.3_Updated.pdf)

\*\* 2015 and 2025 projections developed by AFED, based on actual changes between 2000-2006, and average projected rate of population growth for each country, as per data of the UN Population Division, published in the World Population Prospects, 2008 revision <http://esa.un.org/unpp/index.asp?panel=2>

The figures are mainly indicative trends because of the different methods and tools used to calculate the aggregate main source of water. The projections take the lower side of population growth in the region, and do not take into account the impact of increase in GDP and other variables which push the demand upward, nor factors such as increasing drought and other climate change impacts which drive water availability downward.

## II. WATER RESOURCES IN THE ARAB WORLD ARE SCARCE AND NEW SOURCES ARE EXPENSIVE

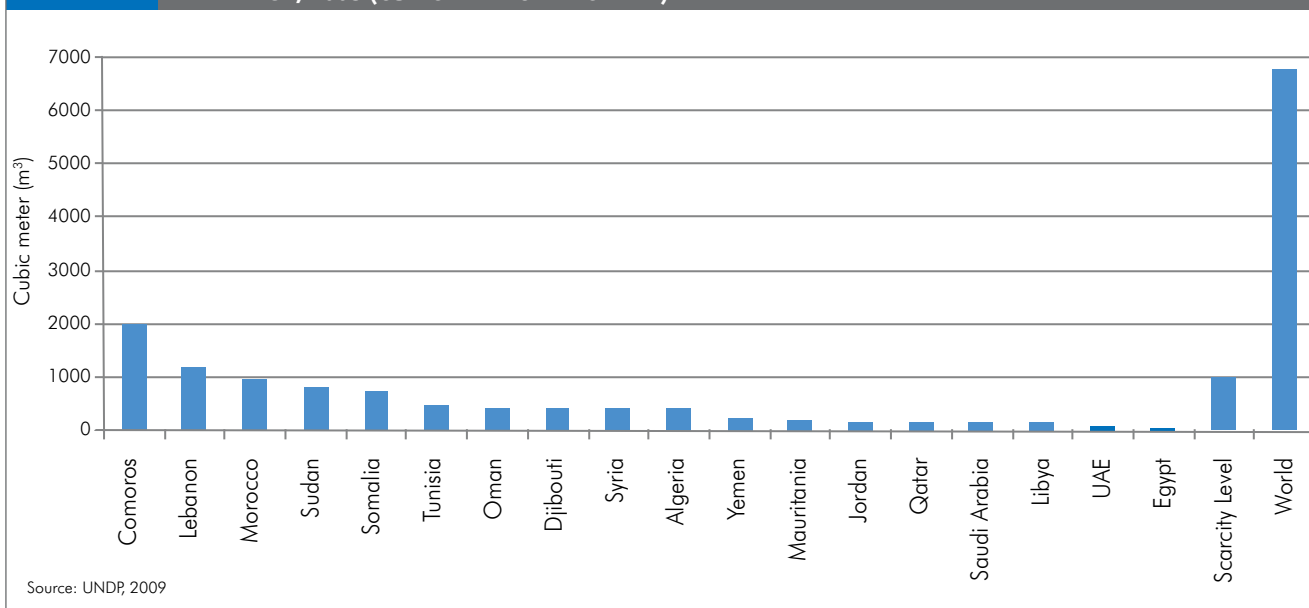
All Arab countries are short of water. A World Bank (2007) report ranks the Arab countries last in renewable freshwater availability per

capita compared to other regions of the world, as shown in Figure 1. High rates of economic growth, rapidly growing populations, and climate change are expected to worsen water shortages in the region.

Table 1 summarizes country data for water

FIGURE 2

## ARAB INTERNAL FRESHWATER RESOURCES ARE OFTEN BELOW SCARCITY LEVELS AND THE WORLD AVERAGE, 2005 (CUBIC METERS PER CAPITA)



availability by source and water usage by sector (domestic, industry, agriculture). In some countries, total water withdrawals exceed available renewable water resources. In fact, per capita internal renewable freshwater resources in most Arab countries are already below the water scarcity level, as illustrated in Figure 2.

Because most countries in the region have limited renewable water resources and their populations are growing fast, water conditions will be particularly severe. Table 2 indicates

that water withdrawal in several Arab countries has increased between the year 1985 and 2000 by about 50 percent. In the same period, the population of these countries increased by 40 percent. This trend is likely to be observed in most Arab countries in the years ahead. The challenges facing these countries are likely to intensify as economic growth continues to increase and water demand rises in crowded urban centers.

Public agencies are being pressured to improve

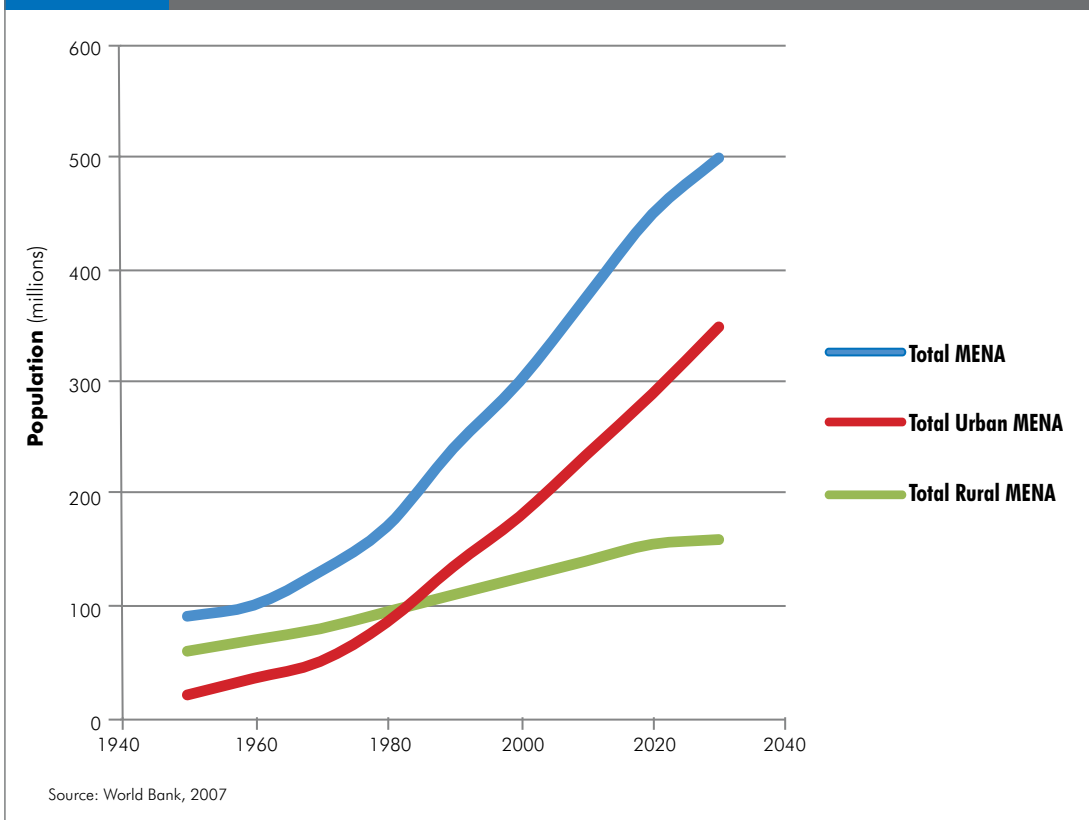
TABLE 2

## INCREASE IN WATER DEMAND IN SELECTED ARAB COUNTRIES

Country	Population 1985 (million)	Population 2000 (million)	Total Water Withdrawals 1985 (10 <sup>9</sup> m <sup>3</sup> )	Total Water Withdrawals 2000 (10 <sup>9</sup> m <sup>3</sup> )
Tunisia	7.10	9.56	2.48	2.70
Algeria	21.86	30.46	3.50	6.07
Libya	3.60	5.31	2.83	4.27
Morocco	22.10	27.84	11.00	12.61
Egypt	46.70	67.29	52.90	68.30
Syria	10.48	16.81	7.01	19.90
Lebanon	2.67	3.40	0.85	1.40
Total	114.51	160.67	77.57	115.88
% Change		40% increase in population		51% increase in water consumption

Source: Plan Bleu/UNEP Database, 2005

FIGURE 3 MORE PEOPLE WILL LIVE IN URBAN AREAS



the delivery of safe and clean water to the burgeoning rural and urban populations. The growth in population in the coming two decades, 90 percent of which will occur in urban areas, will increase the political pressure to meet these demands especially for domestic and industrial use. As Figure 3 indicates, by 2030 more people in the Arab world will live in cities. The total population of the Arab world will exceed that of Europe with only a fraction of the water resources available to the population of Europe.

Several countries in the region have allocated substantial resources for the development and management of water supplies, clean sanitation, and irrigation contributing to significant levels of economic growth and poverty reduction. The economic benefits of expanding irrigation have been shared by millions of small and poor farmers in most Arab countries.

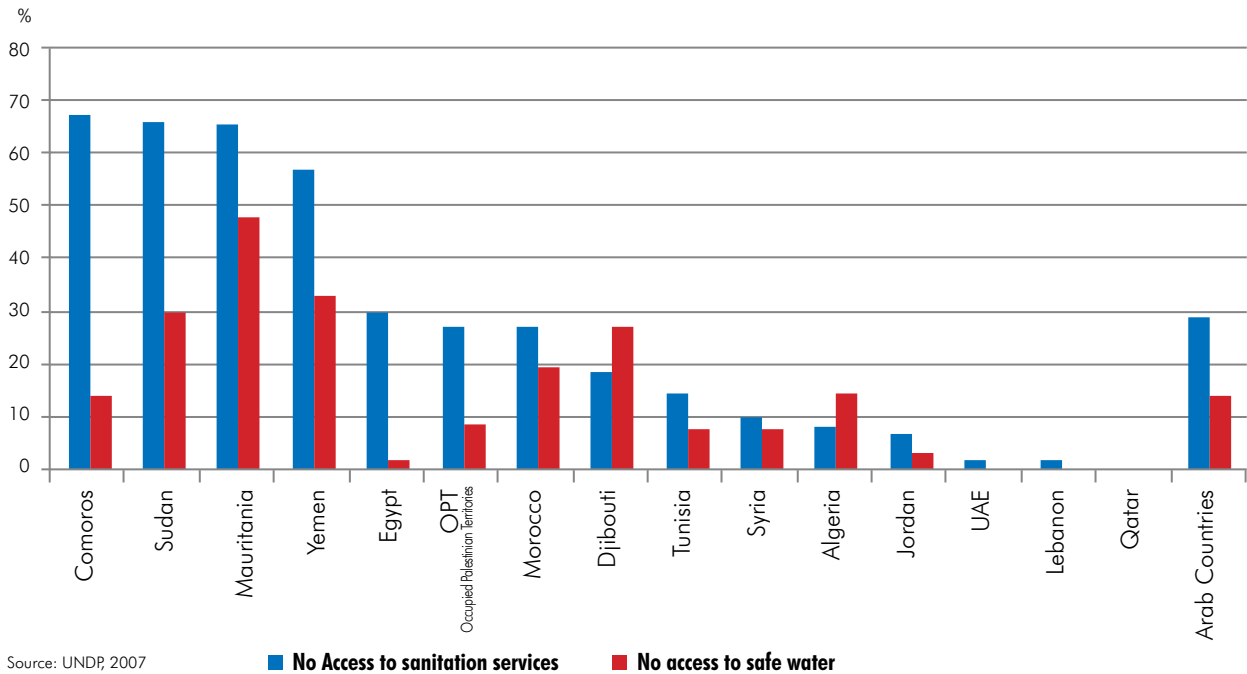
However, more than 45 million people in the Arab world still lack access to clean water or safe sanitation (UNDP, 2009), as Figure 4 indicates. Moreover, in most Arab countries, a large



portion of the water supply is not accounted for. Many cities in several Arab countries are 'leaking buckets'. The poor bear the disproportionate share of the impact of inefficient water and sanitation services. Fewer poor people are connected to piped water supply. When they do have access, the installation has to be shared among many more people. The poor in most

FIGURE 4

## PERCENTAGE OF POPULATION WITHOUT ACCESS TO SAFE WATER AND SANITATION SERVICES, 15 ARAB COUNTRIES, 2007



Source: UNDP, 2007

Arab cities pay high prices for water supply, generally more than those paid by more affluent households connected to the piped system (World Bank, 2007).<sup>1</sup>

The task of achieving universal coverage of water supply and sanitation is becoming more challenging because several Arab countries are experiencing tight financial control over public budgets (World Bank, 2007). The service institutions are extended beyond available technical and financial resources. They can hardly sustain efficient services to the current populations, which are growing at 2-3% annually. Most of this growth is adding pressure on already crowded and inadequately serviced cities and towns.

Several Arab countries are trying different approaches to addressing failing water and sanitation services to poor communities. Some undertake to improve services overall, on the premise that making services work for all is necessary for making them work for the poor (IDB, 2005). Some governments, especially in North Africa and the GCC countries, are inviting the private sector to assist in this effort. The results are not always successful. Governments

worldwide deem it their responsibility to provide, finance, regulate, and build water infrastructure. They do it for two good reasons, namely, market failures and equity concern (World Bank, 1993). Several countries in the region are advancing the decentralization of water services to local governments, town councils, and communities. This process is in its early stages, and more is needed to strengthen ownership and accountability of services, especially to poor communities.

Governments tend to address this problem through an incremental project approach narrowly focused but simple to design and implement. Such procedure may allow for urgent terms of engagement for the implementing agencies, and immediate rewards for the benefiting communities. But the long term reliability and sustainability may suffer if such investment is carried out without an integrated development strategy for the water sector.

That is why the economic and financial health of the water sector in these countries is at risk. Much of the investment has been financed through public expenditure and national budgets.<sup>2</sup> The allocation to this sector has been stagnant or

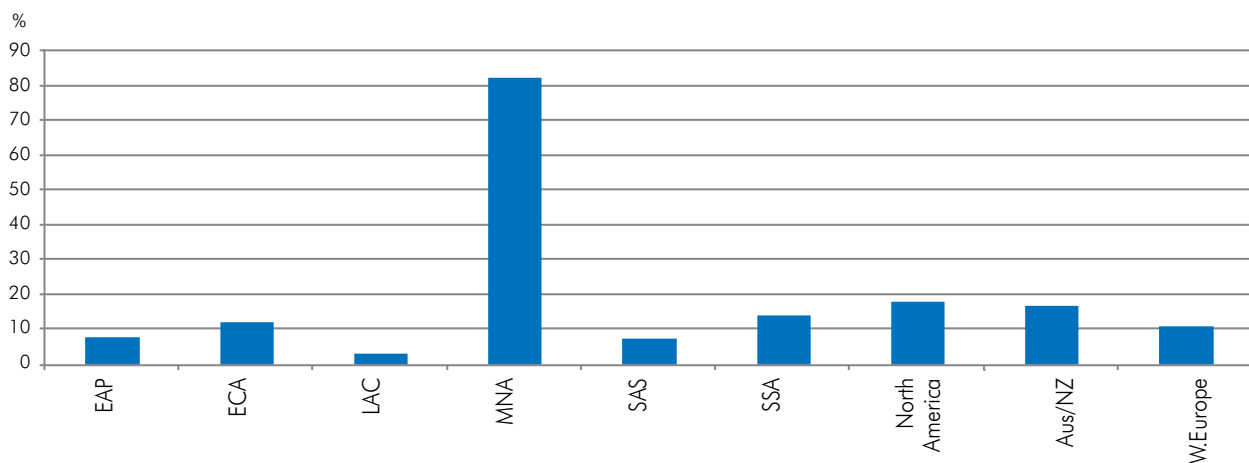
declining (World Bank, 2004a). Allocations of public funds vary by country. Egypt allocates about 10% of its annual budget to the sector and to maintaining its infrastructure, especially the public irrigation systems (World Bank, 2007). It allows for an additional 5% for expansion and development.<sup>3</sup> Kuwait spends about 15% of its annual budget on water subsidies (World Bank, 2004b). A recent study indicates that the United Arab Emirates spends about US\$3.4 billion annually on the water sector (to cover operations and maintenance and investment in new water plants) (World Bank, 2004b). Other member countries of the GCC allocate significant resources to the water sector as they increase investment in desalination and non-conventional sources of water. Yemen and Jordan spend about 9% of their annual budgets on operating and maintaining the services in the irrigation sector (World Bank, 2004b). Data on water supply and sanitation are not available because budget allocations are largely distributed among local governorates and city councils. The figures from other countries are not available because little has been done to review and assess public expenditure especially as related to delivering services to the poor.<sup>4</sup>

The increasing financial burden can be addressed through realistic institutional reform that can improve the efficiency of services and strengthen partnerships with water users. The search for alternative sources of funding should include contribution by water users,

the empowerment of the beneficiaries, and carefully debated partnership options with the private sector. Another dimension relates to the growing concern for better management of shared international water ways. The bulk of water resources, both surface and groundwater, are shared among different riparian countries. Equitable sharing has become a major concern to reduce possible conflicts over disputed water rights, prompting calls for efficient cooperative utilization and joint investment throughout the river basin. The financial requirements needed to achieve this goal are beyond the available resources in many countries in the region (World Bank, 1999).

Current and future water scarcity problems in fourteen Arab countries<sup>5</sup> are so serious that immediate action is needed on multiple fronts: addressing the growing water needs of burgeoning populations, increasing investment in water infrastructure, articulating policy options for equitable and efficient water allocation among various users, investing in new technologies to improve water efficiency in agriculture, and augmenting existing water resources from non-conventional sources. Non-conventional sources include the expansion of seawater desalination as well as utilizing properly treated wastewater and low quality water in agriculture. Many Arab countries are using saline water for irrigation and investing in the recycling and reuse of drainage water for agriculture. These non-conventional sources are likely to play an increasingly larger

FIGURE 5 PROPORTION OF REGIONAL FRESHWATER RESOURCES STORED IN RESERVOIRS <sup>6</sup>



EAP: East Asia & Pacific, ECA: Europe & Central Asia, LAC: Latin America & Caribbean, MNA: Middle East & North Africa, SAS: South Asia, SSA: Sub-Saharan Africa.

Source: World Bank, 2007

role in balancing water demand and supply in the years ahead.

### III. INCREASING COST OF DEVELOPING NEW WATER RESOURCES

For all Arab countries, new water resources are expensive to exploit. Most available water resources have been developed (World Bank, 2007). As Figure 5 indicates, more than 80 percent of all surface water resources in the Arab world have been stored in reservoirs (World Bank, 2007).

Most suitable and accessible fresh water sources have already been developed and the cost of building new dams and storage reservoirs continues to increase rapidly. The mounting opposition from environmentalists and non-government organizations has negatively influenced the support of international development agencies for financing new dams or reservoirs. The rising cost of new dams combined with increased deterioration and sedimentation of existing reservoirs mean net water storage is stagnant or declining in many countries (World Bank, 2004a). Governments do not have the resources to invest in building new water storage facilities. Over-drafting of groundwater resources has intensified in most Arab countries. The declining water tables make the extraction cost too high.

This situation confirms that there are limited and expensive opportunities to utilize additional water resources in the region. Instead, governments have allowed for expanded exploitation of groundwater resources to meet the growing demands for water, at high pumping and transport cost, especially in the burgeoning urban centers and in crowded cities in the region. Some countries are expanding investment in desalination of seawater and in wastewater treatment and reuse.

As a result, the pressure to reallocate water among different users is likely to intensify in the next decade. Since irrigated agriculture is the main user of these scarce resources, pressure is mounting in several countries in the region to adjust water allocation to agriculture. The justification is to meet the growing demands of

the increasing population, satisfy the expanding urban centers, and supply new industries with water (UNDP, 2009). In addition, more water would have to be allocated to ecosystems restoration to maintain their ability to provide environmental services sustainably.

In both urban and rural communities, serious political, economic, and social dimensions are shaping the debate on water allocation. The pressure to satisfy immediate demands may result in hurried reallocation decisions with little attention to the long-term implications on society in both social and economic terms. The debate is intense in Jordan, Yemen, and the GCC countries regarding the justification for allocating significant quantities of water to the agricultural sector despite the fact that the contribution of this sector to national economic growth is diminishing (UNDP, 2009).

According to a World Bank (2007) report, urbanization and industrialization will also increase the demand for energy and hydropower. These developments pose great challenges for governments in their effort to better manage water resources without increasing carbon emissions. The challenges for water supply and sanitation will also need to meet the backlog of demands while meeting the needs of growing populations with rising incomes. There are now increasing demands for expanding sanitation and additional treatment of wastewater. But the existing systems of urban water supply and sanitation in many countries already fail to provide adequate services, and the problems posed by urban pollution are likely to grow (World Bank, 2007). To adequately address these challenges, these countries need to articulate new water policies, invest more in managing the water sector, and develop new approaches and efficient institutional frameworks for better water management and allocation.

A recent study estimated the average tariff charged by water utilities in many cities in the region will increase. In Amman, Jordan, for example, the average incremental cost of water rose from \$0.41 per cubic meter during the 1980s to \$1.33 per cubic meter in the 1990s, as a result of groundwater shortages (Rosegrant et al., 2002a). Similar trends have been reported about the cost of new irrigation systems in

## SALT TOLERANT CROPS

### Shoaib Ismail

Salinity has been critical in affecting agricultural productivity over the past decade. Salinity affects plant growth, particularly in irrigated land where one third of the world's food is produced. Because it contains dissolved salts, irrigation water accelerates and exacerbates soil salinization significantly.

Soil salinization is likely to get worse because of the anticipated reduction in water availability and deterioration in water quality. UN estimates show that globally every minute three hectares of arable land are lost due to salinity. Salinization is caused primarily by the mis-management of irrigation systems. Irrational water use to obtain higher productivity has led to the accumulation of salts, rise in groundwater, and compaction of soil. Open or flood irrigation systems practiced generally for all crops without proper management has resulted in land degradation.

Many crops developed early on for their higher productivity fail to respond under changing salinity conditions. Attempts have been made to develop new crops that are more tolerant to salinity and/or to identify crops that can be adapted to more severe salinity conditions. The latter requires alterations in agronomic practices to optimize production. Technologies to develop new crops range from classical breeding programs to biotechnology methods and gene transfers. However, for many crops (glycophytes) the extent to which the limits of salt tolerance can be extended has reached its maximum limit. Major breakthroughs will only take place by means of a significant change in the genetic make-up of existing crops or through natural selection for new highly salt-tolerant crops/plants (and halophytes). However, not only do crops have to be improved, but the integrated management of resources (soil and water) also has to be adopted for a more sustainable form of agriculture. Use of modern irrigation methods like drip and sprinkler needs to be compatible with the type of production system(s) in order to ensure better water use, availability of water in the rhizosphere, and the prevention of salt built-up in the soil.

During the last few years many salt tolerant crops and vegetables have been developed for cultivation in saline (soil and water) conditions. In addition, significant work has been done on different production systems, e.g., forage, fuel, horticulture, and landscaping, that are tolerant to irrigation with moderate to highly saline water



(total dissolved solids of 7,000-17,000 ppm). The list of plant species/cultivars accessions is extensive and many are related to specific site(s), climate, soil, and water conditions. Many new production systems have been introduced and adapted from the Central Asia and Caucasus region to the Middle East and North Africa region that have been adapted for scaling-up.

There also exists potential to develop crops adapted to the highest salinity levels (sea water salinity) as well where few production systems can be sustainable. Mangroves have been known not only to protect coastal areas, but to provide an ecosystem for marine production. High quality oil can be extracted from *Salicornia* spp., which also has a high commercial value as a vegetable. *Distichlis* spp., which has grain, forage, and landscaping value, can be grown in seawater.

In addition to improved crop yields of these alternative production systems, there are environmental benefits to be gained because many of these adapted agricultural systems can significantly improve the micro- and macro-environment, leading to better soil and water conditions

In summary, the need for improved tolerance to salinity will increase in coming years due to limited land and water resources. Therefore, improved crop varieties and other salt tolerant plants have to be introduced into production systems, whether through natural selection or modern technologies. The search for improved crops and adapted production systems need to be continuous and evolving as will be demanded by changes in soil, water, and climate conditions.

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several Arab countries. The real cost of irrigation have been rising over the past 3 decades, resulting in “low rates of economic return for new irrigation construction” (Rosegrant et al., 2002a). The high costs have been caused by storage construction needed to regulate river flows, severe climate variability requiring high irrigation duties, expensive flood control schemes, construction in remote locations requiring high transportation costs, and basic infrastructure (World Bank, 2006).

Despite the rising cost of developing new water resources, many governments still prefer expanding water supplies, which has led to investment in infrastructure that could have been avoided or postponed. Water users in the Arab world often pay little for their publicly supplied irrigation water (World Bank, 2007). They have few incentives to refrain from growing water-intensive crops or to conserve water. In some arid areas, water prices are so low that it is attractive to grow low value crops. Similarly, many towns and cities charge fees that provide no incentive to conserve water. A recent review by the World Bank (2007) of municipal water supply projects found that the price charged for water covers only about 35 percent of the average cost of supply, and charges in many irrigation systems are much less (World Bank, 2006). The benefits of this cheap water go largely to the middle class and the rich. The poor usually depend on water vendors, and may pay many times more for water than the well-off who usually enjoy piped water. It is therefore believed that cross-subsidies whereby higher-income customers cover part of the cost of serving the poor can be achieved by incorporating a ‘progressive tariff schedule’, but in practice subsidies are often poorly targeted (Rosegrant et al., 2002b).

#### **IV. DEEP GROUNDWATER ABSTRACTION HAS EXHAUSTED STRATEGIC WATER RESERVES**

With the spread of energized pumping in many Arab countries, deep groundwater extraction has increased exponentially to irrigate land and to provide drinking water for the millions of rural communities which are not connected to national water carriers. The expansion of pumping technology has often resulted in dramatic declines

in the water table in areas of low or zero recharge (World Bank, 1999). Great improvements have been made in the methods of drilling in recent years, thanks largely to technology developed by the petroleum industry. Powerful pumps enable users to draw large volumes of water via deep boreholes, thus affecting the water table beyond the confines of their property and depleting distant wells formerly considered to lie safely beyond the drilled zone (World Bank, 1999).

Many countries have recognized this problem and introduced regulations for exploiting groundwater. But the implementation of these regulations is lacking as groundwater, like surface water, is a fluid that recognizes no national boundaries. Conflict is common over groundwater use among both private owners and among nations sharing water aquifers. Criteria for establishing rights and equity in sharing groundwater resources are not adequately well defined in many countries or among countries (World Bank, 1999). Where groundwater flows naturally from one state to another, cooperation is needed in areas such as the exchange of information and data required to better monitor and manage both water quality and quantity. Especially important is the sharing of information on water recharge, and other changes in water tables in order to coordinate and adjust withdrawal rates among the riparian owners or states (Grey and Sadoff, 2003).

Yemen, for example, has expanded abstraction of groundwater with the widespread adoption of tube well technology to better deliver groundwater for agriculture and household use. The groundwater is being pumped at a rate approximately four times more than that of natural recharge (World Bank, 2007). As a result, some productive valleys are experiencing drastic shortage of water and are consequently being abandoned. Conflict over groundwater sharing and allocation is spreading among competing users. Overexploitation of underground water resources is the result of a decentralized process of drilling wells without adherence to a national water plan. Such a plan would have required careful monitoring, data gathering, and regulations to control drilling and define priorities for water use and allocation. Yemen is now preparing, with the assistance of several donors, a comprehensive water resources management plan, which would provide some



guidelines to regulate the process of groundwater use and allocation.

A large percentage of the overall water supply in the GCC countries comes from groundwater resources, mostly non-renewable in nature. Only in Oman does renewable groundwater represent a significant portion of the water supplies used for domestic and industrial purposes. The water is derived from deep aquifers located in Saudi Arabia and Oman. The fossil water in these aquifers was deposited in these formations millions of years ago. Although the GCC countries continue to use modeling tools extensively, the volume of water stored in these aquifers is largely undetermined. These reserves contain large but unknown volumes of brackish water, and the depth of usable water exceeds 500 meters. There are no tariffs on groundwater abstraction in GCC countries, which has led to the cultivation of low value crops such as grains, and high water consuming crops such as alfalfa and green forage for livestock and dairy production.

The over-extraction of groundwater beyond safe yield levels has resulted in the pollution of existing groundwater aquifers, due to intrusion of saline seawater and the up-coming of brackish and saline water supplies from lower aquifers. This is particularly serious in Libya, Jordan, Yemen, Oman, Bahrain, the UAE, and Qatar where deterioration of groundwater quality has been observed and measured over the last few years (World Bank, 2007). Recovery of the aquifers, even with the introduction of appropriate measures, may take generations. The responsibility of the public water agencies is to ensure that these resources are better protected and sustainably managed for future generations. But available technical skills are limited, and the enabling policy environment is largely restricted. The expansion in, and unrestricted use of, non-renewable groundwater supplies in many countries demonstrate the impact of inadequate policies and misguided investment in this sector. The absence of a strategic national water framework to protect non-renewable water supplies is driving many Arab countries to waste precious water resources on activities, such as cultivating low value crops, which have not received adequate economic or environmental assessment and evaluation.

This situation could be addressed through carefully developed and articulated integrated water management approaches specifically designed to change the way groundwater is being abstracted and used. This requires an appreciation that groundwater is part of the integrated water cycle in the country including both surface river basins and below ground water flow networks. This recognition is essential to harmonize water use for high priority social and economic objectives, within a framework that also considers the water needs of future generations. Efficient management of groundwater resources recognizes that some of the tapped aquifers are connected with the national hydrological network, and that they may also be recharged by the irrigation networks distributing surface water to the fields. As such, managing groundwater becomes an integral part of a national water plan.

In Jordan, for example, the public water agency has recognized the important fact that aquifers systems and sub systems are intimately connected with portions of the overall hydrological system in the country, and that the patterns of groundwater use are usually interconnected and often sequential. The government has consequently introduced a new policy framework to regulate and manage the groundwater subsector. The average annual abstraction from groundwater in all sub basins in Jordan is about 160% of the annual renewable average of recharge (World Bank, 2007). The recently enacted national water policy is being supported with tough regulations. It prevents the issuing of new licenses for new wells or the renewal of existing licenses, imposes full control on water drilling throughout the country, and permits only hospitals and educational institutions to renew their license to abstract groundwater. About 90 percent of all wells are equipped with meters to enforce new volumetric water pricing on abstracted groundwater. Also included in the new framework is a new mechanism designed to regularly monitor the status of groundwater resource through observation wells, and to identify and enforce actions required for water resource protection and quality control (World Bank, 2007).

The new procedures clearly define the development priorities for each sub basin, set

guidelines for water allocation, introduce specific policy tools to install and measure abstraction, and enforce targeted rules to prevent illegal drilling. The policy also provides support for long term research on water quality, on managing shared water aquifers, and on communication and education to the public.

## V. DESALINATION TO PROVIDE DRINKING WATER FOR MILLIONS OF HOUSEHOLDS

The Arabian Peninsula and the GCC countries in particular have historically been faced with extreme shortages of reliable water supplies. The Gulf region is underlain by large deep aquifers which contain non-renewable supplies of fossil water. This source has provided agricultural development in some parts of the Gulf, but has a finite life and quality limitations. Because of these limitations, all of the GCC countries have resorted to desalination of both seawater and brackish water to provide high quality and reliable water supplies to their citizens. Seawater desalination in the Arabian Peninsula has been employed since the 1950s. The process initially used was based on distillation. The scale of operations was usually small. Reverse Osmosis (RO) came on stream in the 1970s, but the technology became commercially well-established in the 1980s.

There are unusual demands on water management in the GCC countries because of the pressure to maintain food security and having to rely on scarce water resource to allocate to agriculture. At the same time these countries are facing rapidly expanding demands for high quality water to support expanding populations and growing industries. Governments have provided subsidies to expand irrigated agriculture. Water resources management in the UAE, Saudi Arabia, and Oman is being reviewed within a well-defined process to modernize water institutions, reform water policies, and improve water technologies (GCC, 2008).

GCC member countries continue to invest in mega seawater desalination plants to provide water supplies for millions of households. Table 3 illustrates the expansion in desalinated water capacity in the GCC countries. Recent reports

predict that annual investments to produce, manage, and operate seawater desalination plants in the Arab world is likely to be between \$15 to \$20 billion in the next decade (GWI, 2010). The bulk of this water is allocated to cities and towns, while groundwater is allocated to agriculture.

According to the Water in the GCC Statistics Book (2008), the total use of desalinated water in the region is estimated to reach four billion cubic meters in 2011. At an average cost of one US dollar per cubic meter of desalinated water, the region spends more than US\$ four billion annually on obtaining water from these sources (GCC, 2008). Three countries, Saudi Arabia, the United Arab Emirates, and Kuwait, are by far the largest users of desalinated water with 77% of total regional capacity, with Saudi Arabia alone accounting for 41% (World Bank, 2004c).

Until the 1960s, desalination plants were expensive and difficult to run. The Multi-Stage Flash (MSF) distillation process has been the workhorse desalination technology in all GCC states. It is the method most widely used on a large scale, but there is still room for improvement by making better use of computer modeling, making use of low grade heat, and extending the plant's life (Rogers and Lyndon, 1994). Because it can utilize low-grade heat, MSF is usually installed as part of a dual-purpose plant, along with a power generation function. MSF has an advantage over reverse osmosis (RO) because it requires less specialized technical expertise and is much more robust. MSF is more suitable for desalinating seawater containing large concentrations (greater than 35,000 parts per million) of total dissolved solids, while RO is more suitable for desalination of brackish water containing between 5,000 and 10,000 ppm of dissolved solids. However, more recently RO systems are increasingly being installed and operated to desalinate seawater on a commercial basis.

The economic analysis for desalination revolves around production cost, price, and affordability of drinking water. The cost can be subdivided into capital cost and production cost. Capital cost is related to capital investment, whereas production cost is composed of the variable items that make possible the running of the desalination plant. The greatest single cost of water desalination is energy, followed closely by

capital cost (Rogers and Lyndon, 1994). Often a 20-year lifespan is assumed for capital, but some MSF plants have been operating satisfactorily in Kuwait for as long as 26 years, because of efficient operations and maintenance.

The private sector has been playing an important role in water desalination in the GCC countries at an annual current investment of about \$3-4 billion annually (GCC, 2008). Many governments in GCC countries see private sector participation as the way forward for managing and operating desalination facilities. The key drivers for private sector participation are increased access to private capital, increased managerial and technological capabilities, increased operational efficiency, and reduced need for subsidies. The criteria for determining the right option for private sector participation in the provision of desalination services are whether capital investment is required, whether assets are to remain publicly owned, to what extent governments want to keep control over operations, and which risks governments want to transfer to the private sector. A set of rules and regulations defining the roles and responsibilities is needed and a transparent process for awarding contracts to service providers needs to be adopted. Where privatization is introduced, it should be managed by a regulatory authority which could be an independent body or a government agency.

## VI. WATER QUALITY AND POLLUTION

The Arab Human Development Report states that “water pollution is now a serious challenge in the region” (UNDP, 2009). The report attributes water pollution to high chemical input use in agriculture as well as to increasing inflows of domestic and industrial wastewater into the water cycle (UNDP, 2009). The lack of clean sanitation to large segments of the population contributes to water pollution by raw sewage. Table 4 shows that the main agricultural countries in the region (Egypt, Algeria, Tunisia, Morocco, and Iraq) are also the main water polluters as indicated by data on the daily emissions of organic water pollutants (UNDP, 2009). Also causing environmental pollution is the increased utilization of seawater desalination.

Water pollution problems are caused by the large volume of desalination plant effluents generated in the Gulf countries and elsewhere. According to a World Bank report (2007), “discharge of hot brine, residual chlorine, trace metals, volatile hydrocarbons, and anti foaming and anti-scaling agents are having an impact on the near-shore marine environment in the Gulf.” The brine produced from seawater desalination process is highly saline. In the UAE, the concentration of total dissolved solids (TDS) in brine can reach 65,000 mg/l (EAD, 2009). This high salinity brine can harm marine life and biodiversity in coastal zones. What magnifies these negative effects is the large number of desalination plants located on the coastal areas of the Gulf into which countries dispose of their brine, causing increased seawater salinity. The Gulf countries flush about 24 tons of chlorine, 65 tons of pipe-cleaning anti-scaling agents, and about 300 kg of copper into the Gulf daily (Alshaer, 2009). The Gulf can be considered as a closed sea where water renewal takes years to replace polluted seawater.

## VII. WATER AND FOOD SECURITY

The dilemma in debating policies related to food self sufficiency involves the conflicting requirements to better conserve water, especially in countries where water scarcity is at the warning level, and at the same time, meet the growing demands for basic food

TABLE 3	DESALINATION CAPACITY OF GCC COUNTRIES (MILLION M <sup>3</sup> /YEAR)		
	Country	1990	2000
Bahrain	75	104	371
Kuwait	318	522	1,662
Oman	55	60	294
Qatar	112	178	941
Saudi Arabia	950	1,278	3,341
UAE	502	1,081	4,878
<b>Total</b>	<b>2,012</b>	<b>3,223</b>	<b>11,487</b>

Source: GCC, 2008 and World Bank, 2005

commodities, especially grains. Food policies require fundamental assessment because of the increasing globalization in agricultural trade associated with the removal of trade barriers and improved access to competitive markets for importing grains (Barghouti et al., 2004). The allocation of substantial and precious amounts of water to produce agricultural commodities that can be imported from water rich or highly subsidized regions should be carefully analyzed. The concept of food security and food self-sufficiency in the current global market needs urgent assessment, because of the implications on the water sector (Lipton, 2004). The trade-offs between achieving food self-sufficiency and sustaining water security in several Arab countries is an important issue which requires careful policy analysis and objective assessment of national priorities. Some governments may treat the importation of grains as acquiring virtual water. Each ton of grain (wheat or barley) would require 2000-3000 cubic meters of water-based on the efficiency of irrigation methods

used (Barker and Molle, 2004). In his analysis of grain production, Khan (2003) presents data which indicate that self sufficiency in cereal production is less than 50 percent in several countries in West Asia and North Africa. Table 5 illustrates the significant volume of virtual water embedded in imported cereals in the Arab countries. The annual grain import in West Asia and North Africa was about 59 million tons in 2000-2001.

The virtual water embedded in imported grain is the equivalent of the annual flow of the Nile and double of the annual flow of the Euphrates (IDB, 2005). More virtual water is imported through other food commodities such as meat. The food gap is likely to increase because of population growth and increased income, which would allow for increased and diversified consumption of agricultural products including high quality small grains and livestock products. Therefore, policy-makers should assess the benefits of various policy options regarding the advantages of importing

TABLE 4

WATER POLLUTION LEVELS FROM ORGANIC POLLUTANTS IN 15 ARAB COUNTRIES AND 2 INDUSTRIALIZED COUNTRIES, 1990-2003 (IN DESCENDING ORDER BASED ON 1990 POLLUTION LEVELS)

COUNTRY	Emission of organic water pollutants (metric tons daily) in 1990	Emission of organic water pollutants (metric tons daily) in 2003	Emission of organic water pollutants (kilograms per worker daily) in 1990	Emission of organic water pollutants (kilograms per worker daily) in 2003
Egypt	211.5	186.1	0.20	0.20
Algeria	107.0	-	0.25	-
Tunisia	44.6	55.8	0.18	0.14
Morocco	41.7	72.1	0.14	0.16
Iraq	26.7	-	0.19	-
Syria	21.7	15.1	0.22	0.20
Saudi Arabia	18.5	-	0.15	-
Kuwait	9.1	11.9	0.16	0.17
Jordan	8.3	23.5	0.19	0.18
Yemen	6.9	15.4	0.27	0.23
UAE	5.6	-	0.14	-
Oman	0.4	5.8	0.11	0.17
Sudan	-	38.6	-	0.29
Lebanon	-	14.9	-	0.19
Libya	-	-	-	-
United States	2562.2	1805.2	0.15	0.13
Russian Federation	1991.3	1388.1	0.13	0.18

Source: World Bank, 2007

food grains. To enhance long-term food security, it is key to develop proper management of grain stocks and storage facilities, rather than invest in developing expensive and scarce water resources to increase food production. It is well-established that the Arab countries are major importers of basic food commodities and only export small quantities of high value crops such as fruit and vegetables. Therefore, there is a need to better study the balance in virtual water between the import and export of agricultural commodities in the Arab countries in order to select efficient production systems, which could assure reasonable return on the investment in valuable and scarce water resources for irrigation.

### VIII. REFORM IN THE WATER SECTOR: BEYOND MANAGING WATER INFRASTRUCTURE AND SERVICES TO MANAGING THE SECTOR

Several Arab countries have, over the last few years, prepared water action plans that highlight the importance of water in equitable economic growth and sustained environmental management. Water resources assessment and the reform of water policies and institutions have been or are underway in Yemen, Jordan, Tunisia, Saudi Arabia, Egypt, and the United Arab Emirates. The main elements endorsed by these new policies include managing national water resources as an integrated system of hydrology and development, introducing decentralization as the basis of managing services, and articulating rules, regulations, and incentives to increase the participation of stakeholders, the private sector, and local communities in water management (World Bank, 2007). Several countries have encouraged local communities to assume more responsibility, authority, and control over improvements and operations of water services and to develop local water resources to meet local needs. Rural communities have also been empowered to address evolving community demands. This partnership would ensure equitable management of water for irrigation and water supply through community action in cooperation with water users and public service institutions.

Most countries are shifting their concern from heavy focus on water infrastructure to better

TABLE 5

#### VIRTUAL WATER IN CEREAL IMPORT IN THE ARAB WORLD, 2000/2001

Region	Cereal imported (000 Metric Ton)	Equivalent in virtual water (billion m <sup>3</sup> )
West Asia	32,368	64,736
North Africa	26,687	53,374

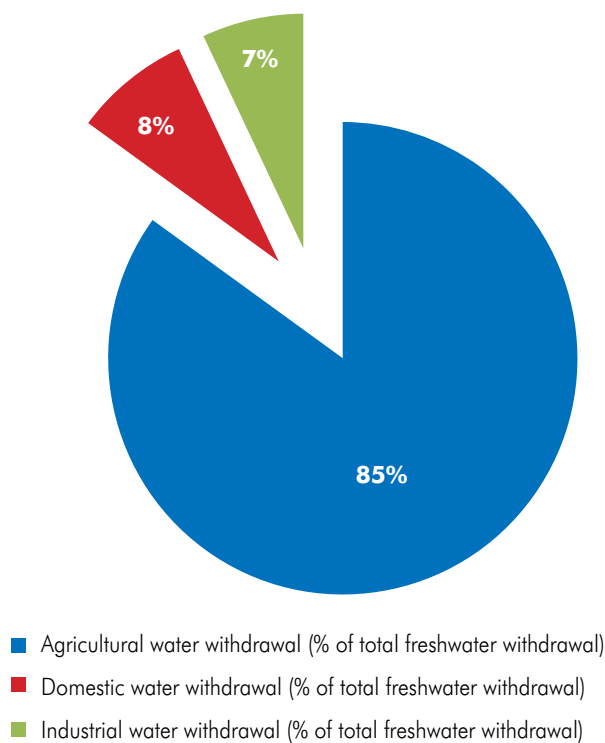
Source: Khan, 2003 and IDB, 2005

management of water resources. The results of this shift are mixed, because intervention in the water sector is a complex process. Some countries face difficulties in articulating clear water policies due to the lack of clear development objectives of the water sector. As mentioned earlier, the water sector can serve several development goals, and they need to be carefully articulated, prioritized, and accompanied by realistic action plans to achieve them. Not all of these objectives are equal. Many countries face difficulties in setting priorities among these objectives. Prioritization should also be supported by reliable performance indicators to measure the results of new policy frameworks. Many countries have been engaged in sector reform, but have not yet articulated field-tested indicators needed to assess the impact of newly recommended policies on the performance of the water sector within national and local settings.

Water issues usually attract the concern of political leaders, both at the national and local levels, especially in times of crises, which are frequent due to repeated droughts and associated water shortages and scarcity in the region. High level public officials in the water sector are frequently engaged in water crises management, thus leaving little time to concentrate on long term strategic planning in partnership with other players from affected sectors. It would be desirable to establish specialized multidisciplinary teams of experts to handle problem solving and crisis management, and devolve responsibilities to the local levels, guided by national strategic goals. Doing so would free public agencies to be strategically focused on policy planning, monitoring, and implementation, especially as related to rules and regulations designed to improve and protect water resources.

Most investment programs and associated

FIGURE 6 WATER CONSUMPTION (%) BY SECTOR IN ARAB COUNTRIES, 1999-2006\*



\*Latest values for all 22 Arab countries

Source: UNDP, 2009

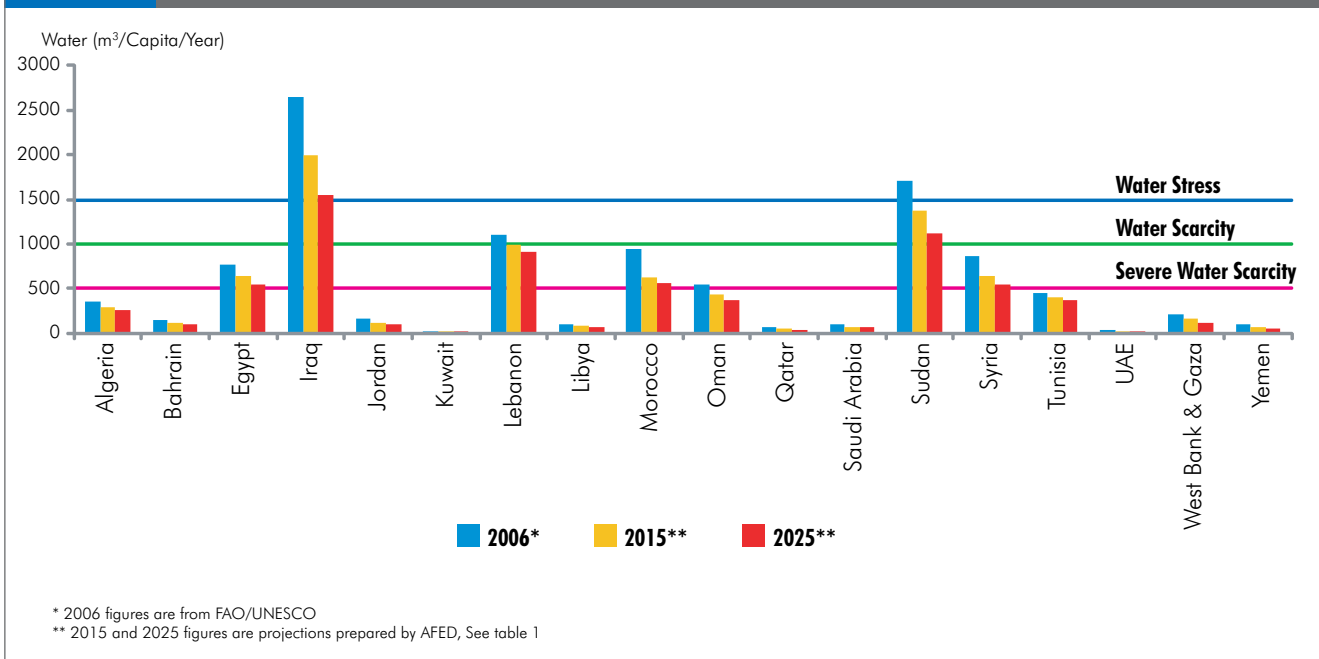
reform packages provide support for institution building and capacity enhancement. The main challenge to overcome is to articulate a comprehensive framework to manage the water sector and to engage major stakeholders, including the private sector and consumers, in the decision-making processes needed to better sustain service provision. Other elements of this approach include a shift in planning from only engineering and construction of new facilities to a more comprehensive planning of the economic, financial, and social needs of the water sector. This shift should be supported by increased reliance on decentralized services and a management system at the local level. The decentralization process should be supported by a clear legal framework. Because most countries do not have centralized national water carriers with branches to reach scattered communities, decentralization of water service provision will allow for efficient responses to local needs and for designing realistic structures suitable to meeting local conditions.

The integrated framework should also articulate policies to guide water and power pricing and cost recovery. Power is increasingly used for pumping water from deep aquifers and for desalination. Energy price subsidies add more distortion to the national effort to better manage water resources. In addition, reform in water policies cannot be carried out in isolation from reforms in the agricultural sector, especially in commodity pricing and trade. Governments tend to justify subsidies to irrigation on the grounds that farmers are required to sell portions of their production to government agencies at pre-determined prices. Pricing policies in water supply and agriculture in many Arab countries tend to favor subsidies and to promote inefficient, inequitable, and environmentally non-sustainable allocation of scarce land and water resources (Barghouti, 1999).

An important area for reform in the water sector is to improve the efficient use of water for irrigation. As indicated in Figure 6, agriculture continues to consume more than 80 percent of all water resources in the region (UNDP, 2009). This is a serious challenge because the return on water investment in many irrigation schemes in most Arab countries is low by international standards (World Bank, 2006). Cropping intensities (which are the ratio between irrigated crop areas where double or triple cropping areas are counted twice or three times, respectively, and the physical areas equipped for irrigation) in most Arab countries vary from less than 0.8 to 2.2. Figures available for some countries show a cropping intensity of 1.66 for Egypt, 1.19 for Syria, 1.15 for Oman, and 1.07 for Jordan (FAO AQUASTAT). In Saudi Arabia, Bahrain, and Kuwait the cropping intensity is reported to be less than 1.00, probably because no cropping is possible in the hot season. Analysis of much farm budget data for irrigated projects shows that cropping intensity less than 1.00 is not always economically viable (Barghouti et al., 2004). Low cropping intensity is hardly profitable for small farmers.<sup>7</sup>

Areas with low cropping intensity usually suffer from low water availability, sustain only low productive agriculture, and produce a low economic rate of return on irrigated farming (FAO, 2001).

FIGURE 7 PROJECTIONS OF FRESHWATER AVAILABILITY IN ARAB COUNTRIES



Policy guidelines and appropriate incentives would be needed to encourage farmers in these areas to invest in water saving technology for irrigation, or compensate them as an incentive for exiting irrigated farming altogether. These changes may cause more efficient use of water in other sectors. In most Arab countries, the issue of rehabilitation and modernization of irrigation systems is becoming increasingly important because of the shortage of suitable arable land and water scarcity (IDB, 2005). Moreover, the increasing competition among sectors using water is affecting the quality and quantity of water being allocated to agriculture. Controlling allocation to irrigation and pricing policies are essential to reducing waste and damage to the resource base. Egypt, Syria, Iraq, Lebanon, and Tunisia do not face immediate water shortages. The main challenges in these countries are to improve the performance of existing investment in the water sector, especially in irrigation, achieve universal coverage in water supply and sanitation, and address emerging issues in water quality and risks to the environment (IDB, 2005).

Tunisia, Morocco, Algeria, Jordan, Yemen, and to some extent Egypt, Saudi Arabia and Syria, have been encouraging farmers to adopt modern irrigation technology systems (IDB,

2005). Such systems can enhance agricultural production, increase water use efficiency, and reduce field level water losses. Traditional irrigation technologies (furrow, border, and flood irrigation), which involve water delivery to plants through gravitation and have usually resulted in substantial water losses and limited uniformity in water distribution (Hillel, 2008), have been replaced only in some areas by modern irrigation technologies, particularly sprinkler and drip irrigation to increase water use efficiency.

Egypt has demonstrated the successful use of modern irrigation system on newly developed land in the Western Delta and other areas covering more than 13 percent of the irrigated land in the country (World Bank, 2007). Improved production and irrigation technology, including the latest in crop breeding, plastic culture, protected greenhouses, fertigation, and pressurized irrigation delivery systems of low volume but high frequency have permitted rapid change in the newly developed areas.<sup>8</sup> But these technologies are being adopted only slowly in other agricultural regions, which constitute more than 87% of the country's total irrigated areas. The success of modern technology in Egypt may pave the way for wider adoption throughout the country, thus converting Egypt's irrigated land to become among the most modern and productive

TABLE 6 CLIMATE CHANGE FUTURE SCENARIOS: WATER AND AGRICULTURE

Scenario	Type of change	Effects on human security	Affected area
<b>WATER</b>	2°C rise in Earth temperature	1 to 1.6 billion people affected by water shortages	Africa, the Middle East, Southern Europe, parts of South and Central America
	3°C rise in Earth temperature	Increased water stress for additional 155 to 600 million people	North Africa
	Climate Change	Repeated risk of drought known in recent years, with economic and political effects	Mauritania, Sudan and Somalia
	Climate Change	Reduced average rainfall	Egypt, Jordan, Lebanon and OPT
	Rising sea levels	Risk of flooding and threats to coastal cities	Gulf coast of Arabian peninsula
	Climate Change	50% decline in renewable water availability	Syria
	1.2°C rise in earth temperature	Decreased water availability by 15%	Lebanon
	1°C rise in earth temperature	Reduced water runoff in Ouergha watershed by 10%	Morocco
	Climate Change	Greater water shortages	Yemen
	Climate Change	Reduced water flow by 40-60%	Nile River
	3°C rise in Earth temperature	Increased risks of coastal surges and flooding	Cairo
<b>AGRICULTURE</b>	2-3°C temperature rise in tropical regions	A drop by 25-35% in crop production (with weak carbon enrichment) and by 15-20% (with strong carbon enrichment)	Africa and West Africa (Arab countries included)
	3°C rise in Earth temperature	Reduced agricultural productivity and unsustainable crops	North Africa
	1.5°C rise in Earth temperature	70% drop in yields of Sorghum	Sudan (Northern Kordofan)
	Climate Change	Flooding of 4,500 km <sup>2</sup> of farmland and displacement of 6 million people	Lower Egypt

Source: UNDP, 2009

in the world. This possibility could also allow for substantial conservation in water resources. The challenge is likely to be in mobilizing large financial resources needed for this desirable development prospect, and would require significant changes in water pricing regimes and the construction of modern water delivery and metering systems.

Barghouti (1999) has argued that these new irrigation systems “have opened greater opportunities to cultivate soils with low water-holding capacity (sandy and rock soils) and to farm low quality lands and steep slopes”. This technology has also enabled farmers in regions

facing limited water supplies to diversify their production systems, and shift from low-value crops with high water requirements, such as grain crops, to high-value crops with lower water requirements such as fruits, vegetables, and oil seeds. It has also allowed the use of low-quality water (e.g., high saline and treated wastewater) in regions with high temperatures and high evaporation rates (Barghouti, 1999).

Even with measures to contain and better manage water demand and improve the efficiency of existing systems, new water supplies will be needed for agriculture and urban areas. As mentioned earlier, the lowest cost and most



reliable sources of water have already been developed in many countries. The new sources of supply currently being considered have higher financial and environmental costs than those developed earlier. The costs of municipal water supply and irrigation will increase even further when adequate drainage and sanitation facilities are included as essential parts of these investments. For most cities in the region the cost of a cubic meter of water provided by “the next project” can be two to three times the cost of current supplies, even before environmental costs are factored in (IDB, 2005). In this context of intensifying competition for finite or dwindling resources, the principal challenge for policy makers is to determine the optimal allocation of water resources for irrigation, while minimizing the negative environment impact of water use.

Expansion of irrigation in the GCC countries, which is totally dependent on modern irrigation technology, has created attractive opportunities to successfully cultivate food crops under harsh conditions. This success was achieved through generous subsidies, and at a very high cost of water abstraction from non-renewable groundwater aquifers (World Bank, 2004c). The use of water under these conditions requires careful assessment, particularly in light of the fact that the contribution of agriculture to gross domestic product (GDP) in these countries is almost insignificant, except in Saudi Arabia. While investments in irrigation can provide employment opportunities for the large number of landless and poor rural labor in many Arab countries, irrigation in the GCC and some countries largely employs an expatriate labor force and contributes little to improving rural employment (World Bank, 2004c).

In their review of water in the Arabian Peninsula, Al Alawi and Abdulrazzak (1994) argue that the countries of the Peninsula, especially Saudi Arabia, which are motivated by achieving food self-sufficiency, have encouraged investment in irrigated agriculture and that “successful subsidy and incentive programs have resulted in a large scale expansion of farming activities using substantial water requirements”. The authors reported in their essay that over a ten-year period (1980-1990), the demand for water jumped from 6 to 22.5 billion cubic

meters per year. Farming activities consumed substantial quantities of water provided mainly from deep aquifers. The authors (1994) present data to indicate that deep aquifer water levels are declining, pumping costs are increasing, and saltwater intrusion is contaminating the aquifers and causing disturbance of the dynamic equilibrium among aquifers. These factors have led to the abandonment of farm land, a decline in agricultural productivity, and an increase in migration away from rural areas (Al Alawi and Abdulrazzak, 1994).<sup>9</sup>

The role of agriculture in the national economy varies from less than 3 percent in the GCC countries to 29 percent in Yemen, but employs a relatively large segment of the labor force (World Bank, 2004b). As water scarcity intensifies, irrigated agriculture and associated reliable food production systems will be at risk, unless serious effort and investment is made to modernize irrigation and diversify agriculture. The prevailing irrigated production system in the Arab world would have to undergo a serious adjustment process, because most of these countries would be forced to make adjustments in the agricultural sector to cope with globalization and trade liberalization in agricultural commodities (Barghouti, 1999; Molden and et al., 2007). This adjustment process needs to be carefully planned and implemented within a comprehensive water policy, which also recognizes the importance of incentives in guiding a smooth transition in agriculture, and related adjustment in traditional water rights and allocation.

The issues facing the reallocation of water away from agriculture in the region are mainly political, economic, and social. Most farmers have acquired the rights to the water they use to irrigate their lands over several generations. Political leaders in some countries would like to emphasize the need for achieving high rate of food self-sufficiency. Achieving this goal may be unrealistic.

Efforts are underway in several Arab countries to treat wastewater and allocate it for irrigation in exchange for fresh water diverted from agriculture to meet the growing demands for urban and rural water supply. The process is complex and some countries have rushed into this exchange with little attention to possible high risks related

to environmental and health hazards associated with the use of wastewater (Qadir, 2007).

## IX. INVESTMENT IN WATER RESEARCH

The complexity of water management and allocation requires an aggressive approach to long term planning based on a systemic process of scientific discovery and relevant research for developing, delivering, and managing water resources. There is an important role for research in the modeling of supply and demand as well as other societal trends such as demographic changes. Several academic and research institutions have developed useful models to study water requirements under alternative options of water planning, population growth, changes in water use and quality, and other economic and social trends likely to have an impact over the long term. Field research and modeling have also been adapted to study the future water capabilities of river basins to meet growing needs under alternative scenarios of growth and development. Research models are also needed to study on a regular basis salt balance in water courses and drainage network, and to assess modern technology for desalination and disposal of salt residues in many Arab countries. Such tools are essential to better understand the technical, economic, and environmental issues affecting the water sector, and to devise proper plans to adequately manage and utilize the mix of different water resources.

The future water needs of growing populations in the Arab countries will not be solved through construction of new water projects alone. The importance of management should not be underrated. However, management of water resources can be sound and credible only if it has access to updated empirical research data and information about water issues and is willing and able to adopt technological innovations. Arab countries could do more to support investment in public research on water.

The water sector is facing complex challenges in the years ahead, and policy makers should develop scientific frameworks to guide national water plans to address these challenges. Only a few countries, such as Egypt and Kuwait, have invested in this type of research. More research

is needed considering that many small countries cannot afford investment in research due to lack of resources, a short supply of qualified experts, and limited capacity to build specialized research facilities in these fields.

The Consultative Group for International Agricultural Research (CGIAR) comprises 15 international research centers, which are supported by more than 60 countries. CGIAR is dedicated to the search for technologies and scientific solutions to meet the growing demands for food and sustainable natural resources management. However, the success of CGIAR can only be possible if it is supported by capable institutions at the national level that could test and adapt new technologies to local needs.

Arab countries should invest more in their national research systems to further develop and strengthen their capabilities in water science and management, and to acquire expertise to address future vulnerabilities and challenges caused by climate change. Several countries have increased their investment in research to assess the impact of climate change on water and agriculture. Arab countries are located in one of the most vulnerable regions where climate change is likely to have serious implications as stated in several UN reports. Table 6 is a summary of some of the anticipated implications.

While the risk of climate change to their already scarce water resources is extremely serious, Arab countries have demonstrated lack of interest in studying the impact of these changes on current and future economic activities. It is unfortunate to report that Arab countries have committed the least amount of public funds to invest in and support their research and technology institutions that are needed to address the growing challenges of climate change (UNDP, 2009).

To address these needs, it is desirable to establish a regional water research center to serve countries of the region. This institution could expand the limited but important research work currently being conducted by the International Center for Biosaline Agriculture (ICBA). Located in Dubai, ICBA has established a strong reputation among international centers of excellence in the use of saline water for agricultural production. Additional support can target and build on the

foundation already established by ICBA. Such an approach would allow ICBA to expand its mandate, go beyond the concern for biosaline agriculture to cover broader issues in water sector management, and establish strong partnerships with national research institutes, such the Water Research Center in Egypt and the Kuwait Institute for Scientific Research (KISR).

It is also important to build partnerships with private sector research programs. These partnerships are needed to catalyze innovations in wastewater treatment and reuse, in improving water quality, in groundwater management and monitoring, and in the desalination of seawater and brackish water. Such partnerships would also assist guide investments in rehabilitating and modernizing existing water facilities including irrigation technology and water supply and sanitation.

## **X. CONCLUSION**

The water sector in all Arab countries will have to contend with a complex set of challenges over the coming decades. Shortages in clean water and sanitation aggravated by unsustainable policies, lack of institutional capacity, and vulnerabilities to climate change top the list. This paper has presented an overview of the strained condition of the water sector in Arab countries, while emphasizing the urgent need for introducing reforms that ensure efficient, equitable, cost-effective, and environmentally sustainable management of water resources.

Water policies in Arab countries have allowed for unrestricted use of scarce water resources. Low water tariffs and high subsidies have compromised the financial health and physical condition of urban and rural water supply networks. Combined with weak demand management policies, the resulting budgetary burden is making it difficult to raise financial resources needed to meet the growing demand. Another key motive for water reform is the intensifying competition among domestic, agricultural, industrial, and environmental uses. These concerns are worthy of careful examination by Arab decision-makers, who should articulate appropriate policy frameworks to guide a strident water reform process. A business-as-

usual scenario threatens to lead to more waste in water allocation and delay the necessary reforms urgently needed to ensure availability of clean water and sanitation to millions in the Arab world who have been deprived because of poorly targeted investments in the water sector.

Arab countries should support the formulation and implementation of policies enforcing water demand management. While the importance of the supply side cannot be overstated, the effectiveness of demand management is now universally accepted, particularly where water is scarce and unnecessarily wasted. Ensuring the efficient use of available supply may yield significant benefits and may often prove to be more cost-effective than traditional supply management measures. Efficient demand management is often less capital-intensive and, therefore, more cost effective, but it is also better adapted for addressing 'emergency' situations. Better demand management reduces waste and unaccounted for water, improves leakage control, and enhances the quality and reliability of water services. Key measures for promoting demand management include regulations and more efficient technology for water delivery and agricultural production systems. Additional investment may be needed to ensure that benefits can be obtained from increasing water use efficiency. Such investment is needed to modernize existing irrigation production and delivery systems. The effects of raising public awareness and inducing behavioral changes through financial incentives along with the use of metering and volumetric water pricing cannot be underestimated.

One of the most critical demand management issues is water re-allocation. This requires that effective policy guidelines be developed to improve the performance of the farming sector, by far the largest consumer of water. Arab governments should increase investments to upgrade traditional irrigation systems through the adoption of modern water delivery technology. Such a technology will improve productivity of water (drop per drop or cash return per unit of water delivered), and could increase diversification and commercialization of agriculture. This shift should be gradual, should involve the beneficiaries, and should be selective in converting traditional systems into high performing delivery networks.

A more aggressive water allocation policy, based on the concept of integrated water resources management (IWRM), could be coordinated with land use policies to regulate unwanted growth in already crowded urban centers. Incentives in water allocation can be used to encourage local industries and housing projects to target poor regions, where they can create jobs and economic opportunities. This is much preferable to investing in large water conveyance projects designed to transport water over long distances to growing cities.

The stressed condition of the water sector in many Arab countries requires a new breed of managers, better able to address a different host of challenges from season to season, such as better management of drought and scarce seasonal supplies. A new class of water managers should also be able to address flooding threats, natural disasters, deterioration in water quality, as well as questions pertaining to shared water resources. National strategic goals for the water sector should be articulated including making shifts in water allocation among sectors, introducing new pricing policies, drafting new rules and regulations to address groundwater abstraction, and designing plans to clean public water ways from industrial waste and pollution. Therefore, visionary management is crucial for articulating these policy and investment plans for sustaining the resource base as well as for managing the long-term implementation of these plans adaptively. These functions are complex and interrelated and require regular upgrading of staff skills and the recruitment of new types of expertise. The organizational structure of many public water agencies has traditionally been heavily dominated by experts in water infrastructure, who believe that most water problems can be solved by building yet more infrastructure water projects. It is difficult to expect that public water agencies that adhere to traditional approaches in staffing and water management to be able to lead this sector as it faces mounting challenges that are multi-dimensional and multi-disciplinary in nature. Therefore, public water agencies in Arab countries should attract a balanced mix of experts who can design, implement, and monitor strategic water plans.

Water governance in Arab countries should be

strengthened by building partnerships with beneficiaries and the private sector. Governments should encourage joint investment by the private sector and the community of beneficiaries in modern, timely-controlled, and well-monitored and metered water delivery services. Increased decentralization and empowering water user associations should be promoted in order to devolve responsibilities to manage and operate local services to user communities. In addition, Arab countries should recognize the important goal of reaching the poor and expanding water services to all communities, particularly in rural areas. Priority should be given to expanding water services to vulnerable communities and encouraging local initiatives in building and managing such services.

In the face of such extensive challenges, drastic changes in institutional structures and outcomes subjected to well-defined monitoring indicators are needed. These indicators can be measured at the policy and institutional level. Legal indicators include actions, rules, and regulations approved and enacted as well as measures taken to enhance the capacity of institutions. Other indicators relate to the social impact on affected people including improved delivery of drinking water and associated improvements in quality of life, health, and hygiene. These indicators measure the extent to which water services have been extended to all segments of the population, especially the poor. Other social indicators could be used to measure the extent of ownership and participation among water users. For large water infrastructure projects, it is suggested to include indicators related to the impact on those directly affected by the construction of new facilities such as dams and canals, and the adequacy of compensation for resettlements and relocation of affected communities.

The performance of the water sector could also be measured by employing economic and financial indicators to assess revenue received from costumers for water use, cost recovery, agricultural water productivity, and private sector investments. Other indicators may also be designed to assess the impact of new policies on environmental protection, pollution reduction, and natural habitat and biodiversity restoration in areas affected by the construction of water projects.

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## NOTES

1. The 2004 World Development Report "Making Services Work for the Poor" provides detailed analysis as to the reasons behind inadequate services to the poor. It argues that the providers of services are generally more accountable to the policy makers than the clients. Poor clients have no political voice and often have no choice among service providers.
2. Data on public expenditure was not available in a time series for this study. Assessment of expenditure on the water sector is difficult to collect because of the fragmentation of expenditure among various agencies. Also expenditure by farmers and communities is not always updated.
3. A rough methodology has been informally developed by experts in irrigation, and is based on reviewing the cost of O&M of irrigation systems in several developing countries assuming that the cost rehabilitation of irrigation infrastructure is about \$150-180 per hectare, and the O&M is \$50-60 per hectare. With three million hectares under irrigation, Egypt allocates about \$1 billion annually for

O&M and for major rehabilitation works. Data on expenditure on water supply and sanitation is not included in this calculation.

4. The World Development Report for 2004 “Making Services Work for the Poor” devotes a special chapter to drinking water and sanitation.
5. The six GCC countries (United Arab Emirates, Oman, Saudi Arabia, Kuwait, Bahrain, Qatar), Jordan, Libya, Yemen, Algeria, Morocco, Mauritania, Somalia, and the West Bank and Gaza.
6. World Bank regional classification: EAP – East Asia & Pacific (China, Indonesia, Lao PDR, Philippines, Thailand, Vietnam), ECA – Europe & Central Asia (Bosnia and Herzegovina, Kazakhstan, Kyrgyz Republic, Russian Federation, Tajikistan, Turkey, Turkmenistan, Uzbekistan), LAC – Latin America & Caribbean (Bolivia, Brazil, Guatemala, Mexico), MNA – Middle East & North Africa (Arab Republic of Egypt, Islamic Republic of Iran, Morocco, Republic of Yemen), SAS - South Asia (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka), and SSA – Sub-Saharan Africa.
7. Data on cropping intensity are available in the FAO statistics database, ([www.fao.org/ag/aquastat](http://www.fao.org/ag/aquastat)). Unfortunately the data are not updated regularly. Cropping intensity in many countries has declined because of water shortages in many irrigation schemes.
8. Different irrigation methods and water delivery systems prevail in the Arab countries. The advent of small scale irrigation, especially tube wells and small water pumps, has facilitated the adoption of water saving methods and improved control on water delivery in several countries.
9. The authors provide detailed discussion on the status of water in the Peninsula, and the emerging challenge between current water supplies and the growing demand for water in the countries of the region.

# Water Resources and Climate Change

HAMED ASSAF



## I. INTRODUCTION

The Arab region stretches across a latitudinal landmass belt known for its acute water scarcity and aridity, which presents Arab countries with a serious water balance predicament that threatens its socio-economic development. These arid conditions are the result of complex global atmospheric circulations that predominantly divert moisture to bordering latitudinal regions. Projected climatic changes are expected to intensify these processes leading to even drier and warmer conditions (Assaf, 2008). The climatic wind system that brings precipitation to North Africa and the Eastern Mediterranean is expected to drift northward removing a large portion of already meager precipitation levels. This grim perspective makes it necessary that Arab countries take active and long-term measures to bridge the widening gap between rising water demands and exhausted and deteriorating water resources.

This paper addresses how climate change may affect water resources in the Arab region and proposes a range of adaptation strategies and measures for consideration by policy-makers. The paper describes a vulnerability-based approach in order to comprehend the role of climate change, among other main stresses such as population growth and land use change, in shaping the status and management of water resources in the region. Specific determinants of vulnerability are emphasized to help decision makers design effective holistic policies that not only address climate change but also consider other pertinent strains on water resources.

## II. PROJECTED CLIMATIC CHANGES IN THE ARAB REGION

The International Panel on Climate Change (IPCC) Report (IPCC, 2007) and its special paper on the impact of climate change on water (Bates et al., 2008) give a general overview of projected climatic changes across the globe. These changes are usually presented in the context of the IPCC Special Report on Emissions Scenarios (SRES) greenhouse gas (GHG) emissions storylines that represent a wide range of global economic and social developments.

Figure 1 presents projected changes in yearly averages of hydro-meteorological variables

(precipitation, runoff, soil moisture, and evaporation) in the last 30 years of the current 21st century vs. those in the last 30 years of the 20th century based on the SRES A1B GHG emissions storyline which represents midpoint conditions. The projections are calculated as the average of output from 15 leading General Circulation Models (GCMs). Stapled areas are those where 80% of the GCMs agree on the direction of change.

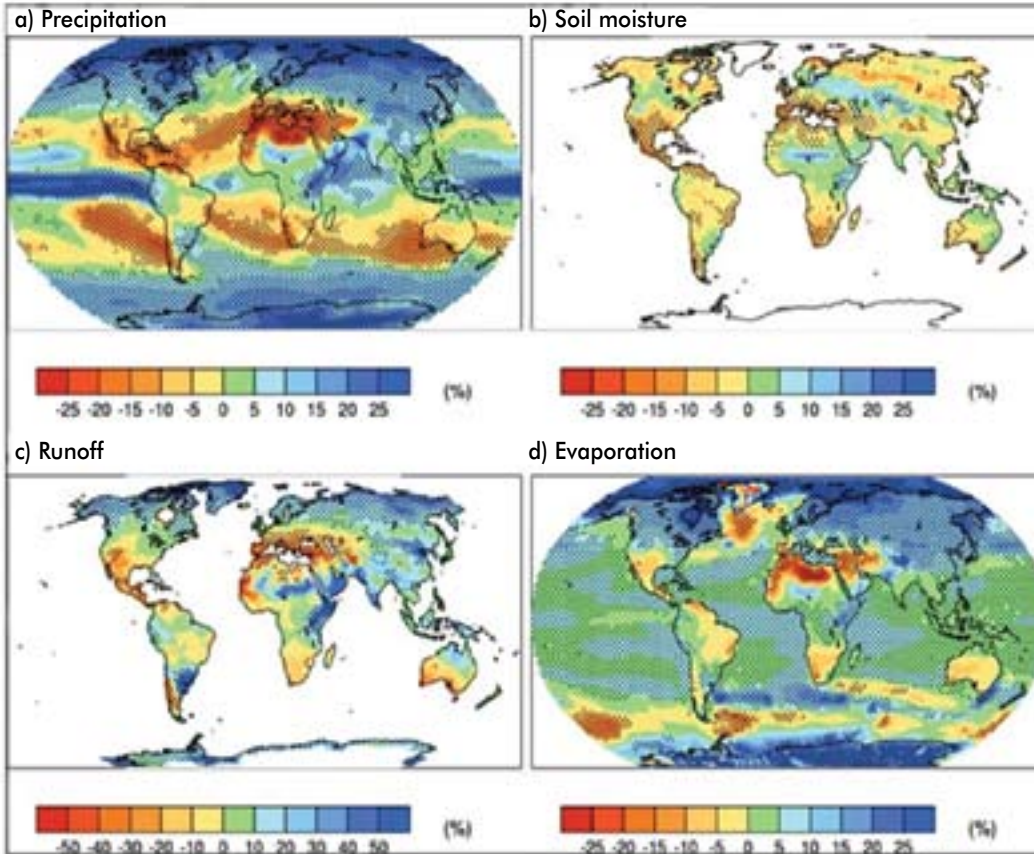
As Figure 1 shows, the majority of GCMs project a grim outlook for the northern part of the Arab region in terms of major reduction in precipitation, increase in evaporation, and subsequent reduction in both runoff and soil moisture. Precipitation is projected to decrease by over 25% which in combination with a 25% increase in evaporation would translate to a drastic 50% drop in runoff by the end of the century. The net effect will be a major reduction in available water resources exacerbating current water scarcity conditions. Some of the reduction in water resources will originate from outside the Arab region in neighboring countries, Turkey and Iran principally, as both countries are expected to suffer similar consequences. However, adaptation measures by these two countries could spill an even greater risk to water resources in the Arab region. Turkey has already developed several complex water storage and transfer projects, enabling the country to transfer vast amounts of water out of the Euphrates and Tigris basins to drier parts of the country. Iran has already constructed a dam on the Khabour River cutting off vital supplies to the wetlands and marshes of Southern Iraq. Both countries are expected to divert even greater amounts of water during extended drought periods, further accentuating the water scarcity problems as well as the risk of more severe drought conditions in Syria and Iraq.

North African nations will be particularly hit hard by a projected shift in the Westerlies exposing Morocco, Algeria, Libya, and Tunis to the risk of extended droughts and crop failures. The situation will be similar in the Eastern Mediterranean with Lebanon, Jordan, and Palestine reeling from much lower rainfall quantities. The GCC countries will undergo less precipitation levels, however this is not expected to significantly change or have a measurable impact on the water balance since water is mostly obtained by desalination. In contrast, the climatic projections



FIGURE 1

YEARLY HYDRO-METEOROLOGICAL CHANGES (2080-2099) VS. (1980-1999)  
 AVERAGED FROM OUTPUTS OF FIFTEEN GENERAL CIRCULATION MODELS RUN  
 FOR THE SRES EMISSIONS STORYLINE A1B



Legend: (a) precipitation (%); (b) soil moisture (%); (c) run-off (%); (d) evapotranspiration (%)

Source: Bates et al., 2008

for the Nile's headwaters in Eastern Africa and to a lesser degree the southern part of the Arabian Peninsula indicate a net increase in precipitation and runoff. Consequently water balance in Egypt and Sudan are generally expected to gain from projected increase in the Nile's runoff. This will be tempered by the projected reduction in precipitation in Egypt and northern Sudan as well as by the overall increase in evaporation as a result of warming.

### III. VULNERABILITY-BASED APPROACH FOR ADAPTATION TO CLIMATE CHANGE

Traditionally, most climate change adaptation studies focus on analyzing the impact of potential climatic changes on a particular sector or sectors

to support development of adaptation policies and measures. Although this is a necessary step to obtain a better understanding of the physical basis of the problem, it is often criticized for relying on evolving climate models that are still in their infancy and compounded with high uncertainties (Adger and Kelly, 1999). These reservations may weaken the argument and the political will to support mitigation and adaptation efforts, as stakeholders may not be convinced in supporting funding efforts to alleviate "potential" rather than certain problems.

Alternatively, Adger and Kelly (1999) call for focusing efforts on identifying vulnerabilities and adaptive capacities of human, physical, and ecological systems. Vulnerability can be readily determined based on existing conditions without necessarily projecting future climatic changes.

Such an approach would yield valuable insights, lending support to adaptation measures that not only address current conditions and stresses, but also take into account future climatic impacts. For example, the Arab region is faced with a very serious water scarcity that undermines its socio-economic development and may threaten the survival of some of its communities. Addressing the determinants of vulnerability to water scarcity will induce the formulation of policies and measures to manage such susceptibilities under current conditions as well as attend to any anticipated exacerbation by climate change.

Vulnerability assumes several meanings and interpretations in the literature particularly those related to food security, natural hazards, famines, and more recently climate change. Even the IPCC Third Assessment Report (TAR) contains different and contradictory definitions of vulnerability (Adger et al., 2004). Part of this confusion relates to the two distinct but interrelated vulnerability concepts: bio-physical and social/inherent vulnerabilities (Adger et al., 2004). The latter is a characteristic of a system, whether it is human or ecological/political/natural, that determines its ability to withstand, cope, and recover from a hazard. The former is a function of the latter and the hazard the system is being exposed to. It is similar to the concept of risk used in the disaster literature, where risk is a function of the impact of hazard on the system and the probability of its occurrence (Adger et al., 2004). In this report, we address the “social/inherent” vulnerability.

#### **IV. IDENTIFICATION OF WATER RELATED VULNERABILITIES TO CLIMATE CHANGE IN THE ARAB REGION**

Vulnerability to climate change is multifaceted and multi-sectoral and relates to a diverse group of players at a wide range of temporal and spatial scales. In semi-arid regions water is the single most important and limiting factor of socio-economic development. As indicated earlier, the Arab countries are situated in climate change hotspots where major reductions in precipitation accompanied with increases in evapotranspiration are projected to result in an even more precarious water balance. The Arab region's historic and extensive experience in dealing with water scarcity at different scales provides an opportunity to gain



insight on how different stressors interact and affect this region, to identify resiliency factors, and learn from the success (or failure) of past adaptation measures. The knowledge gained can help pinpoint strengths and weaknesses in addressing water problems particularly scarcity. This learning can then help articulate a vulnerability-based framework to identify vulnerability determinants, setting up the stage for upgrading existing policies and strategies or developing new ones. This is a holistic approach for reducing vulnerability to climate change as well as other stressors, and improving adaptive capacity.

The vulnerability-based approach is not meant to be a comprehensive and prescriptive framework, rather it provides general guidelines to identify areas of concern in a water sector vulnerable to several strains, such as population growth and land use changes, which are expected to be exacerbated by climatic changes and variability. For example, current shortages in the Amman municipal water supply network driven mainly by natural water scarcity, urbanization, and rapid population growth makes the city population highly vulnerable to further declines in precipitation levels as projected by climate models. A more refined and detailed analysis of this vulnerability can reveal more pertinent problems, such as specific deficiencies in the water network, ineffective pricing policies, and/or inadequate customer service. Knowledge gleaned from this vulnerability analysis can then be used to develop specific or integrated solutions.

In assessing vulnerability to climate change, two broad categories of vulnerability determinants

TABLE 1 WATER SECTOR VULNERABILITIES, CONSEQUENCES, AND ADAPTATION OPTIONS IN THE ARAB REGION

Vulnerability Determinants	Potential Consequences	Adaptation options	Examples
Inadequate municipal water service as a result of natural water scarcity, leakages, poor customer service, and inappropriate water pricing.	Water shortages and interruptions leading to public health problems and lower standard of living. In some cases residents may resort to supplement their water supplies with poor quality water.	Analyze causes to identify and implement solutions including enhancing accountability, setting a proper price structure, rehabilitating network to reduce leakage, and improve customer service and awareness.	Beirut suffers from intermittent water municipal services. The problem is related to excessive leakage in the network, inadequate water supplies to meet demand, lack of proper water metering, and poor customer services. A World Bank report has advised the government to rehabilitate water services with particular emphasis on setting up an effective pricing scheduling based on adequate metering of services (World Bank, 2009).
Deficiencies in wastewater and rainfall drainage systems as a result of underdesign and poor maintenance and/or customer service.	Increase the risk of flooding and overflowing of sewage during intense rainfall events. Generally these conditions have detrimental impact on public health and may lead to extensive loss of life in extreme cases.	Examine hydrometeorological records to redesign and enhance existing infrastructure. Examine urban planning policies to limit development in high risk areas.	The recent flooding event in Jeddah – see case study - throws into the spotlight the negligence and possible corruption in the development of the city’s flood drainage and sewage treatment and disposal infrastructure. As indicated in the case study box, the impact of flooding would have been negligible had the drainage network been properly designed and constructed and the development of the flooded area properly regulated. Also, the consequences would have been much greater had the dam retaining ewage upstream failed during the event.
Lack of agreements on international watercourses and aquifers.	This presents a great risk of conflict and is currently leading to overexploitation of groundwater resources.	Work towards establishing agreements between countries. While this option is generally elusive in many cases, judging by the scarcity of such agreements, countries should establish working relationships to achieve sustainable development of the resources.	The conflict over the Jordan River basin is difficult to resolve due to the hegemonic position of Israel. The weak political position of the Palestinians places them at a disadvantage in securing their rightful share of water resources (Zeitoun and Allan, 2008). In comparison, despite the existence of a single agreement between Egypt and Sudan on sharing the water resources of the Nile, the Nile Basin Initiative has been successful in maintaining a peaceful, yet uneasy relationship among the riparian countries. Internal conflict in Darfour is largely driven by competition over scarce water resources and vegetated areas (UNDP, 2009). The situation is exacerbated by extended droughts.
Large rural populations in poor semi-arid countries, who are highly dependent on agriculture and pasturing.	Such populations are highly vulnerable to climatic variability as extended drought may lead to crop failure and livestock losses.	Crop planning and support of rural populations through agricultural advisory services. Diversification of economy and human resources development.	Large segments of populations in highly agrarian countries such as Yemen and Sudan are particularly exposed to climatic variability and droughts. This has led not only to malnutrition and famine, but also to internal conflicts that have escalated in Sudan to the level of a protracted civil war.

## DAMS TO PRESERVE WATER IN LEBANON

**Fadi G. Comair**

The typically Mediterranean climate in Lebanon is characterized by strong precipitations during winter followed by a dry period with high humidity for the remaining seven months of the year. However, the influence of the sea, the particularities of the topography and the presence of the Syrian Desert in the North create a variation of microclimate inside the country with sharp variations in the distribution of both temperature and precipitation.

The annual precipitation average is estimated at 800 mm, varying between 600 and 900 mm along the coast and 1400 mm over the mountains. It decreases to 400 mm in eastern regions and less than 200 mm in the northeastern regions of the country.

At altitudes of over 2000 m, the essential precipitations are snow and can help in generating good output for 2000 water sources during the dry periods. Precipitations are produced in 80 to 90 days of the year, mainly between October and April. Approximately 75% of the total volume of the surface flow occurs during five months between January and May, 16% in June and July and only 9% for the remaining five months from August till December. In 2000, water resources used in Lebanon were about 1.5 billion m<sup>3</sup> per year, with an increasing annual demand that will lead to enormous water deficit as early as 2015.

The annual total volume of ground water in Lebanon is estimated at 567 million m<sup>3</sup>, whereas the flow in dry period (July-October) in various basins is estimated at around 141 million m<sup>3</sup>. While the country enjoys a favorable situation in cumulative flows, availability is limited during five dry months, coupled with complicated karstic geological conditions. Total annual water demand exceeds 2 billion m<sup>3</sup> in 2010, reaching 3.4 billion m<sup>3</sup> in 2040.

A decennial strategic plan prepared by the General Directorate of Hydraulic and Electric Resource (GDHER) in Lebanon has been designed to ensure that enough water will be available to meet the necessary demand in all sectors. It constitutes an Integrated Water Resource Plan (IWRP) for Lebanon and covers major technical hydraulic infrastructure projects which are essential for the economic development of the country. The decennial strategic plan is based on developing:

- Additional water resources (dams, lakes, recharge of aquifers, sea fresh water springs, desalinations, etc.)
- Drinking water projects (distribution network and efficiency, public-private partnership involvement, etc.)
- Appropriate irrigation projects (ensuring food security, network efficiency, etc.)
- Wastewater collecting and treatment plants (water reuse for irrigation, municipal use and artificial recharge of aquifers, etc)
- Infrastructure for flood mitigation, rectification and alignment of river beds.

The increase in water demand led to increased deficit in urban areas located mainly along the Lebanese coast and in Mount Lebanon, as well as in the rural regions in the south, the Bekaa Valley and the north of the country. The utilization of available and renewable water from springs is not enough to meet the needs during the drought season. Moreover, the intensive use of ground water by the public and private sectors caused many problems, mainly decrease in the flow, reduction of ground water in the aquifers in the Bekaa plain and intrusion of seawater into the coastal aquifers.

Although the strategic plan takes into account the increase of the efficiency of water supply and irrigation networks from 60% to 85% in a period of 10 years, the water balance will still experience a huge water shortage (>600 Mcm in 2020). This explains the inevitability to build dams and mountain lakes to store the surface water generated from the precipitation of the winter season that will then be used during the dry season. The execution of these reservoirs for storing surface water should be preceded by: preparation of detailed geological and hydro-geological maps, controlling of the ground water level, and protecting the aquifers and the water sources.

The Chabrouh dam was the first project of the decennial strategy to be executed. The construction of this hydraulic infrastructure started in August 2002 and was completed in October 2007. This was the only one implemented among 17 major dam projects included in the 10-year strategic plan. In 2005 the construction of the Assi River (Orontes) derivation dam in the district of Hermel commenced, but the work was halted in July 2006 due to an Israeli airstrike on the



construction site. Once the planned dams have been built, Lebanon could have the capacity to store an additional 850 million m<sup>3</sup> of fresh water, helping to alleviate water shortages until 2040.

The study of the water resources in Lebanon shows clearly that the country is blessed with an annual precipitation volume of about 8 billion m<sup>3</sup>/ year, but several disadvantages render the utilization of this water quantity a very complicated task to be accomplished. Those include:

- 90% of the rainfall quantity occurs within a period of three months.
- Evapotranspiration rate is estimated at 50% and this volume is likely to increase with the climate change phenomenon.
- Geological karstic nature of the Lebanese soil induces a high infiltration ratio.
- Relying on groundwater utilization as a major source of water supply for the Lebanese population constitutes a bad design for the water planning and management in Lebanon. This concept leads to an over-pumping of the aquifers, which generates various environmental problems.

- Absence of wastewater treatment plants makes the utilization of non-conventional resources difficult for agriculture and municipal sectors. Also this resource could be used for the artificial recharge of aquifers in addition to the high pressure induced on the ecosystems of the watercourses.
- Absence of surface water storage since the 1960 led to a continuous discharge of fresh water in the Mediterranean, amounting to about 1.2 billion m<sup>3</sup>/ year. This irresponsible behavior from the water administration and the political decision makers constitute a waste of financial input to the national budget estimated at 100 billion US dollars.
- Until 2002, only the Qaraoun dam has been built, and the construction of Chabrouh dam which was completed in October 2007 was the only project executed of the 10-year strategic master plan.
- The drinking and irrigation water networks efficiencies should be improved in order to meet IWRM requirements with respect to water losses and for a better service coverage.
- Other non-conventional resources for the future utilization such as: sea fresh water spring, desalination and reuse of wastewater require a new complementary formulation within the 10 year master plan bearing in mind that the resources utilizations by gravity should be used at first priority.

The effects of climate change on Lebanon tend to make the Lebanese territory progressively drier. The first obvious measure to be taken by the Lebanese government is to reduce the amounts of water discharging into the sea. Unfortunately, the execution of this solution has proved to be difficult, mainly due to two major factors: the first is that while project priorities were set according to actual and future water demand management at the national level, politicians have been trying to tailor them to suit short-term interests; the second is that financing has been constantly blocked by political interests.

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are identified: generic and hazard-specific. The former refers to determinants related to general issues such as poverty, governance, infrastructure, education, and social status which can be used to develop country-wide indicators to categorize highly vulnerable countries. Hazard-specific determinants may include prices of staples, number of storm shelters in a community, and building standards (Brooks et al., 2005). Water related determinants may include services provision coverage, redundancy and condition of water supply infrastructure and networks, access to alternative water supplies such as desalination or water transfer from other regions or countries, strategic storage of food staples, and stable access to friendly food markets that help the country wither through periods of crop failures.

In surveying general water resources and service conditions in the Arab world, several water related vulnerabilities have been identified that need to be addressed to increase adaptive capacity in the Arab region in the face of impending climate change. The determinants of these vulnerabilities along with their potential consequences, adaption options, and examples from the Arab region are presented in

Table 1. As the table indicates, water related vulnerabilities are tied to all aspects of socio-economic development and environmental well-being. Natural water scarcity is a common driver of vulnerability as it restrains urban and industrial development and poses risk to agriculture and food production. Inadequate water services provision is another important determinant

driven by several factors including water scarcity, lack of capital, weak accountability, and lack of pricing incentives. Absence of international agreements or cooperation over transboundary water resources poses special risk to regional stability, which could induce armed conflict under extended drought conditions. All these factors can interact in a vicious cycle that could exacerbate adverse conditions leading to political instability, mass migration, malnutrition, and/or community disintegration.

## V. FOOD SECURITY AND VIRTUAL WATER

Over the past several decades many Arab countries have placed great emphasis on achieving food security through local production even at the cost of depleting nonrenewable fossil water. Faced with the reality of physical water scarcity, sharp increases in pumping costs driven by high energy prices, and declining water levels in strategic aquifers, many Arab countries have started to reorient their food policies by relying on imports and restricting irrigation to high value crops. These strategic changes have created a positive virtual water balance as water became imbedded in imported agricultural produce (Allan, 1997), which would have consumed an equal if not a much larger amount of local water resources, due to the arid conditions. The concept of virtual water trade has been advocated as a method for mediating the asymmetric global distribution of water resources and supporting efforts to manage

## DROUGHT IN SYRIA: ONE MILLION PEOPLE AFFECTED

Drought in eastern and northeastern Syria has driven some 300,000 families to urban settlements such as Aleppo, Damascus and Deir ez Zour in search of work, in one of the "largest internal displacements in the Middle East in recent years," according to a 2009 report by the United Nations Office for the Coordination of Humanitarian Affairs. The lack of water has caused more than 800,000 people in eastern Syria to lose "almost all of their livelihoods and face extreme hardship," stated the report. About 80 percent of the hardest hit "live on a diet consisting of bread and sugared tea."

Syria's water shortages have been worsening year by year. In 2006, northeastern regions such as Hasakeh and Qamishli were the first to feel the effects of a lack of rain. Shortly after, farmers and crop-growers in southern and eastern areas started to suffer from a major drop in rainfall.

The United Nations described the situation as "the most severe drought in Syria over 40 years," and appealed for assistance to help those affected. A report estimated that 59,000 small Syrian farmers lost almost all of their cattle, while 47,000 farmers lost between 50-60 percent.

"Our wells are dry and the rains don't come," said Ahmed Abu Hamed Mohieddin, a wheat farmer from the town of Qamishlimm, in an interview. "We cannot depend on God's will for our crops. We come to the city, where the money is." He and three sons work as porters in the capital's vegetable markets.

Mohieddin said that he left Qamishli when his well ran dry and he could not afford a new pump. He sold a flock of sheep because grazing land had withered and he didn't have commercial feed. He came to Damascus in May 2009 and lives among the dusty lanes separating

do-it-yourself tents of plastic and cotton sheets. "I'm thinking maybe we can build a little house here," Mohieddin said. "We can't go back to Qamishli. We prayed for rain too long."

"For the first time in two decades, Syria has moved from being a net exporter of wheat to a net importer," stated a February 2010 report by the U.S. State Department, adding that agriculture accounted for about 17 percent of 2008 GDP.

"It's an emergency," Syrian economist Nabil Sukkar warned. "If we have two more years of drought, then we do have a crisis...Unfortunately, we haven't introduced modern technology, and so we are totally dependent on rainfall".

But rainfall, or lack of it, is not the only culprit, he says. Syria and Iraq blame Turkey's huge network of dams on the Tigris and Euphrates rivers for reducing water supplies by 50 percent. Turkey is the site of the headwaters of a river system that Syria and Iraq depend on. An informal agreement determines the flow downstream.

"When we had bad relations with Turkey, they reduced the flow of water despite the agreement. Now, thank God, we have excellent relations with Turkey and, hopefully, we will not see any cutoff of water," Sukkar said.

In southeast Turkey, the Euphrates River is clear, blue and deep. The Ataturk Dam harnesses water for one of the biggest irrigation and electric power schemes in the world, the Southeastern Anatolia Project. When the multibillion-dollar project was inaugurated more than a decade ago, then-President Suleyman Demirel said neither Syria nor Iraq could lay claim to Turkey's water, any more than Turkey could claim Arab oil.

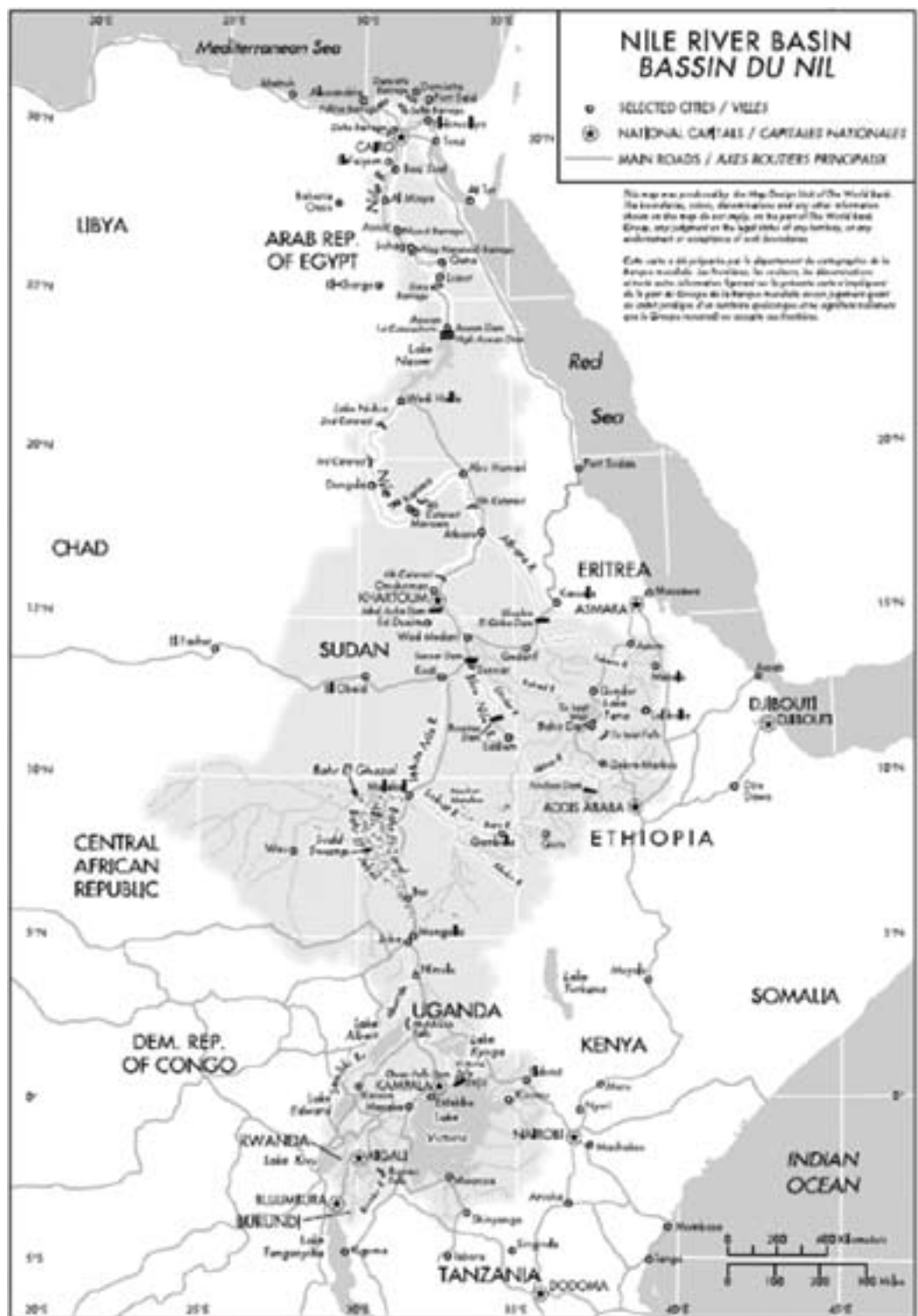
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water scarcity and consequently to decrease vulnerability to climatic changes. Allan (1997) has indicated that the MENA region "ran out of water in the 1970s" and has effectively managed to meet its food requirements and consequently augment its water resources through rapidly increasing imports of food commodities, particularly wheat.

However recent food shortages and subsequent hikes in food prices have exposed the vulnerability

of food importing countries to the volatility of the global food supply and markets. This has opted several GCC countries to seek acquirement of titles to land resources and even fishing rights in developing countries in Africa and Asia to secure food for their rapidly growing populations (Woertz et al., 2008). Although these policies are considered reasonable given that they increase the import of virtual water, they have raised concerns over the sovereignty of food producing countries as many of them are struggling to feed their

FIGURE 2 NILE RIVER BASIN



Source: World Bank, 2004



own populations. The situation is considered particularly sensitive under conditions of global food scarcity, which would hike up prices and may push the poor in food producing countries to malnutrition and possibly starvation.

## **VI. INCORPORATING NONSTATIONARITY IN THE DESIGN AND OPERATION OF WATER RESOURCES INFRASTRUCTURE**

Climate change is projected to alter the stochastic nature of meteorological variables particularly the spatio-temporal distribution of precipitation. However, water infrastructure components are designed assuming stationarity or static statistical properties of meteorological variables. This is problematic from two main design perspectives: optimal capacity and safety. Components designed based on wetter records can be ineffective and may result in squandering scarce financial resources. For example, an extensive water irrigation infrastructure project designed on past wetter periods in Morocco failed to meet farmer's requirements as dams did not fill to half of their capacities and irrigation canals did not have enough water for most of two decades from mid-1980s to mid-2000s (World Bank, 2007). In contrast, overlooking potential upward changes in the frequency and intensity of rainfall events may lead some authorities to underestimate the risk of flooding and develop inadequate drainage infrastructure. Jeddah's recent disaster – see case study – is a testimony to the failure of developers to assess the intensity and damaging potential of rainfall storms. Shortsighted developers have decided against building an extensive drainage network judging it unnecessary due to the extreme aridity of the area.

Dealing with nonstationarity requires adopting a more adaptive and flexible approach in the planning, design, and operation of water resources infrastructure. This requires improving understanding of changes in meteorological conditions through extensive data monitoring and analysis. Operational flexibility can be achieved by tying operational policies to improved long-term and short-term forecasts of runoffs. For example, following an extended dry period in the mid-1980s, the Ministry of Water Resources and Irrigation in Egypt - see case study - established the Nile Forecast Center

(NFC) to provide forecasts of water inflows to Lake Nasser. The NFC applies a remote sensing modeling system developed through technical support from the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Food and Agriculture Organization (FAO) (Conway, 2005).

Hydrologic uncertainty brought about by climate change can be managed through diversifying water supply options and adopting an incremental water supply development strategy. Rather than pursuing costly and ineffective mega infrastructure development, as Morocco's irrigation project attests to, large schemes can be broken into stages starting with the most cost effective components and proceeding progressively as the trajectory of climatic change becomes clearer. For example, the current plan to transfer water from the Litani River to Beirut is structured in two incremental stages: an initial plan that consists of constructing a pipeline to transfer water from an existing water pond, and a complimentary plan that involves constructing a dam to store additional water (Watson, 1998).

Diversification of water supply options provides additional insurance against climatic variability and changes. Groundwater recharge using excess winter rainfall or treated wastewater increases strategic reserves necessary for withering through drier periods. Desalination is increasingly becoming a viable option particularly in the heavily populated coastal areas to augment or replace traditional water supplies (Brekke, 2009).

### **CASE STUDY – EGYPT'S ADAPTION TO CLIMATE VARIABILITY IN THE NILE**

Egypt relies almost exclusively on runoff from the Nile, which travels thousands of kilometers from the Ethiopian highlands and Lake Victoria (Figure 2). Over millennia, Egypt was at the mercy of fluctuations in the Nile that have brought death and destruction from floods and famine in dry years. The construction of the Aswan High Dam (AHD) in the early sixties has effectively shielded the country from annual fluctuations of the river. However, an unprecedented - since 1870 - sequence of especially dry years from

1978 to 1987 reduced the AHD reservoir to alarmingly low levels and brought the country to the brink of extreme water shortages and exposed its vulnerability to the interdecadal variability of the Nile basin (Conway, 2005). In response, the government took several measures to reduce demand including extending a ban on winter irrigation, reducing areas allocated for rice production, and improving hydraulic conveyance and efficiency (Conway, 2005). Although the prolonged drought ended with the abundant yield of 1988, the country has taken concrete steps to develop capacity on hydro-meteorological forecasting by first establishing a “planning and models” department at the Ministry of Water Resources and Irrigation (MWRI) which has developed into the Nile Forecast Center (NFC) through financial support from USAID and technical support from NOAA and FAO (Conway, 2005). The NFC utilizes remote sensing information on the main upper reaches of the Nile to produce river flow forecasts. Moreover, the Nile Basin Management (NBM) decision support system was established based on modeling studies of the hydrologic, infrastructure, and environmental components of the Nile Basin. The NBM is used to formulate and assess different climatic and management scenarios (Conway, 2005) that are necessary for drafting climate change adaptation strategies.

To alleviate tension on sharing the water resources of the Nile, Egypt has championed the development of the Nile Basin Initiative (NBI), which grouped all riparian countries of the Nile as members. The NBI conducts high-level meetings and capacity building workshops and seminars. Although no comprehensive agreement has yet materialized among all riparian countries, the NBI has eased tension and created a forum for dialogue and arbitration of potential conflicts. Therefore, the NBI is an important adaptation strategy that reduces vulnerability to conflicts that could arise from competition over finite water resources made increasingly scarce by climate change and growth in demand, particularly in the upstream riparian countries.

### CASE STUDY – THE JEDDAH FLOODING EVENT



Jeddah is the second largest city in Saudi Arabia. On November 26, 2009, a major storm dropped over 90 millimeters of rain within 4 hours, equivalent to twice the yearly average. By midday the rain accumulated into massive torrents that ripped through the poor southern neighborhoods of the city and swamped thousands of vehicles caught in a heavy traffic jam exacerbated by the earlier light flooding of highways. The flood wave razed hundreds of buildings and swept thousands of cars and buses loaded with passengers. The death toll was over 150 (Usher, 2009), with damages to over 8,000 homes and over 7,000 vehicles (Alsharif, 2009).

Jeddah came also under eminent risk of a major public health disaster as sewage water levels rose high in the upstream “Musk” lake (Abumansour, 2009). Originally planned for flood control and water supply, the lake was later turned into a dumping reservoir for sewage tankers since the city virtually lacks a sewage network. At the peak of the storm the lake was estimated to contain around 50 million m<sup>3</sup> of sewage water.

Although the Jeddah flooding event is not necessarily tied to climate change, it nevertheless highlights vulnerabilities that are relevant to projected climatic change stimuli (increase in precipitation intensity). From a hydrologic perspective, the event is not very significant. However it has manifested into a catastrophe due to several

vulnerabilities at the individual, societal, and institutional levels. The most severely hit parts of the town were built on a “wadi” bed with virtually no drainage system. Poor planning and alleged corruption opened the way to haphazard development of poorly constructed buildings and densely populated shanty houses occupied mostly by migrant workers. The devastated area is crossed by several highway junctions kept busy by inadequate traffic planning and control. Many of the commuters were not aware of the danger nor at first alarmed by the floods, which added to the later chaos and death toll. Many survivors reported lack of response from the police and civil defense and could not reach authorities as emergency lines were reported mostly busy during the event. Many people were trapped and could not get help. The situation was further exacerbated by electric outages as the ravaging floods knocked down power lines.

The high mortality is tied to several key generic and hazard-specific vulnerabilities. The generic vulnerabilities include those of poverty, social status, governance (corruption, accountability), and infrastructure. Those linked to hazard-specific vulnerabilities include the lack of adequate public drainage and sewage disposal and treatment, improper building structure, poor traffic management, improper urban planning, and the inexistence of emergency preparedness planning. This event has exposed several vulnerabilities to climatic hazards that could intensify under projected climatic change. It therefore provides an important lesson for decision makers, homeowners, and society at large to work on reducing these vulnerabilities.

## VII. CONCLUSION AND RECOMMENDATIONS

This chapter addresses vulnerability of water resources in Arab countries to climate change. Being situated mostly in mid-latitudes, Arab countries are expected to undergo a major reduction in their water balance due to projected decrease in precipitation levels combined with increased evaporation rates.



The predicament is particular critical for Arab countries considering that most of their renewable water resources originate outside their boundaries in regions which are also expected to experience a similar fate.

Climate change is one of several stressors, along with population growth and land use change, that accentuates water-associated vulnerabilities. Given that climate change projections are still plagued with uncertainty, a vulnerability-based approach provides a more logical framework to select and formulate adaptation strategies based on accumulated knowledge of the strengths and weaknesses of different sectors and systems to given vulnerability determinants. By addressing these determinants that include water scarcity, climate variability, demographic factors, land use changes, and deficiencies in water services, it would be possible to enhance the resilience of different systems to projected climatic change. This is a win-win situation for Arab countries as they prepare to address current as well as future water challenges.

Two case studies were presented to illustrate different experiences in dealing with climate variability. Jeddah's recent flood is a testimony of the failure of planners in addressing intrinsic vulnerabilities that relate to the inadequacy of the drainage system, poor urban planning, and lack of emergency preparedness. Egypt's experience in managing the Nile's water flows provides a brighter spot where the country has built adaptive capacity to variable river conditions. In both cases, the experience with climate variability acts as a “preparatory exercise” for future events that may become more common

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# State of Freshwater Ecosystems

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Ammiq Swamp

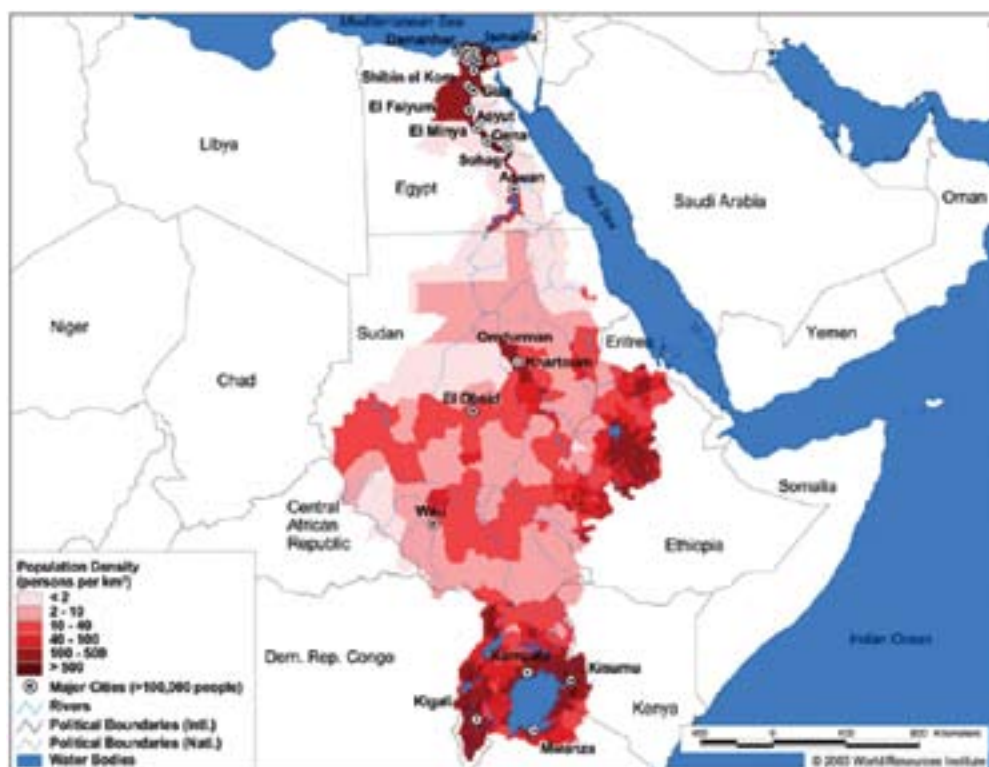
## I. INTRODUCTION

The Arab countries are among the world's most water scarce. The prevailing arid conditions in the region where the average annual evaporation may exceed 2,000 mm/year (El-Quosy, 2009) play a key role in reducing freshwater availability. This is compounded by rising populations in Arab countries at an annual growth rate of 2.7% on average (ESCWA, 2003), which exceeds the average global rate. Despite the fact that two thirds of the renewable water resources in the Arab countries originate from outside the region (El-Quosy, 2009), the sustainable management of much of this water still eludes resource managers and policy makers. Many water resources basins, both surface and groundwater, are also shared among a number of countries. This also presents major challenges for the sustainable management of water resources and leaves Arab countries vulnerable to conflicts particularly as pressure mounts for meeting increasing demands for domestic, agricultural, industrial, and environmental uses.

An additional stress anticipated to exacerbate these strains is climate change.

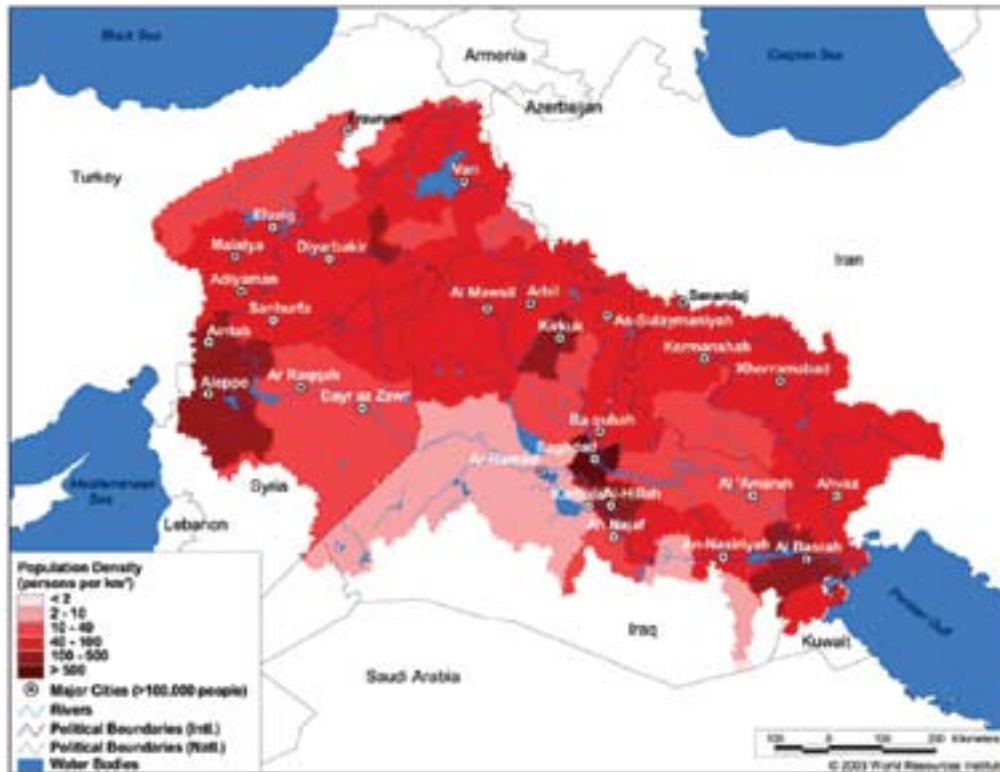
The strained conditions of water resources in the Arab countries have negatively affected the state of freshwater ecosystems as well as species biodiversity significantly. Freshwater ecosystems in Arab countries provide substantial benefits as a source for drinking water, fisheries, and irrigated agriculture. Despite their importance in securing and maintaining livelihoods, many freshwater ecosystems are being severely damaged by human activities. It is thus important to get an appreciation of the state of freshwater ecosystems in Arab countries in order to inform the development of integrated management plans for these systems that ensure sustainable use, restoration, and preservation. However, the lack of data, systematic measurements, and documentation on the status of these systems make the task of managing them extremely challenging. This in turn places a high value on the urgent need for continuous, credible, and relevant data acquisition and monitoring.

FIGURE 1 THE NILE RIVER WATERSHED



Source: WRI, 2003a

FIGURE 2 THE EUPHRATES AND TIGRIS RIVERS WATERSHED



Source: WRI, 2003b

## II. DISTRIBUTION OF FRESHWATER ECOSYSTEMS IN THE ARAB WORLD

### a. Rivers and Streams

There are 34 perennial flowing rivers in the Arab world. However, there are large variations in their flow rates and the size of their catchment areas. Rivers in Arab countries can be classified broadly into three categories:

**Long rivers:** The Nile, Tigris, and Euphrates are the major rivers and contribute almost 80% of the total surface water flow in Arab countries.

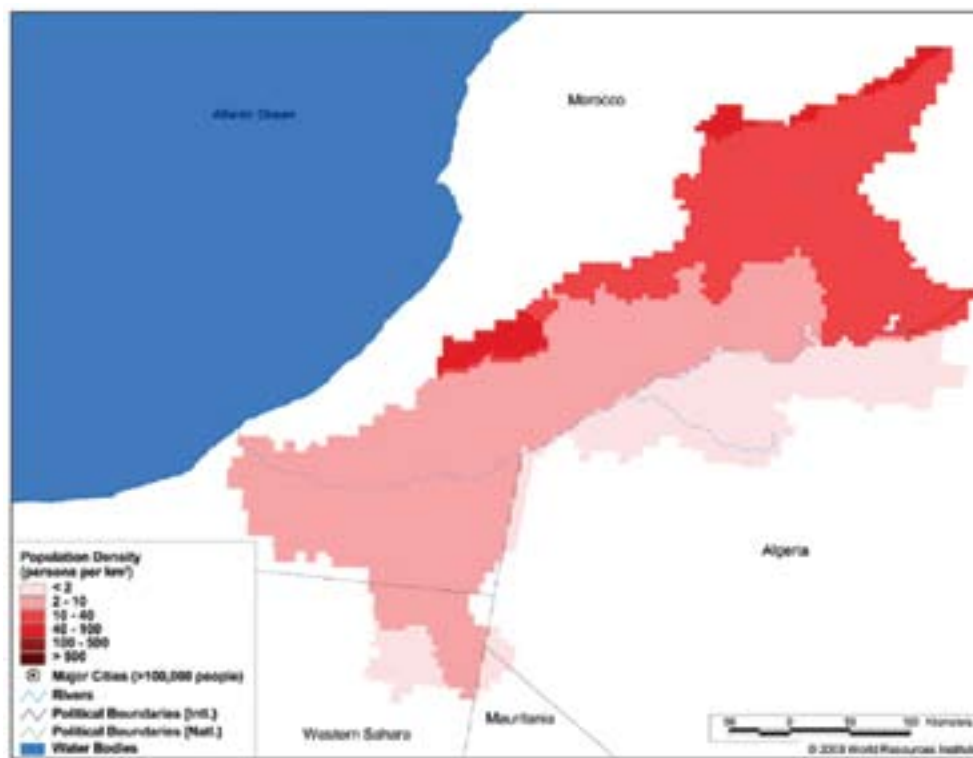
The Nile River is regarded the longest river in the world (6,650 km). Flowing northward, the Nile River has two major tributaries: the Blue Nile and the White Nile. The latter is the longer, yet the former is the source of the majority of the Nile's River water. The White Nile originates in the Great Lakes region of central Africa and flows north through Tanzania, Lake Victoria, Uganda, and southern Sudan. The Blue Nile starts at Lake

Tana in Ethiopia flowing into Sudan from the southeast. The two rivers meet near the Sudanese capital of Khartoum. The Nile empties into the Mediterranean Sea. Figure 1 depicts the watershed of the Nile River basin.

The Euphrates River (2,289 km) originates in the Taurus Mountains in Turkey and flows through Syria and Iraq to join the Tigris to create Shatt al-Arab near Al-Basra City, which in turn flows into the Arabian Gulf. The river surface catchment has a total area of 378,000 km<sup>2</sup> and covers areas in Turkey, Syria, Iraq, and Iran. The Tigris River (1,862 km) originates in the Taurus Mountains in Turkey. As it flows out of Turkey, the river becomes the border between Syria and Iraq. Baghdad stands on the banks of the Tigris River. Figure 2 depicts the watershed of the Euphrates and Tigris River basins.

Wadi Dar'a or Oued Draa (1,200 km), the largest river in Morocco, emerges from the Atlas Mountains and flows into the Atlantic Ocean. Figure 3 depicts the watershed of the Wadi

FIGURE 3 THE WADI DAR'A RIVER WATERSHED



Source: WRI, 2003c

Dar'a River.

**Small rivers:** There are numerous streams and small rivers in the Arab countries. The following is a brief description of the major ones.

The Litani River (140 km) emerges from southern Lebanon in the Beqaa Valley and empties into the Mediterranean Sea north of Tyre. The Orontes (402 km) emerges from the Beqaa Valley, flows through Lebanon, passes through Hims and Hama in Syria, turns to the west in southern Turkey, and empties in the Mediterranean Sea.

In the Maghreb region, there are many rivers that emerge from the Atlantic Mountains and empty either in the Mediterranean or the Atlantic Ocean. Examples of the rivers that flow into the Mediterranean are Al-Mujaradah in Tunisia, As-Slef in Algeria, and Al-Malwiah in Morocco. As for the rivers that flow into the Atlantic Ocean, all are in Morocco such as Sebo, Um-Arrabie', and As-Sous.

**Internal rivers:** The Jordan River and the Barada River are among the main internal rivers in the Arab countries.

The Jordan River (360 km) originates at the Syria-Lebanon border, flows through Lake Tabaryya (Tiberias), and then receives its main tributaries, the Yarmouk River and the Jabbok River. Its other tributaries are the Hasbani, which flows from Lebanon, the Banias River sourced from a spring at Banias at the foot of As-Sheikh Mountain, and the Dan River also sourced at the base of As-Sheikh Mountain.

The Barada River (71 km) flows through the spring of 'Ayn Fijah of Damascus. Its source is Lake Barada, located at about 8 km from Zabadani. The river ends at Utaibah Lake.

#### **b. Wetlands**

There are many wetlands and marshes in the Arab countries. These might be classified into



TABLE 1 MAIN WETLANDS IN SELECTED ARAB COUNTRIES

Country	Main Wetlands
Algeria	Most of the wetlands are coastal wetlands such as that of Sebkhha d'Oran, the Salines d'Arzew, the marshes of the Plain of Habra, the marshes of the Plain of Guerbes, and Garaet el Mekhada
Egypt	Nile Delta, the Bahra el Maryut, the Bahra el Idku, the Bahra el Burullus, the Bahra el Manzala, and the Sabkhet el Bardawil
Iraq	Haweija marshes, the Baquba Wetlands, the Attariya Plains, the Haur Al Shubaicha, the Ramadi Marshes, the Al Musayyib Wetlands, the Haur Ibn Najim, and the Wetlands of Lower Mesopotamia
Jordan	The wetlands may be grouped into four main areas: (1) North Jordan Valley Wetlands of the Yarmouk River basin (including Al Rais Pool), Wadi El Arab and Wadi Ziglab; (2) Middle Jordan Valley Zarqa River and King Talal Dam, and wetlands in the lower Jordan River (Wadi Damia, Kibed Pool, Kafrein Dam, Shu'eib Dam and Swaimah Pool); (3) South Jordan Valley Wadi Mujib; and (4) Eastern Desert Ghadir Burqu
Kuwait	The only natural wetlands are marine and coastal ones such as Al-Jahra Pool Nature Reserve, Dawhat Kazima, Sulaibikhat Bay and Doha Peninsula Nature Reserve, and Al-Khiran
Lebanon	Ammiq Swamp is the only major swamp
Libya	Wetlands are of coastal nature such as that of the West Coast and the Gulf of Sirte
Mauritania	There are tidal and coastal swamps and marshes. Coastal ones include the Marais de Tombos, marshes of the Aftoilt es Saeli, coastal Pans, the Floodplain of the Senegal River, and the Senegal River Delta
Morocco	There are two main types of wetlands; tidal and coastal. For the earlier we have Sebkhha Tazra (Khnifiss Lagoon), Merja Zerga, Nador Lagoon while the later includes Oualidia and Sidi Moussa Lagoons, Douiya Sidi Bou Rhaba (Mehdiya Lagoon), Merja Sidi Mohamed Ben Mansour and Merja Daoura, and the Rio Martine Lagoons and Marshes
Sudan	Permanent swamps include Lotagipi Swamp, Kenamuke/Kobowen Swamp, the Lotilla Swamps, Badigeru Swamp, the Veveno/Adiet/Lilebook Swamps, and the Machar Marshes
Syria	The main ones are Al-Radd and Tual al-'Abba. In addition, marshes that are associated with Euphrates in Al-Jazeera area in Syria are Halabiyat Zulbiyat, Al-Shumaytiyah and Huwaijat al-Mayadin

Source: Based on Scott, 1995

perennial or ephemeral, coastal, tidal, river-fed, or spring-fed wetlands. Table 1 is a summary list of the main wetlands in selected Arab countries.

### c. Lakes

Several natural and man-made lakes exist in the Arab world. Table 2 is a summary list of the main lakes.

### d. Groundwater and Oases

For many Arab countries, underground aquifers are considered the main source for securing water needs since surface water resources are insufficient. This has created water deficits and significant gaps between replenishment and abstraction rates. The Gaza Coastal aquifer is a case in point where intensified exploitation had led to an

average deficit of 30 million m<sup>3</sup> considering that the average total abstraction equals 150 million m<sup>3</sup> (Ghabayen, 2010).

Figure 4 shows the groundwater regions in the Arab World. As can be seen from the figure, the Arab World overlies six different groundwater regions as classified by UNESCO (2009).

The majority of groundwater aquifers in the Arab world are shared. Figure 5 and Figure 6 show the distribution of trans-boundary aquifer systems, while Table 3 and Table 4 present these aquifers in tabulated form. It should be mentioned that many local aquifers within each country do exist, yet they are not described herein.

Available renewable groundwater volumes show

TABLE 2 THE MAIN LAKES IN SELECTED ARAB COUNTRIES

Country	Main Lakes
Djibouti	there are two main lakes; Lake Abbe and Lake Asal
Algeria	Fetzara, floodplain of the Oued el Kebir, Melah Lagoon, Lake Oubeira, Lake Tonga
Egypt	Lake Nasser
Iraq	Tharthar Lake, the Samarra Lake, the Shari Lake, the Lake Al Habbaniya, and the Lake Razazah (Bahr Al Milh)
Libya	Lakes of Wau en Namus
Mauritania	Lake Rkiz, Lake Tianbrank, Mare du Diaouling, Mare de Nter, Lake d'Aleg, Lake du Mal, Mare de Kankossa, Mare de Mamoude, and Lake le Bheyr
Sudan	Lake Keilack, Lake Kundi, Lake Ambadi, Lake Maleit, Lake Yirol, Lake Anyi, and Lake Nyiropo
Syria	Buhayrat al-Khatuniyah, Buhayrat al-Mad, Baath Lake, Sabkhat al-Jabbul, Sabkhat Muh, Lake Qattine, Buhayrat al-Laha, Jabal Sis Lakes, Lake Muzayrib, Lake Mas'adah, Lake Bluran, Buhairat As-Sab'a, Lake Zarzar, Lake Rastan, and Lake Al-Asad. In Lebanon, Lake Qaroun is a man-made lake
Palestine	Lake Tabaryya (Tiberias), Lake Lot (Dead Sea) and Lake Al-Houla. The later was dried by Israel

Sources: Based on (with the exception of Palestine and Syria) Scott, 1995

high variability from country to country, as illustrated in Table 5, with the top ranked being Sudan. Total groundwater withdrawals in many Arab countries exceed by far the total renewable volume as the case of Jordan exemplifies, where many of its aquifers are being overexploited (Arab Environment Watch, 2010).

Oases in Arab countries<sup>1</sup> include many in Libya such as the Oases of the Ghat Region, the Oases of the Sabha District, and the Oases of Kufrah. In Mauritania there is the El Berbera Oasis. In Egypt the main Oases include the Siwa, Qattara, Wadi el Natrun, and the 'New Valley' Oases. In Jordan, Al-Azraq Oasis is the main one in the Eastern Jordanian Desert (Scott, 1995).

### III. THREATS TO FRESHWATER ECOSYSTEMS

Freshwater ecosystems are generally threatened by man-made activities. Human activities resulting from urbanization, economic expansion, and industrialization produce unintended consequences that cause degradation to scarce freshwater resources, threatening more deterioration to already stressed water ecosystems.

When human beings are faced with increasing water demand, the acquisition of additional water generally takes place by diverting river water flow or by building dams. These activities

block migration routes for fish and causes habitat disruption and shrinkage. In addition, urban storm water and irrigation runoffs pose a contamination threat to freshwater ecosystems including both surface waters as well as aquifers.

Urbanization and real estate development adjacent to wetlands often lead to wetland depletion and drainage and sometimes to wetland habitat destruction. Species with aquatic life cycles that rely on wetlands for spawning and feeding are consequently threatened. Because wetlands provide protection from severe weather conditions such as flooding, environmental degradation to wetlands will diminish their ability to ameliorate the effects of extreme flooding and drought events.

A number of examples can be offered. When Egypt's Aswan Dam came into operation, the number of commercially harvested fish species on the Nile has dropped by almost two thirds, and the sardine catch in the Mediterranean has fallen by more than 80 percent (Postel, 1996). Habitats around the Tigris and Euphrates River Basins, shared by Turkey, Iraq, Syria, and Iran, are threatened by river damming and conflicts, raising concerns about the degradation of biologically rich wetlands, such as the Mesopotamian marshlands in southern Iraq, that host numerous important species. "The Mesopotamian Marshes — which once covered an area nearly half the size of Switzerland and

were central to the livelihoods of the half a million Ma'dan or Marsh Arab people — have been all but destroyed” (WWF, 2010).

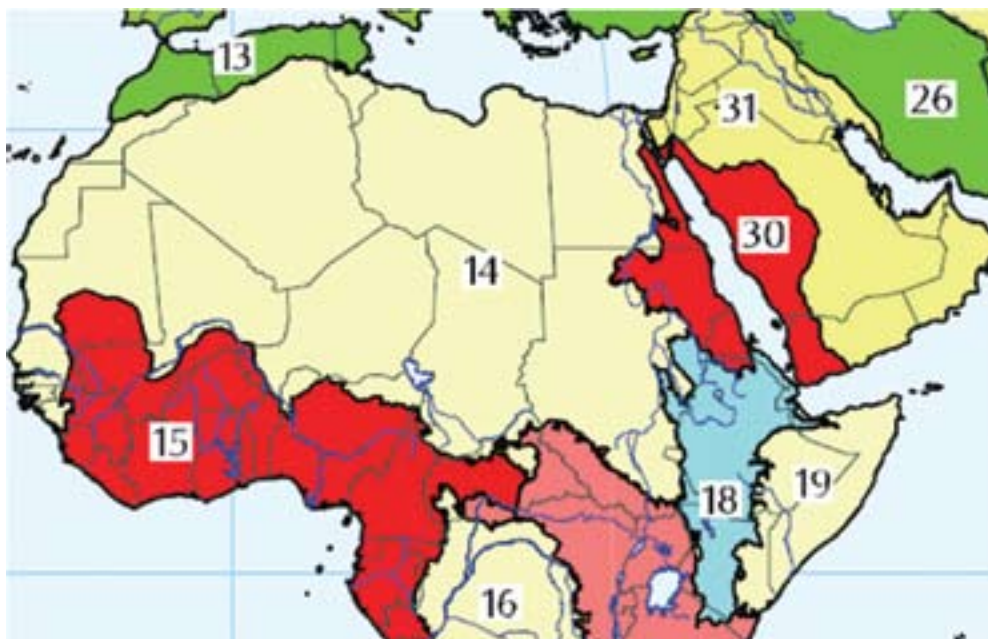
In Jordan, the Al-Azraq Oasis in the Eastern Desert is formerly comprised of a complex of spring-fed marshes and pools. According to Budeiri (2010), “the once extensive wetlands of the Al-Azraq Oasis have been completely destroyed because of over-exploitation of groundwater and dam construction on the major wadis”, thus cutting out the supply of water from the two main springs to the oasis. In addition to the depletion of these wetlands, hunting has caused threats to wildlife around them. “As a result of these various detrimental factors, many aquatic species are now on the verge of extinction in Jordan, if not already extinct” (Budieri, 2010). In 2008, the multi-stakeholder Azraq Oasis Restoration Project has been launched which aims at restoring a substantial part of the Azraq Oasis (Ramsar site), while balancing water uses, maintaining ecosystem services and addressing long-term access and rights to water by underprivileged groups in the targeted communities (IUCN, 2010).

Many wetlands in Arab countries have been degraded by drainage, diversion of water supplies for irrigation purposes, pollution, dredging, urban development, and by other human activities, causing their depletion and the collapse of entire ecosystems (Desert Research Center, 2009; Fishar, 2009; LAS, 2009). Moreover, overexploitation of groundwater resources is an on-going problem in many Arab countries. Examples can be drawn from Palestine and Jordan. In Palestine, the Gaza coastal aquifer is being pumped at rates that exceed aquifer recharge rates, creating severe seawater intrusion and increased salinity in many wells utilized for domestic water supply (PWA, 2007). In Jordan, the average annual abstraction from all basins exceeds the renewable average of recharge and currently stands at 159% of that average (JMWI, 2010).

#### IV. WATER RESOURCES USE AND ALLOCATION IN FRESHWATER ECOSYSTEMS

Generally speaking, resources can be derived from

FIGURE 4 MAP OF GROUNDWATER REGIONS



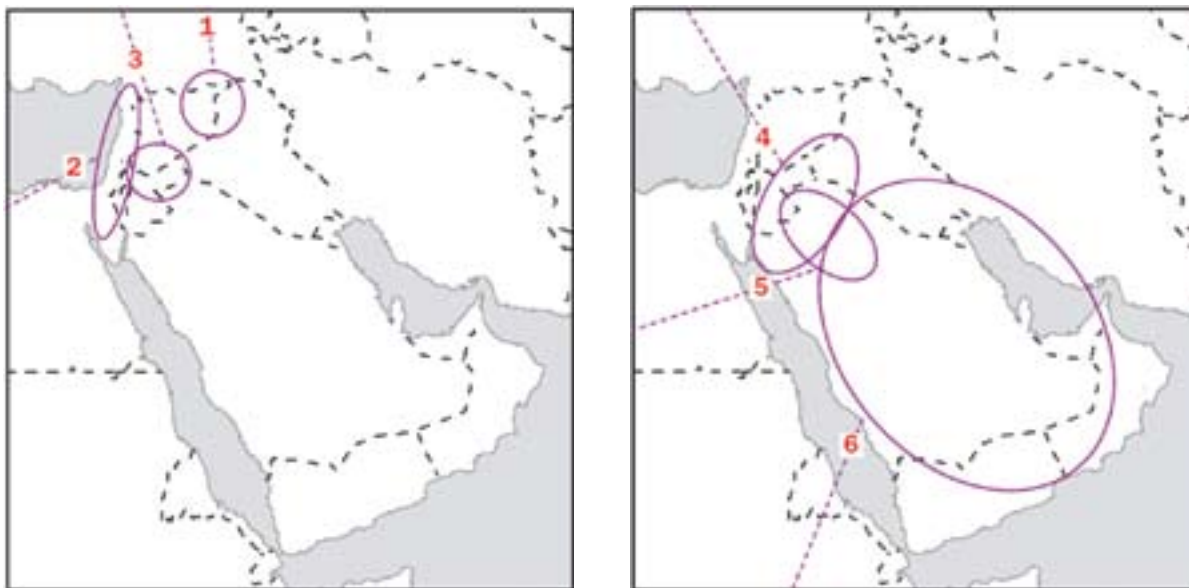
**Legend:**

- 13. Atlas,
- 14. North African basins,
- 15. East Africa rift and associated basins,

- 19. Ogaden-Juba basin,
- 30. Levant and Arabian platform,
- 31. Arabian shield.

Source: Adapted from UNESCO, 2009

FIGURE 5 MAP OF AQUIFER SYSTEMS IN ARAB COUNTRIES LOCATED IN WESTERN ASIA



Source: adapted from UNESCO, 2009  
(Map legend of aquifer systems summarized in Table 3)

a river basin ecosystem. These ecosystems provide services such as freshwater for drinking and cooking as well as for other land-based activities such as agriculture, energy production, industrial use, mining, and urban area development.

However, many other dependent systems exist in river basins such as forested slopes and downstream floodplain wetlands. The need for water by these natural systems may require the reallocation of water use and restrictions on land-use related activities. This might lead to conflict of interests among competing users. In reaching compromises and allocation targets, river basin ecosystems that sustain soils, fish habitats, and aquatic biodiversity may not get their adequate share of water.

Therefore, water use and allocation should take into account ecosystems health and the biodiversity of life that it supports. Integrated land and water management should be considered at the river basin level. Upstream water use should be restricted to address the downstream needs of existing and living species. This also implies the restoration of migratory pathways of freshwater species through improved design or retrofitting of infrastructure. For instance, to retrofit an existing dam may require taking account of the migratory behavior of the target species as well as changes in the physical and hydraulic structure of the water intake facility. There

are many examples of dam retrofitting projects designed to minimize disruption to aquatic life migratory pathways along river basins and dams.

## V. BIODIVERSITY IN FRESHWATER ECOSYSTEMS

In general, freshwater ecosystems are home to a tremendous diversity of fish, aquatic plants, invertebrates, and microorganisms. In the Arab world, rising populations combined with quick urbanization and utilization of increasing amounts of freshwater are placing enormous stress on ecosystems and their floral and faunal inhabitants resulting in a decline of ecosystem services (Krupp et al., 2009).

According to Krupp et al. (2009), habitat destruction is the major cause of terrestrial biodiversity loss in the Arab world, where “deforestation, hunting, overgrazing, and degradation of rangelands have continued for millennia.” In the past century, threats to ecosystems from “urban and industrial developments and pollution have increased at an alarming speed” (Krupp et al., 2009).

Many wetlands and marshes (for instance in Iraq) are reported to have been important staging and wintering areas for migratory waterfowl (Scott,

TABLE 3  
AQUIFER SYSTEMS IN ARAB COUNTRIES LOCATED IN WESTERN ASIA

ID	Aquifer Name	Countries
1	Upper Jezira/Mesopotamia	Iraq, Syria, Turkey
	Eastern Mediterranean:	Palestine, Israel, (Jordan), Syria, Lebanon
	Western Mountain Aquifer	Palestine, Israel
	Northern and Southern Jurassic and Cretaceous Aquifers	Lebanon, Syria
2	Hasbani-Ouazani Aquifer catchment	Lebanon, Israel
	Northeastern Mountain Aquifer	Palestine, Israel
	Eastern Mountain Aquifer	Palestine, Israel
	Gaza Strip Aquifer	Palestine, Israel
3	Huran and Jabal Al-Arab	Jordan, Syria, Saudi Arabia
4	Syrian Steppe	Iraq, Jordan, Saudi Arabia, Syria
5	Disi Aquifer, Saq	Jordan, Saudi Arabia
6	Eastern Arabian Peninsula	Bahrain, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, Yemen

Source: UNESCO, 2009

1995). As stated in the “Directory of Wetlands in the Middle East”, Marchant and Macnab “recorded a wide variety of ducks, shorebirds, and other waterfowl [in Hawejja Marshes] mostly in small numbers, on passage and in winter, including *Botaurus stellaris* and *Marmaronetta angustirostris*. They also recorded up to 2,000 *Anser albifrons* and 75-100 *Hitnantopus himantopus* on passage” (Scott, 1995).

## VI. ECONOMIC VALUATION OF FRESH WATER ECOSYSTEM SERVICES

According to Daily (1997), “ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life.” Different ecosystems provide critical services for human and non-human life forms such as food, water treatment, air purification, flood control, and climate regulation (Daily, 2005). Advances in ecosystem science over the past several decades have shed considerable light on these diverse benefits offered by these ecosystems.

Like other ecosystems, freshwater sources such as groundwater wells, springs, lakes, rivers, and streams provide many services to human society. These services include both market goods and

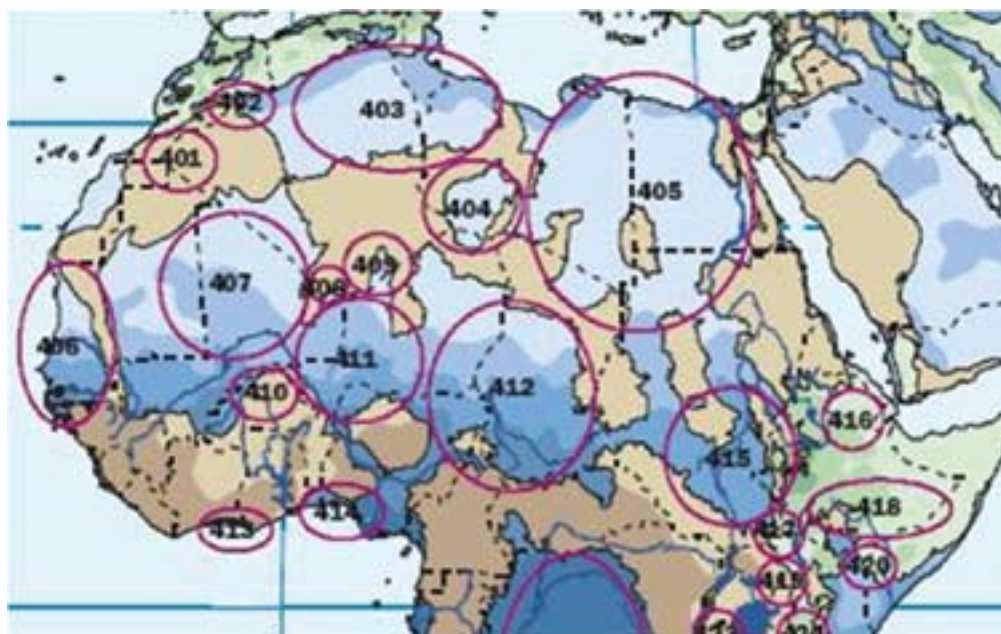
services like drinking water as well as nonmarket goods and services such as biodiversity. Many of the goods and services that may be provided by freshwater sources in the Arab States today are not bought or sold which means that they do not have a declared price. The estimation of the economic value of these services needs to be based on different factors and the quantitative valuation of freshwater ecosystems requires expertise from both social and natural sciences. It is believed that the available methods for the quantitative valuation of freshwater ecosystems economics are still evolving, imprecise, and controversial.

Freshwater ecosystems in the Arab world provide different services that can be divided into two groups:

1. Direct market goods or services in the form of water used in drinking, irrigation, transportation, eco-tourism, and electricity generation; and
2. Non-market goods or services such as sustaining biodiversity, habitats for plant and animal life, and cultural and spiritual needs associated with lakes and rivers.

By estimating the economic value of ecosystem goods and services not traded in the marketplace, social costs or benefits that otherwise would

FIGURE 6 MAP OF AQUIFER SYSTEMS IN ARAB COUNTRIES LOCATED IN AFRICA



Source: adapted from UNESCO, 2009  
(Map legend of aquifer systems summarized in Table 4)

remain hidden or un-appreciated are thus revealed. For this reason, ecologists, social scientists, and environmental managers are increasingly interested in assessing nonmarket ecosystem goods and services (Wilson and Carpenter, 1999). Different valuation methods have been developed to estimate the value of the goods and services provided by ecosystems. Four of these methods have been used extensively to value services provided by freshwater ecosystems.

The most widely used approach to measuring the economic value of environmental services is the contingent valuation method. This method relies on direct consultation with beneficiaries regarding their preferences for paying. This method allows a sample of people who benefit from a particular resource to tell researchers directly, through surveys, what they are willing to pay for some improvement in environmental quality (Kramer, 2005). What is attractive about this method is the ability to capture both use value (e.g., irrigation water use) and non-use value (protection of species biodiversity) of water ecosystems (Kramer, 2005). However, surveys allow participants to state their willingness to pay without registering any actual observed behavior, which means that a potential

bias might exist in their responses.

The travel cost method is also widely used to value water ecosystem services by examining how people value and make choices about their leisure time. This approach employs statistical methods to interpret data about recreational expenditures, frequency of visits to water sites, and site characteristics to infer the economic value of water ecosystem sites (Kramer, 2005).

The third method is the change in productivity method, based on assessing changes in market prices due to ecosystem services. This method recognizes that when changes in environmental quality affect the production of marketed goods, these effects can be captured by observing what happens in a related market (Kramer, 2005). So if freshwater quality changes or water pollution occurs resulting in reduced vegetable production, the impact can be valued by registering changes in the price of vegetables. In this case, the value of freshwater can be measured by the dollar value of lost vegetable sales.

The hedonic property value method presumes that although many environmental goods are

TABLE 4  
AQUIFER SYSTEMS IN ARAB COUNTRIES LOCATED IN AFRICA

ID	Name	Countries
401	Tindouf Aquifer	Algeria-Morocco
402	Errachidia Basin	Algeria-Morocco
403	Northwest Sahara Aquifer System	Algeria-Libya-Tunisia
404	Mourzouk-Djado Basin	Chad-Libya-Niger
405	Nubian Sandstone Aquifer System	Chad-Egypt-Libya-Sudan
406	Senegalo-Mauritanian Basin	Gambia-Guinea-Bissau-Mauritania-Senegal
407	Taoudeni Basin	Algeria-Mali-Mauritania
408	l'Air Cristalline Aquifer	Algeria-Mali-Niger
409	Tin-Seririne Basin	Algeria-Niger
415	Upper Nile Basin	Ethiopia-Sudan
416	Awash Valley Aquifer	Djibouti-Ethiopia
418	Ogaden-Juba Aquifer	Ethiopia-Kenya-Somalia

Source: UNESCO, 2009

not traded in markets, their presence may have an effect on property values (Kramer, 2005). For example, land close to a lake has probably a higher value because of any number of attractive features prized by consumers such as landscape views, recreational sports, or fishing. Statistical techniques are then used to separate out the contribution of ecosystem services from the total value of the property (Kramer, 2005).

## VII. VULNERABILITY AND ADAPTATION OF FRESHWATER ECOSYSTEMS TO CLIMATE CHANGE

Arab countries encounter a variety of climatic conditions that entail high and low amounts of rainfall and temperatures. However, the region is generally characterized by semi-arid, arid, and hyper-arid conditions. According to the International Panel on Climate Change, this aridity implies that the region will be under high vulnerability to climate change (IPCC, 2007). Climate change is projected to bring about increased variability in precipitation, thus adding more stress to a region of scarce water resources. According to Abou Hadid (2009), modeling studies have indicated that Arab countries will encounter by the end of the 21st century an increase of 2 °C to 5.5 °C in surface temperature and a decrease in precipitation from 0 to 20%.

The anticipated climate change indicators described above imply intense rainfall events with shorter winter times. This connotes a considerable decrease in groundwater recharge and an increase in surface runoff. Arab countries that rely heavily on groundwater resources for water supply do not have the needed infrastructure to collect and harvest the increased amounts of surface runoff. When considering that many Arab countries rely heavily on groundwater for securing their water needs, vulnerabilities to climate change become less abstract.

Arab countries in North-West Africa (Tunisia, Algeria, Mauritania, and Morocco) are the most vulnerable to climate change since they are largely dependent on rainfall (El-Quosy, 2009). Syria, Iraq, Egypt, and Sudan are dependent on river flows and thus they can be considered to be highly vulnerable to climate change. Research has shown that the flow of the Nile River to be sensitive to rainfall on the Ethiopian highlands (El-Quosy, 2009). A temperature increase by two degrees Celsius might lead to a decrease in river flow by 50% in Equatorial Lakes and Bahr El Ghazal (El-Quosy, 2009). The countries located in the Arabian Peninsula have the lowest vulnerability to climate change since they have limited internal renewable water resources and thus have nothing to lose (El-Quosy, 2009). In other words, these countries for instance do not rely at all on rainfall for agriculture or water harvesting.

## OPINION

**BREAKING ARAB WATER SCARCITY****Mohamed Kassas**

A major challenge facing the Arab region is its insufficient freshwater resources. The arable land makes up 3.4%, grassland 18.8% and forest and woodlands 10%; thus, 4.1 million square kilometers or 30% of the overall Arab land area is productive land, while the remaining 70% account for dryland and deserts. Therefore, cooperation is needed to streamline efforts for addressing water shortage issues on three levels:

- Increasing available freshwater resources.
- Enhancing the efficient use of available freshwater.
- Maintaining the quality of available freshwater.
- 

Universities and research centers in the countries of the Arab region have great research potentials that can, through integration into a comprehensive and sustained mechanism, help these countries find solutions to the problems related to water resources and thus overcome one of the great obstacles to development and modernization.

The following are the major areas that should be the focus of attention:

1. Water resources in river areas in Iraq, Syria, Egypt and Sudan that depend on irrigated cultivation and where the rivers flow from sources outside the Arab region (Turkey in the eastern sector, and Ethiopia and the equatorial sources that feed the Nile basin). Concerned Arab countries are in a delicate position due to the criticality of policy making and management of regional dialogue between estuary countries and source countries. Any successful dialogue should draw a balance between “prescriptive historic rights” and the international political balance.
2. Rainwater resources in the Arab World are limited, yet vital to rain-fed farmlands and rangelands. Efficient management of such areas must be based on technical surveys and studies that lay down guidelines for the sustained development of such resources, i.e. protecting productive ecosystems against degeneration and desertification. The aim should be sustained - rather than maximized - productivity.

The areas of rain-fed cultivation and grasslands are exposed to severe droughts (below-average rainfall). Management of such natural hazards needs a framework that includes:

- An early warning system (to forestall the occurrence of droughts)
- A social plan that prepares communities to deal with emergencies upon occurrence.
- A program for helping affected communities and enabling them to sustain damages.

3. The Arab region has abundant groundwater resources, and its geologic formations contain aquifers in the Arabian Peninsula stretching to the Levantine countries and in Northern Africa from Egypt to Morocco and Mauritania. Water is plentiful, but unfortunately non-renewable and mostly in deep layers. Efficient management should be based on technical surveys that determine the volume of, and safe withdrawal limits from, such resources. Moreover, development of these resources must comply with time-frame parameters and reflect our sense of responsibility towards future generations. Some huge water resources are in vast trans-border basins; and the conservation and development of such resources require a framework of regional cooperation and neighborly relations. Efficient cooperation, in turn, should inevitably be based on information and technical knowledge that all countries related to a common basin must contribute to.

4. The use of water depends on its volume and quality, mainly related to harmful contamination levels. In many places, rivers are contaminated by pollutants flowing from sources to estuaries and carried, along the stream, from towns and villages where industrial and domestic waste is discharged. Due to the limited supply of water available for irrigation, agricultural expansion, in most countries, depends on the re-use of agricultural wastewater. This is manifested in the development plans of water resources in Egypt and other countries that use irrigated cultivation. The only way to develop technologies for the treatment of agricultural wastewater and re-use in irrigation is through scientific research. It is also the way that will facilitate the choice of crop plants and use of adequate irrigation systems.

Use of groundwater should not expose aquifers to contamination because we do not have the necessary



treatment means and remedial technologies in case water supply in lower strata becomes polluted. This implies that extraction of groundwater should involve preventive measures and controls to avoid seepage of polluted water from the irrigated fields to subsurface layers. In other words, innovative technologies are needed to safeguard groundwater resources.

5. The Arab World can make use of the extensive studies conducted by universities, national research centers, Arab regional and international research centers [the Damascus-based, *Arab Center for the Studies of Arid and Drylands (ACSAD)* and the Aleppo-based, *International Center for Agricultural Research in Dry Areas (ICARDA)*] and the Beirut-based, Economic and Social Commission for Western Asia (ESCWA). Such studies provide assessments of available supplies of water that may serve as the foundation for rational plans for agricultural development in the Arab region. Unfortunately, it seems that authorities responsible for agricultural development plans are not familiar with data and facts, which necessitates bridging the gap between research centers and decision-makers. Relations between the two sides are currently marred by three limitations. First, the approach to scientific facts and data is not holistic, but rather partial and selective. Second, the relation between scientists and technology experts, on one side, and decision-makers, on the other, is characterized by mistrust, which leads to the tragic confusion of scientific views with political considerations. This situation cost the Arab society dear by driving most distinguished scholars to move abroad. Third, the scientific elite and the public Arab society eye each other suspiciously, thus hindering the development of the Arab society and spreading fundamentalist thought which shook our society and promoted the image of our countries as terrorist hotbeds. So we are now preoccupied with defending our position; and the best way to succeed in this mission is by embracing knowledge and technology.
6. As all arid regions in the world, the Arab region needs to increase its freshwater resources in order to expand agricultural production areas and rangelands. There have recently been rainmaking attempts (cloud seeding) in Syria and Saudi Arabia to increase rainfall. However, three ways may be explored to increase the sources of freshwater that

may be used for irrigation:

- Groundwater is abundant, but there is need for new, cost-effective and break-through extraction (pumping) technologies. Present technologies are fuelled by thermal energy from petroleum and petroleum products, and we need new ways to overcome the economic obstacles in pumping technologies and sources of energy used. It is worth noting here that the future of solar and wind energy pumping technologies is very promising.
- Desalination technologies are widespread in the Arab region, especially in the Arabian Peninsula and Gulf area; and production economies make the existing technologies cost-effective and suitable for domestic use. But a technological breakthrough is needed to make the use of desalinated water in agriculture feasible. Egypt had, in 1964-65, a project for building a nuclear power reactor in Sidi Kerir, west of Alexandria, primarily to desalinate sea water for use in irrigation agriculture. But the project was, unfortunately, suspended. There is another project for constructing a water channel between the Gulf of Aqaba and the Dead Sea for the purpose of generating power from desalination of water. The project is still under consideration and open for negotiation.
- The Earth surface freshwater sources include masses of ice in Polar Regions and high mountains. There was an attempt, sponsored by Prince Muhammad al-Faisal, to haul an iceberg to the Arabian Peninsula, but it faced the difficulty of crossing the Bab-el-Mandeb Straits. The idea, however, requires further study and search for new technologies. Elsewhere in the world, North American countries looked into a joint project to transport water from Polar Regions in Alaska and north Canada to the arid zones of Southwestern United States and north Mexico, but nothing has materialized so far.

To sum up: the Arab region, like other arid areas in the world, necessarily needs further scientific research and technological development in order to overcome the negative impacts of water scarcity. Needless to say that any such activity requires regional and international cooperation.

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*Dr. Mohamed Kassas is Professor Emeritus at the University of Cairo and former President of IUCN.*

TABLE 5 ANNUAL VOLUMES OF GROUNDWATER PRODUCED INTERNALLY, ENTERING THE COUNTRY, AND THE TOTAL RENEWABLE

Country	Produced internally (km <sup>3</sup> /yr)	Entering the country (km <sup>3</sup> /yr)	Total renewable (km <sup>3</sup> /yr)	Total renewable (m <sup>3</sup> /capita)
Algeria	1.487	0.030	1.517	43
Bahrain	0.000	0.112	0.112	142
Comoros	1.000	0.000	1.000	1479
Djibouti	0.015	0.000	0.015	17
Egypt	1.300	0.000	1.300	17
Iraq	3.200	0.080	3.280	107
Jordan	0.450	0.270	0.720	114
Kuwait	0.000	0.020	0.020	7
Lebanon	3.200	0.000	3.200	758
Libya	0.500	0.000	0.500	78
Mauritania	0.300	0.000	0.300	91
Morocco	10.000	0.000	10.000	316
Oman	1.300	0.000	1.300	457
West Bank and Gaza	0.740	0.010	0.750	181
Qatar	0.056	0.002	0.058	41
Saudi Arabia	2.200	0.000	2.200	86
Somalia	3.300	0.000	3.300	361
Sudan	7.000	0.000	7.000	179
Tunisia	1.495	0.100	1.595	154
United Arab Emirates	0.120	0.000	0.120	26
Yemen	1.500	0.000	1.500	64

Source: FAO AQUASTAT Database

According to Arnell and Liu (2001), climate change is expected to have significant impacts on water supplies creating or exacerbating chronic shortages and water quality. Sea level rise will result in seawater intrusion into coastal aquifers, potentially reducing water resource availability. Changes in quantity and intensity (and duration) of rainfall are likely to result in more floods and droughts and increased demand for irrigation water.

As for ecosystems, they generally undergo changes that are noticeable and observable such as changes in bird migrations and plant flowering dates. Mobile species like birds and larger animals may be able to migrate rapidly in response to changing climate patterns while many ecosystem components including many tree species have

much lower mobility (Malcolm et al., 2006; Root et al., 2003; Parmesan and Yohe, 2003).

When considering in more specificity freshwater ecosystems, climate change will lead to increased warming level and this in turn will increase the demand for water. In order to secure additional water to meet increased demand, more dams may be built on rivers. This will impede the movement of water and reduce its flow rate. In other situations, more water will be diverted from a river's main course, resulting in significant negative impacts on freshwater habitats. When climate change is accompanied by urbanization and population growth, freshwater ecosystems will experience severe degradation and substantial loss of species diversity is likely to occur (Gitay et al., 2001). The dual effects of climate change

and direct man-made stress will probably alter the hydrological and biogeochemical processes, and, hence, the floral and faunal communities of freshwater ecosystems. This vulnerability will create even more fragile conditions in terms of water availability and utilization in Arab countries.

## VIII. CONCLUSION AND RECOMMENDATION

Assessment studies of the state of wetlands, marshes, lakes, river basins, oases, and other freshwater ecosystems in Arab countries are not conducted systematically or credibly over time. Human interactions with these freshwater ecosystems are dynamic and accelerating. Water diversion schemes, agricultural drainage, dam building, urbanization, resource depletion, conflicts, and climate change will continue to impinge on different water environments. Therefore, available information on the state of freshwater ecosystems needs to be continuously and systematically updated. Moreover, it is recommended to establish a knowledge management system for Arab freshwater ecosystems.

Without the acquisition of proper data and increased capacity to generate and utilize knowledge regarding freshwater resources, protection plans and integrated management for water ecosystems will not be efficient or effective. Up-to-date studies should be conducted to assess the status of wetlands, marshes, oases, rivers, and lakes in Arab countries and to highlight the threats to biodiversity and ecosystem sustainability. In addition, Arab countries should invest more on water monitoring networks.

More applied research should be conducted to assess properly the vulnerability of water resources to climate change in Arab countries and adaptation measures should be developed informed by this research. Mathematical characterization models of freshwater resources should be developed to help perform scenario analyses of the effect of different policies and stresses (for instance climate change, urbanization, and population growth).

The development of a comprehensive information system is key for the integrated management of water resources and its

### POLLUTION IN SHATT AL-ARAB



According to a report by the United Nations Office for the Coordination of Humanitarian Affairs (OCHA), Shatt al-Arab, which is formed by the confluence of the Tigris and Euphrates rivers, in the southern Basra District in Iraq, has become so highly polluted that it could cause a break-out of epidemics and diseases.

Dr Malik Hassan, Director of the Basra University's Oceanography Center, points out that Shatt al-Arab has become critically polluted due to the direct dumping of wastewater in the Tigris and the Euphrates, as well as industrial waste, petroleum materials, and arms scrap after the Iraq wars, especially the Iraqi-Iranian war during the 1980s. Dr. Hassan added that the fact that the two rivers were not dredged turned these remains into toxic materials. The oxidation of old weapons and the reaction of industrial and medical wastes generate toxics that remain active hundreds of years and can permeate human bodies. This might increase cases of cancer among inhabitants living by the river or whose livelihoods depend on the river, not to mention increased infectious diseases contracted from water, such as cholera.

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sustainability. For countries that share surface or underground water resources, research collaboration projects are effective for promoting trust as well as ensuring sustainable use, resource protection, and optimal management of these shared freshwater resources. Proper management of shared water resources requires therefore, a knowledge base of technical, political, and legal issues. To have systematically organized and reliable information database on water resources and water use would be an important success factor. Funding can be attained through the creation of a common fund for Arab water security to finance necessary research.

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## NOTES

- 1 Based on the "Directory of Wetlands in the Middle East" downloadable from: <http://www.wetlands.org/RSIS/WKBASE/MiddleEastDir/Title1.htm>

# Agricultural Water Management

AYMAN F. ABOU-HADID



## I. INTRODUCTION

Water scarcity is a critical constraint to agriculture, which accounts for over 83% of water use in the Arab region (IFAD, 2009). Water shortages will be exacerbated over the coming years by rising populations in the Arab region, but water problems are made worse mainly as a product of current water policies and strategies: reluctance to rationalize water use among competing sectors, poorly-targeted investments, low-performing institutions, inadequate spending, deficiency in trained water professionals, and weak water governance (Molden et al., 2007).

According to a report by the International Fund for Agricultural Development (IFAD), the agricultural sector will have to contend with a number of significant challenges. To begin with, it will have to respond to the pressures of producing more food, combating food and water insecurity, and reducing Arab countries' ballooning spending on food imports, which has reached \$28 billion in 2006 (IFAD, 2009). As the largest consumer of water, the agricultural sector is under pressure to redirect progressively more sizable amounts of its share of clean water to satisfy the growing water needs of domestic urban centers and industry. As the largest employer in rural areas, the agriculture sector will also have to respond to the demands to combat poverty in rural areas and accelerate the generation of new employment opportunities, thus helping reduce rural migration of the young to urban centers. In addition, 37 percent, or 47.6 million people, out of an economically active population of 126 million, were engaged in agriculture (in 2006) down from 47.8 percent in the 1990s. More employment in the rural areas could help reduce the influx of rural-urban migration, respond to increasing market demand and eventually reverse the decline of the sector's contribution to the GDP of Arab countries (IFAD, 2009).

In responding to these demands, the sector must also develop the capacity to adapt to decreased precipitation, droughts, higher temperatures, extreme weather events, and crop-threatening variable weather conditions as a result of climate change. In addition to addressing vulnerabilities to climate change, it is now recognized that agriculture is not only a fundamental human activity at risk from climate change, it is a major



driver of environmental and climate change itself (Abou-Hadid, 2009).

These dilemmas reveal that the agricultural sector will be key to managing water resources in the Arab region now and in the coming years. Undisputedly, agricultural policies and strategies will be decisive in addressing these growing pressures and associated water problems. This paper presents an overview of agricultural water management in Arab countries and suggests changes in agricultural practices to help the sector cope with the challenges mentioned above.

## II. AGRICULTURAL WATER SECTOR REFORMS

### a. Policy reforms

Until recently, the primary drivers of water policies have focused on augmenting water supplies to meet new rising demand, while neglecting to develop regulatory policies to manage demand. Subsidies to most irrigation water projects to support agricultural production are still common, and irrigation water is still offered at well below the cost of service provision (AOAD, 1998). The need for new laws and policies to regulate water use could not be more palpable in the region. According to the Arab Organization

**BOX 1: WATER DEMAND MANAGEMENT IN SYRIA**

*Adapted from: Advances in water supply management (Salman and Mualla, 2003).*

Syria is classified amongst the semi arid countries of the Middle East. It had a population of 18 million in 2002 (20 million in 2010) and its total renewable water resources are estimated at 16 billion m<sup>3</sup> per year. In other words, the per capita share of 889 m<sup>3</sup>/year is less than the water scarcity index of 1000 m<sup>3</sup>/person/year. Although this would rank Syria amongst countries with moderate water stress, it will be soon classified as a country with severe water stress if its population continues to grow at its current rate (of about 3%) and water use efficiency is not increased effectively.

In Syria, agriculture consumes about 87% of the country's water. The domestic and industrial water use stand at about 9% and 4% respectively. While urban water demand is rapidly increasing due to a high population growth rate and industrial expansion, new water sources are becoming scarce and extremely expensive to develop.

The water deficit is expected to worsen, placing additional stress on all uses. Since drinking water needs are given top priority in the government's policy, water availability for agricultural use could face severe constraints. Agriculture contributes about 32% to the country's GDP and employs nearly 31% of the workforce, with another 50% of the manufacturing force dependent on it for employment. In 2000, the cultivated area in Syria was estimated at 5.5 million hectares, which accounts for about 30% of the country's total area. About 20% of the cultivated land area (1.2 million hectares) is irrigated.

Until recently, emphasis has been put on the augmentation of new water supplies to meet increasing water demands. As new water sources have become increasingly inaccessible and the cost of projects to augment water supply has become very high, the emphasis has been shifted to other alternatives of efficient use of water such as the modernization of irrigation and the implementation of water demand management.

for Agricultural Development (AOAD, 1998), "adequate water demand management in the agricultural sector necessitates the establishment of a structure of incentives, regulations, and restrictions that will help guide, influence, and coordinate how farmers use efficiently water in irrigation." The abstraction of groundwater for irrigation purposes needs to be controlled. Inefficient water irrigation techniques need to be curtailed and replaced with more efficient technologies. Adopting wastewater reuse practices needs to be strictly regulated to protect public health. Economic incentives for changing cropping patterns or for modernizing irrigation methods need to be reflected in any new regulatory regime.

The need for an agricultural sectoral reform is gradually resonating within government agencies and institutions. Due to recent budgetary constraints, increasing water scarcity, and increasing water demand, some Arab countries are moving towards reducing such subsidies in order to generate enough revenues for operation and maintenance (O&M) of the irrigated schemes, reduce the burden on government budgets, and, at the same time, create direct or indirect incentives for farmers to invest in irrigation-saving technologies and to cultivate low-water demand

crops. Such sectoral concerns can be addressed through a mix of institutional reforms, changes in incentive structures, and technical innovations. Economic instruments such as rebates, reduced taxes, targeted subsidies, price signals, and other economic incentives are examples of fiscal measures that have proved to be effective.

Water policies, institutions, laws, and strategies have been subjected to changes, revisions, and amendments throughout the region. However, the enforcement of laws through participatory regulation and transparency in decision-making is yet a weak link in the chain of water policy reforms (InWEnt, 2008). Similarly, Kandil et al. (2002) have asserted that "it also is necessary to enhance enforcement of existing water-related laws to reduce continued transgression." Any new or amended water legislation must also attend to questions of social equity. In many settings in the Arab region, the rural poor with limited or no access to groundwater have been losers and it is only those who are rich enough to own and pump progressively deeper wells that have been able to capture the benefits (FAO, 2010). Furthermore, there is growing evidence that gender inequities are being reduced in several Arab countries. However, women often have limited power over the decision-making process and limited access to natural resources.

## A SAUDI PLAN FOR SHIFTING TO WATER-EFFICIENT CULTIVATION

The Saudi Government embarked on a new plan for compensating farmers for shifting to the cultivation of crops that require less quantities of water. Abdullah al-Rubay'an, Chairman of the Agricultural Development Fund (ADF), said that the basic target of the sustainable agriculture strategy is to scale down water consumption to 50% of the present volume. Al-Rubay'an added that the plan presupposes the relinquishment of planting green fodder used in the Kingdom as livestock feed.

Agriculture accounts for 85% of Saudi Arabia's water consumption, i.e. nearly 17.5 billion cubic meters (BCM) mostly sourced from groundwater extraction and desalination industries that are highly subsidized by the state. Al-Rubay'an also asserted that green fodder cultivation consumes some 6 BCM of water every year.

The Government recently started reducing 12.5% of the annual wheat production, thus discontinuing a wheat plantation project that lasted 30 years and achieved total self-sufficiency, but drained the country's groundwater resources. Wheat cultivation, according to al-Rubay'an, consumes 4 BCM of water per year.

The new plan aims at achieving optimum benefits from the huge amounts paid by the Government as annual farmer subsidies to support the Kingdom's agricultural sector. "Eighty percent of the Government's agriculture subsidies go to livestock breeding, yet this sector's productivity is modest", explained al-Rubay'an, adding that Saudi Arabia is still a major importer of red meats since the annual local production is 160 thousand tons from 12 million heads of cattle. "The Kingdom is facing a great challenge, that is water supply." He went further to emphasize that, under the new plan, entitlement for Government subsidies supervised by ADF shall be based on supporting least water consuming crops.

The drop in local green fodder yield shall be offset by increasing the volume of green fodder imports, such as maize, soybean and barley. The Minister of Agriculture pointed out that Saudi Arabia is the world's largest barley importer, with an annual import total of 7.5 million tons that account for approximately 60% of the global barley trade.

The sustainable agriculture plan is scheduled for five years, and also targets the development of the distribution chain and promotion of organic crop agriculture.

There is a new Saudi drive focusing on agricultural investments in various countries such as Turkey, Sudan, the Philippines, Ethiopia, Ukraine, Egypt, Pakistan, India, Indonesia and Thailand.

On the other hand, Saudi markets are, nowadays, the scene of keen competition among importers of rice, being the Kingdom's leading imported foodstuff. Records show that Saudi Arabia accounts for 4.3% of the global rice consumption, amounting to more than 700,000 tons per year, worth some 3 Billion Riyals (equivalent to \$800 Million).

A Ministry of Economy and Planning report found out that the average Saudi per capita consumption of rice was 43 kg per year.

However, following negotiations with a delegation from the Saudi Ministry of Trade and Industry, the Philippines had agreed to allocate an area of 100,000 hectares in Mindanao Island for the cultivation of rice and other grains, to be funded by Saudi investments, provided that the crop yield shall be solely used by Saudi Arabia.

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### **b. Institutional reforms**

While policy reform requires new or amended legislation to bring it about and to provide tools for compliance, it also requires institutional reforms. Institutional transformation should affect organizational structure, coordination mechanisms, accountability, transparency, public involvement, clarity of roles and responsibilities, professional training, and water governance. According to Appelgren (1998), "greater engagement of stakeholders in the oversight and management of

water resources will increase commitment to, and compliance with, new policies and legislation."

Over the past decade, increased awareness of the need for institutional reform has prompted many Arab countries to undergo institutional changes in their agricultural sectors as well as in the water sector in general. For example, Sudan has established an independent agency to address water pricing policies and regulations.

In their macro-economic assessment of water and



agricultural sectoral policies related to reform issues in Arab countries, Abdou and Ahmad (1998) observed that institutional reform is an integral component of any integrated investment strategy for water development and the sustainable growth of agriculture. There is a number of viable options, ranging from institutional reforms involving managerial and organizational restructuring, to decentralization of responsibilities, and to creation of public utility based on the concept of a complete transfer of irrigation delivery to the private sector and farmers' associations. There seems to be greater awareness of the value of farmers' participation in the design and implementation of water distribution at the farm level in the Near East.

One option considered by a number of countries in the region is that of creating water users' associations (WUA) to increase the welfare of farmers and develop irrigation and drainage by providing an alternative to the monopoly of public utilities. According to Abdou and Ahmad, (1998), "in the Near East region, Morocco and Tunisia have been among the first to include farmers' participation in water distribution."

As governments divest themselves from certain functions, due considerations should be given to strengthen the new role of government in managing the water subsector. The new role of government, while not involving extensive intervention in production and physical distribution of activities, is becoming more important and more challenging. In that regard, experience in the region indicates the need to coordinate and streamline responsibilities among the several institutions and agencies responsible for water-related planning and policies within each country. Also, enhancing the efficiency of government's role in managing the water sector may dictate the need to increase the allocation of direct investment in developing and maintaining the irrigation system and reducing the huge expenditure typically allocated to cover the costs of the inflated state administration. Water policy reform should include the necessary institutional reform (Abdou and Ahmad, 1998).

Egypt has recently adopted participatory approaches for managing irrigation water use, with the technical support of international development agencies. The following programs have been initiated:

1. Formation of water user associations (WUA) at the mesqa level;
2. Formation of branch canal water user associations (BCWUAs);
3. Formation of WUAs for groundwater management in the Western Desert;
4. Matching irrigation water deliveries with water demand by crop;
5. Substituting short-duration for long-duration rice varieties;
6. Increased sugarcane irrigation efficiency;
7. Transition from water level-based to volume-based irrigation water management; and
8. Increasing the intermediate reuse of agricultural drainage water.

To get these programs off the ground, intensive training and capacity building activities have been conducted for staffs at the Ministry of Water Resources and Irrigation (MWRI) and the Ministry of Agriculture and Land Reclamation (MALR) as well as for WUAs board members.

### **III. INVESTING IN THE IMPROVEMENT AND MODERNIZATION OF IRRIGATION SYSTEMS**

Developing new sources of water supply to meet rising demand is becoming enormously difficult. Increasingly, there are mounting demands for the agricultural sector to reduce the pressure on water use and even utilize marginal water quality for crop irrigation. That leaves the sector with a critical strategic policy thrust: quickening the pace of adopting water demand management in the sector and facilitating this shift through innovative new policies, capacity building, research, and training. Agricultural water demand management must become a priority for policy-makers and water managers.

In 1998, the Arab Organization for Agricultural Development (AOAD) has outlined strategies for agricultural water management in Arab countries. It argued that the introduction of irrigation charges is an important prerequisite to good management of irrigation demand because it is noticed that despite the observed water shortages, misuse of water in agriculture is widespread in the current irrigation management practices. This is due mainly to the failure in the past to recognize the economic value of water and the real cost of providing its services. It is therefore now accepted that managing water

1. Formation of water user associations (WUA)

as an economic commodity is an important tool in achieving efficient and equitable water use as well as encouraging the conservation and protection of scarce water resources. Yet for many Arab states it is difficult to reconcile the concept of water as an economic commodity with the traditional belief of water as a basic necessity and human right.

In addition, opportunities for improving management of irrigation water demand may be pursued through better systems of on-farm water management, and should focus on reducing irrigation water distribution losses, changing cropping patterns, improving irrigation scheduling, and adopting irrigation-efficient technologies.

Water losses in irrigation in most of the Arab region are very substantial and irrigation efficiency can be improved from its current low level of 30-45% by implementing well-operated lined or

pipelined conveyance systems and the application of modern irrigation technologies and improving the conventional surface irrigation methods. It is quite evident that using systems such as sprinkler and drip in some Arab countries has reduced water losses considerably, for example in Morocco and Jordan, where the rise in irrigation efficiency levels to about 70% is attributed mainly to the adoption of these two techniques (AOAD, 1998).

The application of drip irrigation in most parts of the Arab region has proved to reduce water losses and increase agricultural productivity; for instance, its application in the Jordan Valley to irrigate 60% of the area has increased average yields of vegetables and doubled fruit yields. In Syria, drip irrigation techniques are applied on less than 1% of the total irrigated area, but they have a potential for reducing water losses by 45%, while sprinkler techniques could reduce losses by 20% only. In Egypt, sprinkler irrigation does not exceed 27% of the total irrigated area. In Morocco and Tunisia it covers some 16% and 11% respectively.

In addition to their potential for increasing water use efficiency, drip and sprinkler irrigation technologies can also provide opportunities to cultivate low quality lands, sandy and rocky soils, and enable some countries with limited water resources to change cropping patterns by shifting from high-water-consuming, low-value crops to low-water-consuming, high-value crops (AOAD, 1998).

The primary impediments to introducing more efficient irrigation technologies in Arab countries include the high purchase price, high operation and maintenance costs, lack of a reliable supply chain of equipment, parts, and maintenance services, and shortages in skilled and trained professionals. Among other strategies, modern irrigation techniques need to be carefully selected and adapted to the local physical, agronomic and socio-economic environment, as well as to the technical and managerial skills of local farmers. Upgrading existing irrigation schemes should in most cases be preceded by pilot trials for alternative design concepts. Costly improved technologies can only be justified if their agronomic and economic potential is fully exploited.

Similarly, improved irrigation scheduling both at the system and the farm levels needs to be given high priority to ensure that, within the constraints

### BOX 2: WATER DEMAND MANAGEMENT IN EGYPT

*Adapted from: A demand driven design for irrigation in Egypt (Baletti and Abdel-Dayem, 2008).*

Since the late 1960s, with the support of the government, Egyptian farmers have been reclaiming desert land to compensate for the loss of agricultural land in the Nile Delta to urban uses. One of those areas of land reclamation is the West Delta region, consisting of about 255,000 feddans (1 feddan is 0.42ha) on the fringes of the Nile Delta. Through the exploitation of groundwater resources, the area has developed into a flourishing agricultural economy since the early 1990s.

Today the area contributes \$300-500 million to the Egyptian economy annually, providing high-value fruits and vegetables to the domestic market and to export markets in the European Union. Moreover, the area is now home to 500,000 people and provides 250,000 jobs in the agricultural sector alone. But the rapid development has led to excessive exploitation of groundwater reserves. Groundwater pumping has gone deeper and become costlier as water quality has eroded.

Concerns about the collapse of this thriving agricultural economy prompted the government to introduce a surface water irrigation project that would replace groundwater pumping. The government has also taken advantage of the opportunity to adopt a bold set of reforms in the sector—part of a new approach to irrigation projects founded on full cost recovery, volumetric pricing, formalization of water entitlements, and private participation in financing and management.



of system design and management capabilities, optimum crop water requirements are met with minimum water losses while avoiding soil salinization and waterlogging. In many parts of the world, application of irrigation scheduling in response to soil moisture measurements in association with the adoption of modern irrigation systems has resulted in reducing irrigation rates while at the same time productivity has increased. Such systems have the potential for significant irrigation water savings at relatively reasonable cost. Their introduction in the Arab region is still very limited except in a few cases in the Gulf states, where they are combined with centre pivots for wheat production and have proved successful (AOAD, 1998).

In most of the Arab region there is still a lack of economic and fiscal incentives for irrigation improvement. Hence high priority should be given to improved management of irrigation water demand by encouraging farmers to invest in water-saving technologies and to cultivate crops with low water demand. Economic incentives based upon cost recovery of irrigation water supply may play a major role in improving irrigation water demand by persuading farmers to go for optimum demands. The selection of a cost recovery mechanism suitable for the different individual Arab states is influenced by a number of factors, such as sectoral use, level of subsidies, irrigation water conservation, ability to pay, and rural social welfare. The dual objective of generating income and encouraging irrigation water efficiency through a cost recovery policy would

inevitably require designing innovative approaches with the strong participation of farmers.

Regulation and restrictions can be used as instruments to manage irrigation water demand. For instance, rationing and rotational deliveries can achieve good control of irrigation demand and should be used during droughts and where irrigation demand exceeds the physical capacity of the irrigation systems. The application of such restrictions would result in considerable irrigation water savings, especially during drought periods. Another effective instrument for encouraging changes in irrigation water demand patterns includes fiscal incentives such as rebates and tax reductions for acquiring irrigation water-saving technologies (AOAD, 1998).

#### **a. Investing in groundwater irrigation**

Improvements in pumping technologies have enabled farmers to rely on groundwater as an exclusive source of water or to supplement surface or rain water. There are many benefits to investing in groundwater irrigation. It permits farmers to control when they irrigate their plots. Crop yields per cubic feet are up to three times as high when using groundwater irrigation relative to surface water, according to a World Bank report on the future of water in agriculture. In addition, "groundwater investment, particularly in lower-cost shallow wells, can have poverty reduction impacts, providing improved water supply for domestic use as well as

for gardens and crops” (World Bank, 2005). The report further asserts that the biggest problems are over-abstraction and water-quality deterioration.

In many Arab countries, the rate of groundwater exhaustion is disturbing, so much so that further pumping is becoming less cost-effective. According to the Islamic Educational, Scientific, and Cultural Organization (ISESCO, 1997), mismanagement of groundwater resources have caused a drop in the water table (from 150 meters in the 1980s to 400 meters in the late 1990s) in the northern region of the United Arab Emirates, soil salinization in Oman (caused by thousands of diesel-operated tube wells), and overexploitation of non-renewable

groundwater resources in Kufrah, Libya, and the New Valley in Egypt. Where restrictions to wells drilling exist, such as in the Sana`a basin, they are not enforced. There “it is estimated that over 2,500 wells are depleting the aquifers” (ISESCO, 1997).

Over-extraction is driven by free access to groundwater, inappropriate technology, fuel or electric power subsidies, easy credit, and irrational pricing, resulting in inefficient use of groundwater resources. Therefore, an appropriate price policy would require that, in the long run, marginal opportunity cost be able to ascertain the inter-generational value of groundwater depletion, a value which would take into account the direct cost of resource use, its user cost, and inter-sectorial cost (ISESCO, 1997). Imposing taxes and assigning water rights are additional reform measures available to Arab governments to reduce over-abstraction and halt further deterioration in groundwater quantity and quality.

### BOX 3: WATER DRAINAGE IN EGYPT

*Adapted from: Alleviating the environmental impact of agricultural water development (FAO, 2003) and Water Profile of Egypt (FAO, 2010).*

In Egypt, an extensive National Drainage Program has been developed over the last four decades to control water-logging and salinity. In 2003, slightly over 3 million hectares (ha) of the total irrigated area were drained, of which about 2.2 million ha with sub-surface drainage. The sub-surface drained area represents more than 65% of the total cultivated area. Drainage water from agricultural areas on both sides of the Nile Valley is returned to the Nile River or main irrigation canals in Upper Egypt and in the southern Delta. Drainage water in the Delta is either pumped back into irrigation canals for reuse or pumped into the northern lakes or the Mediterranean Sea (FAO, 2010).

Egypt’s drainage program is one of the largest water management interventions in the world. The total investment amounts to about US\$1000 million. Since the installation of the drainage systems, yields have increased and there has been a substantial improvement in salinity-affected lands (FAO, 2003).

The reuse of treated municipal and industrial wastewater in irrigated agriculture is widespread. In general, many of the treatment plants in developing countries, including Egypt, operate below design capacity, which contributes to the discharge of less-treated wastewater into irrigation and drainage canals. Evidence of uptake of trace elements, such as cadmium, by soils and in crops has been reported at levels that are harmful to human health. Thus, some of the drainage water is unfit for reuse, not because of its high salt content but because of its pollution load (FAO, 2003).

#### **b. Investing in Water Drainage**

Reuse of treated wastewater and agricultural drainage recycling provide opportunities for targeted crop production in some Arab countries. However, this has to be supplemented with the introduction of effective measures to ensure product safety, strict quality standards, and treated water reuse guidelines. Wastewater reuse is of tremendous potential importance for the region. It can serve as an additional supply for irrigated farming and groundwater injection, thereby reducing groundwater overdraws that plague many MENA countries. Fortunately, many countries (e.g., Jordan, Morocco, Oman, and Yemen) have in place legal provisions to regulate the handling, and in particular, the reuse of wastewater.

Intermediate reuse of drainage water is practiced on a very large scale in Egypt, where 5,000 million m<sup>3</sup> of agricultural drainage water (equivalent to 10% of the total water resources) are reused annually after mixing with freshwater. Reuse of drainage water is practiced on a more limited scale in Iraq, Saudi Arabia, and Syria (World Water Forum, 2006).

#### **c. Investing in water management techniques in rain-fed areas**

Rain-fed agriculture is pervasive in many Arab countries. More than half of all arable land in Algeria,

**BOX 4: WATER HARVESTING TECHNIQUES**

*Adapted from: Water Harvesting Techniques in the Arab region (Zaki et al., 2006)*

A survey of traditional water harvesting systems has revealed that the following systems are used in the Arab region:

**Terracing:** Terracing is widely used in Yemen as an effective water conservation technique. Moreover, it is successfully used for rainfall utilization and soil conservation in the mountainous areas of southwestern Saudi Arabia and Oman. In the Arab region, there are a number of terracing systems such as weir terraces across narrow wadis, barrage terraces, linear dry field terraces, and stair terraces. Rain-Fed agriculture is practiced on terraces in many communities in Yemen, where more than 1.5 million hectares have been regularly cultivated.

**Spate Irrigation (flood irrigation):** It mainly counts on water spreading where flood water is diverted from the wadi course to an immediately adjacent cultivated area. Spate irrigation is practiced in Sudan, Yemen, Oman, United Arab Emirates, Tunisia, Algeria, and Saudi Arabia. Agricultural land is graded and divided into basins to allow enough water to be stored for the season. Therefore, soils should be deep with sufficient water holding capacity. In large wadis with high discharges, temporary earthen dams are built in order to retard the flow of the first wave of flood.

**Meskat:** The Meskat System is an ancient method employed in harvesting rainwater, particularly in Tunisia, Morocco, and the north west of Libya. The Meskat is simply a piece of flat land with a mild slope (3 to 6%) with few or no drainage channels. The land is prepared for rainwater harvesting and then water is directed to another piece of land of half its area and located directly below, which is called the collector where crops are planted. At present, the state of these Meskats have been deteriorating because of intensive agricultural development since the middle of the century.

**Dams and Reservoirs:** Dams of various sizes have been constructed in most Arab countries for water storage (for irrigation), flood control, and groundwater recharge. Most of the dams built in Saudi Arabia, the United Arab Emirates, and Oman are used for recharging depleted aquifers. Few large dams in Egypt, Saudi Arabia, Tunisia, Sudan, and Jordan have multiple purposes. Dams are built either at the head of catchments in mountainous regions or in the downstream portions of catchments as in Saudi Arabia, Sudan, Egypt, Tunisia, Jordan, Yemen, the United Arab Emirates, and Oman. Due to flat topography and limited runoff in the remaining countries of Bahrain, Kuwait, Qatar, and parts of Sudan, small diversion structures are used instead of dams to create detention basins.

Iraq, Jordan, Lebanon, Libya, Mauritania, Morocco, Sudan, Syria, Tunisia, and Yemen is dependent on rainwater (World Bank, 2009b). According to the same report, in the Maghreb, Sudan, and Yemen, at least 80 percent of cereal production is rain-fed, and in the Mashreq, from one-half to two-thirds of cereal production is rain-fed.

Rainwater harvesting systems play a significant role in enabling rain-fed agriculture in many parts of the Arab region. Harvesting structures capture, divert, and store rainwater or runoff water for later use. They are also used to rehabilitate rangelands and protect soil from erosion (Zaki, 2006; Droubi, 2006). Water harvesting systems have existed in the Arab region for 9000 years (Zaki, 2006), a testimony to the region's ability to adapt to water scarcity and aridity conditions. Zaki (2006) has classified water harvesting techniques practiced in the Arab region into two categories: (a) Water harvesting and storage

systems (e.g., cisterns, small dams, Hafirs, Ghadirs), and (b) Water harvesting and spreading systems (e.g., terraces, water spreading dykes, Miskats, irrigation diversion dams). A description of some water harvesting techniques is presented in box 4.

Climate change poses real risks to rain-fed agriculture in Arab countries. According to the World Bank (2009a), climate change will induce declining availability, more uncertainty and variability, and declining quality, adding to the strain of imbalance between water supply and demand. Average yearly rainfall is predicted to fall by 10% in the next 50 years according to climate change models (World Bank, 2009b). As a result, rain-fed yields will fluctuate over time and average yields will take a downward trend, decreasing by 20 percent in Arab countries as a whole and by almost 40 percent in Algeria and Morocco (World Bank, 2009b).

#### IV. SALINE WATER USE IN AGRICULTURE

Salinity problems are most pronounced in arid and semi-arid regions because of insufficient annual rainfall to flush accumulated salts from the crop root zone. In such regions, there is an urgent need to use saline water for irrigation because of the limited water resources. The success of using saline water for economic crop production can be achieved by adhering to the best management practices to reduce the negative effects of salinity on crop productivity. In addition, introduction and cultivation of new crops and new varieties tolerant to salinity would be required.

The methods and experiences of using saline water for crop irrigation vary among countries in the Near East and North Africa region. For example, in Tunisia saline water is used to irrigate different crops, particularly fruit trees (such as olives, pistachio, and pomegranate), with positive results on growth and productivity (Abou-Hadid, 2000). Saline water has been tested in the arid lands of Jordan for production of crops such as barely and onion. Studies have documented the best water management system for the use of saline water for irrigation in Jordan (Fardos et al., 1998). The use of saline water for irrigation and reclamation of desert and arid lands is a priority in several Gulf countries.

In Egypt, studies have focused on the analysis of results of agricultural production under saline irrigation conditions for different crops (wheat, barley, rice, cotton, sunflower, soybean, legume crops, sugar beet, tomato, cucumber, strawberry, leafy vegetables, and fruit trees). Studies in Egypt have focused on breeding for salt tolerance (especially in wheat) and application of suitable irrigation systems (Abou-Hadid, 1998). Several studies have been conducted in different sites in Algeria in order to identify the best approach for crop production under saline soil conditions. Salt distribution in the soil was estimated at different soil depths using satellite-based techniques (Bahloly, 1998).

In Iraq, saline water has been used in agriculture for a long time in different areas where rainfall is low. In such areas well waters are very saline, thus negatively affecting crops and soil properties. The crops grown under these conditions include tomato, onion, garlic, cucumber, and fruit trees such as pear, apricot, apple, grape, olive, and pomegranate. The

soils were negatively affected by long-term use of saline water for irrigation and growers were forced to move to other soils as high salt concentrations accumulated (Saleh and Hassan, 1998).

#### V. ASSESSING THE SOCIAL, ECONOMIC, AND ENVIRONMENTAL EFFECTS OF AGRICULTURAL WATER INVESTMENTS

##### *a. Social effects of agricultural water investments*

Equitable access to and allocation of water should draw the attention of policy-makers in Arab countries. Poorly targeted agricultural investments will exacerbate an already stressed situation, but they may also drive social instability. A paper about water scarcity and conflict in Yemen in a World Bank (2009a) report argues that “the process of ‘resource capture’ involved in uncontrolled drilling and extraction of groundwater and in the ‘race to the bottom’ of the aquifer has led to the economic marginalization of those unable to compete in power and money. Small farmers, poor downstream communities, and women and children bear the brunt of scarcity.”

There are multiple reports of communities and villages abandoning their farms and livestock because they have lost their ability to adapt to continued water stress driven by low levels of ground water, droughts, pollution, salinization, and/or conflicts (World Bank, 2009a).

##### *b. Economic effects of agricultural water investments*

Droubi (2009) has argued that current investment patterns in agriculture and irrigation water in many Arab countries are difficult to rationalize. He asserts that “farmers in the Arab region use water from publicly funded irrigation networks to grow low-value crops, often with low yields, rather than specializing in high value crops”, thus compromising potential value-adding opportunities. In addition to changing cropping patterns towards high-value, low-water-consuming plant varieties, Droubi (2009) has called for a new political economy of water, in which some water would be diverted from agricultural use into more economically productive applications or where irrigation water efficiency would be increased.



Sadik and Barghouti (1997) have argued that if irrigation efficiency can be improved to 70-80% from its current 50% ratio, the recovered water can be used to satisfy the increasing demand for drinking water or it can be diverted to irrigate 50% more land.

It has been suggested that assigning water access rights to users may facilitate water trading, which would ensure water supply gets assigned to the highest-economic use. This would shift the focus to cropping patterns that have the highest yield and command high prices. Droubi (2009) asserts that “doing so will allow [Arab] countries to import basic food products, and at the same time to guarantee the availability of the necessary funding for such import in a sustainable manner.”

### **c. Environmental effects of agricultural water investments**

A report by the Food and Agricultural Organization (FAO, 2003) of the United Nations poses a question about “what constitutes success in agricultural production if large yield increases come at the cost of environmental and health problems.” Simantov (1989) rephrases the question by indicating that an

important trade-off will be between a maximum utilization of existing water – entailing in some cases its degradation – and a more rational utilization of water – preserving its quality for the future and not necessitating expensive recycling operations. The adverse environmental effects of agricultural water development are linked to perverse incentives and management practices that contribute to wasteful utilization of water, increases in salinity of water and soil, toxic pollution from use of agro-chemicals, damming of rivers, and the loss of biodiversity associated with wetlands destruction. Degradation to assets comprise not only the natural resources of soil and water per se but also nutrient cycling and fixation, soil formation, biological control, carbon sequestration and pollination (FAO, 2003).

Duffy (2002) has argued that often there is no provision for environmental impact assessment and monitoring of agricultural practices in general and water management practices in particular. According to FAO (2003), environmental impact assessment (EIA) is usually applied to physical project planning (e.g., dams, roads, pipelines, and industries), but seldom to farm practices and rural development projects. As a result, inadequate planning and inappropriate land-use

## DESERTIFICATION AND WATER RESOURCES MANAGEMENT IN THE ARAB WORLD

### Abdallah Droubi

Desertification, as defined by the United Nations Convention to Combat Desertification (UNCCD), is “land degradation in arid, semi arid and semi-humid arid areas resulting from human activities and climate change”. So desertification, by definition, is related to human activities which are among the major causes of land degradation. Such activities and changes account for the reduction of productive lands and consequently land yields. As water and land constitute the base of any agricultural development efforts, the mismanagement of either or both will lead to land degradation and subsequently desertification.

The Arab region, which covers an area of about 14.1 million km<sup>2</sup> extending mostly (90%) over arid and semi arid areas, is considered to be a very fragile ecological system that is highly vulnerable to desertification. Recent studies indicate that about 64% of the Arab region has already desertified (ACSAD, 2007).

Prevailing climatic conditions in the Arab region are the basic cause of increased desertification. Low rainfalls lead to the scarcity of available renewable water resources. The disproportionate seasonal and geographic distribution of rainfall pushes pastures to new areas. This situation creates additional pressure on those lands leading to overgrazing and consequently degradation, which makes such lands prone to desertification. Climate change, manifested mainly by increased drought frequency, has contributed to the decline of rainfall for several successive years as was the case in Syria during 2006, 2007 and 2008.

Such drought has led to a dramatic reduction in rain-fed cereal production which almost dropped to zero, and these areas became more vulnerable to desertification. The consequences of such droughts have been evident by the recurrence of sandstorms that hit in summer 2009 the Syrian cities bordering the Syrian steppe such as Deir Elzour and Raqa, even reaching the capital Damascus. The drought that struck those regions has forced the local population to migrate to more climate-stable areas, which has increased pressure on the natural resources and threatened the stability of those areas. One of the major indicators of climate change is also the increase of rainstorms leading to devastating floods that cause soil erosion and land desertification. Many examples of these events exist such as the floods that recently occurred in



Saudi Arabia, UAE, Morocco, Algeria and Tunisia.

The Arab region has witnessed, during the last three decades, an accelerated developmental boom, which was mainly concentrated on horizontal agricultural development for meeting increasing food demand as a result of high population growth rates, estimated at 2%. Agriculture policies adopted by most Arab countries, during the 1980s and 1990s, under the topic of national food security, played an effective role in promoting the expansion of horizontal agriculture, introduction of new arable areas and extension of irrigated cultivation. A change from traditional agricultural systems to new systems was adopted by farmers, on the pretext that traditional systems are insufficient for meeting the increasing food demand (change from rain-fed to irrigated cultivation and the cultivation of new crops unsuitable for the type of soil). For example, the irrigated lands have increased in Syria from 0.65 million hectares in 1985, to about 1.4 million hectares in 2004 (IFAD, 2004). This increase impaired land productivity and soil renovation capacity. The situation has also aggravated pressures on those lands, threatened their environmental sustainability and widened the risk of desertification. In addition, these agriculture policies, coupled with sedentary policies adopted by most Arab countries for settling nomads in their respective regions, have led to a change in the social systems of these populations. Thus the population in arid and semi-arid areas that depended on limited pastures for their livelihood, progressively turned to agriculture, especially irrigated cultivation, without having any experience in this field and even without any government assistance in rehabilitation. This led to the mismanagement of soil, water and vegetation cover, and caused increased deforestation for the purpose of creating more arable lands, leading to the degradation of vegetation cover and soil, and consequently increased vulnerability to desertification.



This agricultural expansion was based on irrigation using mainly groundwater, due to the scarcity of surface water in the Arab region, which caused the depletion of these resources. The quantity of water used in agriculture in the Arab region is almost 88% of the total utilized water (ACSAD, 2009; UNEP, 2010).

Flood irrigation is nowadays the principal system used in the region; it is used in almost 80.3% of the overall irrigated areas. Sprinkler irrigation is used in about 22.8% and drip irrigation in 2.8% (UNEP 2010). The total volume of water used for irrigation has increased, from about 160 billion m<sup>3</sup> in 1995, to about 200 billion m<sup>3</sup> in 2003 (CEDARE, AWC, 2004, FAOSTAT, 2008). For example, agriculture subsidies for boreholes and energy in the Arabian Gulf countries and other production inputs, including agricultural subsidies and protection programs, and in the absence of any regulations for the extraction of groundwater, have increased the irrigated areas by 300% and caused the depletion of groundwater (UNEP, 2010).

It is worth mentioning that the great extension in irrigation in Saudi Arabia has increased the volume of water used in agriculture threefold, from 7.4 billion m<sup>3</sup> in 1980 to 20.2 billion m<sup>3</sup> in 1994, before measures were taken to impede the widespread system of subsidies for crops such as wheat.

The fast unbalanced expansion of agriculture, the use of inadequate irrigation systems and the irrationalized utilization of water resources have led to over-exploitation of groundwater and even to the degradation of arable lands due to salinization and water logging

The saline soil in Syria and Egypt is estimated at about 45% and 50% of total irrigated areas, respectively (ACSAD, 2009). This situation has pushed the local population to abandon their lands due to the exhaustion of water resources, which further spread desertification. Undeveloped and thin soil characterizes the arid and semi arid areas, making them very fragile to any external intervention, mainly plowing (ACSAD, 2009), and more vulnerable to desertification (for example, the lands threatened by partial or total desertification in Algeria are about 44% of the 9 million hectares of cultivated areas). Algeria is losing around 7,000 hectares of land per year due to desertification. This resulted mainly from the change in agricultural systems, from traditional to modern, including irrationalized use of water and land. The change was mainly from the pastoral system which

was considered as a means of survival for local population to the large-scale breeding of cattle for commercial purposes by wealthy investors living in urban areas and seeking to supply the growing demand in the meat market (Arab Human Development Report, 2009).

Abandoning agricultural lands due to shortage of water, salinization, and aridity increases land fragility and ability to resist wind and water erosion, and consequently leads to degradation and further desertification. In Morocco, for example, water erosion threatens about 12.5 Million hectares of arable lands and grasslands (the loss in soil as a result of water erosion is estimated at 20 t/ha). In Tunisia, about 60% of arable lands is also threatened by water erosion (water erosion is estimated at 9 million t/y). In Jordan, the loss of soil by water erosion is 200 t/y (ACSAD, 2009). In Yemen the lands threatened by water erosion increased from 5.5 million hectares in 1992, to about 12 million hectares in 2000.

Finally, it is important to mention that potable water demand in the Arab region will increase due to population growth and development of urban areas. In 1975, nearly 35% of the Arab population lived in urban areas; this increased to 55% in 2005 and is expected to exceed 60% in 2020 (Arab Human Development Report 2009). This will certainly reduce quantities of water available for agriculture and will lead to a reduction in cultivated lands, ultimately increasing the possibility of desertification. Adequate measures are desperately needed for overcoming natural water shortages including the widespread use of treated water for irrigation and taking effective actions for combating desertification.

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practices have persisted. In many areas, soil, land, and water resources are used inefficiently or are degraded, while poverty and income disparities grow. The FAO report further recommends that EIA policies for agricultural projects “should include transfer of the necessary knowledge to the rural poor, through agricultural extension services, so that they can participate in the environmental assessment of agricultural water resource management and project planning. Duffy (2002) asserts that “the linkage between poverty alleviation and environmental protection and biodiversity conservation makes it evident that investments and improved practices that are environmentally positive can yield enormous long-term benefits. Indeed, this is the main rationale for environmental impact alleviation.” In fact, programs exist today designed to compensate farmers for managing their farms in an environmentally sustainable manner through soil conservation, safeguarding environmental services, and restoring and protecting water ecosystems (e.g., wetlands). According to IFAD (2009), paid environmental or watershed services are increasingly recognized as a potential source of additional income for the rural poor. However, ecosystem services valuation is still at its infancy and the institutional mechanisms for scaling up and implementation are still being debated by a wide array of stakeholders.

#### **VI. INTERACTION BETWEEN AGRICULTURAL AND NON-AGRICULTURAL WATER USES**

Droubi (2009) has argued that water policy reforms in Arab countries have not had satisfactory results because of the strong influence exerted by policies formulated for trade, finance, energy, land use planning, urbanization, and social safety net programs. The arenas for debating and formulating these policies occur outside water institutions. Droubi (2009) makes the point that cropping choices are a key determinant of water use in agriculture and they are affected far more by the price the farmer can get for those crops than by the price of irrigation services, which is typically a very small share of a farmer's costs. The price of agricultural commodities is, in turn, determined by a range of non-water policies such as trade, transport, land, and finance. Therefore, desired water policy outcomes will only be sustainable

when all water users are able to communicate, coordinate, and plan strategically. Because it accounts for 85% of water use in Arab countries, the agricultural water should begin to adapt to increased competition for scarce water resources. Simantov (1989) has also argued that water, as much as other socio-structural factors, ultimately determines the relative size of the various economic sectors in a country: it is an important element in the trade-offs between agriculture and non-agricultural sectors.

To give an example of the need for changing agricultural water use patterns, Simantov (1989) points out that water will become the main point of interaction between agricultural policies and those for the protection of the environment. This will give rise to the need to preserve the quality of water but also to the need to recycle water and to improve its quality. This interaction would create a win-win situation for maintaining the health of water ecosystems while preserving the long-term ability to grow food.

#### **VII. CONCLUSION AND RECOMMENDATIONS**

The Arab region is located in an arid and semi-arid zone where a mixed pattern of irrigated and rain-fed agriculture exists. Therefore, the challenges are great and require new approaches to achieve the efficient management of an already limited water resource base.

Country policies should keep in sight three pivotal themes:

1. Water resources development;
2. Water use efficiency gains; and
3. Protection of public health and the environment.

The first theme involves the development of underground water, without losing sight of the fact that it is largely not renewable even though the process of its development and use necessitates continued control, monitoring, and regulation. In rain-fed areas, water-harvesting and distribution technologies need to be expanded. Cooperation among river-basin countries should also catalyze water resources development for the benefit of all parties to a river-basin initiative.

The second pivotal theme implies a set of policy measures to improve water use efficiency by reducing irrigation water losses and applying good agronomic practices (e.g., precision laser leveling, soil amelioration, short-duration varieties, etc) that promote efficient water use. Agricultural water use can also be improved through farm-level modernization technologies (e.g., marwa/ditch lining or tubing and the associated improvement of water-lifting point, buried pipes, and similar activities). Intermediate reuse of agricultural drainage water is seen in some countries as an option when the continuous flow is reduced due to high demand for water.

Outdated infrastructure need to be either replaced or renovated so as to ensure fair distribution, especially to landholdings on the tail-end of a command area.

Institutional reform is recommended through the formation of WUAs and water boards. Water demand management is expected to rationalize water use. Water service providers for the commercial and industrial sectors should be enabled to cover their operation and maintenance cost and to achieve a margin of profit for their financial sustainability.

The third policy theme includes clustered packages:

- Cluster (1): preclude industrial pollutants from entry into the system and apply the principle of “the polluter pays”;
- Cluster (2): If cluster (1) was difficult to apply, project-owners must be committed to treat their wastewater; and
- Cluster (3): if cluster (2) did not work well, control measures must be adopted to reduce pollution load.

Policy planning must be viewed as a dynamic process. It always requires multi-disciplinary teams and a great deal of knowledge-sharing. Involving the public in policy formulation and implementation gives people a sense of ownership and provides them with a platform to express their views.

Governments should divest themselves from production functions, giving more room for the private sector to assume this role. Instead, they should assume such legitimate roles as regulation and market supervision.

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# Municipal and Industrial Water Management

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## I. INTRODUCTION

Water, like energy, will probably become the most critical natural resource issue facing most parts of the world. By the year 2025, a full 35% of the world population will be living under conditions of water scarcity or stress compared to about 6% in 1990 (Al Radif, 1999). In the Arab world, parts of which were once referred to as the Fertile Crescent, precipitation is low, droughts are frequent, and rivers are few. Under a business-as-usual scenario, countries in the region will experience serious water shortages in coming years, with grave consequences on economic and social development plans. Moreover, many experts warn that disagreements over water have the potential to create political tensions (Darwish, 1994). Thus, water will be a major concern that can catalyze stability and cooperation or inhibit both. The main problem in confronting the water crisis is the lack of the political will to advocate use efficiency, undertake a new discourse, or invest in new research. In an endless attempt to resolve the water deficit, Arab countries are having to rely on non-conventional water resources, namely, desalination and wastewater treatment and reuse, to satisfy increasing demand (Chatila, 2003).

To address water scarcity, governments in the Arab region need to target optimum utilization of available water resources, and possibly augment water supplies through the exploitation of new natural or non-conventional resources. This is accomplished through wastewater reclamation, brackish and seawater desalination, and rainwater harvesting. However, augmenting water supplies will not provide a sustainable answer. Addressing water shortages necessitates the adoption of well-planned policies focused on improving water management, rationalizing water consumption, and protecting water supplies from over-use and pollution. A system of laws and policies is needed, in which governments enforce comprehensive codes and regulations including health standards. This chapter presents a set of proposed regulations and policy recommendations that should be considered.

The high population growth rate in Arab countries exceeds by far the growth rate of developing water resources. Consequently, the annual per capita share of water resources is decreasing at an increasing rate. This chapter tackles the current



problem through three-interdependent venues, namely:

1. It provides a brief overview of demand and supply projections in the member countries of the Economic and Social Commission for Western Asia (ESCWA) up to the year 2050. Population estimates are based on data provided by the statistics section of the ESCWA head office in Beirut. Demand projections were performed for per capita consumption in the domestic, agricultural, and industrial sectors, and a total demand for each sector was determined based on the projected population figures and the respective per capita demand. Then, the break-even year between projected demand and expected supply was estimated for each member state.
2. A set of policies and regulations are recommended in order to reduce water shortages in the near future.
3. Establishing a proper water tariff structure is discussed with suggested principles for pricing domestic, agricultural, and industrial water.

## II. WATER DEMAND AND SUPPLY

### a. Population projection

The ESCWA region, which consists of 13 member states with a total area of 4 million km<sup>2</sup>, is divided

TABLE 1 POPULATION SIZE (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1950 TO 2050 (THOUSANDS)

	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050
<b>Bahrain</b>	115.6	156.1	219.6	347.0	490.0	617.2	713.1	812.2	895.9	947.5	991.6
<b>Egypt</b>	21834.0	27840.0	35285.0	43749.0	56332.8	68469.7	80063.3	90490.7	100371.0	108369.4	114844.2
<b>Iraq</b>	5158.3	6847.0	9356.0	13007.3	18078.1	23114.9	30338.7	37664.3	43929.1	49476.3	54915.7
<b>Jordan</b>	916.0	1694.0	1703.7	2165.9	3423.3	5003.1	6279.7	7837.9	9610.7	11607.6	13837.9
<b>Kuwait</b>	152.2	278.0	744.3	1374.9	2143.0	1971.6	2419.7	2813.4	3115.2	3347.7	3526.9
<b>Qatar</b>	25.0	45.0	111.3	229.2	485.4	599.1	692.2	760.6	793.3	818.0	844.1
<b>Oman</b>	456.4	558.2	722.9	1130.0	1784.5	2541.7	3517.5	4719.3	5996.3	7208.5	8309.9
<b>Lebanon</b>	1442.7	1857.4	2469.0	2669.2	2555.3	3281.8	3722.9	4172.5	4605.9	4928.5	5168.9
<b>KSA</b>	3201.4	4074.7	5744.8	9604.4	16045.3	21606.7	28778.5	36424.2	42990.7	48661.2	54461.0
<b>Syria</b>	3495.1	4561.0	6258.0	8704.0	12386.0	16124.6	20464.1	24555.1	28078.1	31624.6	34490.1
<b>UAE</b>	69.6	90.2	222.8	1015.2	1920.5	2441.4	2851.2	3169.7	3375.9	3509.3	3615.2
<b>WB &amp; Gaza</b>	560.6	740.9	938.5	1207.4	1838.8	2859.6	3244.0	4095.7	5065.3	6153.7	7361.7
<b>Yemen</b>	4316.0	5247.0	6331.6	8218.7	11589.6	18112.1	25366.2	34189.8	43734.1	51855.8	58801.1

geographically and ecologically into two sub-regions, namely, the Mashreq and the Arabian Peninsula. The Mashreq includes Lebanon, Syria, Jordan, Iraq, and Palestine (the West Bank (WB) and the Gaza Strip), in addition to Egypt, while the Arabian Peninsula includes Bahrain, Kuwait, Oman, Qatar, Kingdom of Saudi Arabia (KSA), the United Arab Emirates (UAE), and Yemen. Over 72% of the region has an annual rainfall of less than 100 mm; about 18% receives between 100 and 300 mm annually; less than 10% receives between 300 and 1,300 mm annually (ACSAD, 1997).

In the current study, previous population historic

data and censuses, up to 2000, available from different member states were collected from the Statistics Office of ESCWA. Then, population projections, up to year 2050, were performed using statistical methods and regression analysis. These figures were used to estimate the domestic, industrial, and agricultural demand for water. Table 1 shows past and future projected population figures in the ESCWA member states.

The increase in population is above the world average and much above that in the industrialized countries. Table 1 shows that the rate of growth is high and the population is expected to double in the next 25 years, which will certainly have

TABLE 2 DOMESTIC WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

	Demand (liters/capita/day)									
	1990	2000	2010	2015	2020	2025	2030	2040	2050	
<b>Bahrain</b>	540	555	585	600	620	642	667	723	789	
<b>Egypt</b>	130	135	145	150	157	164	172	191	213	
<b>Iraq</b>	160	170	190	200	214	228	245	282	326	
<b>Jordan</b>	130	135	145	150	157	164	172	191	213	
<b>Kuwait</b>	540	555	585	600	620	642	667	723	789	
<b>Qatar</b>	540	555	585	600	620	642	667	723	789	
<b>Oman</b>	130	135	145	150	157	164	172	191	213	
<b>Lebanon</b>	356	370	380	390	396	404	412	428	446	
<b>KSA</b>	356	370	380	390	396	404	412	428	446	
<b>Syria</b>	130	135	145	150	157	164	172	191	213	
<b>UAE</b>	540	555	585	600	620	642	667	723	789	
<b>WB &amp; Gaza</b>	90	95	105	115	125	136	150	182	221	
<b>Yemen</b>	90	95	105	115	125	136	150	182	221	

TABLE 3 INDUSTRIAL WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

	Demand (liters/capita/day)								
	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	95	100	110	115	119	123	128	139	150
<b>Egypt</b>	30	35	45	50	55	61	68	84	103
<b>Iraq</b>	50	75	125	150	184	221	261	355	465
<b>Jordan</b>	30	35	45	50	55	61	68	84	103
<b>Kuwait</b>	15	20	30	40	50	61	75	107	146
<b>Qatar</b>	95	100	110	115	119	123	128	139	150
<b>Oman</b>	15	20	30	40	50	61	75	107	146
<b>Lebanon</b>	55	65	95	115	142	174	211	299	407
<b>KSA</b>	30	35	45	50	55	61	68	84	103
<b>Syria</b>	30	35	45	50	55	61	68	84	103
<b>UAE</b>	95	100	110	115	119	123	128	139	150
<b>WB &amp; Gaza</b>	5	10	20	25	32	39	47	66	88
<b>Yemen</b>	15	20	30	40	50	61	75	107	146

a major effect on available water resources. The situation is similar in other Arab countries.

### **b. Demand projection**

The goal of the study is to project domestic, industrial, and agricultural water demand in ESCWA member states up to the year 2050. Total demand is computed for each member state and compared with available supply resources in the state. A breakeven year is determined for each country. Demand projection is based on different water resources studies and tables that are established by the ESCWA secretariat or compiled from different sources and meetings of the expert

groups in ESCWA office in Beirut, Lebanon, during the last few years, in addition to personal communication with concerned ministries and water authorities in member states. Although this chapter is concerned with municipal (domestic) and industrial water management, we include water demand projections for the agricultural sector for comparative purposes.

Historic data on the per capita basis for domestic demand and the per capita daily industrial and agricultural equivalent of water was collected from ESCWA sources. Based on current applications, a second-degree function produced a good fit for the data with a very reasonable coefficient

TABLE 4 AGRICULTURAL WATER DEMAND (PAST AND PROJECTED) PER CAPITA IN ESCWA MEMBER STATES FROM 1990 TO 2050

	Demand (liters/capita/day)								
	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	671	554	772	820	866	919	980	1128	1297
<b>Egypt</b>	2,417	2,395	2,119	2,070	2,024	1,982	1,950	1,928	1,934
<b>Iraq</b>	6,853	1,0728	6,087	5,886	5,725	5,617	5,553	5,410	5,253
<b>Jordan</b>	520	433	330	302	352	259	243	219	200
<b>Kuwait</b>	102	139	138	139	140	142	146	158	173
<b>Qatar</b>	615	876	615	500	513	743	763	814	860
<b>Oman</b>	1,766	1,632	1,139	1,014	917	838	776	706	672
<b>Lebanon</b>	938	793	1,171	1,256	1,328	1,402	1,475	1,623	1,781
<b>KSA</b>	2,493	1,874	1,358	1,151	975	826	699	498	353
<b>Syria</b>	1,533	2,612	2,076	2,070	2,087	2,097	2,103	2,134	2,202
<b>UAE</b>	1,355	1,571	1,555	1,602	1,661	1,726	1,798	1,969	2,135
<b>WB &amp; Gaza</b>	209	208	206	202	197	192	188	184	185
<b>Yemen</b>	638	463	315	304	269	229	219	190	171



TABLE 5 ANNUAL DOMESTIC WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M<sup>3</sup>)

	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	97	125	152	167	184	200	218	250	286
<b>Egypt</b>	2,673	3,374	4,237	4,669	5,186	5,712	6,301	7,555	8,929
<b>Iraq</b>	1,056	1,434	2,104	2,482	2,942	3,395	3,928	5,093	6,534
<b>Jordan</b>	162	247	332	386	449	522	603	809	1,076
<b>Kuwait</b>	422	399	517	573	637	695	758	883	1,016
<b>Qatar</b>	96	121	148	159	172	182	193	216	243
<b>Oman</b>	85	125	186	225	270	321	376	503	646
<b>Lebanon</b>	332	443	516	562	603	647	693	770	841
<b>KSA</b>	2,085	2,918	3,992	4,641	5,265	5,855	6,465	7,602	8,866
<b>Syria</b>	588	795	1,083	1,232	1,407	1,575	1,763	2,205	2,681
<b>UAE</b>	379	495	609	659	717	767	822	926	1,041
<b>WB &amp; Gaza</b>	60	99	124	154	187	227	277	409	594
<b>Yemen</b>	381	628	972	1,250	1,560	1,934	2,394	3,445	4,743

of correlation  $R^2$  close to unity in most cases. A power or exponential fit may have produced good fit as well but the second-degree polynomial proved to be more successful. The regression equations were solved and the parameters determined. Typical equations of polynomials were established. Demand projections were performed on per capita basis for the years 2010 to 2050 using statistical methods and regression analysis, as shown in Tables 2, 3, and 4.

Projected population data were used along with projected water demand to obtain the total demand on a volumetric basis in million cubic meters (MCM) for the industrial, domestic, and agricultural sectors, as indicated in Tables 5, 6, and 7.

Table 8 shows the total demand in each ESCWA member state for the period 1990 to 2050 on a volumetric basis (MCM).

Domestic water demand represents a small fraction of the total water utilized, particularly when compared to the agricultural sector. Improvement in the standard of living, delivery services, and urban migration resulted in increased domestic demand. The industrial production structure in most of the ESCWA member countries is geared towards consumer goods and petroleum refinement, where most activities are confined close to urban centers. Some industries have specific water quality and quantity requirements, which vary according to the type of industry.

TABLE 6 ANNUAL INDUSTRIAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M<sup>3</sup>)

	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	17	23	29	32	35	38	42	48	54
<b>Egypt</b>	617	875	1,315	1,556	1,817	2,125	2,491	3,323	4,318
<b>Iraq</b>	330	633	1,384	1,862	2,530	3,291	4,185	6,411	9,321
<b>Jordan</b>	37	64	103	129	157	194	239	356	520
<b>Kuwait</b>	12	14	26	38	51	66	85	131	188
<b>Qatar</b>	17	22	28	30	33	35	37	41	46
<b>Oman</b>	10	19	39	60	86	119	164	282	443
<b>Lebanon</b>	51	78	129	166	216	279	355	538	768
<b>KSA</b>	176	276	473	595	731	884	1,067	1,492	2,047
<b>Syria</b>	136	206	336	411	493	586	697	970	1,297
<b>UAE</b>	67	89	114	126	138	147	158	178	198
<b>WB &amp; Gaza</b>	3	10	24	33	48	65	87	148	236
<b>Yemen</b>	63	132	278	435	624	867	1,197	2,025	3,134

TABLE 7 ANNUAL AGRICULTURAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M<sup>3</sup>)

	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	120	125	201	228	257	286	320	390	469
<b>Egypt</b>	49,697	59,854	61,924	64,431	66,851	69,038	71,439	76,262	81,070
<b>Iraq</b>	45,219	55,076	67,405	73,048	78,704	83,642	89,037	97,698	105,292
<b>Jordan</b>	650	791	756	778	1,007	825	852	928	1,010
<b>Kuwait</b>	80	100	122	133	144	154	166	193	223
<b>Qatar</b>	109	192	155	133	142	211	221	243	265
<b>Oman</b>	1,150	1,514	1,462	1,524	1,580	1,639	1,698	1,858	2,038
<b>Lebanon</b>	875	950	1,591	1,810	2,022	2,246	2,480	2,920	3,360
<b>KSA</b>	14,600	14,779	14,265	13,696	12,962	11,971	10,968	8,845	7,017
<b>Syria</b>	6,931	15,373	15,506	17,007	18,705	20,143	21,553	24,633	27,721
<b>UAE</b>	950	1,400	1,618	1,760	1,922	2,062	2,216	2,522	2,817
<b>WB &amp; Gaza</b>	140	217	244	271	295	321	348	413	497
<b>Yemen</b>	2,699	3,061	2,916	3,304	3,357	3,257	3,496	3,596	3,670

Agricultural water demand accounts for the majority of water use. Data from ESCWA show that the cultivated area in 1997 was about 20.2 million hectares in which 44.6% were irrigated using surface and groundwater sources, while the rest was rain-fed.

### c. Supply projection

The state of development of surface and ground water resources varies from country to country within the ESCWA region, depending on each country's specific context and conditions. Some countries such as Syria, Lebanon, Jordan, Egypt, Iraq, and Palestine have dependable surface water due to the relatively high rainfall. Water sources are in the form of major rivers and springs. The

main rivers are the Nile in Egypt, the Euphrates and Tigris in Syria and Iraq, the Orentis in Lebanon and Syria, the Litani in Lebanon, and the Jordan River in Jordan and the West Bank. Furthermore, water supplies are supplemented by groundwater reserves.

On the other hand, countries like KSA, Kuwait, Bahrain, Qatar, UAE, Oman, and Yemen are known to have a severe desert environment, where surface water resources consist of limited quantities. Thus, they have no option but to rely on non-conventional sources, such as desalination and treated wastewater. Aquifers with varying degrees of salinity provide another source for water. They are used to satisfy the domestic and agricultural water requirements. Based on several

TABLE 8 TOTAL ANNUAL WATER DEMAND (PAST AND PROJECTED) IN ESCWA MEMBER STATES FROM 1990 TO 2050 (MILLION M<sup>3</sup>)

	1990	2000	2010	2015	2020	2025	2030	2040	2050
<b>Bahrain</b>	234	272	382	427	476	525	580	688	809
<b>Egypt</b>	52,987	64,103	67,476	70,656	73,853	76,875	80,232	87,139	94,316
<b>Iraq</b>	46,605	57,143	70,893	77,392	84,176	90,328	97,151		121,147
<b>Jordan</b>	850	1,101	1,192	1,293	1,614	1,541	1,694	2,093	2,606
<b>Kuwait</b>	514	514	665	744	832	914	1,010	1,207	1,426
<b>Qatar</b>	221	335	331	322	348	428	451	500	554
<b>Oman</b>	1,245	1,658	1,687	1,810	1,936	2,079	2,239	2,642	3,127
<b>Lebanon</b>	1,258	1,471	2,237	2,537	2,842	3,172	3,527	4,227	4,969
<b>KSA</b>	16,861	17,973	18,729	18,932	18,958	18,711	18,500	17,939	17,930
<b>Syria</b>	7,654	16,373	16,926	18,650	20,605	22,304	24,012	27,807	31,699
<b>UAE</b>	1,395	1,984	2,342	2,546	2,777	2,976	3,195	3,626	4,056
<b>WB &amp; Gaza</b>	204	327	392	458	529	614	712	970	1,327
<b>Yemen</b>	3,143	3,821	4,166	4,989	5,541	6,058	7,088	9,066	11,547

TABLE 9

CONVENTIONAL ANNUAL WATER SUPPLY (MILLION M<sup>3</sup>) IN ESCWA MEMBER STATES\*

	Surface Water	Groundwater Recharge	Groundwater Use	Total Supply
<b>Bahrain</b>	0	100	258	358
<b>Egypt</b>	55,500	4,100	4,850	64,450
<b>Iraq</b>	70,370	2,000	513	72,883
<b>Jordan</b>	350	277	486	1,113
<b>Kuwait</b>	0	160	405	565
<b>Qatar</b>	1	85	185	271
<b>Oman</b>	918	550	1,644	3,112
<b>Lebanon</b>	2,500	600	240	3,340
<b>KSA</b>	2,230	3,850	14,430	20,510
<b>Syria</b>	16,375	5,100	3,500	24,975
<b>UAE</b>	185	130	900	1,215
<b>WB &amp; Gaza</b>	30	185	200	415
<b>Yemen</b>	2,250	1,400	2,200	5,850

\* Water supply data are based on years 1995, 1996, 1997, and 1999

country papers presented during the Expert Group Meetings held at the ESCWA head office in Beirut in 1995, 1996, 1997, and 1999, the following supply figures in Table 9 compile available annual conventional water resources for member states.

The breakeven point for water supply and demand is estimated for each member state, as indicated in Table 10. Some countries will continue to depend on surface water from major rivers, while others will rely on groundwater and desalinated seawater.

#### **d. Discussion**

The high population growth rate in the West Asia region exceeds by far the rate of developing water resources. Consequently, the annual per capita share of water resources is decreasing at an increasing rate. This study shows that developing water resources on a business-as-usual basis will leave the region with serious water shortages, particularly in the Arabian Peninsula where the annual water deficit could increase to as much as 67% of demand by 2015. It is clear that current water resources cannot satisfy future demand much past 2005 without alternative sources and policies. Water deficits can be reduced, though not eliminated, especially if emphasis is placed on cutting the wasteful use of water in agriculture, which accounts for the majority of water use in the region, and by shifting current policies away from heavy emphasis on food self-sufficiency. Supplies of renewable water in the

region are fully used or already overexploited, whereas demand will continue to rise rapidly. Currently water deficit is partially made up for by desalination and by over-exploitation of groundwater, which is resulting in fast depletion of aquifer reserves, deteriorating water quality, and higher salinity in the soil. Furthermore, existing wastewater treatment facilities may create health hazards due to the disposal of untreated wastewater. In general, the water sector suffers from weak institutions, inadequate technical capabilities, and unsatisfactory coordination among concerned authorities. There is an urgent need to review policies regarding the development and rational use of water resources throughout the region. The development of additional water resources in the region will require well planned, detailed, and integrated studies of the potential for surface, groundwater, and non-conventional water resources to meet rising demand, and cooperation between member states in these studies. Water policy formulation is very data intensive. Reliable data are the basis for sound planning and implementation of these policies.

Several options exist to address the imbalance of water demand and supply. The business-as-usual option assumes that no further development of water resources is anticipated, and emphasis is placed on prioritizing the usage of water for domestic purposes and then industrial and agricultural purposes. In general, the tendency of countries is to exploit easily accessible water resources first. Remaining sources will surely

require heavy investment, laborious investigation, and intensive research programs. Moreover, disputes may arise regarding shared water resources if proper conflict resolution measures are not adopted. A second option would be to emphasize supply augmentation by investing in non-conventional resources to satisfy the needs of water users. This option is not easy to fulfill at a reasonable cost. It should be noted, though, that consistent improvements in technology and operation have somewhat reduced capital and operating costs of non-conventional sources.

An optimal solution would be to adopt policy remedies that can achieve a gradual and rational decrease in consumption patterns by adopting high efficiency irrigation practices, imposing high tariffs on water use, and improving wastewater management. Therefore, extensive investigation, development, and reform programs are essential to develop the additional water resources needed, minimize water losses, and effect the optimum rationalization of water use.

### III. POLICY AND INSTITUTIONAL REFORMS

Water scarcity could result from the lack of supplies and/or the abuse and overuse of available water resources. Pollution by industry, urban wastewater, and agricultural run-off reduces the fitness of fresh water sources. A steady decline in groundwater levels has been documented due to over-pumping of aquifers. Inappropriate irrigation practices contribute to increased soil salinization and erosion, and result in higher sediment loads in watercourses. Industrial wastewater discharged into surface water or mixed with municipal wastewater raises serious concerns about environmental problems and diseases. Uncontrolled wastewater irrigation practices may cause major detrimental effects to public health.

Proper management of municipal and industrial water resources requires policies, standards, norms, and regulations in order to ensure water availability, avoid contamination, and protect public health. The role of government should shift from a provider to that of a regulator and planner. For example, government water institutions should plan for necessary water investments, commission studies, and arrange for

project implementation within an overall national strategic water master plan. Such a plan needs to explain how available water resources will be developed and utilized by the different sectors and should spell out operation and maintenance (O&M) requirements, means of cost recovery, a list of rehabilitation projects, efficiency programs, and the administrative architecture needed to achieve the goals of the master plan.

Water departments should have the primary task of issuing water and health standards, regulating water use, rationalizing domestic, industrial, and irrigation water use, limiting illicit connections, encouraging participation of the private sector, laying down the standards of service, consulting users first, involving the participation of rural communities in O&M activities, and introducing adapted technologies and equipment.

Although not formally and fully documented, most, if not all, Arab countries have a number of technical and operational policies for managing municipal and industrial water use. These include policies pertaining to the levels of service provision to the customer, water quality delivered, system and customer metering, preferred standards, and current practices for materials and construction. A standard practice document should be prepared in each country. This document should provide guidelines to engineers and other interested parties to achieve satisfactory design for the transmission and distribution systems as well as for operational standards in the water supply sector adhering to the requirements set by the water authorities. As a result of current shortcomings, the following policy reforms are suggested:

#### **a. Environmental protection**

Protection, enhancement, and restoration of water quality, and abatement of water pollution should be the focus of operations by the water authorities. It is important to support efforts to improve and expand clean sanitation and the treatment of wastewater. Water authorities are expected to apply efficiency pricing to encourage water conservation. They should also employ the 'polluter-pays' principle through the imposition of pollution charges to reduce pollution from industrial waste, mining runoff, and wastewater discharges. A balanced strategy involving economic incentives, effective legislation, and regulatory standards

and guidelines for levels of pollution control should be used to reduce effluents at the source, particularly if toxic substances are present. For pollution originating from agricultural activities, initiatives to minimize soil erosion and restore and protect surface and subsurface waters degraded by agricultural pollutants should be supported.

Strategies and cost-effective mechanisms for ecologically sustainable management, protection, and restoration of recharge areas and water-dependent ecosystems, such as wetlands, floodplain areas, and coastal zones should be administered. Based on the increasing importance of groundwater, it is critical to establish linkages between ground and surface water in managing river basins and establish programs and policies, including land use policies that restore and protect the quality of groundwater and groundwater recharge areas.

Reducing water pollution in urban areas requires coordinated policies and steps to lower municipal and industrial discharges of wastewater. To reduce the cost of waste treatment, authorities should give incentives to both industries and municipalities to reduce their waste loads. Municipal sewer and sewage treatment surcharges can be applied to water supply fees, preferably on the basis of volume. The industrial use of municipal sewerage systems should be based on clearly established standards for pretreatment and on user charges based on the volume and pollution load of industrial effluents. Best practice guidelines for minimum levels of pollution in both municipal and industrial sources should be developed and enforced. Establishing the appropriate standards requires careful analysis of the costs and benefits, given the very large price tag associated with cleanup operations, monitoring of compliance, and enforcement. Using innovative systems, water conservation, demand management, separation of toxic pollutants, and reuse for irrigation water can reduce the cost of sewage treatment.

### **b. Community and private sector participation**

A new set of laws or policies should be established to encourage private sector participation. In addition, community participation can enhance enforcement. With better information and legal support, such participation could provide a cost-

	<b>Breakeven year based on actual* supply</b>	<b>Breakeven year based on effective** supply</b>
<b>Bahrain</b>	1995	2009
<b>Egypt</b>	2000	2001
<b>Iraq</b>	2007	2011
<b>Jordan</b>	1990	2003
<b>Kuwait</b>	already	2001
<b>Qatar</b>	already	1997
<b>Oman</b>	safe	ample supply
<b>Lebanon</b>	2018	2027
<b>KSA</b>	1995	2010
<b>Syria</b>	2017	2035
<b>UAE</b>	bad	major deficit
<b>West Bank &amp; Gaza</b>	1999	2005
<b>Yemen</b>	2010	2020

\* Actual supply refers to conventional water supplies only.  
 \*\* Effective supply refers to conventional and non-conventional water supplies

effective way to identify enforcement problems. The key is the public disclosure of information on the discharge of industrial and municipal pollution. Disclosure improves compliance by supplementing the limited monitoring resources of public agencies in cooperation with affected communities. It strengthens enforcement efforts by focusing the attention of public officials on health and environmental problems associated with noncompliance. Wasteful use of water should be eliminated, and mining activities that seriously damage water resources should be regulated and controlled. For water investments and projects, environmental considerations should be given importance to protect natural ecosystems and direct development to less sensitive or already altered watersheds.

### **c. Wastewater effluent criteria**

Water authorities should establish general guidelines for the quality of wastewater discharged to streams and other water bodies. These controls should be designed to prevent pollution and the spread of disease resulting from the careless discharge of wastes. The distinction between environmental and human risks for different water uses has led to the formulation of standards, expressed in maximum receiving capacity of water for specific categories of pollutants most frequently discharged into the marine environment.

## TANNOURA IRRIGATES ITS GARDENS WITH GREYWATER

**Have you ever heard of a village where a public phone booth was installed before running water reached the houses? It is the true story of a Lebanese village, Tannoura.**

Children are running back and forth with empty gallons in hands, while mothers are stacking gallons filled with water in the wheel-barrow. The crowd is waiting for Zahia and her daughters to finish filling their last gallon from the Tannoura's small spring. "All this trouble with those gallons for so little water that I can only use to clean floors", says Zahia.

Tannoura not only suffers from water shortage, but it also seems suffering from all water related problems at once. The residents have to buy water by the truckloads costing around \$10 per load of 2000 liters, which is quite expensive for families living on an average of \$450 per month, and needing an average of 4 loads per month.

However, not everyone can afford that, so those who can't are obliged to adopt water saving behaviours. As a matter of fact, most households reuse their water 2 to 3 times before discharging it in the cess-pit. For instance, clothes washing water is collected to be used for floor sweeping, then to be used for toilet flushing.

If there was a global Water Demand Management competition, for sure Tannoura would have won the first prize.

The village of Tannoura is equipped with a water pipe network and two water reservoirs, which were first implemented in late 1960s and then replaced after 20 years. But people never received water at home, because their network was never connected to the Shamsine water source network, which supplies potable water to Rashaya Caza. "Today these reservoirs and networks are corroded because they were never filled with water", said the 'mokhtar' (local mayor) of Tannoura, Mr. Moufid Abou Zor. The new houses, constituting 40% of the total, are not connected to the old water network of the village.

For over 20 years now, the Municipality of Tannoura, with the cooperation of various influential people

in the area, have tried to solve the water issue of the village. However, no projects have been comprehensively implemented and no promise has been fulfilled yet, including the two water supply projects that were implemented during 2007/2008.

However, the year 2006 brought hope to the villagers when the Middle East Center for the Transfer of Appropriate Technology (MECTAT) initiated a Greywater Treatment and Reuse Project in Tannoura, funded by IDRC-International Development Research Center of Canada. The project aimed at reusing treated greywater, which is the wastewater resulting from kitchen sinks, washing machines and showers, as an available resource that has not been utilized so far and which has the potential of making irrigation water available in backyard gardens.

Thirty five houses in Tannoura benefited from this project. Each house was equipped with a 3 or 4-barrel treatment kit, in which anaerobic treatment of the greywater takes place, and then it is pumped into a drip irrigation network, installed in the garden. "Thanks to the greywater project, I can finally make use of my arid backyard, and grow vegetables and fruits for my children by using the greywater that we generate, at no cost and without any effort", said Amal Serhal, a resident of Tannoura.

The project was not only restricted to scientific research. Women empowerment was also undertaken through several training activities.

The success of the greywater project in Tannoura and in 9 neighboring towns would encourage the government to adopt similar greywater projects, simple to implement and with tangible results to be felt at the household and community level.

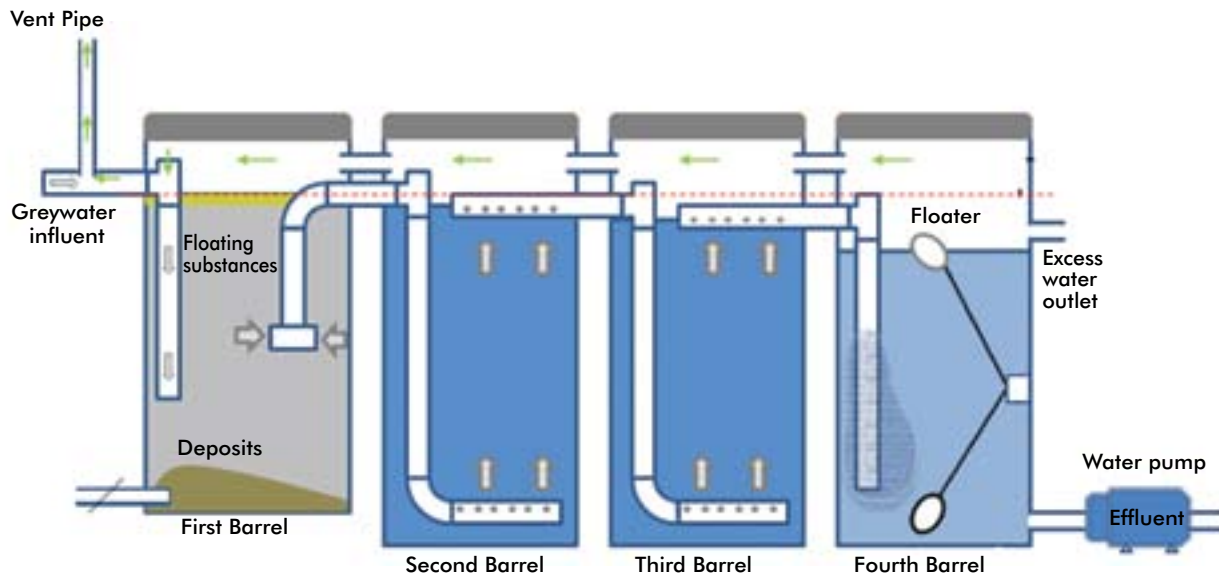
Tannoura is not an exception in the Middle East, as thousands of towns suffer from the water scarcity problems, where environmental conditions, worsened by political negligence, are making water shortage one of the main issues of the 21<sup>st</sup> century.

*Nadine Haddad and Lea Kai, Al-Bia Wal-Tanmia (Environment & Development) magazine*

## DESCRIPTION OF THE GREYWATER TECHNOLOGY

Four plastic (PE) barrels, lined up and interconnected with PVC pipes, constitute the greywater treatment kit. The first barrel acts as a primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease, floats. Once solids and floating material are trapped, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel, and then into the fourth. In the two middle barrels anaerobic bacteria work on breaking down the organic material found in the greywater. The last barrel acts as a storage tank for treated greywater and as soon as it is filled, a floating device switches on the water pump which then delivers the treated water, through the drip irrigation network, to 20-30 trees.

Laboratory results indicate that irrigation with treated greywater is safe and that there are no environmental and health impacts related to it.



*The system is airtight and watertight. Grey arrows indicate the flow direction of GW in the 4 barrels and the green arrows indicate the flow direction of gases that are produced during the digestion process, which are vented through a pipe above the roof level of the house. No odor is detected at the site.*

Industrial discharges should always be considered for treatment. As a further guarantee that the discharge will not exceed the receiving capacity of the marine environment, some basic effluent standards may be applied. Effluent standards are expressed in a statistical form to allow their control by the corresponding authority.

#### **d. Wastewater reuse**

Wastewater treatment is increasingly being utilized as a water source. However, treated wastewater is reused mainly for irrigating fodder crops, gardens, highway landscapes, and parks (Zubari, 1997). The remainder is dumped at disposal areas where it infiltrates shallow aquifers or is discharged into the sea. Reclaimed wastewater can have a larger role as a non-conventional water source provided that proper irrigation practices are applied. In water reclamation, the level of treatment depends on the ultimate use of treated wastewater, whether for irrigation or recharge. It is important to deal specifically with monitoring environmental changes that result from the reuse of wastewater for agricultural practices, and establish technically feasible and cost-effective wastewater reclamation methods for tertiary treatment.

#### **e. Quality of delivered water**

Water quality should meet or exceed World Health Organization (WHO) guidelines for drinking water quality (WHO, 1993). Systematic and random sampling programs should be set up by local water authorities to monitor the variations in water quality throughout the distribution system from the source to consumer's taps. The frequency of sampling should be sufficient to obtain statistically meaningful information and cover systematically all discrete zones within the supply zone. The concerned water authority should perform continuous water quality monitoring at all sites, where water is taken directly from a surface source for immediate treatment, and where a risk assessment indicates a significant risk of producing water after treatment that may not comply with WHO guidelines with risk consequences to public health.

#### **f. Leakage management monitoring**

Leakage in the water distribution network is

a particularly significant source of water loss. Water samples should be taken from permanent sampling points installed at key locations within the distribution on the trunk mains. Pressures should be monitored periodically within the distribution system and on trunk mains. Data from the continuous monitoring of flows, pressures, and water quality parameters, should be assembled to create a database of long-term performance.

#### **g. Demand management**

Demand Management comprises three interrelated policies to reduce leakage and excessive system pressure in relation to the designed level of service and control of flow in service connections.

- **Leakage policy:** Concerned staff should define a target level of leakage for a given supply zone as a whole and set a program to achieve the target. Once district meters are introduced, a detailed assessment of the variation of leakage within each supply zone will be possible. This will highlight any rapid or gradual rise in leakage levels.
- **Pressure reduction:** In some instances when designing both network extensions and district metering, the water authorities should emphasize identifying opportunities for full time pressure reduction where it can be demonstrated to be economic. Consideration should also be given to schemes offering part time pressure reductions either over part of a day or over a season.
- **Consumption control:** the water authorities should reinstate realistic water charges when an acceptable level of service has been achieved. Currently, tariffs are based on flat rates. Water authorities should aim at metering of individual consumers, which is a long-term objective, as one possible method of assessing charges.

### **IV. WATER TARIFFS**

Water authorities should define water tariffs that users have to pay for service provision. In fact, these tariffs should in principle cover the total costs to provide good quality water in adequate quantities. However, in reality domestic water tariffs are mostly not enough to cover the salaries



of employees and the costs of maintenance. Domestic water is sold at a nominal daily flow where rates are lower for smaller towns and increase proportionally. In addition, it is recognized that not all subscribers pay their dues, and water authorities are unable to fully control and limit illegal connections. As for irrigation practices, water is generally priced at a flat rate or at rates that are associated with the area that the users are allowed to invest in. This section describes different aspects of water tariff structure and presents concepts and recommendations for a new water tariff system. It is worth mentioning that economic considerations are becoming important in preparing the framework for decisions regarding future water supply. It is well accepted that major hikes in the marginal cost of water supply could be expected in the future, as fresh water may be imported or produced through seawater desalination. Thus, current low water tariffs will be difficult to maintain, and consumers should be prepared for a substantial increase in the real cost of water supply.

#### **a. Tariff factors**

Several factors may affect water tariffs setting and should be taken into consideration. In the domestic sector pricing should account for factors such as the type of service, subsistence level of consumption, and the purpose for which the water is used. In the agricultural sector, prices should reflect the intensity of water use per crop, the number of water applications, and the size of the irrigated area. In the industrial sector, pricing should take into consideration differences among industries in terms of intensity of use, type of water source, quality of supplied water, quantity of effluent streams, and the type and quality of effluents.

#### **b. Tariff criteria**

Criteria for establishing water rate configurations are based on elements of local acceptability, economic efficiency, cost recovery, and equity. User acceptability, represented by the ability to pay, is an important parameter. Care should be taken to meet the basic needs of the poor or those who cannot afford new water rates. Economic efficiency focuses on achieving water services at minimum cost, which may be reached when the price of water is equal to the marginal cost. Cost

recovery indicates that the rate reflects the true cost of water, where system repairs and expansion costs are adequately covered. Equity is based on sharing the costs of the water delivery system among customers in a fair manner. Consideration must be given to the existence of large industrial or agricultural water users where water authorities may be compelled to maintain larger delivery systems to accommodate their requirements. It is feared that small users may end up compensating for water use charges of a few larger users. Meters, if available, for large industrial, commercial, and institutional consumers should be monitored periodically and compared with the billing records. Efficient rate structuring should include mechanisms for recovering the true cost of water services, without resulting in under-pricing, overpricing, or subsidizing some consumers at the expense of others.

#### **c. Water pricing strategies**

Socioeconomic and political considerations call for a gradual move towards the implementation of a pricing policy that equates the marginal and opportunity costs for water. Prior to the formulation and implementation of pricing schemes, there is a need to evaluate water sources, characteristics of water demand, and socioeconomic conditions. Special consideration must be given to the nature of water resources, which exhibit spatial and temporal variability. If present domestic consumption patterns continue unaltered, governments in the Arab region are required to allocate financial resources towards the construction of hydraulic structures, distribution systems, and support facilities with capacities to accommodate increased demand. A large number of wastewater treatment plants will also be required to handle the resulting higher wastewater volume load. This huge investment may result in considerable economic strain, especially with limited financial resources and constrained budgets. However, proper logistics for integrated supply-demand management and planning, along with just allocation of shared water sources through equitable agreements, will contribute significantly to alleviating water deficits. In this instance, it is important to implement demand management programs, including the application of proper economic criteria that emphasize appropriate pricing schemes to reduce the imbalance between

## SULAIBIYA WASTEWATER TREATMENT AND RECLAMATION PLANT-KUWAIT

### Ibrahim Al-Ghusain

The Sulaibiya Wastewater Treatment and Reclamation Plant in Kuwait is the largest facility of its kind worldwide to use reverse osmosis (RO) for domestic wastewater treatment and reclamation. The plant is also the first infrastructure project of its size in the Middle East to be executed under a 'Build, Operate, and Transfer' (BOT) scheme. This is in line with the government of Kuwait's plan to target the effective participation of the private sector in water infrastructure projects. A joint venture between Al Kharafi Group of Kuwait and GE Ionics has been established in 2001 to undertake the 30-year concession contract for the Sulaibiya Wastewater Treatment and Reclamation Plant with the Government of Kuwait.

The plant is initially designed to treat up to 425,000 cubic meter of raw domestic wastewater per day. The capacity would eventually reach up to 600,000 cubic meters per day during the 30-year concession period. The Plant treats around 60 per cent of Kuwait's total domestic wastewater. The specifications of reclaimed water produced from the Sulaibiya plant exceed World Health Organization (WHO) standards for potable water. The engineering, procurement, and construction (EPC) value of the project is US\$500 million, while the total income to the contractor is estimated at US\$1.8 billion. Over the period of its concession, the project is expected to save the Government of Kuwait in excess of US\$12 billion, representing the price differential between what the contractor sells the reclaimed water for versus what the government would otherwise pay for it. The government will buy all reclaimed water produced by the plant.

The use of reclaimed water is limited to agricultural and

industrial applications and possibly in a variety of other usages such as gardening, car washing, and the cleaning of buildings. Potentially, reclaimed water could be re-charged in an underground aquifer to become a strategic water asset.

### Plant Facilities

The Sulaibiya plant includes the following facilities:

- Preliminary Treatment and Pumping Station at Ardiya;
- Transfer Pipelines from Ardiya to Sulaibiya;
- Biological Treatment in Sulaibiya; and
- Reclamation Plant at Sulaibiya.

Preliminary treatment of the wastewater starts with screening, sand, and grease removal upon its arrival at Ardiya inlet works. The wastewater is then directed to two buffer tanks. Each tank is 67 meters in diameter and 7 meters deep. These tanks regulate the flows arriving to Ardiya before being pumped to Sulaibiya.

The Pumping Station at Ardiya contains 8 pumps, 2 of which are on standby, to transfer the wastewater through three pressure pipelines, extending over 25 kilometers from Ardiya to Sulaibiya. In order to safeguard the environment at the Ardiya inlet works, in view of its proximity to residential areas, all facilities in the site are enclosed. In addition, all facilities at the site are furnished with state-of-the-art odor control treatment system.

The biological treatment system, consisting of 9 biological treatment trains, forms the heart of the Sulaibiya plant. Each train consists of an Aeration tank (147 meters long, 28 meters wide, and 8 meters deep) and a circular secondary clarifier (56 meters in diameter and 8 meters deep). The

demand and supply, and promote effective efficiency measures.

This strategy is based on the perception that water is a marketable commodity, whose value is set by the law of demand and supply. The attachment of economic value to water would promote conservation, efficiency, and encourage privatization in the development, treatment, and distribution of water resources. Also, it can be considered as a criterion to improve water allocation and to set the administrative price level for water. The association of water directly

with its production costs should be considered in the context of the social conditions within the country. The poor must be recognized as having an equal claim to potable water, as everybody else, at an equitable price. Under certain circumstances, subsidies may be used to provide for minimum water requirements. The public must be informed of the importance of pricing policies as a means of water resource management, and its preservation for future generations. The formulation and implementation of appropriate water pricing policy can contribute significantly towards the sustainable management of water resources.



secondary treated water from the biological treatment system is then directed to the reclamation plant.

The settled sludge in clarifiers is thickened in gravity belt thickeners before it is transferred to 8 aerobic digesters (58 meters long, 24 meters wide, and 7 meters deep). Upon digestion, the sludge is pumped to sludge drying beds. After drying the sludge is stored for 6 months in order for it to be considered safe as a natural fertilizer.

Secondary treated water is sent to 5 rotating disc filters before being fed to 5 trains of ultra-filtration (UF) units containing 8,704 membrane modules. The filtered water

then flows to the 3-stage reverse-osmosis (RO) plant for reclamation. There are 6 RO trains. Each train contains 7 skids and the total number of membrane modules in these skids is 20,832. The RO membranes secure the complete removal of suspended solids and microbes. Reclaimed water then flows to the permeate basin. From this basin, reclaimed water is pumped to the network of the Ministry of Public Works at Sulaibiya. Most treatment and reclamation processes in plant facilities are fully automated using process control systems.

*Dr. Ibrahim Al-Ghusain is General Manager, UDC (Kharafi National) Kuwait.*

The proposed water tariff revision, if implemented, would mean additional revenue would accrue. It is important to hike the water tariff to cover the costs of increased power charges, pay scales and wages of O&M staff, repairs of pumping machinery, distribution system, and the cost of material and labor. The water authorities are under the obligation to increase revenues and meet O&M costs. In addition, fines and penalties must be imposed when water misuse occurs.

For urban water supply, the pricing strategy should replace the current flat fees with tariff

schemes consisting of two parts: a fixed charge and a variable charge. The fixed charge gives the service provider a reliable stream of revenue to cover overhead expenses, and the variable charge provides consumers with incentives to use water more efficiently. However, the fixed fee should be large enough to maintain a continuous cash flow to the water authorities even if the users are not using their water. The feasibility of tariffs by consumed volume depends on the practicality of using meters. It is important to use increasing block rates for high consumption, and possibly decreasing block rates for very high



consumption. This diminishes the impact of the pricing structure on consumption patterns. The same rate structure should apply to industries. It is important to investigate the feasibility of applying a special tax on water supplied to industrial enterprises to partly finance drinking water supply projects in villages and semi-urban centers.

For irrigation water, pricing should set charges on the basis of average use rather than the marginal cost of supply. Water authorities should calculate charges by dividing the average cost of service by area irrigated, often adjusting the results by season, type of crop, or technology used. Charges may not be adjusted by region even though regional variations in water availability may be responsible for differential water and technology costs.

#### **d. Recommended tariffs**

Water supply authorities should have the power to set and adjust water rates. Volumetric pricing and metering should be adopted, uniform tariffs removed, and low prices abolished. In addition, there is a need to significantly increase water charges to all users. It is crucial to implement water-pricing schemes to achieve short- and long-term policy goals, recover costs, encourage water conservation, protect the environment, and provide performance related incentives for water suppliers to reduce the costs of water supply and for consumers to use water more efficiently. The

following are proposed water tariffs for the main water users in Arab Countries:

#### **1. Domestic and wastewater tariffs**

Municipal and wastewater tariff structures should operate by means of an increasing block rate, where charged prices increase with increasing consumption. In this type of structure, the income per capita is taken into account in setting the unit cost. The tariff should cover the costs of water from its source, exploration and source development, water treatment, transport, and storage, wastewater treatment, wastewater reuse, water disposal, and associated environmental effects such as reduction in fossil-water stocks. These costs, however, can be summarized into three main categories: (i) capital costs, (ii) operational costs, and (iii) costs associated with the deprivation or enrichment of resources. In short, if the efficiency of water delivery and use are increased, losses in the delivery system are reduced, and illegal connections are terminated, the water revenues can cover the cost of delivery. However, this requires effective monitoring and control processes to be enforced by water authorities.

#### **2. Irrigation water tariff**

The irrigation water tariff imposed on farmers may be operated by means of fixed rating systems or increasing rates. It is more feasible to shift to

the increasing rate system since it is an effective mechanism that allows for proper management of water demand, reflects the extent of water shortage, and provides effective water saving incentives.

### **3. Industrial water tariff**

The industrial sector should adopt the same increasing rate tariff structure as that suggested for the domestic sector, whether industries obtain their water supplies from water authorities or from private wells. In many cases, large and medium size industries, some universities, army units, and governmental organizations have their own groundwater wells. Accordingly, they do not pay for the water they consume. In this instance, they are free to extract as much water as they desire without any control or monitoring. They only pay the costs that are associated with the capital and operation charges of their own equipment. This policy does not promote water preservation or efficiency, and usually leads to wasteful use and the depletion of groundwater resources, which have been observed due to the lack of control on utilization and the excessive use of dilution of wastewater effluents to meet the required guidelines of disposal in the wadis or in other environmental sinks.

## **V. CONCLUSION AND RECOMMENDATIONS**

To meet future water challenges and avert water shortages, water policies and strategies must emphasize an integrated approach to achieve simultaneous management of demand and supply, including economic criteria for water allocation and efficiency. There is a need to evaluate the merits of attaching an economic value to water. As a result, water could be treated as a scarce economic resource and protected accordingly.

Arab countries should adopt water strategies that stress the need to improve municipal and industrial water resources management with particular emphasis on the sustainability of present and future uses. Consequently, water strategies should revolve around the following dimensions: resource development and management, legislation and institutional reforms, management of shared water

resources, public awareness, performance, health standards, private sector participation, public-private partnerships, community involvement, financing, pollution protection, quality monitoring, preventing the depletion of resources, and research and development.

### **a. Demand and supply**

In general, conventional water sources are not sufficient to meet demand for fresh water in the ESCWA region, where rapid industrialization and higher standards of living are expected to drive water shortages. Currently, renewable water resources in the region are fully exploited. Water deficits can be addressed by adopting rational use, higher efficiency, wastewater reuse, conservation, and desalination. The latter will play a greater role in augmenting traditional water supplies. Some countries will continue to depend on surface water from major rivers, while others will rely on groundwater. Therefore, the prospects for water availability are uncertain, requiring new strategic investments by Arab countries in reallocation among competing sectors and increased water use efficiency. These demand management measures can then be succeeded by investments in non-conventional sources to develop additional water supplies. In addition, the reliability of water sources will be of increasing importance in the future, necessitating systematic contingency planning to ensure adequate and effective response to droughts, floods, and other climatic changes and to minimize their adverse effects. Implementation of these policies is the key to deal with water deficit problems. Failure to address the imbalance between demand and supply may result in further deterioration in water quality and quantity.

### **b. Policy reforms**

The adoption of a comprehensive framework for analyzing policies would help guide decisions about managing water resources where significant problems exist, or are emerging, concerning the scarcity of water, the efficiency of service, the allocation of water, or environmental damage. The complexity of the analysis would vary according to capacity and circumstances, but relatively simple frameworks can often clarify priority issues. This analysis should account for all social, environmental, and economic objectives,

## WATER RECYCLING IN TUNISIA

Sanitary wastewater infrastructure in Tunisia has recently been widely developed and expanded. Large-scale projects were completed, notably the wastewater treatment system in “Sidi Hussein al Sigoumi” area, where the building of a huge wastewater treatment plant, with a capacity of 60,000 m<sup>3</sup>/d, is under way, along with the construction of 40 km network. Moreover, the rehabilitation of the Greater Tunis Treatment System, comprising 132 km of ducts, is projected to be completed in 2010. Tunisia has 106 treatment plants that treated 238.5 million cubic meters (MCM) in 2009.

This sector also covers industrial areas and concentrates on widening the scope of industrial wastewater treatment. The first treatment plant in the southern suburbs of the capital was established in “Bin Aroos” area, and industries are encouraged to install primary filtration facilities with government financial aid through the mechanisms provided by the Pollution Prevention Fund.

63 MCM, i.e. almost 27% of the 238.5 MCM treated in 2009, were reused, and the area irrigated by reclaimed water amounted to 10,000 hectares. The volume of reused water is projected to rise in 2014 to above 50% of the total volume discharged by treatment plants.

It is expected that a formidable project shall be launched soon for transporting volumes of reclaimed water from the north to the central regions, where large areas will be used for cultivating fodder crops and fruit trees, in addition to the construction of barriers to control creeping sand and desertification, and the production of grains that can be used for biofuels. The project shall be funded within the framework of the Clean Development Mechanism (CDM).

Under the plan for the treatment of sanitary wastewater in Tunisian villages, the Tunisia International Center for Environmental Technologies was commissioned to explore appropriate, simple and economical techniques for the treatment of water used in rural areas. The Center, in collaboration with the Ministry of Scientific Research and the National Sanitation Utility, has completed a model plant for the treatment of wastewater generated in the north-eastern region, based on the fact that the climate, soil and flora of that region are characterized by special features that



form a natural tool for water purification, instead of traditional electromechanical equipment used in treatment plants.

The Center established a pilot model plant for Juqar village in Zaghwan district which applies the technique of treating used water through aquatic plants, with a capacity of 1m<sup>3</sup>/h. The plant serves nearly 800 inhabitants, and its reclaimed water is used for irrigation. The prevailing trend now is to build similar rural plants compatible with various climates in north-west, central and south Tunisia, and to spread such plants ubiquitously across the country.

It should be pointed out, in this respect, that the National Program for the Conservation of Irrigation Water, launched in 1995, took on all the financial and technical support needed for the provision of water-efficient equipment for 345,000 ha of arable land.

*Suleiman Bin Yusuf, Al-Bia Wal-Tanmia (Environment & Development) magazine*

and evaluate the status of water resources as far as the level and composition of projected demand. Special attention should be given to the views of all stakeholders. From a general understanding of the different water laws, standards, and policies in water management and wastewater treatment process and criteria, one can suggest the following:

- Relieve expected water stresses by necessary water efficiency measures and integrate groundwater recharge into a comprehensive water basin management;
  - Obtain water quality data and other information to establish integrated databank using standardized international methods and integrate training as a part of the whole process;
  - Treat wastewater properly prior to disposal to avoid contamination, integrate reuse, and issue legal and environmental regulations in planning projects;
  - Adopt an integrated watershed management approach for elaborating policies and strategies of water resources development, management, conservation, and select the appropriate technology to fit the socioeconomic capabilities and tradition;
  - Apply geographic information systems (GIS) as important tools for planning water resources projects and emphasize hydro-meteorological conditions when applying modern techniques;
  - Establish a coordination mechanism between concerned ministries and government agencies to avoid fragmentation between authorities and agencies;
  - Develop impact-monitoring indicators to measure the progress in meeting objectives;
  - Improve cost recovery and modernize municipal management and finance systems;
  - Adopt sustainable water use approach for elaborating policies and strategies of water resources development, management, and conservation, in which the following issues are stressed:
- a. **Typical water use:** trends in water use are related to key socio-economic indicators. Often, seasonal and peak use offer potential for cost effective capital savings. But, system losses remain high in many regions.

- b. **Technical initiatives:** apply simple, yet effective, water saving technologies along with pilot programs and campaigns for public education. Also promote leakage reduction technologies, where repair and rehabilitation technologies offer cost-effective solutions.
- c. **Financial initiatives:** cost of service assessment is crucial to the water authorities for efficient operations. Rate setting is needed to promote sustainable systems and enhance increased billings and collections as well as inventory control. In addition, reduced litigation and penalties are effective as well as debt analysis and restructuring.
- d. **Operations & maintenance initiatives:** include privatization and outsourcing, competitiveness and performance, operational audits and evaluations, restructuring & organizational design, incentive pay schemes, and training & development.
- e. **Supplemental sources:** include recycled wastewater, water harvesting, rainwater catchment systems, captured flood runoff, brackish water, submarine springs, crop substitution, and desalination.

The objectives of water policies should be to achieve the following improvements:

For Industry: Apply extensive water efficiency measures to substantially reduce the quantity of water used per unit output. Prevent source pollution or reduce the volume of wastewater generated through process changes. Ensure waste is treated to meet strict regulatory standards prior to disposal.

For Municipal Water Supply and Sanitation: Implement more efficient and accessible delivery of water services and sewage collection, treatment, and disposal, with an ultimate goal to provide complete coverage. Also, extend existing supplies through water efficiency and reuse and other sustainable methods with greater involvement of the private sector, NGOs, and user groups and try to attain cost recovery to ensure financial viability while applying graduated fees to assist the poor.

For Irrigation: Include modernized irrigation practices with greater attention to cost recovery, drainage and salinity control, measures to reduce pollution, improvements in O&M of existing systems, and investments.

For the Environment and Poverty Alleviation: rigorous attention should be given to minimize resettlement, maintain biodiversity, and protect ecosystems in designing and implementing water projects. Conserved water and energy supplies can be used instead of developing new supplies to extend service to the poor and maintain ecosystems. Low-cost and environmentally sound methods should be pursued.

### **c. Tariff structures**

Water authorities should assess rational water tariffs to achieve full cost recovery in a gradual manner. To cater for socioeconomic conditions, tariffs reflecting the effective water supply cost cannot be doubled or tripled overnight. There is a need to establish affordable water tariffs based on the income of different segments of society. Special attention must be given to meet the most basic needs of the poor in order to avoid hardship. The design of water tariffs must be based on factual social, economic, and technical data. The application of tariffs should be accompanied with a public educational campaign to convince people to accept the “consumer pays” principle. Any adequate and feasible valuation policy of water should be linked to the presence of management departments having significant prerogatives and technical and financial means.

There is no denying that implementing water-pricing reforms is very difficult. Subscribers may resist paying for water and may even resort to applying political pressure to reverse any policy reforms. Technical and managerial capacity may be inadequate to assess and enforce new water pricing schemes. In this instance, governments in the Arab region may consider using non-price measures to encourage consumers to use water more efficiently, including transferring management responsibilities to user groups and/or promoting the development of water rights and water markets. It is believed that potential benefits might arise by transferring management responsibility to users, where user groups collect water charges and maintain the physical facilities. Indeed this approach has become the favored approach for improving the financial sustainability of water systems.

A changing water paradigm is occurring in which

environmental, financial, and social constraints are redefining the value of water, which includes not only the cost of production and treatment but should also include the overall impact on the quality of life, health and safety, and economic effects on society and industry. Therefore, societies in the Arab region are called upon to contribute to the reduction of water consumption and to educate children of the practical and ethical value of water efficiency and conservation for future generations and environmental protection. The involvement of the public at large and non-governmental organizations (NGOs) in water affairs should not be viewed as a choice but as a requirement for effective management and for safeguarding affordable drinking water supply.

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# Integrated Water Resources Management

HAMED ASSAF



## I. INTRODUCTION

Water is always portrayed in the common literature and general wisdom as a precious and priceless substance without which life would not have existed on Earth. Yet it is the same material many frown upon paying for and willingly or unwillingly squander, pollute, and show little regard for its prominent role in maintaining life. The largest share of our water consumption goes unnoticed in food production, industrial processing, and simply as a waste carrier and diluter. The benefits from water resources are not equally distributed among different sectors of society or among successive generations, if current resources are not protected for future use. The fast pace of water resources development over the past few decades has taken its toll on the environment in terms of increased pollution, wetlands destruction, fish stocks depletion, and endangerment of marine life in estuaries.

These complex issues surrounding water use are further amplified by water scarcity in the semi-arid and arid regions of the Arab region. Under these conditions water becomes the most critical factor for socio-economic development. With dramatic rise in demand, water development may have adverse impacts on environmental conditions. Water scarcity has been the norm of life in the Arab region over millennia. The region is the birthplace of the oldest civilizations, which have adapted to these harsh physical conditions by developing efficient irrigation systems that reduce evapotranspiration and maintain a viable and equitable distribution of water resources. The Qanat underground system, the Saqia, and traditional water allocation schemes feature some of the innovations that have lasted to our day (Jagannathan et al., 2009). However, the tremendous growth in population at the onset of the twentieth century has outstripped expansion in water supply brought about by investments in water infrastructure. These conditions have quickly dragged many Arab countries into water poverty that would, if not dealt with timely, impede growth, accentuate poverty, and further increase instability in the region.

Following major drought-induced crises in several developing countries in Africa and Asia that have led to malnutrition and famine, the world community has in response made a critical

assessment of the discourse on water resources development and convened in two important summits to introduce the main principles of integrated water resources management (IWRM). Known first as the Dublin water principles in reference to the International Conference on Water and the Environment in Dublin in 1992, they were later refined and incorporated into the agenda adopted by the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, 1992 (Agarwal et al., 2000). With their emphasis on the trio of economic efficiency, social equity, and environmental sustainability the Dublin-Rio water principles still continue to define the central theme of contemporary water resources management. This chapter introduces the paradigm of integrated water resources management and its underlying Dublin-Rio principles and presents a well-established framework for its implementation with emphasis on water resources issues in the Arab region.

## II. EVOLVEMENT OF THE IWRM PARADIGM

Management of water resources has made great strides fueled by better understanding of the physical processes driving the water cycle, improvement in data collection and analysis, and advances in the construction industry that enabled developing extensive and complex infrastructure. North America and Europe have witnessed development of mega water infrastructure projects up to the 1960s that supported large irrigation schemes and urban growth fueled by both greater access to water and better flood protection. However, a shift in the cultural attitude towards natural preservation, increased concern for human and land rights for indigenous communities who inhabit affected areas, and a rise in the number of environmental disasters and incidents ignited a powerful environmental movement in the 1970s and 1980s that confronted government developmental policies. These developments have forced many western governments to alter their water resources development policies from those focusing almost exclusively on economic growth to those that strive to achieve social equity and sustainability. The concept of sustainability embodies achieving an optimal socio-economic development of natural resources while maintaining their viability



for use by future generations and preserving their environmental services and natural ecological balance. As a result of these dramatic policy shifts, construction of large dams has ceased completely and several dams were even decommissioned to help re-establish fish populations, such as salmon in the Pacific Northwest of United States. The US Environmental Protection Agency (EPA) holds a veto power over water resources projects, which it has exercised several times to freeze plans for major water projects. More stringent regulatory rules have been established in North America and Europe to stem pollution of surface and groundwater resources.

As indicated earlier, major devastating drought-related disasters have instigated global efforts to develop the Dublin-Rio water principles, which articulate a holistic approach for integrated water resources management as follows (Solanes and Gonzalez-Villarreal, 1999):

- **1st Principle:** Fresh water is a finite and vulnerable resource, essential to sustain life, development, and the environment;

- **2nd Principle:** Water development and management should be based on a participatory approach, involving users, planners, and policy-makers at all levels;
- **3rd Principle:** Women play a central part in the provision, management, and safeguarding of water; and
- **4th Principle:** Water has an economic value in all its competing uses, and should be recognized as an economic good.

The first principle emphasizes the key role of fresh water in maintaining all forms of life and its necessity for socio-economic development. Despite their abundance in certain parts of the world, fresh water resources have limited physical quantity and can be adversely affected by human activities that not only make them unfit for human consumption, but also disturb ecological balance. This principle implicitly calls upon people to take action to protect and preserve these vital resources.

The second principle recognizes the importance of involving all stakeholders in the process of managing water resources. Failing to do so by

dissuading public engagement in decision-making, restraining accountability, and marginalizing the poor would lead to lopsided water allocation and services.

The third principle brings into the spotlight the plight of many women, particularly young girls, in poor underdeveloped countries, who are kept occupied with strenuous water fetching activities that could involve walking several kilometers everyday. Young girls may lose their educational and developmental opportunities as a result. Improving water services and delivery frees up women to take up education and more productive activities.

The fourth principle underscores the economic value of water which tends to be overlooked in setting water management policies in some countries leading to overexploitation and loss of productivity. Pricing water can be a contentious issue in some countries due to cultural and religious considerations. However, setting proper pricing policies can convey to consumers the real value of water and motivate users to treat it as such, driving them to increase their productivity and rationalize their use.

Despite being universally endorsed, the principles provide only a general sketch of IWRM without offering clear definition of how it could be implemented. There is a general agreement that water resources management should strike a balance among economic efficiency, social equity, and environmental sustainability. The World Bank has adopted this approach in a water resources management policy paper published in 1993 and reconfirmed its commitment to IWRM in a recent strategy setting publication (World Bank, 2004). Citing analysis by the Organization for Economic Cooperation and Development (OECD) of the water sector in advanced countries, the World Bank has acknowledged however that putting IWRM into practice is strewn with a multitude of difficulties even in highly developed countries. Chief among these obstacles are inadequate incorporation of environmental issues into other sectoral policies, non-comprehensive water quality standards, inadequate water pricing structures that capture the full economic and environmental value of water, lack of progress in improving water efficiency, lax water demand management, and

persistence of subsidies in the agricultural sector (World Bank, 2004).

As a staunch advocate of IWRM, the Global Water Partnership (GWP) has led efforts to translate IWRM concepts into a practical conceptual framework that could be adapted in different country settings. The following sections will draw upon these efforts, as published in Agarwal et al. (2000), to discuss the range of challenges, features, and implementation methodologies of IWRM.

### III. ISSUES TO BE ADDRESSED BY IWRM

Managing water resources is a delicate balancing act between meeting demand while maintaining the viability of the resource for future use without jeopardizing the integrity of the environment. Meeting basic human demands constitutes the first objective in utilizing water resources. Although several advanced societies have achieved near completion in meeting these demands, several developing countries are still lagging in securing access to clean water for drinking and sanitation. There are also great disparities among different socio-economic sectors with the well-to-do getting access to low priced, clean water whereas the poor having to contend with over-priced, unreliable, and potentially contaminated water supplies.

In semi-arid and arid regions, water is the critical factor in maintaining a viable agricultural sector which not only produces food but also employs a large segment of the population. Extended droughts can lead to crop failures and loss of livestock which could result in population relocation, epidemics, conflict, malnutrition, and even famine in countries where large segments of the population are engaged in subsistence farming and pastoralisation. For example, extended droughts in the 1980s have plunged the Sub-Saharan countries into several famines that killed hundreds of thousands of people.

Beyond maintaining basic life needs and agriculture, water is a main component in most industrial sectors including production of energy, food processing, and heavy industry. In general, insufficient water supplies preclude socio-economic development and highly

constrained water conditions may lead to general decline in communities.

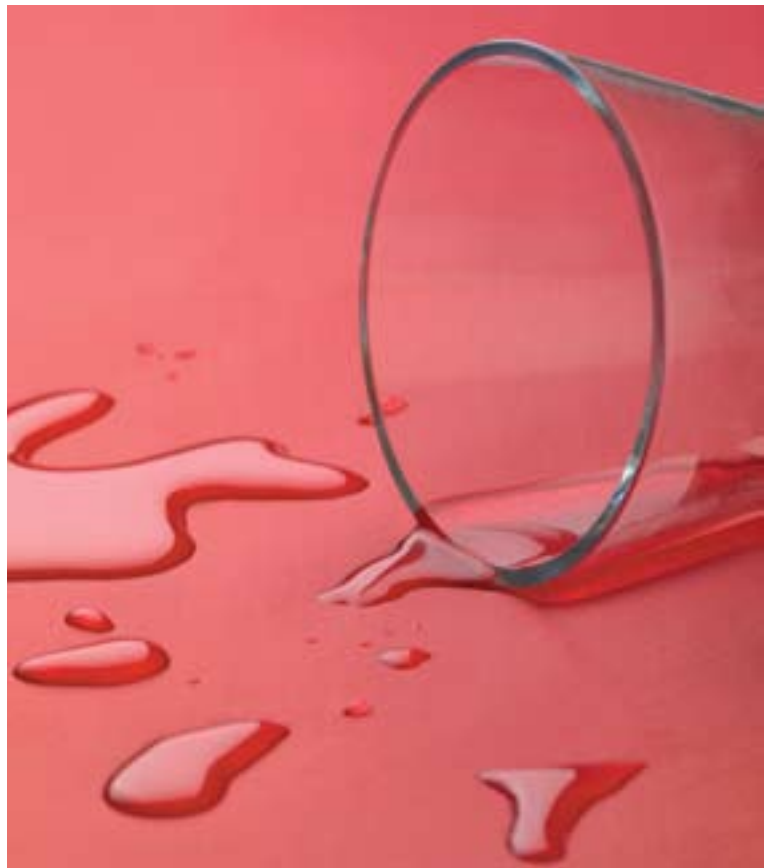
Variability and uneven distribution of precipitation present challenges for the provision of secure water supplies and flood protection. For example, although Lebanon has an overall positive water balance, its heavily populated coastal cities, particularly Beirut which houses half of Lebanon's population, have insufficient local water resources to meet municipal demands. The inability of the Beirut Municipality to meet the demand of its customers has led to the proliferation of illegal extraction from the local coastal aquifer to supplement demand leading to serious sea water intrusion into the aquifer (Saadeh, 2008).

As an example of the difficulties in managing flood risk in arid regions with sporadic rainfall, major cities in Saudi Arabia are vulnerable to the rare yet very extreme rainfall storms such as the one that Jeddah suffered from in late 2009. The Jeddah disaster was compounded by the lack of capacity of the water drainage network. It is reported that infrastructure designers assumed that the region has very minimum rainfall levels and neglected to account for extreme rainfall events.

Demographic and socio-economic changes greatly influence water demand, water quality, and ecological conditions. Arab populations are getting more urban and are still expanding at one of the highest rates in the world. Urbanization has caused an increase in both total demand and demand per capita. Urban encroachment on agricultural land, wetlands, and watersheds has disturbed the ecological balance of these ecosystems and increased their exposure to industrial and municipal pollution. The near extermination of fish in the Manzala Lake in Egypt as result of the large inflow of untreated sewage from Cairo (Abbassy et al., 2003) is a stark example of the how rapid growth can conspire to destroy the health of ecosystems and disseminate the livelihoods of their inhabitants. It also underscores the disparity in power between urban and rural populations in managing water resources.

#### IV. IMPLEMENTATION OF IWRM

As indicated earlier, the Dublin-Rio principles are only general guidelines that leave a significant

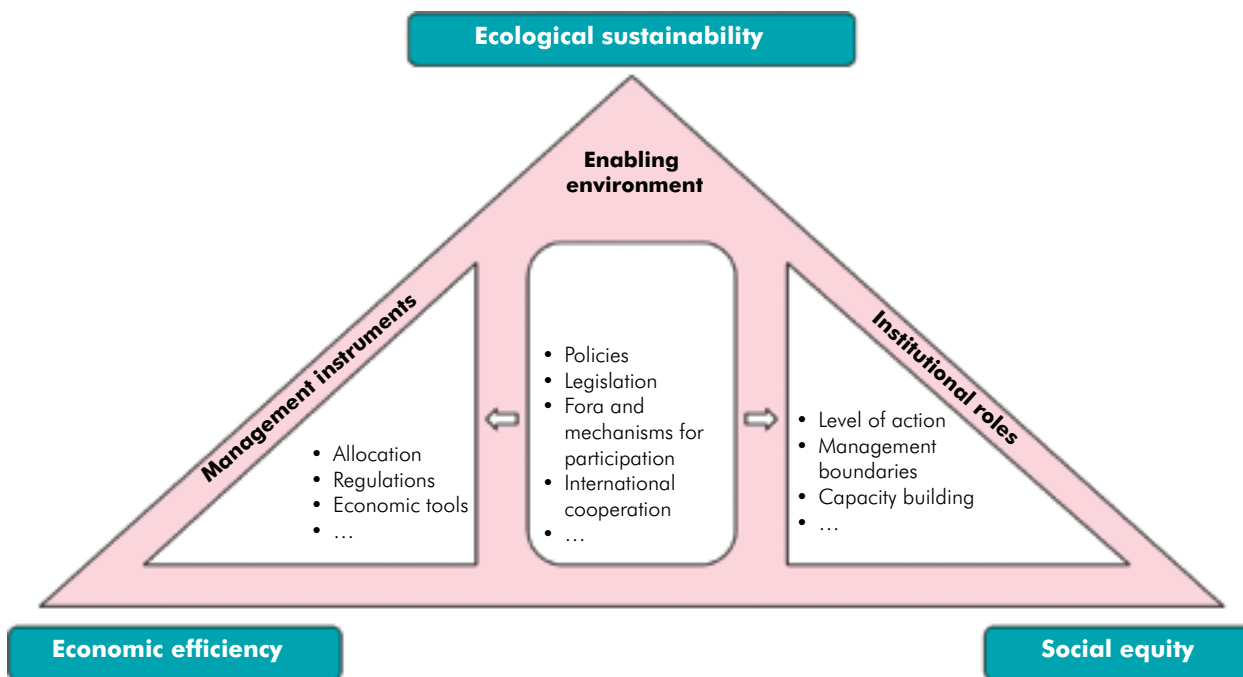


room for interpretation and implementation. The following sections are based on the widely accepted framework proposed by the GWP, depicted in Figure 1. The three key objectives of IWRM, namely, economic efficiency, social equity, and ecological sustainability are placed to surround a triangle representing implementation components in order to underscore the importance of keeping them incorporated in all implementation decisions and methods. The first objective emphasizes the necessity to optimize water usage particularly under conditions of water scarcity. To avoid placing less influential and poor groups at a disadvantage due to the lack of representation or inability to pay for services, the second objective calls for special provisions or compensation for these groups. Any implementation strategy or tool has to observe rules established by the third objective.

Elements of GWP's framework for IWRM are organized under three main elements: "the enabling environment", "the institutional roles", and "the management instruments" (Agarwal et al., 2000).

FIGURE 1

GLOBAL WATER PARTNERSHIP IWRM FRAMEWORK



Source: Agarwal et al., 2000

The first element represents a compendium of policies, legislation, and regulations available for stakeholders. The second element delineates the roles of different institutional players and stakeholders. The third element constitutes a wider range of tools for regulation, economic optimization, and monitoring.

## V. THE ENABLING ENVIRONMENT OF IWRM

IWRM requires a system of policies, laws, regulations, platforms, and mechanisms to support its activities and players. It requires a culture that facilitates and encourages communication and participation of all stakeholders, particularly marginalized groups who tend to be the most affected by it yet have the least say over water resources management decisions.

### a. Government role in IWRM

Considering the public nature of water, governments play a key role in its management. Governments are expected to maintain their roles

in water policy setting, water supply development, flood control, and conflict arbitration. The emphasis in contemporary water governance is for governments to have a lesser role in the provision of water services, while maintaining a regulatory role. Monitored and controlled by transparent regulations, the private sector can deliver more efficient, reliable, and accountable water services. In situations where governments have to take on the role of service providers, they must take an arm's length approach that separates between regulatory and service provision bodies to maintain transparency and accountability.

Regulations have to specifically consider special provisions to mitigate or prevent the adverse impact of water development and/or water pricing policies on the poor. This is particularly important in large cities which have grown considerably in past decades as rural or displaced populations migrated to its poor neighborhoods or slum areas. As one of the largest cities in the world, Cairo exemplifies how uncontrolled growth has outpaced development of water supply infrastructure leaving many people with no access to fresh water or sanitation. To a lesser degree,

Beirut has mushroomed over the past three decades as hundreds of thousands moved into originally uninhabited and poorly served parts of the city to escape the wrath of Israeli occupation in the eastern and southern parts of the country.

Some have advocated creating water markets as an effective mechanism to achieve optimal use of water resources. Markets are expected to shift water use from low-value to high-value sectors. In practice, inadequate or disparate access to information, ill-defined water rights, risk of monopoly, exclusion of the poor, and underestimation or total neglect of social and environmental values of water create unfavorable conditions for water markets. Governments are expected to develop and implement regulations that control these adverse conditions to facilitate successful water markets.

#### **b. Water legislation for facilitating IWRM**

Legislation establishes the powers, responsibilities, and rights of different stakeholders in water resources management. In particular, it gives authority for the government to take action to implement and enforce water regulations. It also clarifies the role of different stakeholders and sets the rules for managing water resources.

Several issues need to be considered in developing a new legislation or updating an existing one. A national water resources policy supportive of IWRM should be in place to lay the ground for developing an effective legislation. The policy should address water as well as non-water sectors in setting up priorities to achieve optimal socio-economic development and environmental protection. It should encourage participation by all stakeholders particularly by setting special provisions for the least dominant groups. Legislation should clearly delineate water rights to protect basic property rights, and to facilitate dispute resolution and efficient water markets. It should also set safeguards against monopoly of water services (Agarwal et al., 2000).

#### **c. Roles and responsibilities in water resources development and investment**

There is generally no well-defined delineation between the contribution of public authorities

versus the private sector in water resources development and investment. Generally, however, governments are expected to be responsible for developing and managing infrastructure that offers public goods and services such as storage and transfer facilities to manage water variability, uneven distribution, and protection from floods and extended droughts. Moreover, infrastructure projects, such as dams, have long life and cost recovery times and thus it is difficult to attract private funding to finance their construction.

In contrast, municipal water services – water service provision and wastewater collection and treatment- where individual benefits are well defined can be more efficiently developed and managed by private investors. However, privatization of public utilities does not necessarily result in improved and more cost-efficient services. Corruption, inflexible water policies, political interventions, and lack of information can derail or even result in the failure of water services. Moreover, the lack of proper legislation or mechanisms to shield the poor from unaffordable water prices may create great disparities in access to utility services.

#### **d. Coordination among sectors and national watershed/aquifer users**

Water plays an important role in different sectors including energy, housing, tourism, and commerce. Consequently, overall planning for water resources should involve different ministries to ensure an optimal allocation of water resources, coordinate public spending on water resources development, and avoid conflicting policies. For example, ministries responsible for urban development, irrigation, and environmental protection should coordinate their policies and activities to ensure an optimal socio-economic and environmental allocation of water resources. In some countries, an atmosphere of counterproductive competition among different ministries may result in an unsustainable management of water resources.

The dynamic nature of water as a fluid flowing within a watershed or an aquifer makes cooperation among different users very critical for its sustainable use. Users of water resources in a watershed or an aquifer should coordinate their activities to ensure a fair and sustainable



allocation of these resources and mitigate potential conflicts. Integrated watershed/aquifer management represents a successful model for managing watersheds or aquifers lying within single national territory. For example the Litani River Authority (LRA) in Lebanon succeeded in securing substantial international funding in 1950s to develop the hydroelectric potential of the upper part of the basin. The LRA hydroelectric system was instrumental in the socio-economic development of the country as it provided over 70% of the country's total electricity requirement up to the mid 1970s. Although the LRA faced substantial difficulties due to the lack of funding, management issues, and extended occupation and civil strife, it is now planning crucial water supply and irrigation projects.

#### ***e. Managing water across national boundaries***

As indicated above, integrated watershed/aquifer management has merits in coordinating efforts at the national level. However as water crosses national boundaries, national sovereignty arises

as a major obstacle for productive collaboration. Although international water laws exist for resolving conflicts among riparians, countries are not obliged to abide by them and may choose not to do so if potential resolutions are likely to undermine their current privileges. Zeitoun and Allan (2008) assert that power balance is a determining factor in managing transboundary waters. Though lacking a binding agreement, some initiatives such as the Nile Basin Initiative (NBI) offers a forum for riparian countries to coordinate efforts and exchange information and technical expertise. Although the NBI succeeded in maintaining peaceful conditions in the Nile Basin, it has not yet been successful in helping riparian countries agree on a final treaty.

Despite these obstacles, riparian countries should strive to reach agreements that facilitate sustainable management of shared water resources. Failing to do so would in the long run hurt the interests of all parties not only with respect to the contested-over water resources, but to their overall mutual activities such as trade, tourism, and cultural exchange. Influential independent parties such as the World Bank with its extensive international



influence over water projects financing can play an important role in resolving contentious issues among riparian countries.

## **VI. WATER MANAGEMENT INSTRUMENTS**

Agarwal et al. (2000) provides an extensive overview of established methods and approaches that could be employed in water resources management. They comprise a wide range of instruments used in assessing water resources, regulation, economic management, conflict resolution, communication, and new technology. This section partially covers some of these methods.

### **a. Assessment of water resources**

Assessing water resource involves getting information about their spatio-temporal distribution, quality, and social and environmental services in addition to determination of demand in different sectors, potential development options, and potential issues of conflict. The list of important information varies depending on the focus of development.

Developing an information base is an important prerequisite for reliable assessment of water resources. This task is particularly challenging in Arab countries considering the significant gaps in information that have accumulated over the years, mainly due to assigning lower priorities to data collection and analysis. Evans et al. (2004) describe the Middle East as one of the most “data-sparse” regions in the world. This deficiency has particularly complicated many water research and development efforts in the Arab region. It is imperative that Arab countries invest in monitoring and data collection of water related information.

Understanding and managing social and environmental implications of water resources development is at the core of IWRM. There is a general improvement in the Arab region with respect to consideration of these issues driven mainly by public pressure and the requirement by many international funding agencies, such as the World Bank, to carry out comprehensive environmental impact assessments (EIAs) for water projects as a prerequisite for approval.

Commonly associated with climate change, there is mounting evidence of increased frequency of extreme flooding events (e.g., Saudi Arabia and Algeria), extended droughts (e.g., Syria and North Africa), and outbreaks of violence over scarce water resources (e.g., Darfour). Given the high uncertainty and high consequences of these episodes, they are better handled through a risk management approach that ties investment in mitigation measures to benefits of reducing loss of life and material damage.

### **b. Regulatory methods**

Depending on the method of application, Agarwal et al. (2000) categorize regulatory instruments into three types: direct controls, economic instruments, and self-regulation. Direct controls are those applied by public authorities to dictate or influence the use of water. Governments resort to executive regulations to enforce certain rules such as restrictions on groundwater extraction or discharge of wastewater. Under certain circumstance, especially when dealing with impending crises, executive regulations can be effective and efficient. For example, Jordan has frozen granting permits to the drilling of wells and put a cap on existing ones in the Amman-Zarqa basin in an attempt to stem the dramatic drop in groundwater levels and deterioration of water quality. Despite stiff resistance from powerful landlords, the government imposed heavy fines and imprisonment to enforce the regulations. Interestingly, the dramatic increase in diesel fuel prices, almost an order of magnitude higher from the mid 1990s to 2007, along with government’s gradual lifting of fuel subsidies, have further suppressed water extraction (Assaf, 2009).

Establishment of water rights is another direct regulatory method that has been successfully applied in the US and Australia to allocate water for higher value uses. However, water rights are not generally received favorably or regulated properly in most Arab countries, where water is perceived as a public good. Interestingly, well established systems of water rights and trading such as the one in Morocco based on the Jrida - a publically available list of water rights defined in terms of hours of full flow - have been practiced for decades despite the more recent regulations by the government restricting sale by farmers of fresh water to urban users (World Bank, 2007).

## ABU DHABI WATER RESOURCES MANAGEMENT MASTER PLAN

**Mohamed A. Dawoud**

### 1. Background

Since the 1960s water use in Abu Dhabi has exploded as a result of desert greening policies, and the expansion of agriculture into the lands surrounding traditional oases. Discovery of substantial groundwater reserves at Liwa and between it and Al Ain enabled the expansion of agriculture into formerly desert areas. Large tracts of desert and transportation routes have been afforested. Over the same time period, the population grew exponentially to its current 1.5 million people. While groundwater provided potable water supplies in the 1960s, the subsequent increase in demand for both power and water required the building of large thermal powered co-generation plants.

The rapid growth of the rural and urban economy over the last 48 years has had a profound effect on Abu Dhabi's natural resources. Traditional oases dried up and the small pockets of fresh groundwater that sustained rural and coastal communities were exhausted primarily to satisfy the voracious demand by the agricultural sector. The declining water table has caused the influx of more saline water from lower levels in the aquifer and laterally from surrounding areas. In the near-shore regions of the Gulf, very high withdrawals of seawater for desalination threatens the biodiversity of the marine environment and are contributing to raising sea temperatures – currently amongst the highest in the world.

These concerns are captured in the Plan Abu Dhabi 2030 that provides a vision of a global capital city that puts a high premium on environmental sustainability.

The Abu Dhabi Water Resources Master Plan aims to achieve three objectives:

- Preparing a strategic environmental assessment of the role of water in the Emirate;
- Identifying actions needed in the water sector to restore and protect water ecosystems; and
- Strengthening the structure of water and environmental management.

### 2. Reform of groundwater use

Agriculture and forestry use two-thirds of Abu Dhabi's renewable groundwater water resources. Neither sector uses the resource efficiently because of extensive support subsidies, including those supporting farm construction, land preparation, and irrigation infrastructure. Electricity and input subsidies reduce running costs while output

subsidies guarantee good incomes. These policies have contributed to the rapid development of irrigation, which peaked in 2007.

Forests are exotic in Abu Dhabi's arid desert climate, yet they cover over 300,000 ha of land area and are a source of national pride. While they potentially offer important ecosystem habitats, many are in poor condition and are maintained only through irrigation by brackish groundwater provided at high cost.

### There are three strategic options:

- To do nothing and allow the agricultural system to gradually fail over the next 20-40 years;
- To take positive actions to reduce water demand; or
- To meet the demand by agriculture with expensive desalinated water.

Doing nothing is not an option, as it would have important social consequences. Consistent with option 'c', agriculture consumes officially 11% of the country's desalinated water production. In practice the percentage is likely to be far higher. There are no economic or financial analyses to provide an economic justification for this approach. Rigorous analysis following the precedent set by the reform of the date industry under the leadership of HE Sheikh Hamed bin Zayed Al Nahyan could be replicated in other parts of the agricultural sector. Alternatively, the government can adopt progressive policies for agriculture and power and implement option (b). A program to reduce agricultural subsidies should be accelerated. Plans to promote drought-tolerant species should be supported. This could reduce water usage by half. Power consumed in the agricultural sector is very under-priced – farmers pay only 14% of actual electricity costs – and there are sound financial reasons to increase tariffs to recover costs. Tariffs are an effective policy instrument. Global experience shows that a 10% increase in tariffs reduces demand by 4-7%. Thus increasing power tariffs would force farmers to increase water use efficiency and adopt new cropping patterns that use less water – vegetables in preference to field crops. While many farmers may quit farming, the social consequences are better addressed by direct income support programs that are transparent and do not have such unforeseen environmental consequences.

### 3. Excessive household consumption of water

The latest projections by Abu Dhabi Water and Electricity Company (ADWEC) for peak power demand

indicate existing co-generation capacity will be unable to meet demand for water after 2012. New capacity will be needed unless demand can be reduced. As most desalinated water is produced by co-generation of power and water this will affect the future supply of potable water to meet demand by households, government, commerce, and industry. Consideration of gas supplies and alternative energy sources indicate that stand-alone electricity stations may offer the most flexible solution to meet future demand. And a decision to explore nuclear power generation has been taken. In this sector there are three options to ensure future water supplies:

- Demand reduction.
- Supply augmentation.
- A combination of the two.

Currently only 17% of water is lost in transmission and distribution. With state-of-the-art management this could possibly be reduced to 10% but the marginal cost becomes increasingly high for lower-losses. The technologies to reduce losses are well-known and are being introduced in the Abu Dhabi water supply sector which is among the best-managed and regulated in the Middle East. In terms of meeting demand, leakage reduction programs only delay the demand-supply gap from 2012 until about 2014. Beyond that the supply-demand gap rapidly increases. As with electricity, water tariffs have proved to be an effective instrument to lower demand and they behave in a similar way too. Thus a progressive increase in water tariffs could reduce demand by more than half.

An important finding is that the sewage collection system is very efficient, probably better than 90% at collecting indoor household wastewater. Water tariffs would primarily affect household's outdoor use of water, little of which is captured by the sewerage system. Therefore increasing tariffs will not necessarily lead to a reduction in treated wastewater which is an important water source for landscapes and amenity use.

Turning to supply, recent new water production plants have been large and very costly, typically more than US\$2 billion. These lumpy investments take up to six years to come on-line considering design, contracting, and construction. In the absence of demand management there is no choice but to build new capacity. Global best practice indicates that reverse osmosis plants (RO) have significant cost and environmental advantages over the current multi-stage flash (MSF) distillation processes

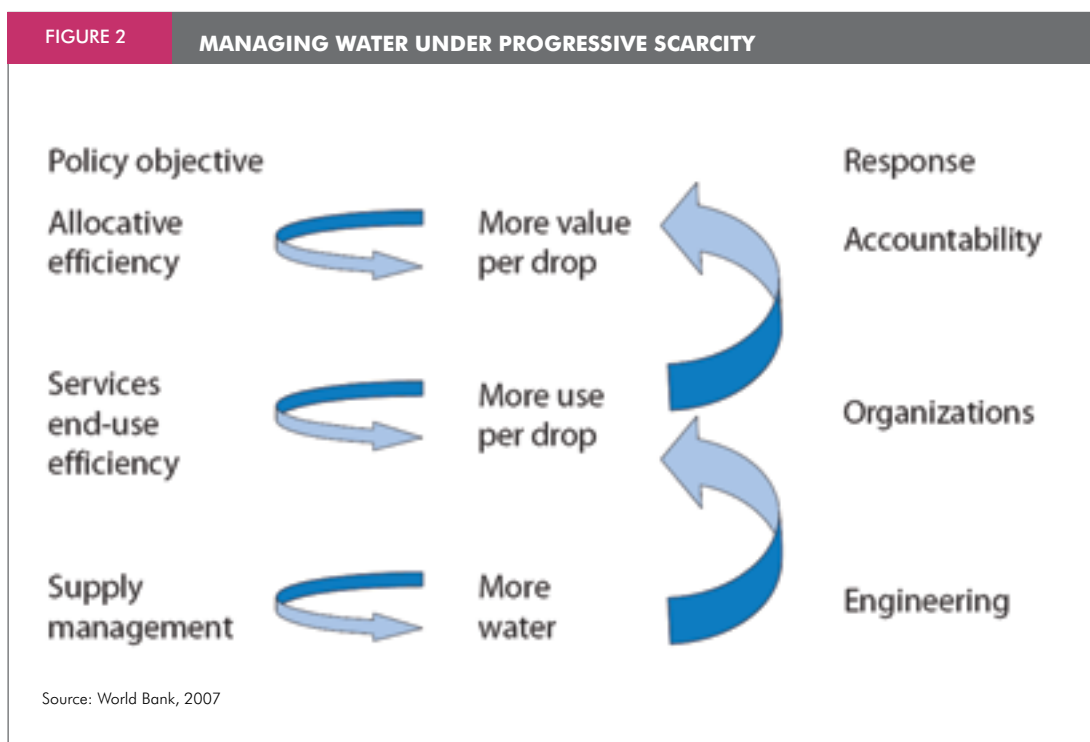
when not used in co-generation. With the national move towards nuclear energy it is suggested that the immediate future strategy should be to fill the demand-supply gap in relatively small increments. Brackish groundwater RO could be run at half the costs of desalinating seawater with RO. Furthermore, it has the additional advantage of generating half to three-quarters less concentrated brine and significantly lower greenhouse gas emissions when power supply is factored in. This proposal will run into fierce opposition because of the vested interests that have monopolized water generation in the Gulf region since the 1960s, and this will require much greater in-depth analysis than has been possible in this Plan. Singapore and Australia provide excellent examples of the economic and environmental advantages of RO.

#### **4. Institutional reform will be necessary**

To bring about the proposed changes of this strategic assessment, there is a need to develop the institutional structures of Abu Dhabi emirate in both water and environmental management. The most important recommendation is the creation of a Water Council in Abu Dhabi, which would be responsible for strategic planning and development across all the water sources and users. The present system operates as a series of silos with limited strategic communication between the various major water resources system management groups and user groups. The new Water Council would ensure integrated and coherent water policies in the future. It would provide independent guidance and oversight to come up with the most rational strategy economically for meeting water needs across all water consumers, and ensure that these needs are balanced within possible water and energy supply futures that meet national environmental policy objectives. In tandem with this is the very real need for an environmental regulator. The setting of acceptable standards, regulations, and practices and for exploiting natural resources and controlling waste discharge to the environment is needed to control the impacts of burgeoning developments, including water and energy supplies. Without regulatory oversight, the sustainable use of water and other natural resources will be further compromised in the future with significant deterioration in economic well-being. Additional planning and support for capacity building and for developing the Emirate's human and financial resources for monitoring and enforcement are essential.

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Land use can be regulated to control water use, reduce pollution, and provide social services. Governments in some countries routinely place restrictions on housing or industrial development to prevent pollution of water supplies. For example, Jordan has cordoned off selected areas to prevent pollution of groundwater resources. Egypt has directed urban growth away from its main cities into desert areas to relieve pressure on water supply systems and reduce pollution from sewage disposal.

Although direct regulatory methods are more common, economic instruments are increasingly used to influence users' consumption behavior and provide funds to support administrative costs. Chief among these instruments is setting water prices to recover the full cost of water. Subsidies can be applied to alleviate potential hardship to the poor. Direct subsidies that target poor users through reliable identification are more preferable to across-the-board subsidies since the latter do not encourage water user conservation and may provide inadequate protection to the needy segment. Alternatively or in conjunction with subsidies, a progressive water fee structure can be designed effectively to discourage wasteful use while providing protection to less advantaged groups.

Fees on wastewater discharges can both curtail demand for water and encourage reuse of wastewater. Urban users are typically charged fees for wastewater discharge based on the volume of water used, which would encourage conservation. Interestingly, in places where sewage networks are not available and cesspools are used such as in small villages in Lebanon, Jordan, and the Palestinian territories, water users conserve water to avoid paying heavy fees to private operators for wastewater discharge services. Levies on the quantity and quality of industrial wastewater discharges induce water conservation and reuse.

## VII. MEETING THE CHALLENGE OF PROGRESSIVE SCARCITY

The World Bank (2007) argues that managing water resources under scarcity conditions goes through three stages of policy changes and response (

Figure 2). At first, the emphasis will be on securing water supply from resources having the least cost of development. This has been largely achieved in Arab countries which boast the highest global percentage of stored water per renewable water resource (World Bank, 2007). When the most affordable water resources have

been developed, emphasis shifts to develop and strengthen organizations responsible for serving users to optimize use of water at the user level. With mounting scarcity, there is a more urgent need to devise policies to achieve more efficient allocation of water among users. This last and most challenging task requires a transparent institutional system that ensures accountability and creates an atmosphere of trust and confidence between users and policy makers.

### VIII. WATER AS AN ECONOMIC GOOD

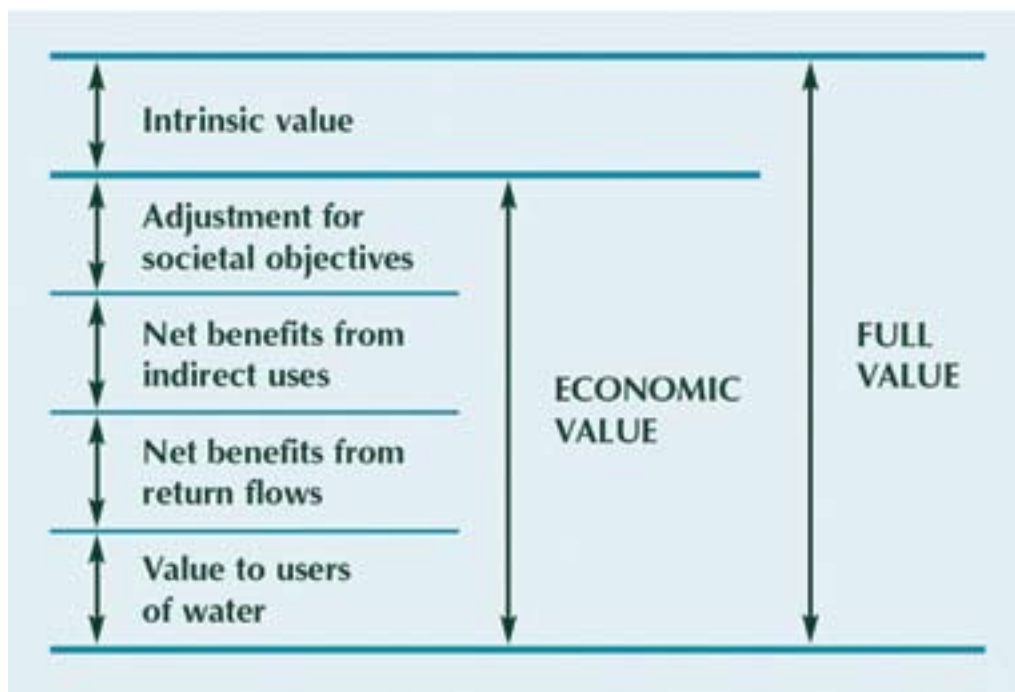
The emphasis on water as an economic good reflects a practical reality that financial viability of water services necessitates full cost recovery. Offering water services below their real cost encourages wasteful usage and imposes on society water opportunity costs. Emphasizing the economic worth of water was surrounded with controversy since its application may result in neglecting water's social and environmental role particularly in potentially reducing access of less privileged groups to freshwater and in potentially destroying natural habitats.

To resolve this complex paradox, a differentiation needs to be made between “valuing” and “charging” for water (Agarwal et al., 2000). The value of water relates to its benefit to its users and its own presence. The former can be expressed in economic, i.e., material, terms and is composed of its value to its direct and indirect users, net benefits from return, unused flows, and benefits for social objectives such as helping the poor (Figure 3). Understanding the various components of water value is necessary in setting up policies and measures to optimize uses of water.

Distinct from its value, the full cost of water relates to the cost of using it. This not only includes capital outlays and the operating and maintenance costs of its extraction, treatment, transfer, distribution, and waste treatment, but also includes opportunity costs – i.e., forfeited benefits from other potential uses – as well as economic and environmental externalities (Figure 4). Economically prudent operation of water services requires that the full cost be retrieved. Failure to achieve this objective results in the failure of privately run operations, or in the case of public utilities, in transfer of payments from

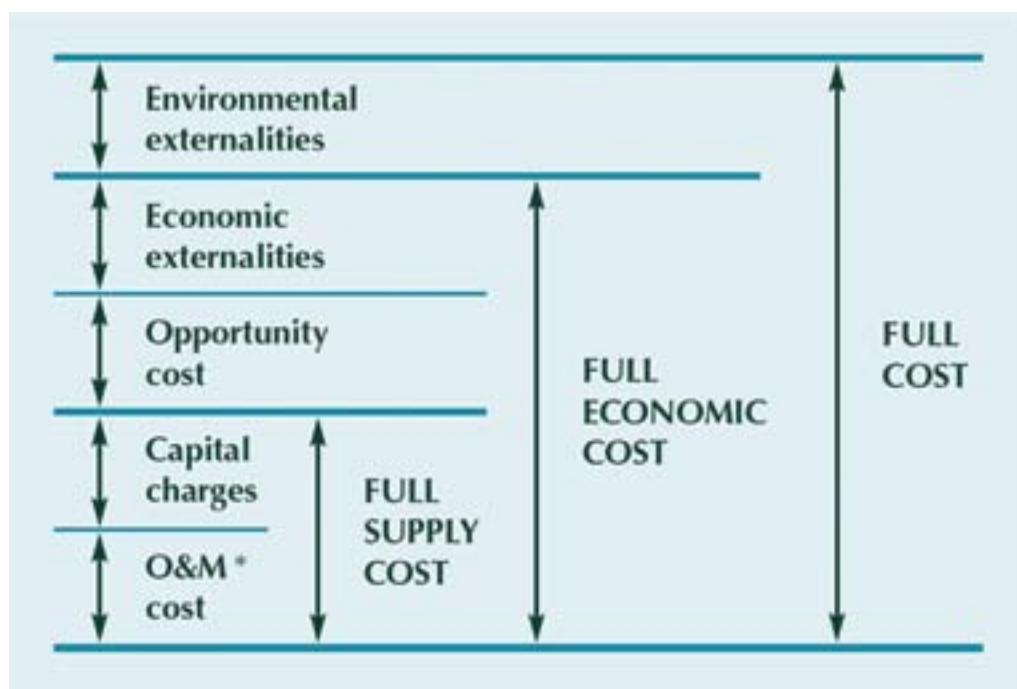
FIGURE 3

THE VALUE OF WATER



Source: Agarwal et al., 2000

FIGURE 4 THE FULL COST OF WATER



Source: Agarwal et al., 2000

government reserves. This is the norm in most Arab countries where water is highly subsidized. In Gulf countries for example, desalinated water is sold at a fraction of its cost. Irrigation water in most Arab countries is highly subsidized, sticking to general policies motivated by achieving food self-sufficiency and supporting agrarian populations.

### IX. CASE STUDY – THE SANA'A BASIN WATER RESOURCES MANAGEMENT PROJECT

The Sana'a Basin, home to Yemen's capital, is facing overexploitation of both its surface and groundwater resources. Absolute lack of control over drilling, indiscriminate pollution, and inefficient irrigation practices have taken their toll on the availability and quality of water resources in the Basin (World Bank, 2004). The World Bank is funding a 10-year project that would instigate a dramatic shift in the rural economy to become less water dependant. This will be achieved by integrating land and water resources management, strengthening of legal and

institutional frameworks, introducing modern irrigation equipment and methods to improve agricultural efficiency and water productivity, rehabilitating water storage transfer infrastructure to reduce losses and improve efficiency, facilitating public participation in decision make, and capacity building in information management and decision-support systems (World Bank, 2004).

### X. STATUS OF IWRM IN THE ARAB REGION

Wagdy and AbuZeid (2006) have reviewed several studies for the Centre for Environment and Development for the Arab Region and Europe (CEDARE) that have examined the progress of IWRM adoption by Arab countries. The studies span over the period from 2000 to 2006. The first study in 2000 indicated that towards the end of the 20th century, Arab countries had started to earnestly consider water demand options after running into serious water shortages that could not be managed through developing the few remaining untapped water resources. Water quality and environmental issues were not yet

adequately addressed. A later study by CEDARE in 2003 pointed to improvement in awareness and support of IWRM at the policy making level as well as increased involvement of stakeholders through the establishment of national water committees and boards (Tunisia and Libya), water users associations (Egypt), and the development of integrated basin management authorities (Algeria) (Wagdy and AbuZeid, 2006).

In 2006, CEDARE conducted a more elaborate survey study based on a questionnaire designed by the Danish Hydraulic Institute in cooperation with the United Nations Environment Programme (UNEP). The questionnaire addresses the status of IWRM in a country including the availability and maturity of national water policies, legislation, and regulations; institutional frameworks, capacity, and constraints; and awareness of IWRM among different stakeholders (Wagdy and AbuZeid, 2006). Responses to the survey indicated that all Arab countries have national water policies, laws, and legislations that support public participation, recognize water as a public property, and do not differentiate based on gender. Despite the incorporation of IWRM in water legislation, the study showed less faith in the effectiveness of water regulations. This was attributed mainly to the lack of awareness among users and officials as well as to weak institutional capacity, and to a lesser extent, to the complexity of regulations and weak enforcement of sanctions.

The study also looked at the main elements of institutional capacity for implementing IWRM. Weak monitoring and lax recovery of costs were deemed the most deficient. To a lesser extent, resource planning, protection, and conservation were assessed to be inadequate. On the positive side, policy formulation, data collection and management, and to a lesser extent water resources and environmental assessments and legislation drafting were considered satisfactory. Several factors were identified that constrain the development of healthy water resources management institutions. They include inadequate equipment, overlapping in the roles and responsibilities among different institutes, ambiguous mandates, poor governance, and underfunding. The study has also pointed to deficiencies in the levels and relevance of staff training.

Without identifying countries by name, the

study indicated that out of the eight countries considered in the study, three have an IWRM action plan, four are in the process of developing a plan, and a single country has no specific plans to design one.

## **XI. CONCLUSION AND RECOMMENDATIONS**

This chapter has provided a general overview of integrated water resources management (IWRM), emphasizing economic efficiency, social equity, and environmental sustainability. It discussed the challenges in implementing IWRM particularly in dealing with water scarcity, and social and environmental issues. The chapter introduced an implementation framework for IWRM as proposed by the Global Water Partnership with emphasis on the Arab region.

Scarcity driven by natural causes, rising demand, and changing climate are the most pressing water challenges to Arab countries. The Arab region has outpaced other regions in the world in developing infrastructure in relation to renewable water resources. Faced by a rising demand outpacing affordable water supplies, Arab countries need to take strong action on strengthening institutional capacity, regulatory systems, and accountability in water resource planning. A more integrated approach involving other non-water sectors should be adopted to prioritize water allocation and to achieve efficiency, while offering protection to the poor and maintaining environmental sustainability.

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# Wastewater Treatment and Reuse

REDOUANE CHOUKR-ALLAH



## I. INTRODUCTION

In most Arab countries limited water resources pose severe constraints on economic and social development and threaten the livelihood of people. Available surface water is declining and the over-pumping of groundwater, beyond natural recharge rates, has resulted in lowering the water table and causing an increase in groundwater salinity, ground water depletion, and ecological degradation (World Bank, 2009).

In the last three decades the Arab world has witnessed growing water stress, in terms of both water scarcity and deterioration of its quality. This looming crisis has prompted many governments to seek a more efficient use of water resources and develop interventions to narrow the gap between supply and demand in the region.

Municipal wastewater reuse is believed to be one potential intervention strategy for developing nonconventional water resources. In most Arab countries, “agriculture is by far the main water consumer, accounting for about 80% of the total water supply in Tunisia and up to 90% in Syria” (AHT Group AG, 2009). Therefore, the extended reuse of reclaimed (treated) wastewater for irrigation and other purposes could contribute considerably to the reduction of ‘water stress’ and ‘water scarcity’ in Arab countries as part of an Integrated Water Resources Management (IWRM) approach (Qadir et al., 2007). In fact, it has been argued that “in terms of quantity, the greatest potential

for wastewater reuse is through using properly treated wastewater for irrigation purposes, as substitute for conventional ground and surface water sources” (AHT Group AG, 2009).

The reuse of treated wastewater in the Arab region targets agriculture predominantly, particularly in Tunisia, Syria, and Jordan. Irrigation for landscaping and golf courses is also on the rise in member countries of the Gulf Cooperation Council (GCC) as well as in North Africa (World Bank, 2007). However there are economic, institutional, health, and environmental constraints that hamper the sustainable and safe re-use and recycle of wastewater. To address these limitations will require concerted effort and commitment by Arab governments as well as support from regional and international organizations to boost the volumes of wastewater treated as well as the fraction of treated wastewater that is reused.

The scarcity of water and the need for protecting the environment and natural resources have motivated Arab countries to introduce wastewater treatment and reuse as an additional water resource in their national water resource management plans. In some Arab states, treatment and reuse of wastewater has become an institutional practice to a certain extent, but there is still a great scope for extending its application.

This paper reviews wastewater reuse practices, experiences, and applications in Arab countries. The data are based on conventional literature surveys, an in-depth survey of a large number of Arab water reuse projects, and on the findings of scientific papers. This assessment indicates that for an increased utilization of reclaimed wastewater, clearer institutional arrangements, more dedicated economic instruments, and the establishment of water reuse guidelines are needed. Technological innovation and the establishment of best practices will certainly help, but what is greatly needed is a change in stakeholders’ perception of the water cycle.

## II. POTENTIAL OF WASTEWATER REUSE IN THE ARAB REGION

The major challenge for most Arab countries is to secure access to safe water and clean



TABLE 1

**TOTAL WATER WITHDRAWAL, RAW WASTEWATER GENERATED, AND TREATED WASTEWATER IN THE DIFFERENT ARAB COUNTRIES**

Country	Total water withdrawal (10 <sup>9</sup> m <sup>3</sup> /year)	Total wastewater produced (10 <sup>9</sup> m <sup>3</sup> /year)	Volume of Treated Wastewater (10 <sup>9</sup> m <sup>3</sup> /year)
<b>Algeria</b>	6.070 (2000)	0.8200 (2002)	-
<b>Saudi Arabia</b>	23.670 (2006)	0.7300 (2000)	0.5475 (2002)
<b>Bahrain</b>	0.357 (2003)	0.0449 (1991)	0.0619 (2005)
<b>Comoros</b>	0.010 (1999)	-	-
<b>Djibouti</b>	0.019 (2000)	-	0.0000 (2000)
<b>Egypt</b>	68.300 (2000)	3.7600 (2001)	2.9710 (2001)
<b>United Arab Emirates</b>	3.998 (2005)	0.5000 (1995)	0.2890 (2006)
<b>Iraq</b>	66.000 (2000)	-	-
<b>Libya</b>	4.326 (2000)	0.5460 (1999)	0.0400 (1999)
<b>Jordan</b>	0.941 (2005)	0.0820 (2000)	0.1074 (2005)
<b>Kuwait</b>	0.913 (2002)	0.2440 (2003)	0.2500 (2005)
<b>Lebanon</b>	1.310 (2005)	0.3100 (2001)	0.0040 (2006)
<b>Morocco</b>	12.600 (2000)	0.6500 (2002)	0.0400 (1999)
<b>Mauritania</b>	1.700 (2000)	-	0.0007 (1998)
<b>Oman</b>	1.321 (2003)	0.0900 (2000)	0.0370 (2006)
<b>Qatar</b>	0.444 (2005)	0.0550 (2005)	0.0580 (2006)
<b>Syria</b>	16.700 (2003)	1.3640 (2002)	0.5500 (2002)
<b>Somalia</b>	3.298 (2003)	-	0.0000 (2003)
<b>Sudan</b>	37.320 (2000)	-	-
<b>Palestine</b>	0.418 (2005)	-	-
<b>Tunisia</b>	2.850 (2001)	0.1870 (2001)	0.2150 (2006)
<b>Yemen</b>	3.400 (2000)	0.0740 (2000)	0.0460 (1999)

Source: FAO AQUASTAT Database

sanitation. The Arab Water Council (AWC) (2006) estimates a further 83 million need to be supplied with safe water and 96 million are still in need of clean sanitation services in order to meet the Millennium Development Goals (MDGs). The needs of a rising population, estimated at 343.8 million (AOAD, 2009), has put an added pressure on total water withdrawal. The agriculture sector consumes 86% of this total (Qadir et al., 2009). Furthermore, water demand for domestic, municipal, and industrial use is slated to increase fuelled by rapid urbanization, industrialization, and rural migration to towns and cities.

Based on estimates by the Food and Agriculture Organization of the United Nations (FAO AQUASTAT), the volume of wastewater generated by the domestic and industrial sectors in the different Arab countries is shown in Table 1. Qadir et al. (2009) have reported that the ratio by volume of treated wastewater to that

generated in the Arab region (54%) “is higher than Asia (35%), Latin American/Caribbean (14%), and Africa (1%).”

### III. REUSE PRACTICES IN THE ARAB REGION

Within the Arab world Tunisia, Jordan, and the GCC countries are the leaders in the area of wastewater reclamation and reuse.

#### a. Tunisia

Tunisia has long experience (since 1965) in using treated wastewater to irrigate the citrus orchards and olive trees of the Soukra irrigation scheme (8 km North East of Tunis) covering an area of 600 hectares (Bahri, 2008a).

In 2008, the number of wastewater treatment plants operating in Tunisia were 61, collecting



0.24 billion km<sup>3</sup> of wastewater, of which less than 30% is reused to irrigate vineyards, citrus (Chenini, 2008), trees (olives, peaches, pears, apples, pomegranates), fodder crops (alfalfa, sorghum), industrial crops (cotton, tobacco), cereals, and golf courses in Tunis, Hammamet, Sousse, and Monastir. The wastewater effluent is treated to secondary levels and farmers pay subsidized prices for the treated wastewater they use to irrigate their fields (Bahri, 2008a).

#### **b. Jordan**

Wastewater has been used for irrigation in Jordan for several decades. The inclusion of wastewater reuse in the country's National Water Strategy since 1998 was a signal of placing high priority on the value of reclaimed water. Wastewater represents 10% of Jordan's total water supply (WaDImena, 2008) and up to 85% of its treated wastewater is being reused (MED WWR WG, 2007). It should be noted however that 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. To further support wastewater reuse in irrigation, the 2008-2022 plan proposes, among others, to:

- Introduce appropriate water tariffs and incentives in order to promote water efficiency in irrigation and higher economic

- returns for irrigated agricultural products;
- Manage treated wastewater as a perennial water source which shall be an integral part of the national water budget;
- Ensure that health standards for farm workers as well as consumers are reinforced and that all treated wastewater from all municipal or industrial wastewater treatment plants meets relevant national standards and is monitored regularly;
- Periodically analyze and monitor all crops irrigated with treated wastewater or mixed waters;
- Design and conduct programmes on public and farmer's awareness to promote the reuse of treated wastewater, methods of irrigation, and handling of produce.

Jordan claims 21 domestic wastewater treatment plants which in 2008 have generated more than 100 million m<sup>3</sup> of treated wastewater (JMWI, 2009a). The treatment plants are located in large cities but do serve large areas surrounding these cities. All effluents from treatment plants 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 treated wastewater used for irrigation will reach 223 million m<sup>3</sup> by 2020 (FOEME, 2010). Since 2002, the government of Jordan, with the support of international organizations, has been implementing several direct water reuse activities

in Aqaba and Wadi Musa 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 and 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).

#### **c. Lebanon**

In 2001, 310 million m<sup>3</sup> of wastewater were produced in Lebanon by the domestic and industrial sectors (FAO AQUASTAT). In 2006, 4 million m<sup>3</sup> of wastewater were treated and 2 millions m<sup>3</sup> were used for informal irrigation (FAO AQUASTAT). Raw wastewater is also being reused for irrigation in several regions of Lebanon. Such is the case in the Bekaa region where some of the sewers are purposely blocked to allow sewage to be diverted for irrigation. In other regions, wastewater is being discharged in rivers or streams used for irrigation such as in Akkar and Bekaa (Ras El Ain, Zahleh).

The illegal and uncontrolled reuse of raw sewage, directly or indirectly, is sometimes a common practice in Lebanon dating back to ancient times. Reuse for agricultural irrigation dominates and crop restrictions are not respected. Farmers or workers who handle untreated wastewater do not always follow public health recommendations and often neglect to wear protective boots and gloves. Experience has shown that contact with secondary-treated wastewater can provoke allergies and other serious dermatological or gastrointestinal illnesses. The consumption of produce irrigated by untreated wastewater can pose substantial health risks to consumers. Untreated wastewater used to irrigate produce and vegetables eaten uncooked could cause transmission of helminthic diseases caused by *Ascaris* and *Trichuris*. Further evidence has demonstrated that cholera could be transmitted through the same channel. To avoid the spread of these diseases, wastewater should be suitably treated to match the type of crop to be irrigated

in compliance with the adapted health protection measures.

#### **d. GCC countries**

In the GCC countries, about 40% of treated wastewater is used to irrigate non-edible crops and fodder as well as for landscaping (Al-Zubari, 1997). In Kuwait, the Sulaihiya Wastewater Treatment and Reclamation Plant is considered by far the largest facility of its kind in the world to use reverse osmosis (RO) and ultrafiltration (UF) membrane-based water purification systems. The plant's initial daily capacity is 375,000 m<sup>3</sup>, which could be expanded to 600,000m<sup>3</sup>/day in the future. It is believed that treated wastewater will contribute to 26% of Kuwait's overall water demand, reducing the annual demand from non-potable sources from 142 million m<sup>3</sup> to 26 million m<sup>3</sup>.

#### **e. Syria**

According to the World Health Organization (2005), the Damascus and the Homs wastewater treatment plants in Syria account for more than 98% of all treated wastewater with capacities of 177 million m<sup>3</sup>/year and 49 million m<sup>3</sup>/year, respectively. Since then, new wastewater treatment plants under construction may have come on line in other cities such as Aleppo and Latakia. According to the World Health Organization (2005), "About 177 million cubic meters per year of treated wastewater are reused for irrigating 9000 hectares in Damascus."

#### **f. Egypt**

Egypt produces about 3.5 billion m<sup>3</sup>/year of municipal wastewater, while current treatment capacity is in the range of 1.6 billion m<sup>3</sup>/year. An additional treatment capacity of 1.7 billion m<sup>3</sup> is targeted by 2017 (Tawfic, 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<sup>3</sup>/year, mostly originating from Egypt's two greatest urban centers, Cairo and Alexandria. Treatment plants serve 55% of the population in towns and cities (Tawfic,

## GREYWATER: EXPERIENCES IN MENA RURAL COMMUNITIES

**Boghos Ghougassian**

As freshwater is increasingly becoming scarce in the Middle East and North Africa (MENA), the region is being faced with a dire need for alternative sources of water. As a non-conventional water source, treated greywater (GW) can potentially be used by households to irrigate their backyard gardens on a decentralized basis, particularly in rural and peri-urban areas.

Greywater is generated in every house as the less polluted wastewater from kitchen sinks, washing machines, dishwashers, hand washing basins, and showers. It does not include “black” wastewater from toilets that contain large concentrations of fecal matter and urine. Even though its contribution to the national water budget is modest, GW is considered a tool for water demand management (WDM). It is similar to rainwater harvesting, where one can generate useful water at one’s own premises, particularly in rural areas.

Since 1998, the International Development Research Centre (IDRC) of Canada has supported and funded ten research projects on GW treatment and reuse in MENA, namely in Palestine, Jordan, Lebanon, and Yemen between 1998 and 2008. The total IDRC investment has exceeded US\$2,000,000. With the application of GW treatment systems, families in water-stressed areas generate from 100 to 150 m<sup>3</sup> of GW per year, which is enough to irrigate 20 to 30 trees in their backyards and produce additional crops. GW accounts for 50%-70% of wastewater generated by households and its treatment and reuse contributes towards improvement of public health and the environment, in addition to generating economic benefits to its users.

Many different technologies have been used in various countries based on their effectiveness in treating GW. IDRC-supported projects in the MENA region have developed the 4-barrel and confined trench (CT) types of treatment systems, which are simple to use and have a low cost. These systems are now considered dependable GW treatment units for decentralized use. Their performance complies with the 2006 World Health Organization (WHO) Guidelines for the Safe Use of Wastewater, Excreta and Greywater, which look at health-based targets and proper management of GW, rather than water quality standards.

To date, IDRC’s research partners have outfitted more than 2,000 homes in Jordan, Palestine, and Lebanon with GW treatment systems, and the results generated have been



promising. Installing a GW system in every poor household with a backyard, every school with a patch of land for a garden, and every mosque across the MENA could have a significant impact on poverty, food security, and water availability.

The treatment system is simple. No mechanical equipment is involved. Four plastic barrels, each with a capacity of 160-200 liters, make up the GW treatment kit. The 4 barrels, interconnected with PVC pipes, are lined up next to each other. GW flows from the house gravitationally into the first barrel, which traps the floating and settleable material. As GW rises to the top of the first barrel, relatively clear GW then flows into the bottom of the 2nd barrel and then to the bottom of the 3rd barrel. During the upward flow of GW in those two barrels, the anaerobic bacteria digests organic pollutants found in GW. The fourth barrel acts as a storage tank for treated GW from which it is automatically pumped into the drip irrigation network, to irrigate trees and other plants.

The GW treatment system is airtight and watertight, and no mosquitoes or other insects can breed in the system. No odor is detected at the site. The gases that are produced during the digestion process in the barrels are vented above the roof level of the house. However, during the pumping cycle, which lasts for 10 minutes per day, some odor is released through the drip irrigation network.

The 10 GW research projects that have been implemented in 4 MENA countries have revealed that there are no health risks associated with the use of treated GW for irrigation. But public acceptance of GW treatment is seen as the cornerstone to successful adoption of GW reuse at the household level. Fortunately, after initial hesitation, beneficiaries have usually

adopted the use of GW, when the accepted norms for effluent quality were met. No taboos have been revealed in the use of treated GW. And those who have done proper maintenance to their GW systems have produced more crops and benefitted economically. They have also been highly satisfied with the performance of their GW systems.

In the case of Lebanon, the satisfactory results of the two IDRC-supported GW research projects, implemented in 2002-2008, have motivated other communities and donors to replicate GW technology applications in other towns. For instance, in 2008-2010 three new GW projects were implemented in South Lebanon, where 100 units of the 4-barrel type were installed at households in three towns, and 5 confined trench (CT) units were installed in 4 mosques and a kindergarten. And because of the observed benefits that were realized, new homes are now being built with proper GW separation and reuse in mind.

From a public policy perspective, successful implementation of GW treatment projects in Lebanon has led into a fruitful cooperation with the Lebanese Ministry of Energy and Water (MEW), which recently integrated the concept of GW reuse in its Ten Year Water Plan for Lebanon. On the other hand, various municipalities are now interested in the promotion of GW reuse. A case in point is the Union of the Municipalities of Bint Jebail Caza, which in March of 2010 decided to promote GW reuse in their 12 towns.

In Jordan, the implementation of three GW projects has led to efforts to include in the country's building code language pertaining to greywater treatment. The Jordanian Institution for Standards and Metrology is working now on adopting the Uniform Plumbing Codes (2006 & 2009) which includes in one of its chapters specifications to separate greywater from blackwater.

In Yemen, after the successful implementation of pilot GW treatment and reuse projects at gardens adjacent to mosques "miqshama", the concept of GW reuse is being promoted in many other mosque-adjacent gardens in the country, in cooperation with the government, the National Water Resource Authority, and local NGOs.

The GW research projects in all countries of Middle East have proven that there are net benefits to reusing nutrient-rich treated GW for irrigating crops, especially if the alternative is to dump the GW into cess-pits, valleys, and surface waters.

GW reuse has brought three types of benefits to users who demonstrated ownership for their units. It has provided them

with irrigation water for additional crop growing. It has contributed towards food security of households and has addressed the septic tank overflow and sanitary problems.

Research projects that have been implemented in the MENA region indicate that an average net annual benefit of more than \$300 per family has been achieved for households who properly maintain their GW systems, without even considering indirect benefits, such as reduced capital investment in septic tanks, environmental and other benefits.

The financial feasibility of GW reuse has been demonstrated as well as its technical feasibility and ethical soundness. However, there are barriers that hinder further use, acceptance, and wide scale replication of GW reuse technologies. The barriers include:

- Short project lives of 2-3 years, not enough to realize tangible results for beneficiaries;
- Lack of a sense of ownership by some beneficiaries;
- Lack of valuation of irrigation water by households, due to their traditional rain-fed dry farming habits. But those who maintain their GW kits, get good results and adopt the GW systems;
- Unhelpful washing habits of household occupants such as permitting oil, grease, and large particulates in kitchen sinks to be mixed with water channeled for treatment;
- From a technical perspective, the performance of GW treatment systems needs further improvement, to allow trouble free operation and less maintenance; and
- Odor is a major criterion for evaluating GW treatment system by some beneficiaries. Odor is released at the beginning of pumping.

Government action is needed to:

- Include greywater treatment and reuse as an integral part of water reuse programmes in ministries;
- Provide economic incentives to potential users of GW, by municipalities, and ministries of water resources;
- Develop national guidelines for GW treatment and reuse, based on the 2006 WHO guidelines and local GW research results;
- Encourage GW applications in rural areas, through appropriate building codes; and
- Set standards for the proper construction of GW treatment system, and encourage research on greywater treatment and reuse.

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TABLE 2 WASTEWATER REUSE GUIDELINES FOR SOME ARAB COUNTRIES

	E. Coli Or Fecal Coli /100ml	Nematode eggs/l	Other <sup>1</sup> parameters	Crops eaten uncooked is allowed	Code of practice
<b>WHO</b>	1000	<1	No	Yes	Yes
<b>Jordan</b>	100	<=1	Yes	No	Yes
<b>Morocco</b>	1000	Absence	Yes	Yes	No
<b>Palestine</b>	1000	<1	Yes	No	Yes
<b>Syria</b>	1000	<1	Yes	No	Yes
<b>Tunisia</b>	-	<1	Yes	No	Yes
<b>Kuwait</b>	20	<1	Yes	No	Yes
<b>Oman</b>	200	<1	Yes	Yes	
<b>Saudi Arabia</b>	2.2	<1	Yes	No	Yes
<b>Yemen</b>	No specific standard				
<b>Egypt</b>	Decree 44/2000, but no specific standard				

1. BOD<sub>5</sub>, COD, NO<sub>3</sub>, TSS, EC  
Source: Xanthoulis, 2010

2008). Most of the treated wastewater is reused to irrigate food, industrial, fuel, and cosmetic crops, green belt, trees along the desert roads, and woodland forest. The regulation of water reuse in Egypt is based on Decree 44/2000 specifying the kind of soil, the method of Irrigation, and the crops to be irrigated.

#### IV. CONSTRAINTS TO WASTEWATER REUSE IN THE ARAB REGION

##### a. Policy and political factors

The lack of political commitment and of a national policy and/or strategy to support wastewater treatment and reuse act as significant constraints in most Arab countries.

For instance in Morocco, in addition to financial constraints and the lack of awareness within public authority institutions, there is no national policy for wastewater reuse. Recently, a National Master Plan for sanitation has been launched in order to protect water resources. In fact, with assistance from international organizations, Morocco has allocated a budget of about 4 billion Euros for sewerage projects to be completed by 2015. Experimental trials to irrigate several crops (vegetables, forages, cereals, and ornamental crops) have demonstrated the benefit of utilizing treated wastewater in increasing crop production, saving fertilizers,

and protecting the environment (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 Marrakech, Benslimane, and Agadir cities covering a surface area of 3000 ha.

In the Arab region, many people remain suspicious of reuse since they are uncertain of the quality of treated water. The availability of untreated wastewater free of charge makes it difficult to convince farmers to pay fees for reclaimed water that is perceived not to be of high quality. Numerous projects indicate that demand for reclaimed water by farmers is generally lower than it is for alternative sources of freshwater. This distrust is apparent in Tunisia, where the price charged to farmers for reclaimed wastewater is four times lower than fresh water prices. Perhaps most importantly, the fact that reclaimed water cannot be used for high-value vegetable crops is discouraging to nearly half of all eligible farmers (Bahri, 2002). Shetty (2004) has indicated that social acceptance, regulations concerning crop choices, and other agronomic considerations strongly influence decisions about water reuse.





In Palestine, wastewater reuse projects in the West Bank are associated with political obstacles, in addition to financial, social, institutional, and technical ones. “Wastewater reuse is still tied to the political issues concerning Palestinian water rights” (Samhan, 2008), since Israel considers reused wastewater as part of Palestinian total freshwater allotment. An integrated vision for wastewater reuse issues is still missing, which should include political and institutional aspects, water policy, awareness, marketing, and tariffs (Samhan, 2008).

For all of these reasons, wastewater recycling in Arab countries usually requires a long-term government commitment. Greater effort should be devoted in producing good quality treated wastewater to be used for non-restrictive irrigation. Public awareness, regulatory compliance, and monitoring should be reinforced.

#### **b. Health impacts and environmental safety**

According to Fatta et al. (2005), “concerns for human health and the environment are the most important constraints in the reuse of [treated] wastewater.” It is frequently the case that sewage treatment plants in Arab counties do not operate satisfactorily and, in most cases, treated wastewater discharges exceed the legal and/or hygienically acceptable maxima. This is

attributed to the lack of adequately trained staff with the technical skills to operate these plants, as well as the lack of an adequate budget for plant maintenance and operation.

Irrigation with inadequately treated wastewater poses serious public health risks, as wastewater is a major source of excreted pathogens - bacteria, viruses, protozoa, and helminths (worms) that cause gastro-intestinal infections in human beings. “Inappropriate wastewater use poses direct and indirect risks to human health caused by the consumption of polluted crops and fish. Farmers in direct contact with wastewater and contaminated soil are also at risk” (WaDImena, 2008). Reuse of unsuitable wastewater in agriculture may also lead to livestock infections.

The concerns of reusing reclaimed wastewater is not limited to “the relevant treatment infrastructure and applied treatment technology”, but extend to “other key parameters such as the quality of the influents as well as the subsequent reuse options according to current quality standards as defined in the national legislation” (AHT Group AG, 2009). Wastewater in the Arab region is increasingly loaded with further potentially harmful substances such as heavy metals, trace pollutants including organic and inorganic compounds, and emerging contaminants such as pharmaceutical substances, all of which must be removed prior to wastewater reuse. Dissolved inorganic constituents, such as

calcium, sodium and sulphate, may also have to be removed for wastewater reuse. The discharge of untreated industrial streams into the sewerage network causes an additional burden on the quality of treated wastewater (ultimately to be reused in agriculture). This is the case of the fishery industries in Agadir, Morocco, which discharge high loads of salt leading to increased salinity in the Lamzar plant effluent.

In environmental safety terms, unregulated irrigation with wastewater may lead to problems such as deterioration in soil structure (soil clogging due to high content of suspended solids in treated wastewater), which results in poor infiltration, soil salinization, and phytotoxicity (Choukr-Allah and Kampa, 2007). In Jordan, salt levels in the soil tended to increase in some areas that have been irrigated with treated wastewater, which was attributed to the salinity of wastewater as well as on-farm management (Fatta et al., 2004). Higher salinity implies that a certain number of less resistant crops cannot be irrigated by wastewater.

Potential environmental impacts from the reuse of wastewater in agriculture may also include groundwater and surface water contamination as well as degradation to natural habitat and ecosystems. In Tunisia, for instance, the main environmental quality constraint to the reuse of wastewater is the excess of nitrogen.

### **c. Standards and regulations**

An important element in the sustainable treatment and reuse of wastewater is the formulation of standards and regulations that are achievable and enforceable (AHT Group AG, 2009). Unrealistic standards and non-enforceable regulations may do more harm than having no standards and regulations at all, because they create an attitude of indifference towards rules and regulations in general, both among polluters and administrators. For instance, “the cost of treating wastewater to high microbiological standards can be so prohibitive that use of untreated wastewater is allowed to occur unregulated” (Fatta et al., 2004) to meet throughput goals.

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 (Choukr-Allah and Kampa, 2007).

Usually, the makeup of standards and regulations is based on other international practices. Most wastewater reuse standards in the Middle East and North Africa region “are based either on the United States Environmental Protection Agency (USEPA) or World Health Organization (WHO) guidelines” (WaDImena, 2008). In some cases, however, there is need for establishing more adapted standards and guidelines that take into consideration the scheme- and country-specific conditions (Abu-Madi, 2004).

Some countries in the region have developed health guidelines for water reuse as detailed in Table 2. For example, Bahrain, Jordan, and Morocco have adopted fully or partially World Health Organization and Food and Agricultural Organization guidelines. Other countries, namely, Kuwait, Oman, Saudi Arabia, and the United Arab Emirates have adopted stringent health reuse guidelines similar to those employed in some USA states (e.g., fecal coliforms less than 2.2 MPN/100ml). Such countries have established the treatment infrastructure needed to achieve those requirements. Still, other countries employ national public health laws to regulate reuse practices, while some lack any kind of regulatory guidelines (MED WWR WG, 2007).

Arab countries have developed different approaches to protect public health and the environment. However, the main factor driving wastewater reuse regulatory strategy is economic, specifically the cost of treatment and monitoring. Most Gulf Cooperation Council (GCC) countries have established conservatively low risk guidelines or standards (e.g., California standards) based on a high technology, high-cost approach. However, high standards and high-cost technologies do not always guarantee low risk because insufficient operational experience, high operating and maintenance costs, and regulatory control can have adverse effects.

Low-income Arab countries advocate another strategy for controlling health risks by adopting

## RECYCLING ABLUTION WATER FOR THE IRRIGATION OF A MOSQUE GARDEN IN OMAN

Researchers in Oman's Sultan Qaboos University (SQU) have designed a cost-effective system for recycling ablution water to be reused for irrigating the garden of a mosque. Ablution water is "greywater" (GW) since it is not mixed with "black" sanitary wastewater.

Ablution water passes first through a sand layer for trapping solid matter, then through a layer of enriched carbon for deodorization. Water is then disinfected by passing through a chlorine pump. Treated water is gathered in a ground storage tank connected to a sprinkler irrigation system.

The filter, designed by an SQU Department of Soil, Water and Engineering research team, cost only \$390, which is far less expensive than imported GW treatment units. The overall cost of the imported system was \$3,900.

Engineer Sayf Al-Adawi, who was involved in devising the homemade filter, said that the annual maintenance costs do not exceed \$200 including scrapping off a 5 cm layer of the sand filter and replacement of enriched carbon. He added that the service life of the filter was ten years.

The new treatment system was dubbed "WWW", an acronym that stands for "Wadu' [ablution] Water Works".



It is presently operated at Mohammed Hamoud Mosque in Al-Sib, near the Omani capital, Muscat. The system treats an average of around 1,000 liters of GW per day, with additional quantities on Fridays and during the month of Ramadan. Its maximum capacity is 4m<sup>3</sup>, which is enough to meet any possible future increase in utilization.

This inexpensive system, if used on a large-scale in the Gulf states and other Islamic countries, will potentially lead to considerable water saving, in countries that are in arid and semi-arid belt and suffer from water scarcity.

*Al-Bia Wal-Tanmia (Environment & Development) magazine*

a low technology, low-cost approach based on WHO recommendations. Attention should also be paid to cases where existing regulations are not adequate to deal with the demand of water reuse activities. For instance in Egypt, strict direct reuse standards are set in the Code of Use and the types of crops which can be irrigated with treated wastewater are very limited. However, none of these strict regulations are applicable to the indirect reuse of wastewater via agricultural drainage canals, which is a common practice in Egypt. Here, relevant laws only regulate the standards for discharge into agricultural drainage canals. In practice, the effluent quality of many treatment plants and direct dischargers does not comply with these standards. In addition, no restrictions of the crops irrigated with drainage canal water are stipulated (AHT Group AG, 2009).

### d. Wastewater Reuse Guidelines

Arab countries can be divided into three main

categories according to their wastewater disposal practices as follows:

**Category 1:** This group includes Bahrain, Oman, Saudi Arabia, Qatar, Kuwait, and UAE. All countries in the GCC follow similar methods in the disposal of wastewater effluent. A high percentage of wastewater after post treatment is reused in irrigation of agriculture land or in landscaping while the remainder is disposed into the sea after many advanced treatment steps. This practice is common in the Gulf region due to the availability of well-equipped and advanced treatment plants. Strict quality standards are followed before disposal and reuse, but it is thought that certain criteria parameters could be relaxed in order to fully utilize the ever-increasing volume of secondary treated effluent.

**Category 2:** This group includes Egypt, Iraq, Jordan, Morocco, and Syria. These countries follow moderate regulations for the disposal of wastewater effluent. Effluent from wastewater

## WAFEER INITIATIVE ENABLING A MARKET FOR WATER EFFICIENCY IN SAUDI ARABIA

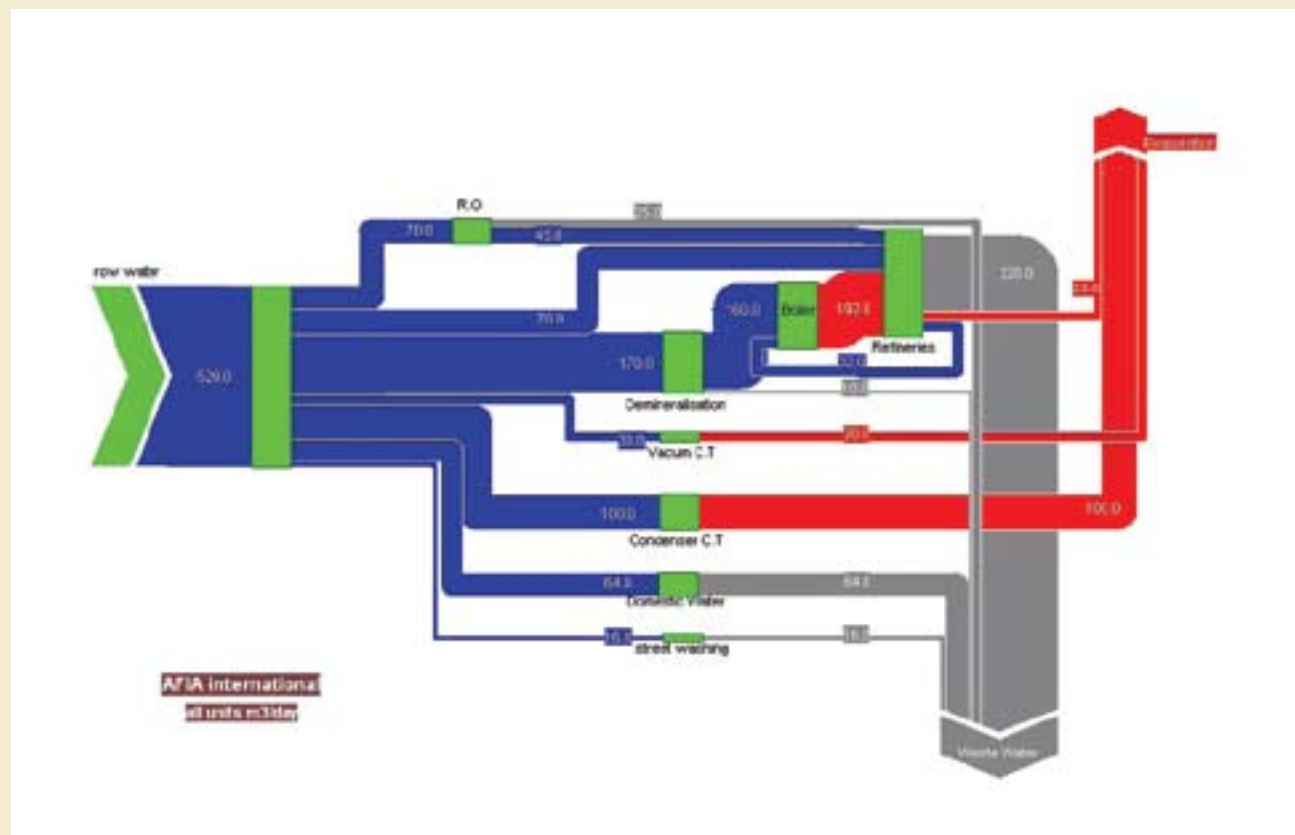
### Tareq Emtairah

Significant saving potential is believed to exist in all economic activities of the private sector of MENA countries. However this potential is hardly explored in systematic ways. Particularly in the context of a country like Saudi Arabia, where the cost of water production is among the highest in the world, the incentives to examine this potential should be high. In 2007, a group of private sector actors and with support from the Saudi Ministry of Water and Electricity (MoWE) launched Wafeer Initiative mainly for this purpose of exploring the potential of water efficiency in the Saudi Arabian industrial sector.

Faced with lack of data and local technical expertise in industrial water efficiency, the organizers of the initiative developed a pilot program in collaboration with international partners to work with selected companies from the industrial city of Jeddah to test a systematic methodology for water rationalization in industrial

facilities and to identify the economic and technical opportunities for water savings through reduce, recycle and reuse measures. The lessons from working with the pilot companies and the results of intervention measures were then to be documented for dissemination purposes and possibly for expansion of the program into other cities in the Kingdom. Another objective from the pilot programs is also linked to the component on capacity building and training of local engineers on water audits and water accounting tools.

The initiative's pilot program kick started in early 2008 and concluded in October 2009. During this period, the program attracted thirteen companies to participate in voluntary water audits. These audits were designed to map the water flow cycle and to enable the program team to draw visual water maps showing the in-flows and out-flows in each facility (e.g. Sankey Diagram). In discussions with the participants, the program team found the diagrams to be very useful in communicating with company managers about the potential for water





saving in their facilities.

Example Sankey Diagram for one of the participating facilities

Following the mapping step, the program team worked with seven facilities from the pilot companies to further identify and assess water rationalisation measures through, for instance, good house keeping measures, internal reuse of clean process water, internal recycling before discharge, and/or opportunities for use of externally recycled water. In some cases the program team also looked into the feasibility of investing in alternative process technologies that are less water intensive, for instance, alternative cooling tower technologies.

Based on these assessment it was possible to develop water efficiency management plan for five facilities. Common across the assessment results is the potential for water saving through simple measures with little or moderate investments and a pay back of less than one year. While the potential for closing the water cycle through internal reuse and recycling is high, these measures on the other hand require more investments and longer pay back periods. These along with other documented results from the initiative's program are published on the initiative website ([www.wafeer.net](http://www.wafeer.net)). Some of the key observations and lessons drawn from this initiative point to missed opportunities for efficient water management and to key institutional barriers that are most likely to extend across the MENA region.

On the practice side, the program experience shows a lack of systemic approach to water management and clear understanding of the water cycle in nearly all audited facilities. For instance it was difficult to get answers from production personnel on questions such as:

- Which operations require the most water?
- What are the water losses in process steps or pipes?
- Are there opportunities for internal re-cycle and re-use?
- Which of the operations can be connected to recycled water?
- Do you see a need to separate waste water streams to increase the potential for re-use?

In such cases, the use of water accounting and systematic mapping tools like the one used above helped the participants to assess the cost associated with water use in every step of the production process and to examine where the highest potential lie for intervening in the water cycle.

What also became apparent from the assessment results are some of the barriers related to the institutional context. For instance, the weak enforcement of regulations regarding industrial waste water discharges in the industrial estate does not encourage investments in water saving measures. This combined with lack of trained and qualified staff in industrial water management and shortage of water characterization facilities in the industrial estate made it even more difficult to proceed with many of the suggestions made in the assessment reports.

If the right measures are put in place in terms of stringent enforcement of waste water discharge tariffs, curbing of illegal dumping, and provision of technical support incentives, investments in water efficiency and related services can be very promising in a country like Saudi Arabia. Building on the initiative's conclusions, the annual water saving potential from investments related to internal improvements, within existing small to medium industrial facilities alone, is estimated to be around 30-50 million cubic meter for a country like Saudi Arabia. Given the current market prices and waste water discharge fees, the savings in monetary terms can range between \$60-100 million per year. Reaching these goals surely will require investments in capacity building and implementation measures. Even if these investments reach the level of \$200 million as projected by the program, a natural market for industrial water efficiency is most likely to emerge given that key distortions are corrected.

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treatment plants doesn't meet national or international standards. This may be due to the less than ideal condition or inability of existing treatment plants to cope with high loads of raw wastewater influent. Based on this fact a high percentage of the effluent wastewater is disposed to surface water bodies for later use in irrigation. The regulations in these countries specify the types of crops that can be irrigated using this type of treated water. Moreover, this water may be used for landscaping and for industrial purposes. The government does not allow the disposal of raw wastewater in wadis or by land discharge. Violation of this regulation may appear in the rural areas since they are not served or connected to the sewer (collection) system.

**Category 3:** This group includes the West Bank, Yemen, and Lebanon, where a large fraction of wastewater effluents is disposed of in wadis and subsequently used for irrigation of cropped lands without treatment. In the West Bank, raw sewage is disposed of in wadis from where it is used for irrigation of all kinds of crops and vegetables. No environmental or health control consideration is given to the workers, products, soil, or the possibility of groundwater contamination. In Yemen, raw wastewater is used for irrigation wherever it exists without any treatment necessary to meet standards of wastewater reuse.

### **e. Monitoring and evaluation**

In several cases, the outflow of wastewater treatment systems does not meet specified quality standards, either because standard operating procedures are not followed (as mentioned above) or because technically qualified personnel to control and monitor plant operations is unavailable. Wastewater authorities in most of the countries in the Middle East and North Africa region are unable to monitor continuously operational parameters in the treatment plant. Trained operators is a prerequisite for the control and monitoring of all treatment and reuse operations (Fatta et al., 2004).

Monitoring and evaluation of wastewater reuse systems in many Arab countries are irregular and not well developed. According to Choukr-Allah and Hamdy (2004), "this is mainly due to weak institutions, the shortage of trained personnel, lack of monitoring equipment, and the relatively high cost required for monitoring processes". Neglecting monitoring procedures and/or performing monitoring irregularly and incorrectly could bring about "serious negative impacts on health, water quality, and environmental and ecological sustainability" (Choukra-Allah and Hamdy, 2004). In addition, it is important to introduce appropriate technical and organizational measures that can systematically and reliably issue warning of impending breakdowns in wastewater treatment plant operations to wastewater reuse managers, in order to avoid the flow of untreated wastewater into the distribution network (Choukr-Allah and Kampa, 2007).

The choice of appropriate wastewater technology

could alleviate the finance and monitoring problems. Wastewater plants are generally capital-intensive and require highly trained, specialized operators. Therefore, before selecting and investing in a wastewater treatment technology, an analysis of cost effectiveness needs to be made and evaluated against other available options. Simple solutions that are easily replicated, that allow further up-grading as needs change, and that can be operated and maintained by a local trained workforce are often considered the most appropriate and cost effective. The choice of a technology should be dependant on the type of reuse. The selection of a reuse option should be made on a rational basis. Reclaimed water is a valuable but limited water resource; investment costs should be proportional to the value of the resource. In addition, reuse site must be located as close as possible to the wastewater treatment and storage facilities. Wastewater treatment technologies should be environmentally sustainable, appropriate to local conditions, acceptable to users, and affordable to those who have to pay for them.

Arab countries should allocate the required funds to support applied research geared to the development of sustainable wastewater treatment processes adaptable to the socioeconomic and climatic conditions of the Region.

## **V. RECOMMENDATIONS**

It is desired to bring attention to actions and research needs which are seen as priorities for overcoming the key constraints, discussed earlier, to wastewater treatment and reuse in Arab countries. The recommendations are based on a review of the relevant literature as well as on expert exchange in the context of several European Union (EU) Coordination Actions projects.

These recommendations seek to develop a common Arab framework of guidelines for treated wastewater reuse planning, water quality recommendations, and treated wastewater applications. This framework moreover would provide a consistent approach to the management of health and environmental risk. Although not mandatory and having no formal legal status, the proposed framework shares a common objective

while allowing flexibility of approach suited to national, regional, or local contexts.

### **a. Political and organizational aspects**

The reuse of treated wastewater in the Arab region needs fervent political support and the development of appropriate strategies promoting reuse in the context of each country's overall water resources management plan. Commitment to wastewater reuse should be part of proclaimed water policy and strategy in all countries of the Arab region. The lack of organization in the reuse sector should be addressed as a matter of urgency in order to identify the proper institutional structure needed to develop the sector and its regulatory regime. Standards in line with existing or new regulations need to be enforced to preserve the environment and protect consumer health. Arab countries are urged to develop a comprehensive plan of action for reusing treated wastewater with clearly assigned executive roles. The plan should be periodically reviewed and adapted as learning is gained.

Tunisia and Jordan are good examples of countries that made important steps towards garnering political support for wastewater reuse (WaDImena, 2008; MED WWR WG, 2007). Notably, these two countries have achieved the highest rates of wastewater reuse in the region so far.

### **b. Health and the environment**

To mitigate health and environmental risks, common norms and standards for the reuse of treated wastewater in Arab region should also be established (Al Salem and Abouzaid, 2006). So far, different Arab countries have taken different regulatory approaches and standards to manage the reuse of treated wastewater and sludge. In this context, it is important to comply with the framework criteria given in the WHO guidelines for the safe use of wastewater.

To be relevant and responsive, the WHO guidelines need to be adapted to conditions local to each Arab country. In fact, different levels of accepted quality standards will give incentives for improvement in wastewater quality over time. Viable options based on different treatment levels and different end-uses of

wastewater (including food and non-food crops, landscaping, or groundwater recharge) should be assessed in order to define the parameters for social acceptance in the Arab region.

Besides mandatory requirements, it is recommended to set up codes of best practices for the use of wastewater in the different countries for various applications. The codes of best practice should contain certain provisions for not impairing the quality of groundwater, for the prevention of leaching from storage, and for the selection of application periods in terms of weather conditions. Best practices should also include selection criteria for crops and for appropriate irrigation methods. The choice of wastewater irrigation application method depends on the quality of the effluent, crops to be grown, farmers' tradition, background, and skills, and finally the potential risk to workers and public health. Localized irrigation techniques (e.g., bubbler, drip, and trickle), offer farm workers the most health protection because they apply wastewater directly to the plants.

Jordan was one of the earliest Arab countries to adopt WHO and FAO effluent reuse guidelines for irrigation (Al-Uleimat, 2008), which served as the basis for the Jordanian Standard (current version 893/2006) on "Water-Reclaimed Wastewater" and "Domestic Wastewater" (GTZ/JVA, 2006). With the support of the Reclaimed Water Project, additional guidelines for irrigation water quality and crop quality and for monitoring and information systems were proposed (GTZ, 2009). The Project also developed agronomic guidelines for the safe use of reclaimed water in the Jordan Valley (Abdel-Jabbar, 2008), seeking to reduce the use of commercial fertilizers and associated costs. In addition, the implementation of monitoring activities has contributed to more transparency regarding health and the environmental impacts of irrigation with reclaimed water (Vallentin, 2006).

Detailed plans are also needed for reducing the amount of potentially hazardous materials, elements, or compounds that end up in the sewer, and therefore in wastewater or sewage sludge. These chemicals owe their presence in wastewaters to daily use of cleaning products, detergents, personal care products, and medicines (Oller et al., 2009). Therefore, consumers

should be informed of the composition of these substances or materials that could end up in the sewer and how to dispose of them in a manner that does not pollute wastewaters.

### **c. Water Demand Management**

According to Kfoury et al. (2009), "demand management and water conservation strategies clearly are the most cost effective approaches to reduce withdrawals", and therefore, "for reuse to make sense, it must be part of a larger water strategy" that manages and regulates demand effectively. A good example is Kuwait's Sulaiybiya Wastewater Treatment and Reclamation Plant, which will contribute 26% of Kuwait's overall water demand, reducing the annual demand from non-potable sources from 142 million m<sup>3</sup> to 26 million m<sup>3</sup>.

Wastewater reuse should be oriented to demand-driven planning by focusing on projects that are committed to reuse. A good example is illustrated by the partnership between the water distributor agency of Marrakech (RADEEMA), the state of Morocco, and the owners of 24 golf courses. The distributor agency will contribute up to US\$46.7 million, the golf course owners US\$36.7 million, and the state US\$16.1 million. The plant will produce 24 million m<sup>3</sup> of tertiary treated wastewater to be used for irrigation. Another good example is the partnership developed between the golf courses of Agadir and Marrakech in Morocco and the water agencies in those cities to supply them with continuous treated wastewater. The demand for treated effluent is driven by the scarcity of this resource in Marrakech, and to the high salinity of the ground water in Agadir area.

### **d. Awareness**

Arab countries should develop a platform for disseminating knowledge gained from existing wastewater treatment facilities in the Arab region. Knowledge sharing would lead to improved availability of information on the economic and financial benefits, the volumes of treated and reused wastewater, benefits to the water economy, and cost recovery of water reuse systems.

Policy-makers should develop national



dissemination plans and awareness campaigns to educate about and advocate using treated wastewater. It is also necessary to communicate up-to-date information on appropriate processing and crop protection technologies to authorities responsible for wastewater treatment and reuse as well as to the end users.

## VI. CONCLUSION

The Arab population in 2008 stood at about 343.8 million (AOAD, 2009) with 55% located in urban areas (World Bank, 2007) producing around 10 billion m<sup>3</sup> of wastewater. We urge Arab governments to devote serious effort and clear commitment to promote the reuse of this non-conventional water as an integral part of their water resources management (AOAD, 2007).

All Arab countries of the region have programs for reusing treated wastewater in irrigation. Fodder crops, cereals, alfalfa, olive, and fruit trees are most widely irrigated with treated water. However, few countries have institutional guidelines for regulating the reuse of treated wastewater (MED WWR WG, 2007).

It appears from several reuse projects in the Arab region that we should examine thoroughly whether reuse of treated wastewater outside of agriculture might also be economically feasible and ecologically sustainable. In fact, the reuse of wastewater in industry, for recreational areas, in forestry, and to meet the needs of golf courses seems to be more economical, and could also increase the percentage of reused wastewater. This could contribute to increasing the efficiency of national overall water use.

Still, the full value of treated wastewater has been recognized in only a few water stressed Arab countries (Tunisia, Jordan, and the GCC countries). 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 means of increasing water availability. Therefore, water reuse should be considered an integral component in every country's national water strategic plan.

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# Desalination

ADIL A. BUSHNAK



## I. INTRODUCTION

Desalinated water represents a very small percentage of the water used in the world, however, it represents close to 100% of water supply for many Arab cities and for an increasing number of countries in the region. The cumulative capacity of all desalination plants contracted for in Arab countries since 1944 according to the Global Water Intelligence report is over 24 million m<sup>3</sup>/day (GWI, 2010). This represents about 50% of total world's desalination capacity. The role of desalination as a major source of domestic water supply will continue to increase in Arab countries because of population growth, increased urbanization, industrialization, and depletion of non-renewable sources. However, reforms in policies and management practice are needed in most Arab countries in order to make desalination a sustainable water source. This paper highlights what reforms are needed and stresses the urgent need to put them in practice.

## II. DESALINATION PRACTICES IN ARAB COUNTRIES

Water scarcity in the Arab region has brought desalination solutions thousands of years ago into Mesopotamia, Alexandria, and Palestine (Al-Sofi, 2000). In modern history, desalination came back to the Red Sea during the late 19th Century in cities like Sawakin, Abu-Qair, Aden, and Jeddah. According to Al-Sofi (2000), "In Jeddah, the first single effect distiller was deployed around 1895." It was known locally as Kindasa, and was refurbished after WWI and again after WWII, making Jeddah the first city to rely on seawater desalination for meeting its drinking water needs for more than 100 years. Similar units were deployed in Bahrain and soon after multi-effect distillers were installed in Kuwait, Dhahran, Ras Tanurah, and Al-khobar. Al-Sofi (2000) reports that "During the fifties, Multi Stage Flash (MSF) was applied commercially first in Kuwait." The first seawater desalination plant to employ reverse osmosis

FIGURE 1

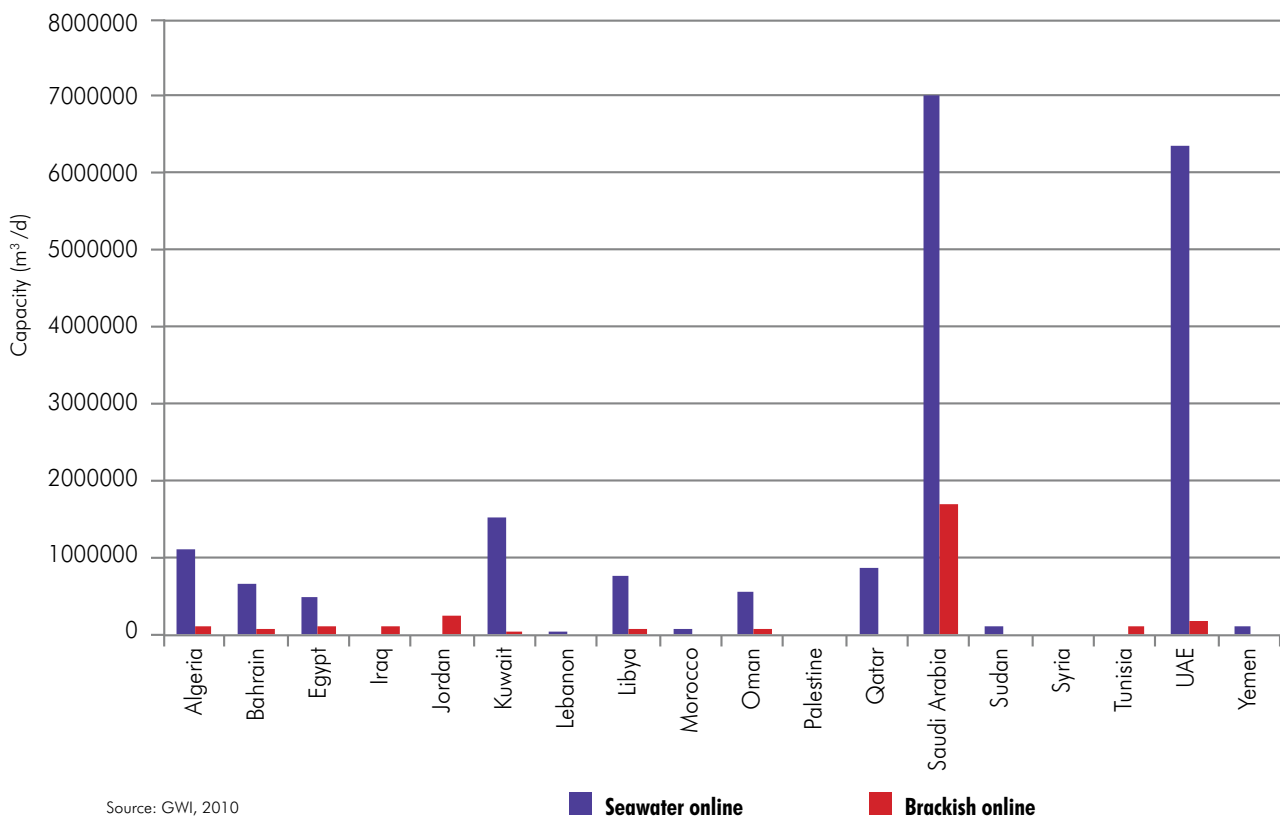
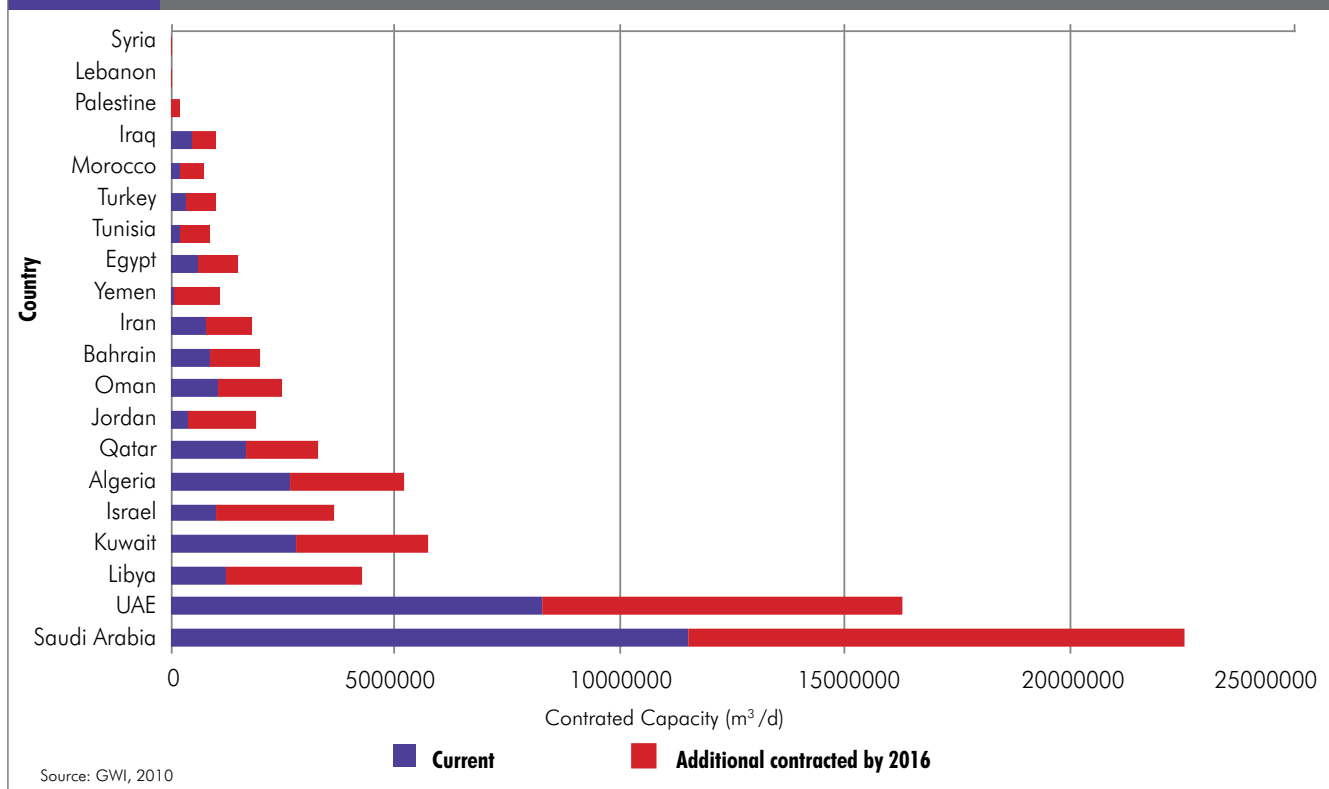
**TOTAL CUMULATIVE CONTRACTED CAPACITY OF DESALINATION PLANTS SINCE 1944 IN CUBIC METERS PER DAY**


FIGURE 2

## ACCUMULATED CURRENT AND NEAR TERM TOTAL CONTRACTED CAPACITY IN MENA



(RO) for municipal water supply outside the USA was commissioned in Jeddah in 1978.

As outlined above, most present day commercial desalination technologies have been developed through large-scale applications in a number of Arab countries. Today, member countries of the Gulf Cooperation Countries (GCC), Algeria, Libya, and Egypt are the largest users in the region, as indicated by their total cumulative contracted capacity of desalination plants since 1944 in Figure 1.

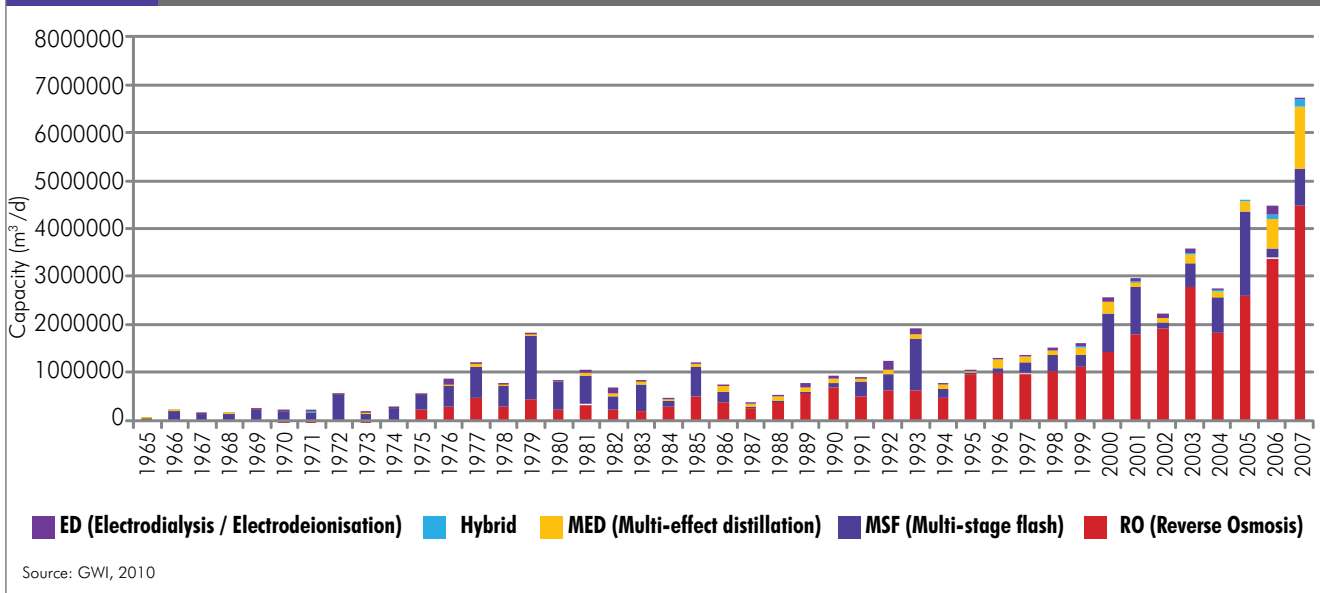
The high rate of annual increase in contracted capacity will be maintained over the next decade (GWI, 2010), as shown in Figure 2. This large expansion requires a review of present policies and practices including how to increase local capacity, knowledge, and added value to the local economies.

Most large desalination plants are built by government utilities such as the Saline Water Conversion Corporation (SWCC), Abu Dhabi Water & Electricity Authority (ADWEA), and Dubai Electricity and Water Authority

(DEWA), or by government water ministries. It is customary for governments to take a number of years before agreeing to a major water plant contract, followed by a multi-year construction period, while the demand growth in major cities continues to rise at a high rate. This leads to a time gap between demand peak and supply and causes known cycles of water shortage and over-capacity. This predicament could be addressed by introducing reforms to water plant procurement and announcing in advance any new or expanded capacity needed to be contracted in each city or region. More details on reforming this process will be discussed later in this paper.

Another policy reform that should be introduced is giving priority to reducing water leakage and unaccounted for water in the distribution system before building additional desalination capacity. Integrated water resources management (IWRM) principles provide a practical framework for introducing such practices. Before sinking large amounts of capital into augmenting supplies, less expensive investments that reduce water losses should be implemented first.

FIGURE 3 GLOBAL CONTRACTED CAPACITY BY TECHNOLOGY



In the region, local capacity and knowledge are focused on operations and maintenance (O&M), but not on plant design, manufacturing, or construction even in countries heavily dependent on desalination even in countries heavily dependent on desalination for meeting a major percentage of their domestic water. Exceptional local talent is available but it is not adequate to meet the enormous demand for additional thousands of technicians and engineers needed every year to meet the growing demand for skilled labor in Arab countries. Without strong government support, the state of the desalination industry and business will remain fragile, meeting the same fate of other technology-based industries.

### III. DESALINATION TECHNOLOGY TRENDS

Reverse Osmosis (RO) technology has been the most widely used process in the world over the past 25 years as shown in Figure 3. GCC countries tend to cogenerate electricity and water in large plants in order to increase fuel efficiency. This is why thermal desalination technologies are most common in these countries. However, when electric power is available or brackish water is the feed source, membrane technologies are used.

Commercial technologies used today in desalination can be grouped into two categories, namely, thermal and membrane, as follows:

#### Thermal:

MSF : Multistage Flash  
 MED : Multiple Effect Distillation  
 VC : Vapor Compression

#### Membrane:

SWRO : Seawater Reverse Osmosis  
 BRO : Brackish Water Reverse Osmosis  
 ED : Electro-Dialysis  
 NF : Nano-Filtration

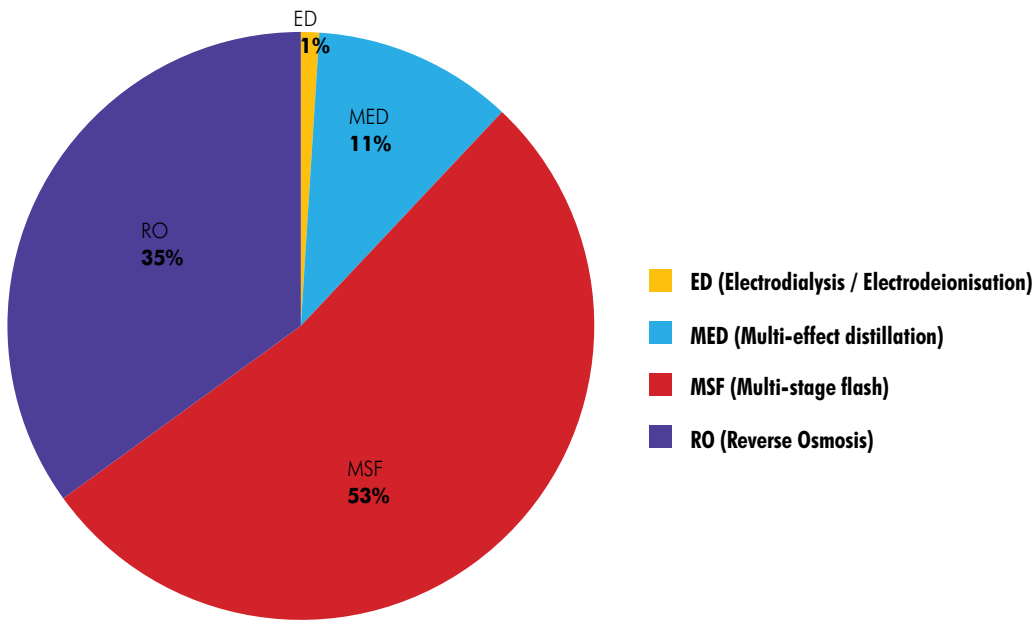
The choice of technology used for desalinating brackish water is dependent on the level of salinity. Reverse osmosis is used mostly today for higher salinity brackish water, while electro-dialysis is more efficient for lower salinity brackish feed.

Figure 4 provides a breakdown of the cumulative contracted capacity by technology in the MENA region since 1944. The multistage flash (MSF) process still dominates the market, although installed capacity for reverse osmosis has increased recently.

RO is increasingly used in the world today because of its lower cost and improved membranes. Hybrid technologies, e.g., MSF/RO or MED/RO, can be used in the future to increase efficiency when power generation is required. Future large cogeneration plants may combine NF/MSF/MED/RO if present pilots and technical solutions prove to be commercially competitive.

FIGURE 4

CUMULATIVE CONTRACTED CAPACITY BY TECHNOLOGY SINCE 1944 IN THE MENA REGION



Source: GWI, 2010

There are a number of new desalination technologies under development in many parts around the world. These new technologies include membrane distillation, carbon nanotube membranes, aquaporin (biomimetics) membranes, thin film nano-composite membranes, forward osmosis, and electro-dialysis/deionization. However, some desalination experts doubt that these technologies hold great promise for desalination of seawater (Hanbury, 2010).

#### IV. DESALINATION CHALLENGES

For Arab countries to make desalination a sustainable source of water, local challenges must be overcome and specific policy and management reforms must be implemented.

##### a. Managing Cost

Desalination is capital and energy intensive. The lower cost options are sensitive to operating skills and variations in feed water quality. The capital cost depends on water quality, production capacity, required infrastructure, plant efficiency, material selection, and other location factors. From my experience, the unit capital cost in 2010 for seawater desalination plants typically ranges from

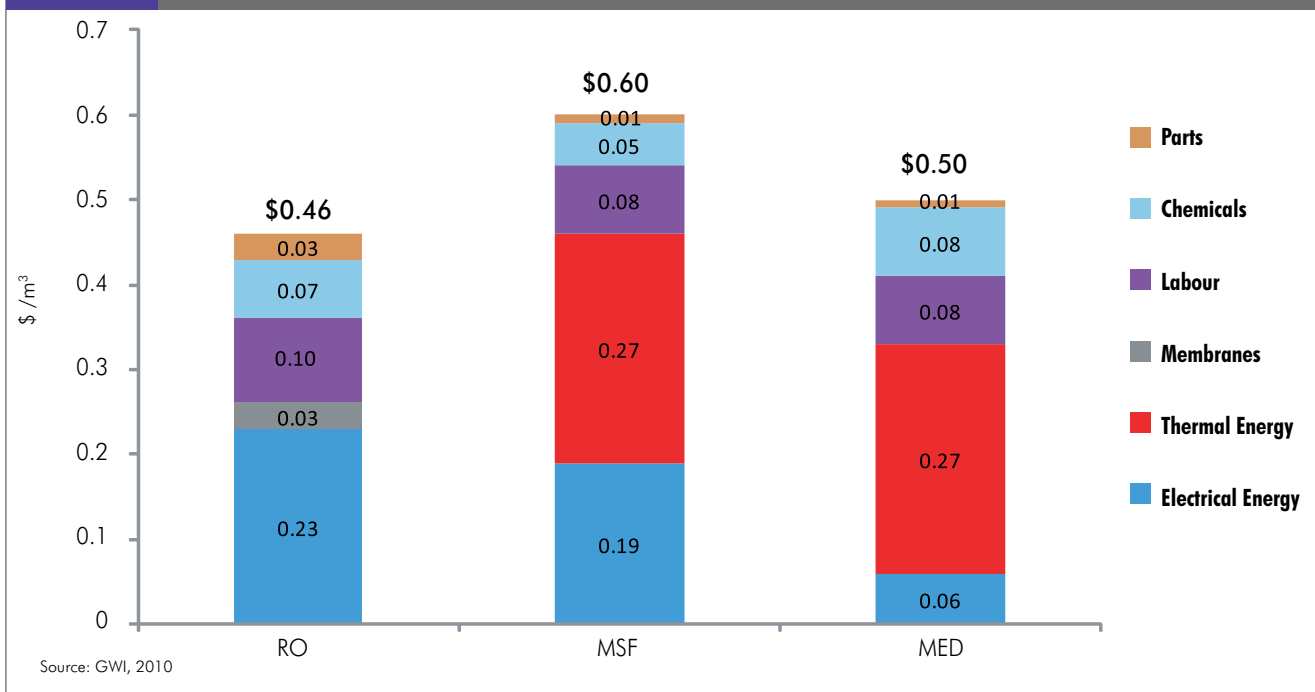
\$1000 to \$2000 /m<sup>3</sup>/day of installed capacity. The unit capital cost for brackish water plants is estimated at 25%-45% of the above unit cost for seawater plants. The relative operating costs of the three main desalination processes is shown in Figure 5 for cogeneration plants. The operating cost of thermal plants is much higher than those shown below if waste heat or steam is not available on site. Desalination is usually the most expensive water source option among other local options.

The above analysis illustrates why cost management is a challenge for decision makers. A different policy discourse, as detailed below, can make a difference.

- The first source option that needs to be implemented is to reduce leakage in the distribution network along with promoting water saving policies and incentives before embarking on building new desalination plants. This course of action may take years to realize its advantages. However, it will bring about significant savings in capital costs resulting from reduced outlays for new water plants.
- Government agencies should consider a shift in their role from a procurer of desalination plants to a purchaser of water. This policy

FIGURE 5

RELATIVE OPERATING COSTS OF DESALINATION PROCESSES IN COGENERATION PLANTS



shift would guarantee the most efficient technology and operation are deployed. It would also contribute significantly to the building of local skills and capabilities and the enlargement of the role of the private sector in the desalination industry. More critically, the role of government would shift to that of a regulator rather than an operator. To maximize the benefits of this policy, government agencies should make public the quantity of water they anticipate to purchase by year in each city.

- If government organizations continue to be charged with building and operating large desalination plants, steps should be taken to manage these assets based on minimizing the life cycle cost of water. Government corporations should be set up for this purpose. Acting like business enterprises, these government corporations should be expected to value energy at world market prices and grant incentives to set up research and development (R&D) departments to promote in-house innovations in technology and operation. They should be expected to take some risk by piloting new technologies. Internal audits can be used to monitor their performance
- Governments should revisit the assumption

that bigger plants reduce cost. Mega plants are usually built at locations remote from dense urban areas, particularly if cogeneration is used. The additional costs of transporting, storing, and distributing water could make smaller decentralized plants less expensive, strategically safer, and less disruptive. In addition, more bidders for smaller size plants will be able to compete for contracts, leading to reduced capital costs and shorter construction times.

- Recovering selective, high-value minerals and metals from the brine of mega desalination plants may increase the economic return on investment and contribute to reducing water cost.

### **b.Sustainable Desalination**

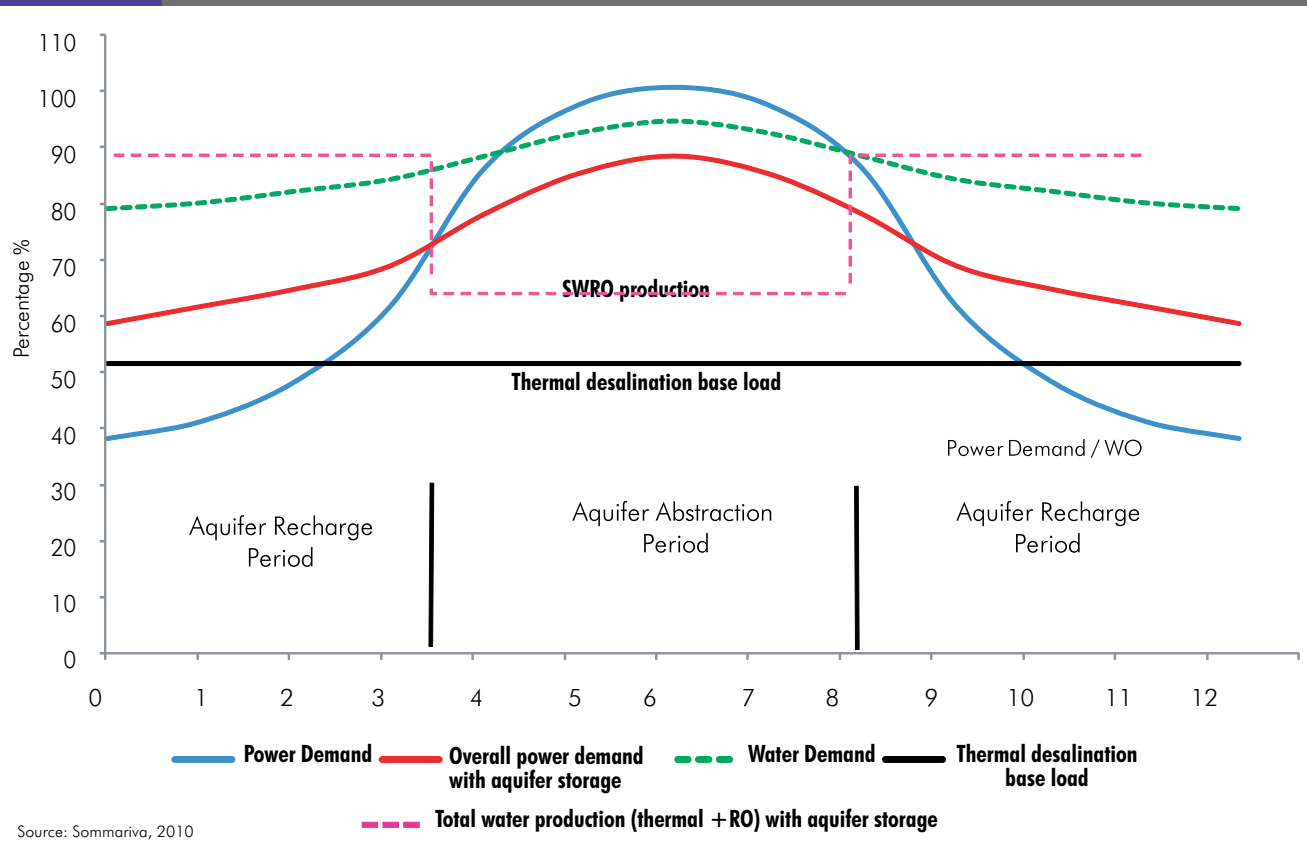
To achieve financial and environmental sustainability for desalination as a water source the following challenges must be addressed:

- Water tariffs must be imposed to recover the total cost of water and wastewater including distribution, allocation, treatment, and environmental impact. To ensure water access to the poor, only targeted subsidies may be used.



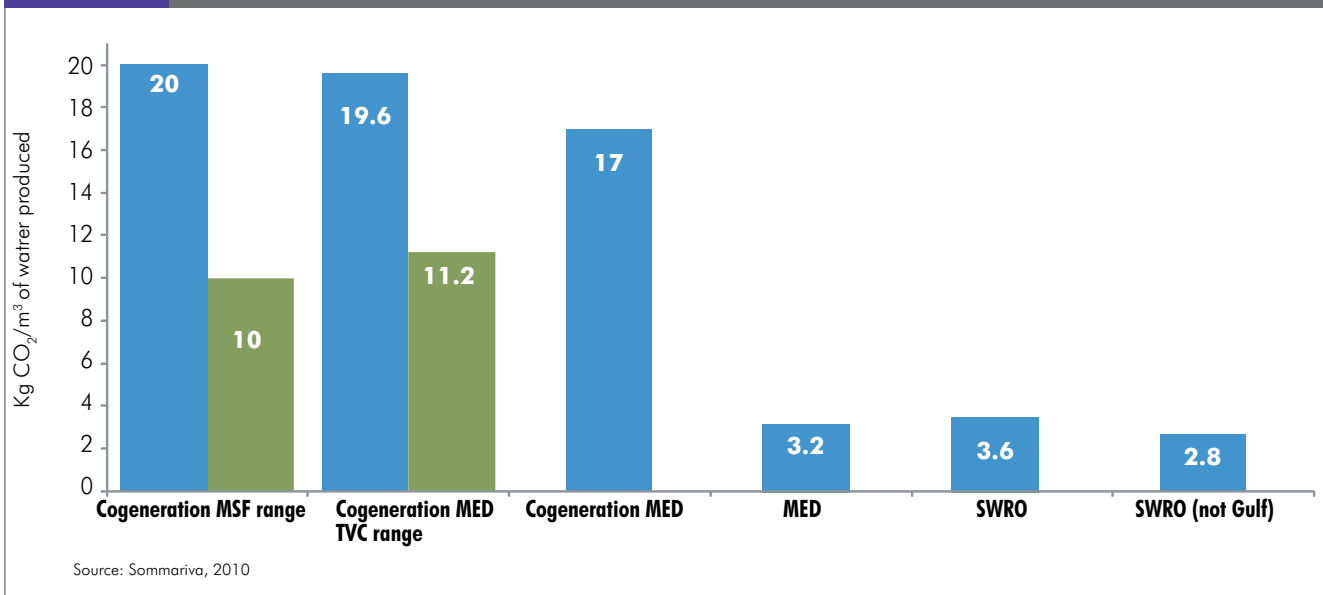
FIGURE 6

## OPTIMIZATION OF ENERGY SUPPLY USING AQUIFER STORAGE AND RECOVERY



- Using renewable energy sources abundantly available in Arab countries, such as solar power, for desalination can contribute greatly to achieving sustainability, reducing the carbon footprint, and transforming the local economy to knowledge based production with proper R&D incentives and support to small local businesses. Arab countries should cooperate regionally to maximize the use of their tremendous solar power, particularly for water supply.
- Energy efficiency should be a key criterion in commissioning new plants and upgrading old plants. However, energy efficiency will not be enabled if available fuel is accounted for at well below the market price, as is the case in most GCC countries. At present, 25% of Saudi oil and gas production is used locally to generate electricity and produce water (Al-Hussayen, 2009). With present demand growth rates, this fraction will be 50% by 2030 (Al-Hussayen, 2009). It is clear that the Saudi economy cannot prosper under this business as usual scenario.



FIGURE 7 CARBON EMISSIONS IN KG CO<sub>2</sub> PER UNIT VOLUME (M<sup>3</sup>) OF WATER PRODUCED IN COGENERATION PLANTS

- A source of energy efficiency is to use the large standby electric generating capacity available in most GCC countries to produce and store water during off peak hours as shown in Figure 6. Aquifer storage and recovery under or close to desalination plants should be investigated and developed to realize the potential of this solution. Water and power cogeneration experts believe that such an initiative makes sense in countries like the UAE but not in Saudi Arabia because the latter uses the electricity generated from its cogeneration plants for base load (Al-Sofi, 2010).
- Adopting a decentralized system of smaller desalination plants should be pursued in order to (a) increase the overall availability, (b) reduce transport, leakages, and associated distribution system costs, (c) achieve short implementation schedules for project sourcing, construction, and management, (d) ensure water security through multiple unit availability, and (e) provide opportunities to local contractors who would be able to manage smaller projects efficiently and economically as opposed to mega projects which require the logistical expertise of only global contractors.
- Governments should design incentives for local businesses to attract investments in manufacturing locally key components of the desalination plants such as the RO membranes, high-pressure pumps, and energy recovery devices. This can be achieved by initially assisting local manufacturers produce in accordance with international quality standards and by forcing turnkey contractors to procure locally.
- Governments should support local start-ups and investments in knowledge based sectors of the economy in order to cultivate innovation locally and to attain economic sustainability in strategic industries such as desalination and solar energy. Arab countries should be world leaders in products and services in these two strategic sectors because their economies are dependent on those two sectors and will be the first to benefit.

### c. Environmental Concerns

Desalination plants pose a number of serious environmental concerns that need to be addressed.

- The main environmental impact of most desalination plants is related to the source of its energy and carbon footprint. Figure 7 shows the large variance in the carbon footprint of common processes used today in cogeneration plants. The carbon footprint of MSF plants ranges from 10-20 kg CO<sub>2</sub>/m<sup>3</sup> and for MED/TVC the range is 11.2-19.6 kg CO<sub>2</sub>/m<sup>3</sup> depending on the rate of the heat cycle (Sommariva, 2010). For single purpose thermal plants (not shown in Figure 7), the

## FOG WATER IN SAUDI ARABIA AND RAINMAKING IN THE UNITED ARAB EMIRATES

Fog water collection is a scientific process employed in many places around the globe. The Saudi Fakieh Research and Development Center conducted a field project in three different locations within Asir region in Saudi Arabia. These were the Rayda Reserve, Al-Sahab Park (both in al-Sooda district) and the city of Abha.

Researchers compared the economies of this process and other methods of obtaining water such as desalination and pumping out groundwater; their findings confirmed that the costs of fog water were much less than the other methods, not to mention producing better quality water.

The research team designed and constructed three standard fog collectors (SFCs), based on the design of the collectors previously used in Chile. Each SFC consists of a 1 m x 1 m cloth mesh of a certain shading degree, metal trough, conduits and pipes, and collection containers; in addition each unit was protected by a metal lattice cage around it. These three sites were chosen in the light of a field study of the locations where fog is common.

Water collection from fog, on a daily basis, started at the end of March 2006, with special attention to obtain the highest daily average amount of water collected from fog, especially in winter, since the season of thick fog starts usually with the beginning of winter.

By comparing the amounts of fog water collected in Asir Region with the yield of collecting devices in some other parts of the world, it was evident that al-Sooda volumes were the highest globally. This is due to the high elevation above sea level (2260 - 3200m), the geological and climate conditions, the location of the Asir mountain range near the Red Sea and the prevailing wind direction in the area (from the sea towards the mountain range).

It should be noted that water sources available in the area of the project are limited to desalinated water, groundwater and fog water. The average amount of collected fog water in the experiment area reveals the considerable economic benefits of this technology. In the absence of any large-scale fog water collection project, so far, a preliminary economic comparison shall be made between the provision of 28m<sup>3</sup> of desalination water for the inhabitants of the project area (al-Sooda) and the collection of an equivalent volume from fog,



over a period of 12 years, which is the service life of the mesh used in the collectors.

Based on the adequate results of fog water collection in al-Sooda, and considering that fog is common in the area all year round, especially in winter when it becomes more dense with less rain, the study concludes with a recommendation that this method of obtaining water be deployed- even for potable water after proper treatment. Moreover, fog water collection had been used in other places in the world with lower altitudes and less fog than Asir region.

In the United Arabs Emirates (UAE), successful attempts have been made to raise precipitation levels by 10% through cloud seeding, by designated aircraft that disperse silver iodide powder into cumulus clouds, thus increasing water droplets and inducing the fall of rain.

UAE needs to increase its available water supply to meet the needs of its growing population, especially in the absence of any rivers or lakes, in spite of the fact that groundwater is found in desert oases such as in Al-Ain and Liwa. Water desalination plants are the major source for drinking water and irrigation, but are highly expensive and energy-guzzling.

A cloud seeding project is under way in the mountainous Al-Aiyn area, east of the capital Abu Dhabi, where most arable lands lie. In 2009, 97 aircraft flights were made to increase precipitation. However, rainmaking attempts will be enhanced since the UAE has recently bought of a fleet planes that it used to charter.

*Abdul - Razzaq Sultan, Al-Bia Wal-Tanmia  
(Environment & Development) magazine*

### SOLAR DESALINATION PLANTS IN ABU DHABI

The Environment Agency-Abu Dhabi (EAD) established two pilot stations powered by solar energy for the desalination of highly-saline ground water. Dr. Mohamed Dawoud, Manager of Water Resources at EAD, says that using renewable energy sources in desalination is a significant turning point in the development of desalination industry in the region, because it will lead to lower costs and increased efficiency. The process involves solar energy collection technology and desalination units employing reverse osmosis membranes.

The real challenge, according to Dawoud, is to increase the efficiency of such solar collector systems and minimize the environmental impact. However, EAD is currently setting up a mechanism for the safe disposal of discharge water, by raising the two stations' efficiency by more than 80% and possibly using the high-salinity water in producing salts, livestock feed or agricultural fertilizers. This will eventually enhance the economic efficiency of such solar systems and minimize the environmental impact of dumping discharge water in the Gulf or injecting it in deep aquifers.

*Al-Bia Wal-Tanmia (Environment & Development) magazine*

carbon footprint is many multiples of these figures if waste heat is not available. It is also important to note that, in order to save capital cost, almost all thermal plants built in the GCC countries do not use a low heat cycle, which results in a higher carbon footprint. It is also useful to note that the carbon footprint of power generation plants ranges from 0.5-0.8 kg CO<sub>2</sub>/kwh depending on the type of fuel used and plant efficiency (Sommariva, 2010).

- The impact of the reject water from thermal



desalination plants has not been studied in depth at a regional level. There are concerns raised, however, about the effects of brine discharge on the marine environment. According to a World Bank (2007) report, "discharge of hot brine, residual chlorine, trace metals, volatile hydrocarbons, and anti foaming and anti-scaling agents are having an impact on the near-shore marine environment in the Gulf." The increasing number of plants on the Gulf and the rising temperature of its water warrant extensive studies and modeling to resolve future environmental challenges and possible solutions.

- The impact of SWRO brine on marine life can easily be minimized by proper dilution and outlet design. However, brine of BRO plants continues to have environmental and cost concerns. Reducing BRO brine and utilizing it for other benefits like energy production should be a priority.
- No immediate health concerns have been observed for decades in GCC countries linked to the quality of drinking desalinated water. However, more studies are needed to establish the health limits of certain minerals in local environments.
- Environmental laws regulating the building and operation of desalination plants exist in some Arab countries but they are not enforced. Resources should be allocated to ensure compliance by both private and government-owned facilities.

#### d. Capacity Development

Developing local capacity includes acquiring the ability to create leading edge knowledge and the capability to utilize this knowledge to add economic value through innovation and global marketing. It also includes nurturing local leadership and providing financial and logistical support to enable local human talent to create world-class value from their ideas. The following reforms can help realize the above:

Arab governments should provide generous financial support to help develop and pilot test new technologies. They should also endow local and regional universities with trust funds to jumpstart the establishment of new venture capital companies. This would bridge the existing gap between business and most universities in Arab

countries. Some countries (e.g., Saudi Arabia) have large allocations for ambitious science and technology initiatives based on the above model. It remains to be seen how local universities will be able to convert their intellectual research ideas through entrepreneurship into high-value economic assets.

Most Arab countries do not have venture capital funds or government-supported funding for high-risk new technology firms. Tunisia, followed by Morocco, are the only exceptions. The vital role of government planning and support to build and enhance capacity for locally-based knowledge is best seen in Japan and South Korea which enabled their economies in a few decades to be world leaders in new industry and technology.

Arab governments should grant generous scholarships for promising students and offer financial support to allow local utilities build training centers. The Saudi government in partnership with local companies builds and equips such specialized training centers to increase job opportunities for citizens. The saline Water Conversion Corporation (SWCC) has the only desalination focused training center in the region.

The Arab Water Council is taking a proactive role in capacity building by establishing the Arab Water Academy (AWA) and the Arab Desalination Technology Network to facilitate networking, capacity building, and cooperation among desalination experts in Arab countries and the world at large. The Arab Water Academy, based in Abu Dhabi, is a good example of the benefits of regional Arab cooperation. The AWA has already started its capacity building programs in water governance. It has also organized in 2010 the first meeting gathering key leaders in charge of water organizations in Arab countries, which is expected to generate more useful inter-Arab initiatives and joint programs in capacity development.

The National Water Company in Saudi Arabia is embarking on an ambitious project to build a National Training Center in Jeddah to serve the whole region and be a world model in combining training with technology development to sustain knowledge and innovation in all water related fields including desalination.



## V. RECOMMENDATIONS

The following actions are suggested to make seawater desalination a more sustainable source of water:

- Increase water tariffs to recover the total cost of water supply and wastewater services in order to achieve financial and environmental sustainability of water services provision. Smart, targeted subsidies directed to the poor, as opposed to general water subsidies, must be used in order to ensure conservation and social equity.
- Reduce network water leakage and unaccounted for water before augmenting supply by expanding the capacity of desalination plants or constructing new ones. This is essential to ensure conservation of natural and financial resources.
- Shift the role of municipalities and major water users to purchasing bulk water at a minimum unit price at specified quality and quantity instead of buying turnkey desalination plants. Governments should opt out of owning and operating physical desalination plant assets and assume a regulatory role. Public-private partnerships as well as water trust/waqf models should be expanded.
- Establish government utilities as independent water trusts (Waqf) or operate them as self-financed business corporations in order to provide reliable and sustainable water at minimum cost for present and future generations.

- Require all new desalination plants to reduce energy consumption and reduce carbon footprint per unit water produced. Arab governments should set a maximum limit on water carbon emissions.
- Developing new solar powered desalination technologies for small and large systems must be among the top priorities of Arab countries' research and development programs. Arab based technical solutions and products for solar desalination and cogeneration can provide a strong economic base for many countries in the region. Arab countries need to plan for exporting solar power for their future prosperity as much as they rely on oil and gas exports today.
- Establish and enforce existing environmental standards for all desalination plants whether they are owned by the private sector or public government entities. Air and water pollution from many government-owned and operated plants must comply with regulatory standards according to set deadlines.
- Governments must provide generous support to private investments in R&D, training, high technology venture capital, and knowledge based local industries. Such support should be integrated to achieve desired national local economic outcomes and meet export targets in strategic industries like desalination and solar power.
- Arab countries should develop joint R&D programs in desalination and renewable energy and maximize the value of new ideas and research findings emerging from new institutional knowledge hubs such as King Abdullah University for Science and Technology (KAUST) and Qatar Foundation.

## VI. CONCLUSION

Desalination can be a sustainable source of water for Arab countries and a driver to a knowledge based economy if the reforms and recommendations outlined in this paper are implemented. Governments should start by implementing water tariff reforms, water conservation, and integrated water resources management programs. Solar powered desalination should be a priority for technology development for Arab countries. Water conservation and demand management for all water uses, especially agriculture, should also be a priority area for policy reform.

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# Water Laws and Customary Water Arrangements

TAREK MAJZOUB



## I. INTRODUCTION

Water is essential not only for survival, but also for environmental and physical health, social stability, and economic growth. Government's endeavors to turn underperforming water utilities into sustainable service providers may - as one option among others - benefit from involving stakeholders and civil society institutions. However, experience throughout the last decade shows how difficult change processes in the water sector tend to be. Friction between stakeholders over priorities and means, lack of clarity about roles and responsibilities, and major concerns about private involvement often result in high transaction costs and hamper success. The critical lessons learned demonstrate the need to focus on integrated water resources management (IWRM) and water governance as decisive elements for water sustainability in the Arab region.

Although there is no agreed upon definition of good water governance, issues and basic principles for its achievement include participation of all stakeholders (government, private sector, and civil society), transparency, anti-corruption, promotion of water legislation, and regulations.

Legislation ought to emphasize the principles and concepts in support of IWRM, namely, holistic management, sustainability, equity, gender balance, economic value of water, and governance. It establishes the basis for the implementation of water policies and strategies and provides the context in which government and non-government entities and individuals take regulatory actions.

This chapter reviews possibilities for translating customary water arrangements and water laws into sound water legislation. It provides, where possible, some case studies to highlight success stories and/or lessons learned in water management. Furthermore, there is a broad discussion of what may constitute the core of water legislation. At the end, some conclusions and recommendations are drawn to facilitate legislative processes.

## II. CUSTOMARY WATER ARRANGEMENTS

Ancient water systems or institutions are living monuments of the ingenuity of our predecessors:

the dams of Shaba, Mesopotamia, the gardens of Alhambra, the 'Tribunal de las Aguas de la Vega de Valencia' (Water Court of Andalusia), and the aflaj in the Sultanate of Oman all testify to the importance attached to water in the past. Throughout the centuries, Arabs have contributed much to the world's water civilization, working out some of the finest examples of good water governance. A better understanding of ancient water systems and institutions will no doubt help increase their relevance and contribute to addressing current global water challenges. In several Arab states, "access to land and water for irrigation is regulated according to customary arrangements of which most are unwritten and somehow flexible" (Majzoub et al., 2010a). In the following case studies, we focus on the application of customary arrangements to guide management of water resources.

### a. Case study 1: The Aflaj

The Aflaj (sing. Falaj) or foggaras are considered the main traditional water system in the Sultanate of Oman. It is estimated to be 2,700 years old. Despite the introduction of underground and surface wells, the Aflaj still play the main role in the irrigation of agricultural land in the Sultanate, in securing drinking water, animal watering, and other domestic purposes (ROSTAS, 1986).

The Falaj is known as the Qanat in Iran. Comparable systems still exist in many parts of the world, including Afghanistan (Kariz), Algeria (Foggara), Canary Islands (Galerias), China (Kanjing, Karez), Italy (Ingruttato), Japan (Manibo, Mappo), Korea (Man-nanpo), Morocco (Khattara, Rhettara), and Yemen (Felledj).

The main structure of the Falaj consists of the mother well that may reach a depth of 65 to 200 feet, the main channel, and the access shafts that are built every 50 to 60 m along the channel. Each farmer has a share of water depending on the size of his farming plot(s) and on his contribution to the Falaj construction. Although most Aflaj are fully owned by farmers, some are owned, fully or partially, by the government.

At the very top of the Falaj, where the Falaj canal is opened, drinking water may be drawn (called Sharia). After drinking facilities, bathing places for men, then for women and children, water





passes through the forts and mosques until it reaches the Mughisla for washing the dead. In every Falaj, these water shares are not owned by individuals but allocated for the community. After domestic use, the Falaj is utilized first to irrigate permanent cultivated land (mostly date palms), then seasonal cultivated plots (called Awabi). If drought occurs farmers reduce the area of seasonal crops. In the Falaj irrigation system, water is distributed on a time basis. Only in a few cases is volume used as a basis. The system of water distribution is complex. But it is both fair and effective (Majzoub et al., 2010a).

Typical large Falaj administration consists of a director (Wakeel) to manage the Falaj organizational system, two foremen (Areefs) to deal with technical problems, one for underground services and the other for surface water services, a treasurer (Qabidh or Amin Al Daftar) to manage financial matters, an auctioneer (Dallal) to help the treasurer with water shareholders sale, and daily laborers (Beedars). The head of the village (Sheikh) assigns the Wakeel to his job based on a recommendation from the Falaj-owners. Selling water shares for one water rotation or one year is carried in an open auction (Majzoub et al., 2010a).

The Wakeel is in charge of the overall administration of the Falaj (e.g., water distribution, water rent, expenditure or Falaj budget, solving water disputes between farmers, emergencies, and other decision-making activities). In case of conflicts, either the Wakeel

#### BOX 1: WHY THE FALAJ SYSTEM WORKED SO WELL?

- Water is considered as a source of life within Omani society, and Aflaj play a major role to sustain life. Therefore, respecting the Falaj organization is a necessity to maintain and guard the main source of life.
- The Falaj system is managed and maintained by local communities through a time-honored administrative system embedded in a social structure derived from interdependence and communal values. With the advent of Islam, this hydro-political system became a social contract deeply rooted in religious principles.
- The system is based on the dominant sacrosanct religious obligation; honor for ancestral traditions; tribal loyalty; and basic human respect, person to person, family to family, and family to community.



### BOX 2: WHAT ARE THE MAIN FEATURES OF THE WATER COURT?

- **Simplicity:** the Warden or injured party and the accused can put forward their case before the Official and bring evidence and witnesses with no complicated protocols and legal formulae.
- **Verbal:** all phases of the trial, including case submission, enquiries (made to clear up, explain, or justify the facts with the intervention of the President and officials who verbally question the parties), and sentencing are oral.
- **Speedy:** the court meets weekly and addresses infringements committed since the previous Thursday. Matters can only be postponed for at most 21 days, and only due to failure to appear by the accused.
- **Economic:** the trial does not involve any type of procedural costs. Officials do not receive any salary or expenses. The accused has to pay traveling expenses of the Warden or Court plaintiff. Compensatory damages are not procedural expenses

(Majzoub, 2005).

or the owners can lodge a complaint with the Sheikh. If the Sheikh cannot solve the problem, the matter is raised to the governor (Walee) who transfers the matter to ordinary courts applying Islamic law. One of the Areefs arranges the schedule of the Dawran (water rotation) among farmers or water shareholders. The Qabidh's job is to control the Falaj income (water shares, land, and/or crops). As the "Falaj book holder", the Qabidh organizes water shareholders sale auctions with the assistance of an auctioneer (Dallal) employed by him. The Beedar's duties consist of channel and tunnel cleaning, repair of minor collapses of rooting stones or walls. Generally, water rents provide most of the Falaj income. Those revenues are deployed to operate, clean, maintain, and upgrade the system, as well as to deal with emergencies like flooding or drought (Majzoub, 2005).

The government of Oman regularly takes steps to maintain and preserve the Aflaj systems in the country. The most recent law on conservation of water resources was promulgated by Royal Decree No. 29/2000 (15/04/2000), which abrogated Royal Decree No. 82/88. Five months later, a by-law, or a ministerial order, was issued to organize wells and Aflaj. Chapter 5 of the by-law regulates granting Aflaj permits (articles 29 and 30). This case study illustrates how formal legal arrangements interact with customary arrangements to manage water resources in Oman (Majzoub et al., 2010a). Box 1 summarizes why Aflaj have survived for a long time.

### **b. Case study 2: The Andalusian Water Court**

The "Tribunal de las Aguas de la Vega de Valencia", better known by its shorter name of "Tribunal de las Aguas" (Water Court), is without any doubt the most ancient European institution of justice. We owe the organization of this water institution to the Cordoba Caliphate (Abd El-Rahman III and Al-Hakem II). This Court was in charge of preserving peace among farmers and ensuring fair water distribution (Majzoub et al., 2010a).

The Water Court revolves around the river Turia and its eight main canals, five on the right bank, and three on the left.

For Turia water distribution, a simple and efficient formula is applied: all farmers irrigating from a channel are the common owners of the water provided; water is granted in proportion to the land owned. The aggregate of all irrigated land, from the main canal via a system of smaller channels, form what is known as an Association of Irrigators. In times of little flow, a variable volumetric unit was invented, called “fila” which enabled a wise distribution (Majzoub, 2005).

The Canal Associations are governed by ancient Ordinances. Strict observance of the rules is supervised by an Administration Board, which is renewed every 2 or 3 years. The head of this Board, called the Official, is elected by all members of the Irrigators’ Association, and must directly farm his own plot(s), of a size that must be large enough to make him earn a living. The Official must also have a good reputation as an ‘honest man’.

The Court is made up of the eight canal officials. Cases are filed because of any number of the following transgressions: water theft in times of scarcity, breakage of channels or walls, pouring too much water into neighboring fields, altering of irrigation turns, keeping irrigation ditches dirty, or irrigating without asking for a turn. The accused is summoned by the Channel Warden on the following Thursday. If he does not appear, he is summoned two more times. If he fails to appear, the accusation is validated and he is sentenced. In order to guarantee maximum impartiality, the Official for the canal to which the party belongs does not get involved in the case. As a matter of a rule, if an accused belongs to a canal on the right bank of the river, the sentence is rendered by the Officials from the left bank, and vice versa. No appeals can be made, and sentence execution is secured by the Channel Official (Majzoub, 2005).

This Andalusian institution has survived centuries of political turmoil, and improvements were introduced over time. The main features of the Water Court are explained in Box 2.

Behind the Andalusian Water Court features lays a model of justice the Valencians have always respected. It has never been necessary to resort to ordinary Spanish courts to have court

sentences implemented. This is another example of how customary arrangements can act in concert with prevailing Spanish legislation. This Spanish customary Water Court gave birth to “statutory” Water Courts in several developed countries (Majzoub et al., 2010a).

### **c. What can we learn from the above case studies?**

Both case studies focused on the complementarities between statutory and customary arrangements in the processes of water resources development, addressing water management problems and resolving conflicts. They are by no means offered as a toolkit or as ready-made answers for all cases in the Arab region, but rather as a suggestion that it is always useful to acknowledge other experiences. However, states can somehow benefit from this “living” customary arrangements crafted by tradition.

The Dutch “waterschappen” is an example of customary arrangement for water management that has become, de facto, legislation. This Dutch example may illustrate that some governments cannot do away with ongoing social processes affecting the best devised water legislation. Even determined policymakers and powerful legislators cannot ignore the power of customary arrangements.

But can every customary water arrangement be incorporated into IWARM related legislation? Multiple forms of oral/unwritten customary arrangements co-exist and sometimes may conflict with recognized standards of human rights (individual rights vs. community rights), legislation or laws. Mistakes or failures are tolerated if statutory arrangements are used, but mistakes or failures are prohibited in the case of customary arrangements.

In addition to those broad ideas, probable political manipulation of customary arrangements could lead to some ‘undesired’ consequences, such as political unrest by legally recognized minorities. Nevertheless, marginalized communities are often the least well served by statutory arrangement.

The next section explores the concept of water

users associations (WUA) and puts it in the framework of customary practices.

### III. REACTIVATION OF WATER USERS ASSOCIATION

Until recently, water management in the Arab region was highly centralized and for the most part managed at the national level with little local stakeholder and civil society participation. Today, local community stakeholders and user associations are established in Egypt, Jordan, Libya, Morocco, Oman, Tunisia, and Yemen.

A water users association (WUA) is a non-profit organization that is initiated and managed by the group of water users along one or more hydrological sub-systems regardless of the type of farms involved (FAO, 2003). By water

users we mean the ordinary cultivators of land, individual members of lease-holding farms, and owners of home garden plots among others. The supply of water and payment of fees to the water service provider is based on contracts and/or agreements between the WUA and the irrigation service provider, where rights and obligations of both parties to the contract, time of delivery, and agreed-on volumes are specified.

The Arab region's fresh experience shows that some of the water users associations (WUAs) have been established through a bottom-up consultative approach, where authorities have conferred with ordinary water users. In these cases, water users took the initiative to kick off the process of establishing WUAs. In many cases, such WUAs have succeeded in recovering the costs of water and of operating and maintaining the irrigation and drainage facilities. Cost

#### BOX 3: THE ROLE OF WATER USER ASSOCIATIONS IN REFORMING IRRIGATION IN EGYPT

Extracted with adaptation from GWP Tool Box – Case study No. 110

##### Description

Egypt's water resources are severely constrained. This calls for increasing water use efficiency by improving irrigation management practices, as the agriculture sector is the primary user of water. Much of the irrigation infrastructure is old and in need of rehabilitation. The irrigation improvement program (IIP) is one of the large-scale projects to help Egypt sustain its ambitious development plan. The program involves a combination of technical changes and infrastructure investment, together with institutional and organizational changes in irrigation water management. A key component of the program is the major role of Water Users Associations in decision-making and in the operation and maintenance of the pumps and mesqas (irrigation ditches), with minimal assistance from Irrigation Advisory Service (IAS) staff. The fundamental change introduced by the IIP is to replace individual farmer pumping at multiple points along the mesqa by collective single point pumping. In addition, intensive training seminars and workshops are held for water users, IAS staff, and other involved personnel from all levels to help implementation of the program.

##### Lessons learned

The new program has benefited from the experience of earlier irrigation programs; there is a body of knowledge that has been tested and piloted which

provides underlying foundation to the new reforms.

In order to increase the efficiency as well as the performance of the system, users' participation in resource management is a must because users' decisions and ideas have a great impact on the operators and the modernization process of the system. Self-governance would assure the sustainability of the system. Increased crop production and attaining real water savings in the system is dependent on the awareness and understanding of users, operators, and managers of the system.

Enhancing the capacity of all these stakeholders requires intensive training. Today in Egypt a new generation of water farmers, operators, and managers have embraced the concept of users' participation in water management, and the Ministry of Water Resources and Irrigation has legalized the formation of Water User Associations.

##### Importance of case for IWRM

The case study demonstrates the importance of building appropriate institutional structures in parallel with the introduction of technical changes and sets the irrigation reforms in a broader policy context, e.g., general agricultural and economic liberalization. The case also illustrates the importance of testing and piloting programs over several years as a basis for strong institutional structures (GWP, 2008a).

#### **BOX 4: COMMUNITY MANAGEMENT OF WATER RESOURCES IN THE IMLIL VALLEY NEAR MARRAKECH, MOROCCO**

Extracted with adaptation from GWP Tool Box - Case study No. 77

##### **Description**

Amidst water shortages, seasonal fluctuations, and remote water point locations, five communities in the Imlil Valley came together to improve the availability and regularity of water supply with the support of Amrash, a Moroccan non-governmental organization. The project called for elaboration of a water code, drawing on the Jmaa`a tradition of community-based water organization. The new code defined conditions of access to and use of water. It also defined priorities of water users, lists of water committee members, rights and responsibilities, and fines. Consultation helped resolve conflicts over the location and type of water supply systems between private and collective lands, and over the type of organization that should be in charge of water management. Training was provided to local associations, which contributed to generating knowledge and acquiring technical, legal, health, and communication skills. As a result of payments, local associations were able to provide credit facilities to villagers.

##### **Problems encountered:**

Increasing demand for water due to improved availability has created stress on water resources during the dry season;

Women were insufficiently involved in decision making;

Improved supply of water was not linked to management of wastewater, causing public health problems (e.g.,

diseases);

Because of the migration of people from higher mountains to the valley, there is a larger population to be served with water resources;

Some conflicts arose when a foreign NGO overcame the Jmaa`a system and installed a water point in the house of the president of the association. Amrash did not have enough experience on integrated water management.

##### **Lessons learned:**

The case demonstrates the importance of setting up clear regulations at the outset (water codes) and building on existing institutions such as Jmaa`a, mutual aid, and solidarity mechanisms;

The case reveals the importance of looking at water resource management from a river basin perspective and not on a village base, and to link water supply with the management of wastewater;

Gender issues were not dealt with early in the process, because of resistance from elders and conservative segments of villages, which meant that women were little involved.

##### **Importance of case for IWRM**

The experience highlights the need to plan for increased water consumption when water supply is improved, and to set localized reforms in a wider socio-economic context (GWP, 2008b).

recovery was possible because ordinary grassroots water users do feel ownership and tend not to avoid fee payment.

There are still significant hurdles to overcome in the implementation of WUAs in the Arab region (World Bank, 2009). Taking regional challenges into account, water user associations can be revived in the Arab region by taking the following 9 steps:

- Recreating awareness about WUAs, and its benefits, role, organization, and functions;
- Identifying essential components of irrigation and drainage service plan;
- Consulting the water users on appropriate institutional arrangements (structure and organs of WUA, membership criteria,

tenure of representatives, election procedure, rules and by-laws), characteristics of the elected representatives, and representation along each watercourse for forming the representative assembly;

- Selecting a WUA council, WUA chairperson, and dispute settlement and revision commissions' members;
- Preparing the founding documents (charter, by-laws, various maps, service area);
- Adopting the normative charter, by-laws (cropping plans, water demand, water allocation, maintenance of the system, membership fee, eligibility for membership, termination of membership or from office, duties and functions of different office bearers, meeting time and procedures, fund raising, dispute settlement mechanisms,

- sanctions), and other relevant documents;
- Capacity building and training for managers;
- Developing indicators and benchmarking to measure progress in participatory management; and
- Transferring system management to the WUAs.

Two case studies are presented (GWP Tool Box-Case Studies). First, we showcase the role of water users' associations in reforming irrigation in Egypt (Box 3). Second, the community management of water resources in Morocco is described (Box 4).

The following case study describes community management of water resources in the Imlil Valley of Morocco.

Arab regional experience suggests that if WUAs are established using a top-down approach, they would be weak and would have a high risk of failure. WUAs should rather be established through a bottom-up approach. To revive water user associations in Arab countries, it is strongly suggested to work with farmers and water users

at the ordinary grassroots level in order to give them a stake in ownership, benefits, and success. By joining a WUA, water users may enjoy equitable water distribution, more reliable water supply responsive to crop needs, quick dispute settlement at the local level, well-maintained canals, and reduced water theft. The challenge for water legal drafting in the region lies in aligning customary arrangements and practices with the realities of integrated water resources management (IWRM).

#### IV. WATER LEGISLATION

Water scarcity has compelled most Arab states to focus attention on the need to implement measures to improve management of water resources, and formulate effective institutional arrangements and legal instruments (Majzoub et al., 2010b).

A number of problems and constraints characterize the performance of the water sector in most Arab states and threaten the sustainability of water resources in the near future. Some of the legal and institutional water constraints are hereby noted:

- Water responsibilities are scattered among many ministries, water authorities, committees, and entities, which has contributed to poor coordination, mismanagement, duplication of efforts, and inefficiencies in water distribution and use. Moreover, control of water pumping and extraction is either absent or very limited;
- Enforcement of water regulations is limited due to acquired water rights, political attitudes (such as confessionalism, tribalism, or nepotism), and the inflexibility and resistance of most farmers;
- Lack of accurate data and information about water resources, quantities, and quality; and
- Inadequate qualified technicians and maintenance personnel, the lack of funds to train staff, and political interference in staff recruitment, have all left their negative mark on the overall quality of manpower in the water sector.
- Sound water legislation (Box 5) is needed in most Arab States for several reasons:

#### BOX 5: WHAT IS WATER LAW? WHAT IS WATER LEGISLATION?

“Water law is made up of all the provisions which one way or another govern the various aspects of water management, i.e. water conservation, use and administration, the control of the harmful effects of water, water pollution and so on.” Water law can be derived from the constitutional, administrative, civil, criminal, agricultural, mining, natural resources/environmental/public health legislation of a country, in addition to judicial precedents and scholarly opinions.

Until recently, there was no well-defined legislation passed in any Arab state by a law-making body (Parliament) called water legislation. Different water related legislation have been drawn up over time to deal with different water purposes. None of these was strictly about water.

The policy makers' challenge is to find a way to integrate the different water related legislation and to develop a coherent water policy that is conducive to effective national water legislation. In the last few decades, IWRM has become a central feature of any water legislation.

*(Adapted from Caponera, 1992)*

TABLE 1 WATER LEGISLATION IN SELECTED ARAB STATES

	Legislative status		Ownership	Use	Institutions
	Past	Present			
<b>Jordan</b>	Vestiges of Majalla and a few laws, 1937-1988	Fragmented, most recent laws are Nos. 18 and 19 of 1988	State property (explicit)	Regulation by permit for both surface water and groundwater	Single, Ministry of Water and Irrigation, with two water authorities, 1988
<b>Lebanon</b>	Vestiges of Majalla and French code and a few laws and decrees, 1925-1985	Fragmented, but there are plans for a comprehensive law	Public domain (implicit)	Regulation by permit and old irrigation code	Ministry of Hydraulic and Electric Resources; a few other ministries and many regional commissions
<b>Oman</b>	Sharia, customary practices, and well and aflaj registration laws, 1975-1988	Fragmented regulatory decrees for wells and aflaj, 1995	State property (explicit)	Extensive regulation by permit for development of groundwater and aflaj	Single, Ministry of Water Resources, 1989
<b>Saudi Arabia</b>	Sharia and customary laws, water conservation regulations and many decrees, 1932-1988	Planning for a comprehensive law	State property (implicit)	Regulation by permit, mainly groundwater	Single, Ministry of Water and Electricity (formed in 2002 and consolidated all water-related agencies: Saline Water Corporation, wastewater, etc.)
<b>Syrian Arab Republic</b>	Vestiges of Majalla code, sharia, and many decrees and laws, 1925-1995	Comprehensive water law under preparation	Public domain (implicit)	Elaborate permit system; regulation for both surface water and groundwater sources	Ministries, mainly of irrigation (1982) but also of housing, agriculture, public work and water resources
<b>United Arab Emirates</b>	Sharia, customary laws and a number of decrees, 1980-1994	Comprehensive water law drafted in 1995	Public domain (implicit)	Limited regulation by permit system for groundwater	Ministries, including agriculture and fisheries, electricity and water, and municipalities and the Higher Water Council, 1981

Source: ESCWA, 1997

- To establish a mechanism to control/regulate access to and abstractions from water resources;
- To promote water use efficiency (allocative priorities, incentives);
- To promote appropriate economic instruments and principles (e.g., water charges, cost recovery);
- To enable metering of abstractions;
- To enable pollution control and environmental impact assessment (EIA) enforcement;
- To set institutional arrangement for planning and coordination mechanisms (institution building, guiding principles such as demand management);
- To establish protected areas around water resources;
- To provide for control and planning of land use; and
- To set fines and penalties for violations which cause damages to water resources.

Many laws have been enacted by Arab states addressing specific concerns, but the coverage of most of their respective mandates tends to be

## THE SOCIAL AND ECONOMIC VALUE OF WATER: THE CASE OF THE WEST BANK

**Annette T. Huber-Lee**

Water in a situation of competition or dispute is typically understood as a zero sum game. What one party gains, the other one loses. This represents a limited view of the role water plays in both society and ecosystems. Water has value that is dependent on the quantity available. The first liter of water for drinking is nearly priceless to an individual. But in the other extreme, during a flood, water has no value and in fact imposes a cost to that same individual.

Looking at the scale of a country, if it has a seacoast, the possibility of seawater desalination puts a ceiling on the value of water. And that ceiling can be surprisingly low – so low that, with rational thinking, the assertion that the next war will be about water is a myth. But the important lesson here is not that desalination is an answer to water disputes, it is that water is not beyond price and that thinking about water in terms of its value rather than in terms of quantities and ownership leads to powerful results. Together with colleagues, we have developed models on that basis: the first, called “WAS” for “Water Allocation System” was developed in the late 1990s for Jordan and Palestine; the improved version, “MYWAS”, for “Multi-Year Water Allocation System” is now in development and use by the Palestinian Water Authority. In both versions, water is treated as a special commodity with the user enabled to impose constraints reflecting social values that are not just private ones.

MYWAS takes a list of possible infrastructure projects and alternative hydrological conditions and returns advice on which ones should be built, at what time, in what order, and to what capacity. It also can be used to guide aquifer management and to study the effects of climatic uncertainty and climate change.

Beyond this, the models lead to a plan for cooperation in water – a plan in which all parties benefit, which could in theory take the form of buying and selling short-term permits to use each others’ water. Water disputes thus become win-win situations rather than zero-sum games. Further, while use of this system does not affect any party’s ability to assert claims to water rights and water ownership, we show that participation need not wait for such claims to be settled. Water is a soluble problem.

An early application has been created for Southern West Bank in Palestine, including Bethlehem, Hebron, and Jericho. A number of scenarios were developed to try to find ways to ease the current water crisis. Water is so constrained now – with per capita water use rates four times lower than that recommended by the World Health Organization – that the value of an additional cubic meter of water is more than 20 US\$ per cubic meter.

The Palestinian Water Authority is in the process of evaluating several infrastructure options to alleviate the crisis, particularly in Hebron and Bethlehem. One option involves putting in new wells near the Dead Sea where there is brackish groundwater, desalinating that water and pumping it up several hundred meters to a small holding reservoir to then supply Hebron and Bethlehem. This option is relatively expensive, but given the overall shortage and value of water, proves to bring benefits over and above the capital costs on the order of hundreds of millions of dollars.

As is well known, increased Palestinian access to water in the Mountain Aquifer and the Jordan River is one of the items on the agenda for final status negotiations. A much more cost effective way to increase water supply to Hebron and Bethlehem is to allow access to the Aquifer – with much lower capital (saving tens of millions of dollars) and operating and maintenance costs (saving \$0.50 to \$1 per cubic meter).

An awareness of the economic and social tradeoffs of different infrastructure and changes in access to water is key to informing any decision-making and negotiations. Looking at water from the perspective of its value increases the resilience of the system by allowing for more flexibility in allocation to higher value uses – using economics that is informed by social values. These values can range from prioritizing allocation to those who are poorest in society, to valuing water for agriculture or ecosystems. The key point is to see that it is not just the quantity of water one owns, but the social and economic value that can be derived from water. This way of thinking increases society’s ability to resolve disputes under changing climate and social conditions.

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limited as illustrated in Table 1. In most Arab states, there is either only minimal legislation dealing with water resources, or overlapping laws that are outdated and do not satisfy current requirements. Therefore, the preparation and proclamation of rational and up-to-date water legislation are the most important measures to be taken by decision makers in most Arab countries.

Several states in the Arab region have begun to realize the importance of sound water legislation and have consequently taken steps either to update and modernize existing laws or to introduce new legislation and laws and strengthen institutional arrangements. Egypt, Jordan, Morocco, Oman, Palestinian National Authority (PNA), and Yemen have made an effort to revise or modernize existing water laws during the last 15 years. In fact, “Morocco and Yemen have been two of the first countries [in the Arab region] to put in force a framework water law that reflects modern water principles and attempts to address the country-specific issues faced in these countries ... Of the two countries with framework laws, Morocco’s is the most complete” (World Bank, 2009).

In Arab countries, water use sectors in general are facing dramatic changes as the management focus shifts from sectoral approaches towards more integrated, inter-sectoral management principles. This has far-reaching consequences for how the sectors are being organized and

for managing implementation frameworks. Thus, IWRM will not take place if the legal framework is not adapted and the necessary institutional arrangements are not made. The enabling conditions for creating a strong IWRM framework are:

- Enabling institutional framework, including the legal roles and responsibilities of institutions and their inter-relationship;
  - Mechanisms to strengthen the role of women and other stakeholders to participate in water management;
  - Conflict resolution mechanisms;
  - Water services and associated rights and responsibilities (right to water, standards of service);
  - Tariff and water pricing systems, including principles of fairness, affordability, and protection of the poorest; and
  - Clear mechanisms for water markets to minimize conflicts and risk of social unrest.
- (Adapted from García-Pachón, 2005)

#### **a. Water policy translated into legislation**

A national water policy must exist with clear government objectives pertaining to IWRM. Water legislation will naturally take different positions on a number of water topics: water rights, water privatization or concession, public or private water use, among others (Box 6).

**BOX 6: CATALOGUE OF WATER OWNERSHIP**

Over the last two thousand years, six different water related legal systems (water law families) have developed: Roman, Islamic, Communist, Hindu, Civil, and Common laws.

Common law entrusts the ownership of water to the community. Private water includes rain and groundwater. In Roman law, water resources were of three kinds: water common to everybody, community, and municipal water. Civil law legal systems were influenced by Roman law. In Shari'a, running water was considered to be a common entitlement. People had two water rights: the right of thirst and the right of irrigation. In Communist law, water was owned by the State, except for very limited types of water. In Hindu/Buddhist law, private ownership of water could not exist.

The diffusion of these legal systems is encountered all over the world. However, there is still an ambiguity between the rights of the people and state ownership of water. Increasingly, water is becoming public property; individuals can only claim user rights (separating land ownership and water use). (Adapted from Gupta and Leendertse, 2005)

In order to frame such a water policy, a country must have a rough assessment of its water resources, present and future requirements, the extent of historical or acquired water rights.

A well-conceived water policy facilitates the implementation of water legislation and allows for necessary adaptation to unforeseen phenomena. The Arab region will face not only increasing temperatures but, more importantly, also disruption of the hydrological cycle, resulting in less or more erratic rainfall that will aggravate even further the already critical state of water scarcity and difficulties with water allocation among different development activities (AFED, 2009).

Good water policy incorporates scientific knowledge about nature and adapts to experience. Neither science nor water policy can deliver certainty in the age of climate change. The characteristics of water (surface or underground) is so diverse and uncertain that we cannot subject it to stringent legal provisions, nor build upon it a system of permanent rules, as is done in the case of normal conditions. As natural phenomena change, so does flexible water legislation and water rights allocation to

reflect changing realities (Majzoub, 2005).

If the stated goal of water policy is the application of integrated water resources management (IWRM) principles, this policy may not have considerable effect if it is not translated into sound legislation or strengthened by a robust institutional support. In a nutshell, effective water resources management must take into consideration the three major components of water resources management: policy, law, and institutions (Box 7).

Legislation ought to emphasize the principles or elements in support of IWRM such as polluter pays principle, equity, social justice, allocation, economic efficiency, financial feasibility, licensing, as well as the river basin management approach.

The appropriate institutional structure for a river management approach must answer a set of questions: how should the policy be developed by the river basin organization (commission, council, committee), implemented, and coordinated? Who does what for whom, and to whom are they accountable?

**b. Components of national water legislation**

Water legislation ought to be simple and drafted in broad terms. Though such legislation needs not to be immutable, it must be lasting and serve as a basis for government intervention (through by-laws, decrees, and administrative acts).

National water legislation has to define the core issues starting with definition of general provisions taking into account the use terms (*Omnis definitio in jure periculosa est* – Every definition in law is dangerous), and enforcement of the water legislation/Act. Ownership of water resources ought to be clarified and environmental considerations must be tackled (e.g. minimum flow). Institutional arrangements such as river basin committees, councils, commissions, and catchment management agencies need to be addressed. These arrangements should incorporate powers, mandates, and responsibilities as well as rights, obligations, and roles of stakeholders (e.g. water users associations, gender roles). Regulatory

approach, prioritization of water allocation, determination of framework for dispute resolution, and well-defined water infractions as well as transitional and final provisions should be made (Majzoub et al., 2010b). Components of a national water legislation are described in Box 8.

The water legislation should impart the proper guidance and provide a framework to be subsequently developed by means of by-laws/ decrees/administrative acts that can be modified and adapted to changing circumstances.

The gathered experience teaches the following lessons:

- Comparison of water legislation and national experiences of selected Arab and non-Arab states has to be conducted before and during the drafting process;
- Inclination to use terminology which has been tested in previous controversies, and the desire to avoid uncertainty when more than one water related law may be involved;
- Water legislation should be socially acceptable and administratively feasible;
- Water legislation needs to strike a balance between completeness and flexibility;
- Relationship between land and water (quantity and quality) ought to be reflected in water legislation;
- Existing water rights ought to be smoothly revisited and transitional provisions made; and
- National water legislation has to take into account International Conventions.

## V. CONCLUSION

Despite huge investments in water supply and sanitation sectors in the Arab region, overall immediate results have been unsatisfactory, whether in qualitative or quantitative terms. Full benefits from these investments have not been sustainable because the underlying institutional and legislative foundations have been lacking or ineffective.

In most Arab states, legislation is often unresponsive to the demands for stakeholders and civil society participation. Moreover, water management is usually in the hands of institutions implementing a top-down approach, which has increasingly been questioned for its lack of legitimacy and effectiveness.

This chapter has suggested that some Arab states are updating existing water laws or formulating new water legislation in order to strengthen their water institutions. However, the substance and scope of these water laws/legislation may fall short of what is needed for the implementation of an integrated approach, and for the application of optimal development and management of water resources.

Water legislation is multi-layered reflecting different national dynamics and priorities as well as customary and statutory arrangements. However, several Arab states have focused on the use of statutory arrangements, although some of them have relied upon diverse customary arrangements for getting access to and utilizing water resources. It has been suggested that few activities can be regulated by statutory arrangements alone, and

### BOX 7: THREE MAIN COMPONENTS OF AN EFFECTIVE WATER RESOURCES MANAGEMENT

Issue:	Policy	Law	Institutions
Water resources management	IWRM	Water legislation/Act	<ul style="list-style-type: none"> <li>- Centralized water management system</li> <li>- Decentralized water management system</li> <li>- De-concentrated water management system</li> <li>- National/Higher Water Council</li> <li>- River Basin Committees/Councils/ Commissions</li> <li>- Water/River Basin Agencies</li> </ul>

**BOX 8: SUGGESTED CORE ISSUES IN A NATIONAL WATER LEGISLATION/ACT**

*Introduction (Statement of motives, with a brief summary of the underlying water policy principles and priorities)*

## Part I: GENERAL PROVISIONS

- (a) Definition of general terms used in the Act
- (b) Authorities responsible for enforcement of the Act

## Part II: OWNERSHIP OF WATER RESOURCES/CLASSIFICATION OF WATER

- (a) Surface water (such as wadis)
- (b) Groundwater

## Part III: CONSERVATION AND PROTECTION OF WATER RESOURCES

- (a) Flood control
- (b) Ecosystem protection and environmental sustainability

## Part IV: MANAGEMENT OF WATER RESOURCES

- (a) Institutional arrangements (river basin management, catchment management agencies)
- (b) Powers, mandates, and responsibilities
- (c) Rights, obligations, and roles of the stakeholders (water users associations, gender role)

## Part V: REGULATION OF WATER SERVICES

- (a) Water pricing
- (b) Public-private partnerships (PPP), concessions, and privatization

## Part VI: WATER ALLOCATION

- (a) Domestic water and right to water
- (b) Agricultural, aquaculture, coastal management, and industrial water
- (c) Water permits, licenses, and authorizations
- (d) Dam control
- (e) Water trade/allocation/transfer

## Part VII: DISPUTE SETTLEMENT

- (a) Courts and tribunals
- (b) Arbitration and alternative disputes resolution (ADR) techniques

## Part VIII: INFRACTIONS TO WATER RESOURCES AND SANCTIONS

- (a) Police powers of water services officers
- (b) Procedures
- (c) Penalties

## Part IX: TRANSITIONAL AND FINAL PROVISIONS

- (a) Existing water rights and entitlements of indigenous communities
- (b) International cooperation on shared watercourses (rivers)

*(Majzoub et al., 2010b)*

neglect of some customary arrangements may cause water legislation and/or water legal reforms implementation to fail.

**VI. RECOMMENDATIONS**

The role of water legislation is essential for enabling the implementation of water policies and strategies. Water legislation provides the legal frameworks for water governance, institutional reform, regulatory standards, management systems, and enforcement of regulations. The following recommendations are suggested to guide policy-makers in Arab countries introduce new water legislation and/or water legal reforms:

Preparation and proclamation of rational and up-to-date water legislation are the most important measures to be taken by decision makers in most Arab countries. A national water policy must

exist with clear government objectives pertaining to integrated water resources management (IWRM);

Institutional reforms need to be introduced through a participatory and consultative process, involving formal and informal arrangements, to develop understanding and ownership of the change process. Arab water managers are encouraged to rediscover and deepen their understanding of ancient water systems and institutions and benefit from the 'living' customary arrangements crafted by tradition, building on existing institutions such as Jmaa'a, mutual aid, and solidarity mechanisms;

Effective reforms require an appropriate legal framework to provide a sound basis for a more participatory form of bottom-up water governance involving water users and civil society institutions. Enhancing the capacity of

all stakeholders requires intensive training and public awareness campaigns;

Policy-makers in Arab states are urged to integrate the different water related laws into an overarching, holistic, and comprehensive legal instrument and to develop a coherent water policy that is conducive to effective national water legislation;

Care must be taken to build appropriate institutional structures in parallel with the introduction of technical changes to ensure their longevity; and

Water policy makers should conceive and set customized reforms within the wider socio-economic context.

A well-formulated legislation facilitates efficient water demand management, conserves its supply, and protects the environment. Yet, legislation has to be socially acceptable and administratively enforceable as well as sensitive to the prevailing political, technological, social, economic, institutional, and legal context in a given country. This is inherently true, for there is always a strong relationship between water and human activities.

To the degree that the Arab region's destiny is so tied up with water, we should be looking to our water past. Each country has yet to experience the influence of customary arrangements on its political culture and on the utilization of its water resources.

No civilization can create a sense of destiny without a sense of history. To an alarming degree, we have not called on one of our great resources, our water history, to help us build this new sense of destiny. There is an old adage: "There can be no destiny without a sense of History". Looking at the past is essential if we are to actively create promising water futures. Nevertheless, our debates are often mired in syndromes, which, unknowingly, cut us off from our celebrated water past.

We can be reactive or choose to be proactive. To do nothing is likely to be an invitation for a dysfunctional water management system. To be proactive carries awesome responsibilities and can be frightening, but we need to tap our rich water history of stakeholder participation.

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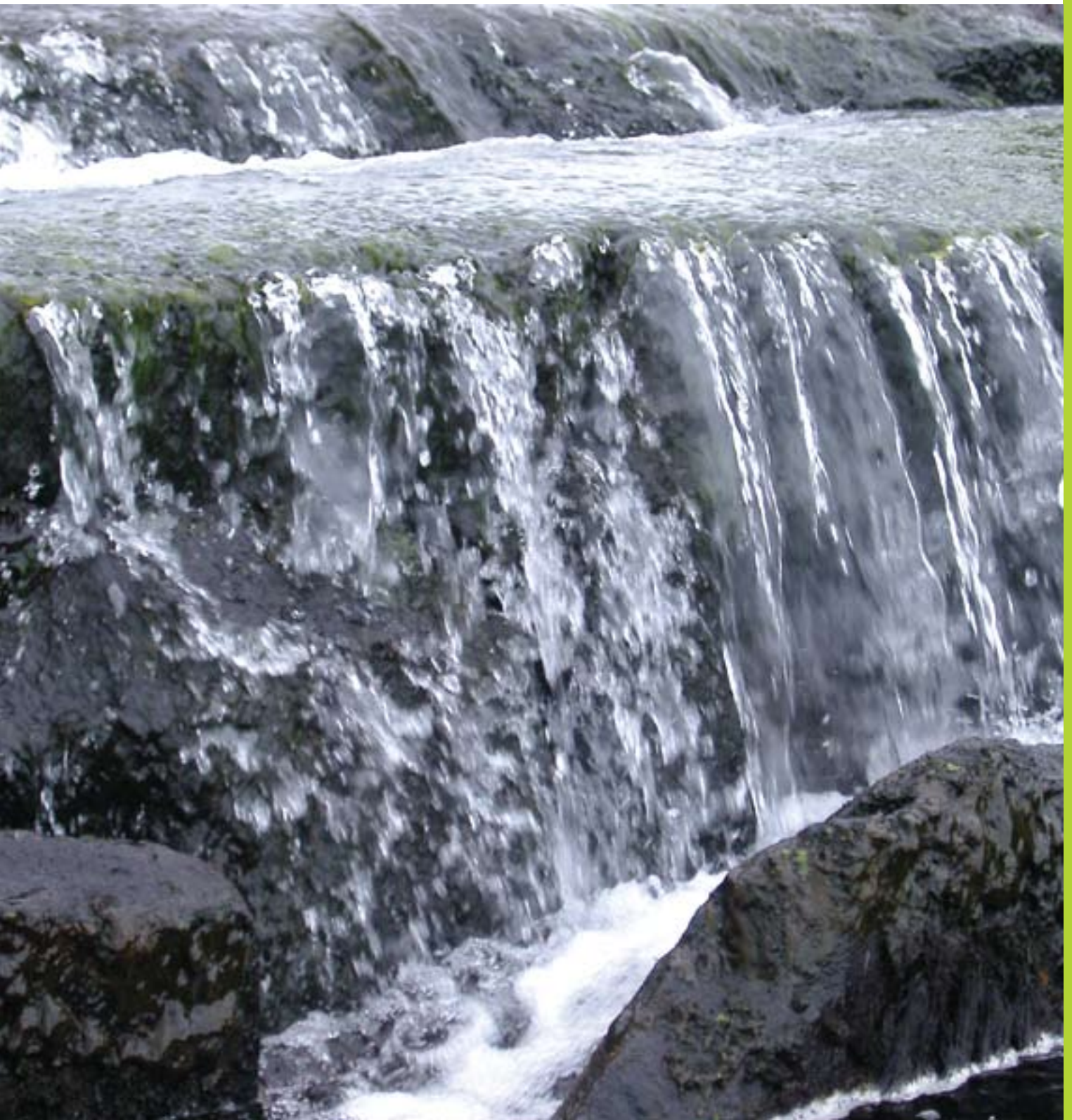
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# Trans-Boundary Water Resources

RAYA MARINA STEPHAN



## I. INTRODUCTION

The Arab region is one of the most water scarce regions in the world. Of all renewable water resources in the region, two thirds originate from sources outside the region (El-Quosy, 2009). Surface and underground water resources are shared among countries within the region and with countries from outside the region. Three rivers, namely, the Nile, the Tigris, and the Euphrates account for the majority of the region's surface water. All three rivers are shared amongst more than two riparian countries. Other shared surface waters include the Jordan River, the Nahr Al-Kabir, and the Orontes.

The Arab region relies also heavily on groundwater which is found in a number of shared' aquifers such as the basalt aquifer shared by Jordan and Syria, the Palaeogene aquifer shared by Oman and the United Arab Emirates, the Disi sandstone aquifer shared by Jordan and Saudi Arabia, and the Nubian Sandstone Aquifer System (NSAS) shared by Chad, Egypt, Libya, and Sudan. As with surface water, the major aquifers in the region are shared between two or more countries. In fact, the majority of territorially contiguous states in the Middle East and North Africa share both renewable or nonrenewable groundwater aquifers.

It is therefore recognized that most Arab states depend for their water supply on rivers and/or aquifers that are shared with neighboring countries. As shared surface water resources are becoming increasingly exhausted, in terms of quantity and/or quality, there is more and more reliance on shared groundwater resources, leading to their over-exploitation. A major challenge is thus confronting the region. Undisputedly, the sustainable management of a shared water body has to involve all riparian countries. Cooperation in managing shared water resources in a water scarce region is imperative in order to ensure resource preservation and its sustainable development. The region already experiences some cooperation modalities, some formalized by inter-state agreements, some less formally set up through technical committees, experts meetings, or joint projects. However, numerous shared water basins are still managed in a unilateral manner by the concerned states, without any cooperative effort. Even where cooperative modalities exist



in exchanging data and developing models and information systems, actual joint management of the shared water systems has not taken root yet. Therefore, much effort still needs to be exerted before the region's shared water resources can be beneficially used sustainably, equitably, and in accordance with the principles of international water law. This paper will give an overview of the current situation regarding shared waters in the Arab region, and will address pathways for creating sustainable cooperation agreements on shared waters.

## II. CURRENT SITUATION

Cooperation modalities over shared waters are not totally absent in the Arab region. On some basins (surface or groundwater) formal inter-state agreements exist, with a more or less developed cooperation.

### A. Existing agreements

Some 263 surface water basins in the world are shared between two or more countries, with numerous existing agreements on these basins. The number of transboundary aquifers identified worldwide as of today is around 270, although the exact number is not yet completely established (UNESCO, 2009). However, the number of treaties on such



aquifers is very limited. While there is only one comprehensive agreement on the management of a transboundary aquifer<sup>2</sup>, there are very few others and only with a more limited scope. Two are found in the Arab region.

### **1. Agreements on shared surface waters**

Lebanon and Syria have signed two agreements on their shared rivers. These are the agreements on the Orontes signed in 1994 and the one on the Nahr Al-Kabir Al Janoubi signed in 2002.

#### **a. The agreement on the Orontes**

The Orontes is a shared river making its source in Lebanon, flowing into Syria, and ending in Turkey. Lebanon and Syria have signed in 1994 the Accord Concerning the Distribution of the Orontes. The agreement does not involve Turkey. Negotiations between Syria and Turkey did not lead to any result. An annex was added to the Syrian-Lebanese agreement in 1997, which was ratified only in 2001 by the Syrian-Lebanese Higher Council. Under this agreement, a dam was built in Lebanon on the Orontes with a capacity of 37 million m<sup>3</sup> (ESCWA, 2006).

#### **b. The agreement on the Nahr Al-Kabir al Janoubi**

The Nahr Al-Kabir Al Janoubi forms Lebanon's northern border with the Syrian Arab Republic. The total river watershed area is about 990 km<sup>2</sup>, of which 295 km<sup>2</sup> lies in Lebanon (ESCWA, 2006). Discussions between Lebanon and Syria on sharing the waters of the Al-Kabir Al Janoubi river began as discussions on sharing the waters of the Orontes were progressing. An agreement was reached in 2002. The agreement draws on principles from the UN Convention on the Non-Navigational Uses of International Watercourses (May 21, 1997), which both Lebanon and Syria have ratified.<sup>3</sup> Its main provisions are based on the articles of this Convention. The focus of the agreement is the fair and optimal distribution of waters of the Nahr Al-Kabir Al Janoubi and it is based on the principle of realizing mutual benefit for the two sides. The agreement has also established a process of cooperation between the two countries through a joint committee to share information and results. Based on identified needs and requirements for both countries in all

sectors (potable, irrigation, and industrial), the construction of a joint dam<sup>4</sup> in the location of Idlin (Syria) – Noura al-Tahta (Lebanon) was decided, with a storage capacity of 70 million m<sup>3</sup>, according to technical and economic feasibility studies (ESCWA, 2006).

The agreement is considered to have established a good basis for cooperation between Lebanon and Syria. However, implementation of the agreement seems to have been held up due to financial, administrative, and political problems (ESCWA, 2006).

#### **c. Agreement on the Yarmouk**

The building of a dam, with a hydropower station, was also the purpose of the agreement between Jordan and Syria on the Yarmouk river, the main tributary of the Jordan river. A first agreement was signed in 1953, but it was not implemented and was updated and replaced by a second agreement in 1987. In the second agreement, Jordan and Syria agreed to “build the Unity Dam on the Yarmouk River with a height of 100 m and a storage capacity of 225 million m<sup>3</sup>. In 2003, the height of the dam was reduced to 87 m and the storage capacity became 110 million m<sup>3</sup>” (FAO, 2008). The dam was finally inaugurated in 2008. Because of the political conflict in the region, the case of the Yarmouk cannot be considered completely settled so far. The river is part of the Jordan River basin. It needs therefore to be integrated into an agreement governing the whole drainage basin.

### **2. Agreements on shared aquifers**

As mentioned earlier, the Arab region relies significantly on groundwater resources, which are found mostly in aquifer systems underlying the territories of two or more states. Some of these aquifers are large systems, such as the systems in the Arabian Peninsula. The North Western Sahara Aquifer System (NWSAS) and the Nubian Sandstone Aquifer system (NSAS) are even larger. The riparian states of the NWSAS and NSAS aquifer systems have entered into respective agreements among themselves on the joint management of these shared aquifer resources. These agreements are part of the very few agreements worldwide on a shared aquifer.

### a. Agreement on the Nubian Sandstone Aquifer System

The Nubian sandstone aquifer system (NSAS), extending over more than 2 million square kilometers, is one of the largest aquifer systems in the world and extends into eastern Libya, Egypt, northeastern Chad, and northern Sudan. Consisting of a number of aquifers that are horizontally and/or vertically connected, “the Nubian aquifer is a strategically crucial regional resource in this arid region, which has only few alternative freshwater resources, a low and irregular rainfall, and persistent drought and is subject to land degradation and desertification. Under current climatic conditions, the Nubian aquifer represents a finite, non-renewable groundwater resource” (Yamada, 2004).

In July 1992, Egypt and Libya signed an agreement on the ‘Constitution of the Joint Authority for the study and development of the Nubian Sandstone Aquifer Waters’, which both Chad and Sudan joined subsequently. “The Joint Authority is responsible for collecting and updating data, conducting studies, formulating plans and programs for water resources development and utilization, implementing common groundwater management policies, training technical personnel, rationing the aquifer water, and studying the environmental aspects of water resources development” (Yamada, 2004). However, the Joint Authority has not properly and completely fulfilled its mandate so far.

### b. Cooperation on the North Western Sahara Aquifer System

The North Western Sahara Aquifer System (NWSAS), as shown in Figure 1, is shared between Algeria, Libya, and Tunisia and covers an area of more than 1 million km<sup>2</sup> (700,000 km<sup>2</sup> in Algeria, 80,000 km<sup>2</sup> in Tunisia, and 250,000 km<sup>2</sup> in Libya) (OSS, 2008). The system represents the only perennial source of water for about 5 million inhabitants. Its total theoretical reserves are estimated at 60 million km<sup>3</sup>.

Scientific characterization studies of the NWSAS had started in the 1960s, and developed in 1980 mainly between Algeria and Tunisia. Libya joined later. Bilateral commissions were established such as the technical committee on water and environment between Algeria and

Tunisia (in the 1980s), the technical committee on water resources between Algeria and Libya (in the 1990s), and the sectoral commission between Tunisia and Libya on agriculture (in the 1990s) (OSS, 2008). In 1998, the three countries launched a joint project with a provision for the establishment of a concertation mechanism.

A first temporary mechanism among the three countries was set up in 2002. Its main task was the management of the database and the regular updating of the aquifer system model. This mechanism evolved towards a permanent structure in 2008. As illustrated in Figure 2, the mechanism is composed of:

- A Council of Ministers in charge of water resources in the three countries;
- A Steering Committee composed of the national institutions in charge of water resources in the three countries;
- National Committees including other institutions concerned with water resources, users associations, and non-governmental organizations (NGOs);
- National and regional working groups composed of engineers and technicians; and
- A coordination unit led by a coordinator at the Tunis-based Sahara and Sahel Observatory.<sup>5</sup>

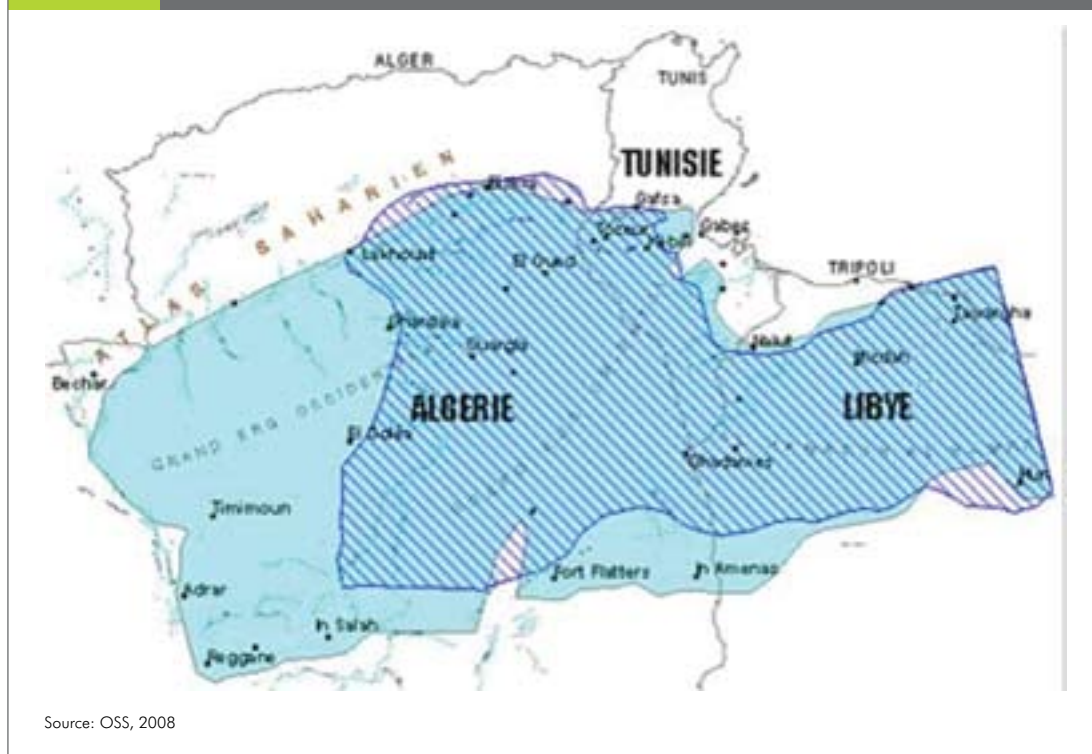
The role of the coordination mechanism is to offer a framework for exchange and cooperation among the three countries by:

- Measuring water resources indicators and water demand;
- Elaborating management scenarios for the development of the basin;
- Enforcing and updating the common database by the exchange of data and information; and
- Developing and managing common monitoring networks of the aquifer system.

### c. The Special Case of Shared Water in the Peace Process Agreements

The two agreements of concern here are the 1994 Treaty of Peace Between the State of Israel and the Hashemite Kingdom of Jordan and the 1995 Interim Agreement on the West Bank and the Gaza Strip or Oslo II. These two agreements

FIGURE 1 THE NORTH WESTERN SAHARA AQUIFER (NWSAS) FORMATION SYSTEM



Source: OSS, 2008

do contain provisions on shared water resources, strongly linked to a context of political conflict and exercise of power.

The agreement between Israel and Jordan includes an annex II on “Water related matters” covering the Yarmouk River, the Jordan River, and groundwater in Wadi Araba. The Jordan River is shared among five riparian countries: Israel, Jordan, Lebanon, Syria, and the Palestinian Territories. The agreement is between only two of these riparians, Israel and Jordan, not leading however to any joint management of the Jordan River. Rather the annex is concerned with the allocation of water between the two signatories. It is also worth adding that so far the right of access to the Palestinians to the Jordan River is not recognized.

Article 40 of Protocol III of the Oslo II agreement deals with water issues between Israel and the Palestinian Territories concerning, for example, use of the Mountain Aquifers. While it seems to recognize Palestinian water rights, the Oslo II agreement maintains the policy applied under the military occupation, legalizing Israeli control over the shared water resources.

It remains clear that in the absence of a political settlement of the conflict between Israel and its neighbors, control over shared water resources will continue to reflect the balance of power relations in the region, as these two agreements patently illustrate, and cooperative endeavors for joint management will continue to be blocked.

### **B. Other initiatives and attempts for cooperation**

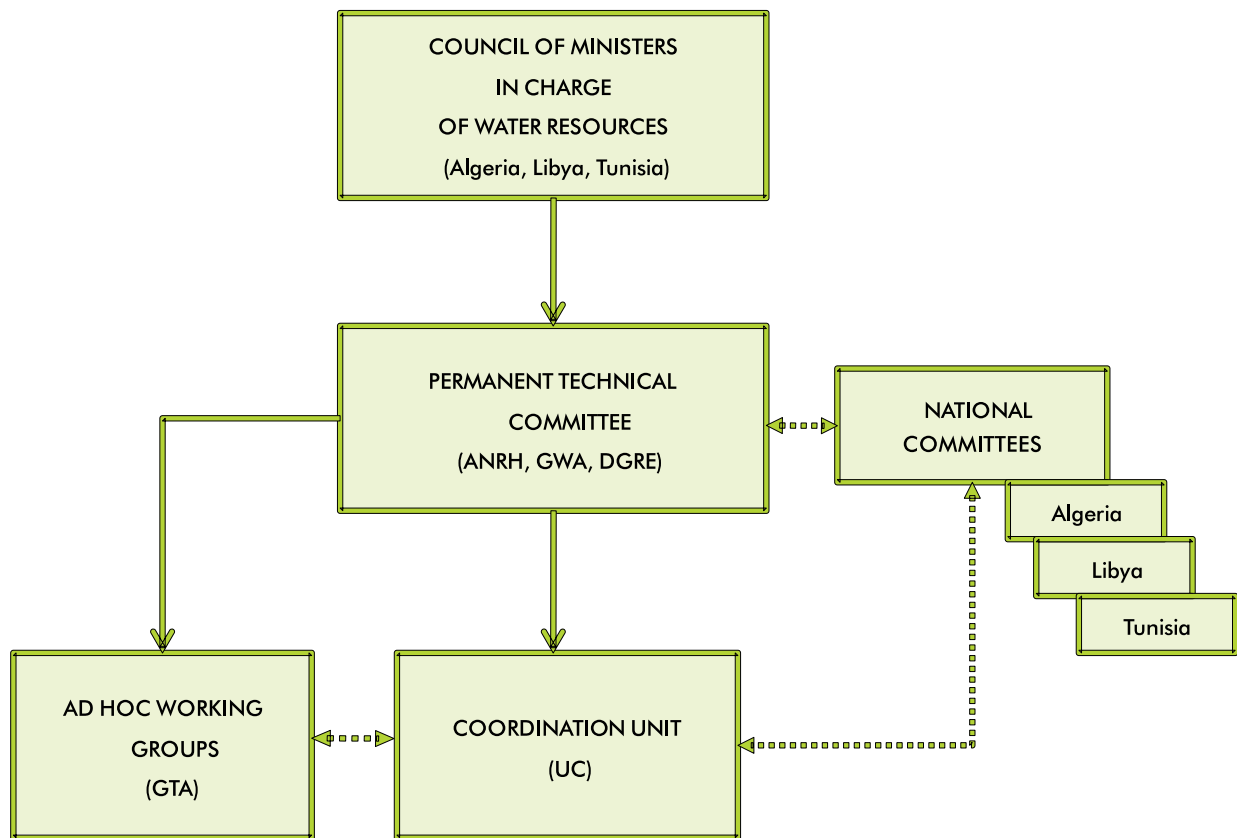
The aim of the first part of this overview was to describe the current situation of shared water resources in the Arab region and present cases where cooperation was formalized by an agreement. The next section will focus on basins where initiatives are undergoing in order to bring the riparian states to cooperate.

#### **a. The Euphrates and Tigris**

Although bilateral agreements, treaties of friendships, joint technical committee meetings, and protocols have existed for the cooperative management of the Tigris and Euphrates river basin, the three countries, Turkey, Syria, and Iraq, have failed so far to reach a far-reaching agreement or framework particularly “as

FIGURE 2

STRUCTURE OF THE PERMANENT CONSULTATION MECHANISM OF THE NWSAS



Structure of the permanent consultation mechanism of the SASS  
(Latrech, oral presentation, Tripoli 2008)

**Notes:**

ANRH = Agence Nationale des Ressources Hydrauliques (Algeria)  
GWA = General Water Authority (Libya)

DGRE = Direction générale des Ressources en Eau (Tunisia)  
GTA = Groupes de Travail ad hoc  
UC = Unité de Coordination

Source: Latrech, 2008

a result of conflict over the development of Turkey's Southeastern Anatolia Project and the filling of the Ataturk Dam" (ESCWA, 2009). The situation remains tense in this two-river basin as Turkey has pursued its unilateral GAP project. There is plenty of blame to go around, however. In fact, "the Euphrates is so choked by Turkish, Syrian, and Iraqi dams that the river-end residents of Basra must reach hundreds of kilometers back upstream for their supply" (Zeitoun, 2010).

### b. The Nile River

The Nile River, the longest river in the world, has two major tributaries: the Blue Nile and the White

Nile. The White Nile originates in Lake Victoria in east central Africa, and flows north through Uganda and into Sudan where it meets the Blue Nile, which rises in the Ethiopian highlands. The Blue Nile is the source of the majority (85%) of the Nile's River water. From the confluence of the White and the Blue Nile, the river continues to flow northwards into Egypt where it forms a delta before reaching the Mediterranean. Egypt gets 97 percent of its water from the Nile River. Sudan receives substantial amount from both the Blue Nile and the White Nile before they join near Khartoum.

The Nile Basin Initiative<sup>6</sup> (NBI), launched in

## THE NILE BASIN INITIATIVE

The Nile Basin Initiative (NBI) is a good model to learn about the benefits and risks of joint management of shared water resources. It is led by the council of ministers of water affairs of the ten countries sharing the Nile Basin<sup>7</sup>. The Initiative's strategic action program is guided by a shared vision to develop the basin through equitable utilization of the Nile Basin water resources. The Initiative includes a basin wide program for technical assistance, and sub basin investment programs to curb poverty, promote growth, and improve environmental management. The Nile Basin Initiative (NBI) was launched in 1999. It provided an agreed basin-wide framework to fight poverty and promote economic development in the region. A draft text of cooperative framework was produced in early 2000. The immediate objective is to attain a regional cooperative framework acceptable to all Basin countries to promote basin-wide cooperation in integrated water resources planning and management. The NBI is comprised of a council of ministers of water affairs of the Nile Basin (Nile-COM), a technical Advisory Committee (Nile-TAC), and a secretariat (Nile-SEC) located in Entebbe. The basin-wide shared vision program includes seven projects. Four of these are thematic in nature, addressing issues related to environmental management, power

trade, efficient water use in agriculture, and water resources planning and management. The remaining three are facilitative, supporting effort to strengthen confidence building and stakeholders' involvement, applied training, and socio-economic development and benefit-sharing. Two subsidiary action programs were developed: The Eastern Nile currently includes Egypt, Sudan, and Ethiopia; and the Nile Equatorial Lakes Region includes six countries in the southern portion of the basin as well as the downstream riparian Sudan and Egypt. These subsidiary groups have identified joint investment opportunities, which warrant further investigation and preparation. An international consortium for cooperation on the Nile has been established to support the NBI action program.

Recent meetings among the riparian countries have not produced tangible progress in three areas: protection of the historical share of the Nile water for the downstream countries, governance, and the decision making process where the parties did not agree on the proposed unanimous agreement for decision making especially in approving investment operations in the basin.

**Shawki Barghouti**

1999, has brought together the ten riparian countries of the Nile (Egypt, the Sudan, Burundi, Democratic Republic of Congo, Eritrea (observer), Ethiopia, Kenya, Rwanda, Tanzania, and Uganda). The objectives of the initiative are to develop the river in a cooperative manner, share substantial socioeconomic benefits, and promote regional peace and security. Under this initiative, a Cooperative Framework Agreement (CFA) was prepared. Despite the strong opposition of Egypt and Sudan, which claim historic rights on the Nile waters, the Agreement was opened for signature on May 14, 2010, for a period of one year during a ceremony held at Entebbe, Uganda. Five states have already signed it: Ethiopia, Kenya, Rwanda, Tanzania, and Uganda. Burundi and the Democratic republic of Congo are expected to sign the new agreement. The new Cooperative Framework Agreement is influenced by the UN Convention on the Law of Non-navigational Uses of International Watercourses. The CFA does not include any figures about water sharing. It establishes a framework for cooperation among the Nile River Basin states (Le Monde, 2010).

The CFA will formalize the transformation of the Nile Basin Initiative into a permanent Nile River Basin Commission, which will manage water resources on behalf of all the Nile Basin states. The new agreement promises a win-win outcome and benefits for the Nile Basin states. It is expected that the agreement will ensure sustainable development of the shared Nile water resources. The CFA necessitates six ratifications to enter into force. While both Egypt and Sudan have dismissed the CFA, stating that they will not sign it and that it is not a binding treaty, they have nonetheless engaged in diplomatic efforts and dialogue in the region since the signing of the agreement.

### III. THE WAY FORWARD

The first part of this paper has presented a general overview<sup>8</sup> of the current situation in some shared surface and groundwater basins in the Arab region. There are other river basins in the Arab region that have not been discussed. In the majority of

these basins, no joint management action has been taken, leaving the riparian countries to make their own use of shared water resources without any consultation among themselves. However there are possibilities in establishing cooperation and for improving existing agreements that can bring about long-term mutual benefits of water use to all riparian countries.

### **A. Achievements and results: Lessons learnt**

Cooperation on the North Western Sahara Aquifer System (NWSAS) represents today the most achieved one in the Arab region. The emergence of the first signs of deterioration in the state of the aquifer system prompted the three sharing countries, Tunisia, Algeria, and Libya, to launch the first joint project on the aquifer system. Signs of trouble included “increased potential for conflict among countries, water salinization, disappearance of artesian flow well drilling, outlets drying up, and excessive drawdown in pumping wells” (Mamou et al., 2006). These signs of decline have resulted from the continued over-exploitation of the aquifer system by the three countries. While the countries had previously cooperated on issues related to the aquifer system, cooperation had remained bilateral as mentioned earlier. Recognition of impending increased risks affecting the aquifer system has brought the three countries together. The first phase of the project (1998-2002)<sup>9</sup> included studying the hydrogeology of the aquifer, setting up an information database system, developing mathematical models, and establishing a consultation mechanism, and had generated as an outcome “a database containing all present and historical information on all water points, their levels, and their flows” (Mamou et al., 2006). The database as well as the mathematical model of the aquifer system are accessible to all three countries.

Prior to the joint project, there existed two parallel concepts of Saharan hydrogeology resulting from earlier isolated studies:

- A model on the Algerian-Tunisian side treating the two parts of the system separately and designing them as single independent aquifer layers; and
- A model on the Libyan side, adopting a multilayer structure.

The joint project however has succeeded in elaborating a common model ensuring the best simulation conditions and giving a global picture of the system. The database was built with the information provided by the three countries requiring an enormous work of harmonization and adaptation, resulting in a common base compatible with the individual databases of the three countries (Mamou, et al., 2006).

The first responsibility of the temporary consultation mechanism established in 2002 was to guarantee the maintenance, development, and the permanent updating of these tools and to allow the regular exchange of data (OSS, 2008). The sense of partnership developed during the project has contributed to building confidence among the technical teams and has created a recognition that water problems encountered by one country are most probably the result of individual actions. Ultimately, there developed a conviction that common actions contribute to better results and increased efficiency and a strong belief that information exchange is a necessity (Mamou et al., 2006).

The above example is very informative and highlights important factors necessary in developing cooperation:

- Identification of the national entities in charge of data collecting and documentation with the participation of national experts was highly important. More critically, sharing of data by all three countries and the development of scientific knowledge of the system was indispensable;
- Involvement of national experts in all phases of the project was vital.

In the case of the NWSAS, cooperation was built step by step and was based on scientific cooperation that had been previously developed among the riparian countries in order to improve knowledge about the aquifer system. Rather than building formal and heavy joint institutions at the outset, there was an orientation towards establishing a flexible joint institutional setting that has evolved to a permanent structure. The regional organization, the Sahara and Sahel Observatory (OSS), played a central role, notably by hosting the database and the consultation

mechanism (OSS, 2008). However, the results produced by the common database and from the model are utilized by each country individually for water use planning purposes. A more integrated and collective management of the aquifer system still eludes the three countries. Recognizing the significance of data sharing and joint technical projects, it is hoped that water institutions in the three countries would build up on current achievements and move beyond conducting joint scientific studies to managing the entire aquifer system collectively. It would be highly desirable therefore to develop a cooperation mechanism towards common decision-making and joint management and investment of water resources in the NWSAS aquifer system. Only then will the social, economic, and environmental needs of the region be fully provided for.

While the Nile Basin Initiative (NBI) seems to be at an uncertain turning point, it has nevertheless introduced a change in the landscape of the Nile River. For decades, the river had been dominated by Egypt and Sudan basing their arguments on two agreements from 1929 and 1959, which gave them preferential rights on the River Nile waters. The NBI has brought together for the first time all the riparian countries of the river. Even if the fate of the new Cooperative Framework Agreement (CFA) seems unsure yet, many believe that the status quo is no longer tenable and therefore it is more sensible to view questions of water sharing as evolving. The merit of the NBI is to have started a mechanism of consultations and to have created an irreversible process where all riparian countries are involved. It is now prudent for all Nile basin countries to draw on principles from the UN Convention on the Non-Navigational Uses of International Watercourses to continue to find an equitable and sustainable formula for sharing the waters of the Nile. It is noteworthy that national diplomats and ministers of foreign affairs, rather than water ministers, have been involved in the most recent rounds of negotiating the CFA, reflecting the high and strategic profile attached by Nile riparian countries to any future arrangements concerning share use and management of the river water.

Cases from other regions may provide models for emulation. In the case of the Danube River, cooperation among the riparian states had been going on for a long time because of river

navigation. However, in 1991 the Environmental Program for the Danube River Basin (EPDRB) was initiated. Under this initiative a Strategic Action Plan (SAP) was prepared, and it was agreed for SAP to be the tool for implementing the Danube River Protection (1994). The EPDRB has closely been linked with the development of the agreement (ICPDR, 2006).<sup>10</sup>

## **B. Developing cooperation modalities**

Developing cooperation modalities in the Arab region can be accomplished. A key issue is to take a practical, step-by-step approach, and to persist in conducting long-term joint cooperation projects and in implementing provisions of current agreements.

### **1. Building on and reviving existing agreements**

As mentioned in Part I, agreements are already in place for some shared basins, however their implementation has been held up. Such agreements and the mechanisms they have established should be the starting point for reviving cooperation in a constructive manner.

The case of the Nahr Al-Kabir has been earlier developed. The agreement on the Nahr Al-Kabir had seemed promising when it was signed and has been held as a model for concluding shared water agreements successfully by employing provisions derived from the relevant United Nations Conventions and resolutions. However, implementation of the agreement has been mired in administrative and financial problems (ESCWA, 2006). The agreement may also have fallen victim to the ebbs and flows in the state of political relations between the two countries over the years. A first step would be the revival of the joint committee, which represents the mechanism of cooperation between the two countries. The joint committee should be allowed to play its role by providing it with the mandate and the resources needed to execute provisions of the agreement.

Another issue for consideration in this basin is groundwater, which has not been addressed by the agreement. The Nahr Al-Kabir basin is very rich in groundwater due to the high average rate of precipitation. Moreover, the basin geology

is conducive to the formation of aquifers. The sustainability of water resources in the basin requires adequate attention and monitoring of both surface and groundwater through a joint management arrangement. The hydrological monitoring needs of the basin were identified so far to include mainly the quality of the surface water and the quantity and quality of the groundwater (Drouby, 2008).

Another example of cooperation where no formal agreement exists is the case of the Basalt aquifer between Jordan and Syria. A joint study was initiated by ESCWA on this aquifer in 1994, working with the respective water authorities in both countries. In view of pursuing and enhancing the cooperation and coordination between the two countries, a memorandum of understanding (MOU) was prepared in 2002 but it was never signed (ESCWA, 2006). Today the text of the MOU might need revision, and the study might need to be updated.

## **2. Regionally: Building on results of various meetings/projects on shared waters**

At the initiative of regional organizations such as the Economic and Social Commission for Western Asia (ESCWA), Sahara and Sahel Observatory (OSS), and others, various workshop meetings, projects, and training seminars on shared water resources have been held. These initiatives have brought water experts representing government Ministry officials in charge of water resources in Arab countries together with international and Arab experts from outside the region. These meetings and projects have produced recommendations and frameworks, which could be considered for bringing the issues of shared water management high on the agenda. ESCWA has itself held meetings and training related to the topic such as the 'Workshop on Legal Framework for Shared Groundwater Development and Management in the ESCWA Region (2003)', and the 'Workshop on Training of Trainers on the Application of IWRM Guidelines in the Arab Region (2005)', which included a module on the 'Management of the shared water resources in the region'.

ESCWA had coordinated in partnership with the Economic Commission for Europe (ECE),

the Economic Commission for Africa (ECA), and UNESCO's International Hydrology Program (IHP) the project 'Capacity Building for Sustainable Utilization, Management, and Protection of Internationally Shared Groundwater in the Mediterranean Region'. The project covered only the Mediterranean countries of ESCWA, but the intention was to extend its result to other countries, which were invited to participate in the last workshops. The main objective of the project was to increase awareness and application by the MEDA countries of the international norms in the sustainable management of shared aquifers. A major outcome of the project was the production of guidelines and a policy framework for the management of shared groundwater in the MEDA region. On December 1-3, 2009, ESCWA has organized in Beirut an Experts Group Meeting in cooperation with BGR (German Geological Survey) on 'Applying IWRM Principles in Managing Shared Water Resources: Towards a Regional Vision'. The objectives of the meeting<sup>11</sup> were to:

- Provide a forum for discussions on the linkages between international water law principles and IWRM principles within a regional context;
- Identify on-going and planned initiatives, informed opinions, interests, and needs from the participants, and discuss challenges to promoting IWRM in shared water resource management; and
- Identify opportunities, synergies, and ways of coordination towards improved cooperation for the integrated management of shared water resources.

Another meeting related to shared waters in the Arab region was organized by the UNDP/RBAS Water Governance Program for Arab States (WGP-AS)<sup>12</sup> on June 7-9, 2010, on the 'National Capacity Needs for the Effective Joint Management of Shared Water Resources in Arab States'. The meeting touched on an important topic for Arab States. Its objective was to come up with a set of recommendations on the best national institutional configuration, legislative arrangements, multi-disciplinary human resources capacities, technical infrastructures, and negotiating capacities required to ensure proper joint management of shared water resources while considering Arab regional specificities (WGP-AS, 2010).





There is no doubt that regional organizations can play a crucial and central role in developing awareness and understanding of the legal frameworks inspired by international water law principles for managing shared surface and groundwater resources. However, the capacity of Arab governments to avail themselves of these workshops and meetings seems to be limited. There is little evidence that these resources translate into on-the-ground progress in fostering joint management of shared water basins or aquifers. It would be instructive to discern why this is so. Water institutions in Arab countries should make a more determined effort to take a better advantage of these workshops and meetings. Moreover, joint management of shared water resources should not be held hostage to the changing political winds in the region. Inaction will make the costs of unilateral actions and political ambivalence untenable. Arab governments should also take advantage of the credible and relevant role of independent parties, such as the Sahara and Sahel Observatory, in creating a neutral arena for hosting data and models, holding consultations, and providing analysis.

### **3. International references/guiding tools for riparian states**

At the global level, two international instruments were adopted to provide a legal framework that is used as a reference and a guiding tool for the management of shared water resources. The first instrument is the UN Convention on the Law of Non-navigational Uses of International Watercourses (1997). This Convention is not in force yet because it has not yet garnered the necessary number of ratifications (35) needed. Seven Arab States, namely, Iraq, Jordan, Lebanon, Libya, Qatar, Syria, and Tunisia have ratified the Convention. Yemen has signed the Convention, but has not yet ratified it. The Convention has codified the core principles of International Water Law, which are now part of customary international law. The principles include equitable and reasonable use and the obligation not to cause harm. The UN General Assembly adopted in December, 2008, Resolution A/RES/63/124 on the Law of Transboundary Aquifers. The Resolution is a non-binding text. However, it encourages the states concerned to make appropriate arrangements for the proper

management of their transboundary aquifers, based on the principles of the draft articles prepared by the International Law Commission included in its annex. The resolution offers therefore a reference framework for states regarding shared aquifers.

It was suggested earlier in this section that building on and reviving existing agreements must be taken seriously to bring states closer to implementing provisions of their agreements. However, in certain circumstances trying to breathe life into a 'bad' or a dysfunctional agreement, more reflective of the balance of power than any legal principle, may not yield any positive change in direction. It would be more productive in these cases to pursue a new agreement based on adherence to UN conventions and resolutions and the principles of 'equitable and reasonable use', 'equity-first', and 'cause no harm', mentioned above. It is advisable for Arab countries, who are not parties to the UN Convention on the Law of Non-navigational Uses of International Watercourses, to make every effort to sign and ratify the Convention. More critically, they should draw on principles of the Convention to establish a basis for joint management of their shared water resources.

#### 4. What obstacles to overcome?

The obstacles for proper cooperation on shared water resources in the Arab region come in a first place from the national level. At the national level, the institutions in charge of water resources are

often numerous and lack a clear mandate which leads to overlaps and gaps in responsibilities. There are often no local institutions to manage water basins. Therefore, it is not clear what institution or agency is in charge of the water body shared with a neighboring country.

The national legal frameworks on water are often not comprehensive on the main issues regarding the management of water resources. Yet, these frameworks are important since the shared water body is managed at first at the national level. The significance of these domestic frameworks lies also in the fact that in case of an agreement with other riparian countries the decision taken at the transboundary level would need to be compatible with and translatable to the national legislation.

#### C. What possible triggers and steps forward?

The development of common projects is an important possibility to trigger and develop opportunities for establishing cooperation among states on a shared water resource. Havasné (2007) has suggested that joint projects are the best way forward.

Joint projects among countries sharing a water resource can facilitate cooperation by:

- Bringing water managers from each side of the border together in a forum;
- Catalyzing confidence building processes through consultations and joint scientific projects; and
- Generating scientific knowledge and utilizing it for a better understanding of the shared water system, and adopting the proper recommendations for its management.

Bringing technicians and water managers of riparian countries together to work on joint projects creates an awareness that sustainable management of shared water resources has to involve all riparian countries. In the Arab region the case of the NWSAS is instrumental in this sense, although joint management has not yet taken root. The case of the project on the Guarani Aquifer System (Argentina, Brazil, Paraguay, Uruguay) (2003-2009) could be cited here as a model for regional cooperation. The objectives of the project were "to support the four countries in jointly elaborating and implementing a common



institutional and technical framework for managing and preserving the GAS for current and future generations” (Rucks, 2009). The project is seen as to have provided a strong catalyst for cooperation at the local, national, and regional levels. Two important documents were prepared during the project:

- The Tranboundary Diagnostic Analysis which has allowed the identification of joint needs; and
- The Strategic Action Plan which has identified selected priorities to public policy development.

Both documents were prepared with a strong participatory process, thus planting the seeds for an effective governance process.

#### IV. CONCLUSION

In the Arab region, many states rely for their water supply on surface and/or groundwater resources that are shared with neighboring countries. Despite the importance of establishing cooperation for managing these resources, there is no case of a sound joint management of shared water resources in the Arab world. There are cases of data sharing and consultations, of agreements on a specific issue (such as a dam), and of agreements whose implementation has been hampered, but a genuine joint management of a shared water system has not taken root so far. The NWSAS is a successful case of cooperation, but is still limited to data exchange and model development and updating. It needs to transcend data sharing to joint decision-making and joint investment in the aquifer system. Building trust and cooperation in collective management of a shared water system can be a lengthy process but such an investment pays dividends in the form of socio-economic development, reduced tension, and environmental sustainability of the entire water ecosystem all for the mutual benefit of inhabitants whose livelihoods depends on the river basin or aquifer. The following actions are suggested for water policy-makers in the Arab region to advance the cause of equitable and sustainable joint management of shared water resources:

- Develop joint projects involving the riparian

states of the shared water body in order to generate new knowledge about the resource and improve the capacity to utilize that knowledge, especially in the case of aquifers which are invisible;

- Seek the assistance of regional and international organizations in providing a neutral, credible, relevant, and trustworthy arena for hosting data and models, conducting analyses, and holding consultations;
- Sign and ratify the UN Convention on the Law of Non-navigational Uses of International Watercourses;
- Seek agreements with all riparian countries sharing surface or ground water resources by drawing on principles derived from the UN Convention on the Law of Non-navigational Uses of International Watercourses and the UN General Assembly Resolution on the Law of Transboundary Aquifers;
- Develop agreements that move beyond sharing data and technical studies to establishing credible and empowered mechanisms for a genuinely joint management and investment in the shared water resource;
- Seek accommodations reflecting the principles of equitable and reasonable use and the obligation not to cause harm, rather than relying on existing power imbalances;
- Learn from earlier experiences/initiatives on shared water resources, draw lessons from their successes and failures and their achievements, and make adaptations;
- Participate actively in international fora on shared waters, and be involved in related processes (such as the UN), in order to be informed of best practices or new legal frameworks;
- Involve regional and international organizations as facilitators in the process of building cooperation and benefit from their expertise;
- Learn from the experiences of other regions of the world; and
- Improve the governance of the shared water resource locally at the domestic level.

The topic of shared waters seems to have reached a high level regionally as the Arab Water Ministers in their first meeting in June 2009 have considered the UN Watercourse Convention (1997) and acknowledged the idea of having a common Arab position.

## NATIONAL GEOGRAPHIC MAGAZINE: TESTIMONIAL ON JORDAN RIVER

**PARTING THE WATERS****Don Belt**

For a biblical stream whose name evokes divine tranquility, the Jordan River is nobody's idea of peace on Earth. From its rowdy headwaters near the war-scarred slopes of Mount Hermon to the foamy, coffee-colored sludge at the Dead Sea some 200 miles downstream, the Jordan is fighting for survival in a tough neighborhood—the kind of place where nations might spike the riverbank with land mines, or go to war over a sandbar. Water has always been precious in this arid region, but a six-year drought and expanding population conspire to make it a fresh source of conflict among the Israelis, Palestinians, and Jordanians vying for the river's life-giving supply.

All of which makes the scene one morning last July all the more remarkable. Accompanied by military escort, three scientists—an Israeli, a Palestinian, and a Jordanian—are standing knee-deep in the Jordan River. They are nearly 40 miles south of the Sea of Galilee, under the precarious ruins of a bridge that was bombed during the Six Day War of June 1967. The scientists are surveying the river for Friends of the Earth Middle East (FOEME), a regional NGO dedicated to building peace through environmental stewardship. It's a scorching hot day in a former war zone, but if these men are concerned about the danger of heat stroke, getting clonked by a chunk of falling concrete, or stepping on a mine washed downstream by a flood, they're hiding it well.

"Hey, Samer," says Sarig Gafny, an Israeli ecologist in a floppy, green hat, "check this little fellow out." Samer Talози, a tall, self-possessed young environmental engineer from Jordan, peers over his shoulder at the tiny invertebrate his Israeli colleague has scooped into a glass sample jar. "It lives!" he says with a laugh.

"That is one tough crustacean!" A few yards away, Banan Al Sheikh, a stout, good-natured botanist from the West Bank, is absentmindedly wading upstream while focusing his camera on a flowering tree amid the tall reeds and other riparian species along the riverbank. "Watch your step, my friend," Gafny calls out after him, "and whatever you do, don't step on a bleeping mine."

Besides lethal munitions, this stretch of the Jordan River—perhaps 25 feet wide and a few feet deep—is so polluted

that any sign of aquatic life is worth celebrating. Part of the reason is water scarcity: In the past five decades the Jordan has lost more than 90 percent of its normal flow. Upstream, at the Sea of Galilee, the river's fresh waters are diverted via Israel's National Water Carrier to the cities and farms of Israel, while dams built by Jordan and Syria claim a share of the river's tributaries, mostly for agriculture. So today the lower Jordan is practically devoid of clean water, bearing instead a toxic brew of saline water and liquid waste that ranges from raw sewage to agricultural runoff, fed into the river's vein like some murky infusion of tainted blood.

The fight over the Jordan illustrates the potential for conflict over water that exists throughout the world. We live on a planet where neighbors have been clubbing each other over rivers for thousands of years. (The word "rival," from the Latin *rivalis*, originally described competitors for a river or stream.) Worldwide, a long list of watersheds brims with potential clashes: between India and Pakistan over the Indus; Ethiopia and Egypt over the Nile; Turkey and Syria over the Euphrates; Botswana and Namibia over the Okavango. Yet according to researchers at Oregon State University, of the 37 actual military conflicts over water since 1950, 32 took place in the Middle East; 30 of them involved Israel and its Arab neighbors. Of those, practically all were over the Jordan River and its tributaries, which supply millions of people with water for drinking, bathing, and farming.

Armed confrontations over the Jordan date to the founding of Israel in 1948 and the recognition that sources of the country's needed water supply lay outside its borders. Its survival depended on the Jordan River, with its headwaters in Syria and Lebanon, its waters stored in the Sea of Galilee, and the tributaries that flow into it from neighboring countries.

Israel's neighbors face a similar situation. Their survival is no less at stake - which makes the line between war and peace here very fine indeed. In the 1960s Israeli air strikes after Syria attempted to divert the Baniyas River (one of the Jordan's headwaters in the Golan Heights), together with Arab attacks on Israel's National Water Carrier project, lit fuses for the Six Day War. Israel and Jordan nearly came to blows over a sandbar in the Yarmuk River in 1979. And in 2002 Israel threatened to shell agricultural pumping stations on the Hasbani,

### LIFELINE IN THE HOLY LAND

In quieter parts of the world, the 200-mile-long Jordan might be considered a minor stream. But here, coveted by rivalrous neighbors in a rain-starved region, the river has sparked more than its share of conflicts—and occasionally, cooperation.

- Dam
- Canal
- Groundwater divide
- Flow direction**
- Diversion
- Surface water
- Groundwater



#### 1 HEADWATERS

From springs around Mount Hermon, three rivers converge in Israel to form the Jordan. After 1948 Israel treated any upstream diversion by Syria or Lebanon as a hostile act.

#### 2 HULA VALLEY

To boost agriculture in the 1950s, Israel drained swamps bordering the Syrian Golan Heights. Skirmishes there continued until 1967, when Israel captured the Golan.

#### 3 NATIONAL WATER CARRIER

Completed by Israel in 1964 despite fierce Arab opposition, the canal was built to move water from the Sea of Galilee to Tel Aviv and farms in the Negev desert.

#### 4 YARMUK RIVER

Largest tributary of the Jordan, the Yarmuk is tapped by Syria, Jordan, and Israel. Secret talks between Israel and Jordan over its water foreshadowed a peace agreement in 1994.

#### 5 GROUNDWATER

Israel's occupation of the West Bank after 1967 gave it control of the area's three major aquifers, or basins; negotiations over groundwater began during the Oslo peace talks in the 1990s.

#### 6 LOWER JORDAN

Partly an international border and used as a waste canal, the lower Jordan is flanked by military zones and minefields and is so polluted that it hardly supports life.

#### 7 RED SEA-DEAD SEA CANAL

Barely replenished by the Jordan, the Dead Sea has fallen to alarmingly low levels. One controversial solution: a canal connecting it to the Red Sea.



another of the headwaters in southern Lebanon.

Yet fights over water have also led to dialogue. “There are few major sources of water that don’t cross one or more political boundaries,” says Gidon Bromberg, the Israeli co-director of Friends of the Earth Middle East. “That creates a natural interdependence between countries.” Sharing resources can actually be a path to peace, Bromberg says, because it forces people to work together. In the 1970s, for example, Jordan and Israel agreed on how to divvy up water even when the countries were officially at war. And cooperation between Israelis and Palestinians over water has continued even as other tracks of the peace process hit a wall.

“It seems counterintuitive, but water is just too important to go to war over,” says Chuck Lawson, a former U.S.

official who worked on Israeli-Palestinian water issues in the 1990s. “Regardless of the political situation, people need water, and that’s a huge incentive to work things out.”

One day last April, Bromberg led me to the natural spring that provides water to Auja, a Palestinian village of 4,500 people that climbs the barren hills a few miles west of the Jordan River near Jericho. Fed by winter rains, the spring was flowing from a small, boulder-strewn oasis, and we trekked along the narrow concrete trough that transports water to the village, several miles away. “Auja is totally dependent on this water for agriculture,” Bromberg said. “As soon as this spring dries up, there’ll be no more water for farming.”

Part idealist, part political operative, Bromberg was

born in Israel and raised in Australia, then returned to Israel in 1988 to help build peace in the region. By challenging his own country to share water equitably, Bromberg has rattled the cages of hard-line Israeli politicians who see water as a national security issue—and as a resource to guard jealously.

Since occupying the West Bank in 1967, Israel has built a few dozen settlements in the Jordan Valley, in addition to the 120 or so elsewhere in the West Bank. The settlers' water is provided by Mekorot, Israel's national water authority, which has drilled 42 deep wells in the West Bank, mainly to supply Israeli cities. (According to a 2009 World Bank report, Israelis use four times as much water per capita as Palestinians, much of it for agriculture. Israel disputes this, arguing that its citizens use only twice as much water and are better at conserving it.) In any case, Israel's West Bank settlements get enough water to fill their swimming pools, water their lawns, and irrigate miles of fields and greenhouses.

In contrast, West Bank Palestinians, under Israeli military rule, have been largely prevented from digging deep wells of their own, limiting their water access to shallow wells, natural springs, and rainfall that evaporates quickly in the dry desert air. When these sources run dry in the summer, Bromberg said, Auja's Palestinians have no choice but to purchase water from Israel for about a dollar a cubic yard—in effect buying back the water that's been taken out from under them by Mekorot's pumps, which also lower the water table and affect Palestinian springs and wells.

As Bromberg and I followed the Auja spring east, we passed a complex of pumps and pipes behind a barbed-wire fence—a Mekorot well, drilled 2,000 feet deep to tap the aquifer. "Blue and white pipes," Bromberg said. "This is what water theft looks like in this part of the world."

Israel's chief water negotiator, Noah Kinnarti, disagrees. Underground water knows no borders, he says, and points out that Israelis must also purchase the water they use. "Palestinians think any rain that falls in the West Bank belongs to them," he told me at his kibbutz near the Sea of Galilee. "But in the Oslo talks, we agreed to share that water. They just can't get their act together to do it."

FOEME began confronting these tough issues in 2001,

during a period of intense Palestinian-Israeli violence. But by focusing first on ways to improve water quality, the NGO mobilized support and built trust through its Good Water Neighbors program, a grassroots education initiative. It's also working to establish a Jordanian-Israeli peace park on a midstream island. Perhaps most important, it has pressured governments to live up to the water-sharing commitments embedded in the region's peace agreements, seeking to make the Jordan River a model for the kind of cooperation needed to avert future water wars.

"People all over the world associate the Jordan River with peace," says Munqeth Mehyar, FOEME's co-director in Jordan. "We're just helping it live up to its reputation!"

When I returned to Auja in early May, its spring had been reduced to a trickle, leaving the village as dry as a fistful of talcum powder. The fields around it lay empty and exhausted, while on Auja's one plot of flat ground, boys were playing soccer amid a swirling dust cloud they were kicking up, chasing an old leather ball worn to the consistency of flannel.

I stopped by the home of an elderly farmer named Muhammad Salama. "We haven't had running water in my house for five weeks," Salama said. "So now I have to buy a tank of water every day from Mekorot to supply my family and to water my sheep, goats, and horses." He also has to buy feed for his animals because there is no water to irrigate crops. To meet these costs he is selling off his livestock, and his sons have taken jobs at an Israeli settlement, tending the tomatoes, melons, and other crops irrigated from the aquifer that is off-limits to Palestinian farmers. "What can we do?" he asked, pouring me a glass of Mekorot water from a plastic bottle. "It's not fair, but we're powerless to do anything about it."

It was a clear day, and from his front window we could see across the parched, brown valley all the way to the thin line of gray-green vegetation marking the path of the Jordan River. For a moment, its water seemed within reach. "But to get there I'd have to jump an electric fence, cross a minefield, and fight the Israeli army," Salama said. "I'd have to start a water war!"

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*Don Belt is Senior Editor for Foreign Affairs for the National Geographic magazine. This feature was published in National Geographic, April 2010, Water- Our Thirsty World – A Special Issue. It is reproduced in AFED Report under license.*

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- NOTES**
- When an aquifer spans the territory of more than one state, the international community has adopted the expression "transboundary aquifer" (see UN General Assembly Resolution on the Law of Transboundary Aquifers (A/RES/63/124) (2008)). However the Arab region has always expressed its preference for use of the word "shared", therefore it is this word that will be used in this paper.
  - It is the Convention on the Protection, Utilization, Recharge and Monitoring of the Franco-Swiss Genevois Aquifer between the Community of the 'Annemassienne' region, the Community of the 'Genevois' Rural Districts, the Rural District of Viry, and the Republic and Canton of Geneva (January 1, 2008).
  - This Convention is not yet in force, since the required number (35) of ratifications has not been reached yet. Seven Arab States have ratified the Convention. They are: Iraq, Jordan, Lebanon, Libya, Qatar, Syria, and Tunisia. Yemen has signed the Convention, but has not yet ratified it.
  - The dam has not been constructed yet.
  - The Sahara and Sahel Observatory (or OSS as per its French acronym) is an international organization based in Tunis with a mission directed at issues related to water and land degradation. [http://www.oss-online.org/index.php?option=com\\_frontpage&Itemid=200](http://www.oss-online.org/index.php?option=com_frontpage&Itemid=200)
  - Details about the Nile Basin Initiative are available at <http://www.nilebasin.org/>
  - The ten countries sharing the Nile established a forum for a process of legal and institutional dialogue in 1997. The UNDP provided initial funding of about US\$3.2 million to finance cooperative activities. The Nile Basin Initiative (NBI) was launched in 1999. Cooperation between Egypt and Sudan in managing the Nile water has been productive since the 1920s. Egypt supported Sudan in building Jabal Awliya Dam on the White Nile to better utilize its share of the water. In the 1959 agreement between the two countries, Sudan and Egypt agreed on seasonal sharing of the Nile water for agricultural production through which Egypt produces cotton in the spring and summer months ( flood season), and Sudan grows cotton in the winter months. Egypt and Sudan cooperated in building the High Dam, and Egypt supported Sudan in building the Atbara Dam and the New Halfa irrigated schemes to help settle affected people who lost their land under Lake Nasser.
  - The first part did not pretend to be exhaustive on shared waters in the Arab region.
  - There was a second phase including a study on the humid zones and a third phase under implementation focusing on socio-economic aspects.
  - Details about the International Commission for the Protection of the Danube River are available at [www.icpdr.org/icpdr-pages/history\\_of\\_cooperation.htm](http://www.icpdr.org/icpdr-pages/history_of_cooperation.htm)
  - Details about the meeting are available at <http://www.escwa.un.org/information/meetingdetails.asp?referenceNum=1131E>. The final report is not yet available.
  - Details about the WGP-AS are available at <http://www.wgpas-undp.org/>



# Water Governance

SAFWAT ABDEL DAYEM  
NANCY ODEH



## I. INTRODUCTION

Fresh water is a finite element constituting only 3 percent of the water on earth, of which 70 percent is captured in glaciers. The remaining portion is available in rivers, lakes, and groundwater. It is not uniformly distributed and some regions have smaller shares than others. The Arab region, which is home to 5 percent of the world population, has only 1 percent of the global available fresh water resources. Climate in Arab countries is arid to hyper-arid with little rainfall and more than 60 percent of the surface water originates outside the region. Average per capita water share in the region has been declining to less than 1,000 m<sup>3</sup> a year compared with an annual world average of 7,000 m<sup>3</sup>. The projected per capita share is expected to fall to about 500 m<sup>3</sup> before 2025. In some Arab countries such as Jordan, Palestine, and Yemen the per capita share of water is already below 200 cubic meters per year.

Rapid population growth and the acceleration of economic and social development in Arab countries during the second half of the 20<sup>th</sup> century have been associated with weaknesses

in institutional infrastructure and a deteriorated water governance system. This is reflected in water inequitable allocation, wasteful use of water, increasing pollution trends, lack of transparency, and inefficient water services. Increased demand for water combined with poor governance has resulted in intensified pressure on natural resources to serious levels. Improved water governance and management are becoming imperative if the needs of current and future generations are to be met in a sustainable manner and environmental protection is to be assured.

In this chapter, we define the governance challenge, review the water governance discourse that can achieve water sustainability goals in Arab countries, summarize the progress achieved in improving the governance system, and review potential desired outcomes of water governance reform and their impacts. Where possible some case studies are given to highlight success stories and/or lessons learned.

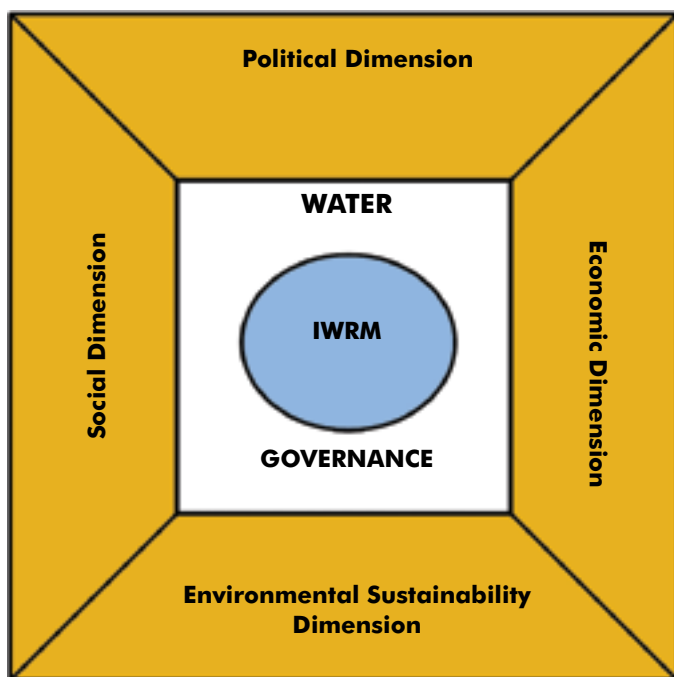
## II. WHAT DOES WATER GOVERNANCE MEAN?

The term ‘water governance’ is relatively new in the global discourse on water management. Water governance was emphasized during the Second World Water Forum at The Hague when the Global Water Partnership (GWP) stated that “the water crises is mainly crises of governance” (GWP, 2000). “Water governance refers to the range of political, social, economic, and administrative systems that are in place to regulate the development and management of water resources and provision of water services at different levels of society” (GWP, 2002), while recognizing the role played by environmental services (Rogers and Hall, 2003).

When comparing the definition of water governance with that of integrated water resources management (IWRM), the linkages become obvious. They both include four dimensions: social, economic, political, and environmental as depicted in Figure 1. IWRM provides a comprehensive approach to the development and management of water resources, addressing its management both as a resource and as a framework for water services provision (WWAP,

FIGURE 1

THE IWRM-GOVERNANCE NEXUS



2006). Water governance “provides the context in which the IWRM approach can be applied”, and addresses the “manner in which allocative and regulatory politics are exercised in the management of resources (natural, economic, and social)” (Rogers and Hall, 2003).

In broader terms governance can be regarded as “a container or an umbrella concept that considers multi-faceted processes where societal goals are pursued through the interaction of all interested actors in specific fields of development. Such processes require the promotion of decision-making dialogues and the participation of multiple stakeholders. It also takes into consideration the ways governments and social organisations interact, how they relate to the public, how decisions are taken, and how accountability is rendered” (Graham et al., 2003).

### III. WATER GOVERNANCE CHALLENGES IN ARAB COUNTRIES

The water sector in Arab countries is characterized by vast disparities in socioeconomic needs, access to financing, institutional arrangements, regulatory frameworks, stakeholders’ participation, private sector involvement, trans-boundary challenges, and water stress levels. However there are common challenges, although they differ in their level and extent by country. Water scarcity in Arab countries has created competing demands for its services that have greatly complicated the challenge of governance. For decades water management was supply driven where governments developed infrastructure to capture and distribute water to users while neglecting to manage demand. This was associated with the lack of adequate policies and economic instruments, inefficient public sector service delivery, and significant expansion in irrigation. Today, water used for irrigation represents 85 percent of total fresh water consumption. However, water usage in irrigation is wasteful because incentives for farmers to adopt modern, water-conserving technologies are mostly inadequate. Significant amounts of water supplied for municipal use remain unaccounted for.

A review of the water policies that prevailed in



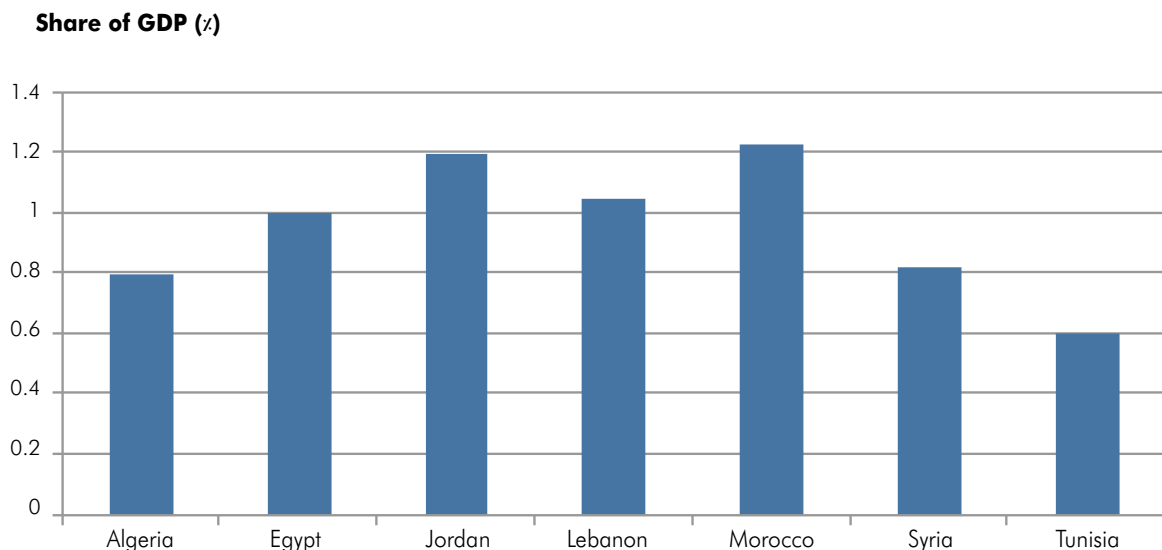
the 20<sup>th</sup> century reveals a misalignment between water management strategies on one hand and emerging resource realities, socioeconomic concerns, and development needs on the other hand. Water policy and management paradigms that dominated in that period can no longer be

#### BOX 1: MINING NON-RENEWABLE GROUNDWATER RESOURCES

The boom associated with a heavily subsidized desert irrigation in the Kingdom of Saudi Arabia (KSA) that started in the early 1980s portrays a worrisome picture when seen from a water scarcity perspective. It tripled the total volume of water used for irrigation, from around 6.8 billion m<sup>3</sup> in 1980 to approximately 21 billion m<sup>3</sup> in 2004, totaling 463 billion m<sup>3</sup> during the last 30 years (almost six times the annual flow carried by the Nile). The sharp increase in groundwater abstractions reached its peak in the early 1990s (22.7 billion m<sup>3</sup>), when wheat production was at its peak. The result was a steep decline of Groundwater levels of the main aquifers in the period 1980-2000. In the Eastern Province, groundwater levels dropped at a rate of 10 m per year with a total drop of 150 meters, with the expansion of alfalfa production when dairy became a profitable activity. The same pattern have been observed with more or less severity in all the principal aquifers of KSA. This trend was a main driver for policy changes during the past 10 years.

Source: Personal communication.

FIGURE 2 COST OF ENVIRONMENTAL DEGRADATION OF WATER IN SOME ARAB COUNTRIES



Source: World Bank, 2007

sustained in an era of water scarcity exacerbated by climate change, growing populations, and ambitious development agendas. Saleth and Dinar (2004) have argued that “the emphasis on engineering solutions, the treatment of water as a free good, and bureaucratic allocation and management are now inconsistent with the requirements and challenges of the new era” of water scarcity. A great challenge was, and still is therefore, to introduce policy reforms and new institutional arrangements that can adequately address the new realities of water resource scarcity and meet the demands of economic and social development in an environmentally sustainable manner.

Increasingly, there is recognition that the crisis in the water sector has lingered for so long because of the lack of supporting institutions. It is argued that the water crisis has “revealed the inherent limitations of today’s institutions in dealing effectively with the new set of problems related more to resource allocation and management than to resource development” (Saleth and Dinar, 2004). Most public sector organizations in Arab countries (serving both irrigation and urban water supply needs) do not function properly and have been unable to serve their customers efficiently. Responsibility for managing water and water services is

dispersed across multiple institutions, which rarely communicate or coordinate among themselves. Decision-making processes take top-down direction with absent or ineffective stakeholders’ participation. Information is hardly shared between policy makers and authorities charged with implementation or between governmental and non-governmental actors. The challenge is to develop alternative institutional arrangements involving the public sector, the private sector, and communities and equip them with the right technical, economic, and legal tools to function properly.

Poor water governance manifests itself in a number of ways with undesired economic, social, and environmental consequences. For example, most Arab countries extract underground water well beyond the renewal rate, mainly because energy subsidies make it cheaper for many users to do so (Box 1). Water use is becoming less and less efficient even as water grows scarcer. Apart from efficiency concerns, there are serious equity problems with current water practices. In urban areas, people in unserved quarters rely on water supplied by private vendors, often at 10–20 times the official tariff rate. Lack of clean water for drinking in rural areas forces people to travel long distances to fetch their needs, a task often delegated to women and children who usually

pay the cost. The poor always suffer the most.

Untreated wastewater from municipal and industrial sources as well as agricultural runoff is polluting shallow aquifers, rivers, streams, and lakes. Increased water contamination combined with poor water supply and sanitation is causing damage to public health, increased utility costs, reduced fish catch, reduced wetland services, and salinization of agricultural land and thus generating significant opportunity costs. Studies of environmental degradation in some Arab countries due to water pollution estimate the costs at 0.5 to 1.2 percent of their GDP (World Bank, 2007), as shown in Figure 2.

Figure 2: Annual cost of environmental degradation of water in some Arab countries

Moreover, the water sector in the region did not recognize for a long time that many of the decisions governing its performance are made outside the sector. Thus, water policies missed the critical linkages with other economic sectors, viewing water resource management problems as the exclusive domain of the water sector (Saleth and Dinar, 2004). According to Saleth and Dinar (2004), “it is inappropriate to insulate the water economy from market forces through the politically rooted system of public provision and subsidized water charges”, particularly in a water scarce region. As a result, the economic value of water is often not considered in setting agricultural and trade policies in many Arab Countries. For example, scarce water is used in irrigation of high water consuming crops such as rice, sugarcane, and banana. By 2009, the area cultivated with rice in the Nile Delta was more than double the area proposed in the post High Aswan Dam (HAD) era and significant part of the yield has been exported to foreign markets.

Thus the ability to address the challenge of managing scarce water resources with the least ecological and social costs, will depend on introducing policy reforms and institutional frameworks that create the new governance structure needed for sustainable water allocation and management (Saleth and Dinar, 2004). For example, Arab countries need to adopt a water policy that can achieve a balance between the cost of delivering water for agricultural use and the revenue associated with crop cultivation. They should cultivate crops of high productivity

FIGURE 3

### THE ENABLING ENVIRONMENT FOR GOOD GOVERNANCE



and high added value. Doing so would allow countries to import basic food products while guaranteeing the availability of necessary funding to pay for such imports in a sustainable manner. Therefore, water and agricultural policies should be coupled. They should also be adaptable to changes in the global markets while efforts should be expended to raise the efficiency of water and production inputs and achieve higher revenue per unit water.

#### IV. ADVANCING THE WATER GOVERNANCE AGENDA

Governance becomes ‘effective’ or ‘good’ when conditions of equity, accountability, participation, transparency, predictability, and responsiveness prevail (Tiihonen, 2004). Building on Kooiman’s (2003) conceptual work, governance is a complex product of social-political interactions in which various societal actors are involved at different levels. In the case of water governance, these interactions will directly generate policy outcomes affecting agriculture, food, health, education, economic development, and poverty alleviation. For these complex interrelationships to succeed, they have to take into consideration

that they are interdependent and that no one agent, group, or sector has all the knowledge and facts required to set policy, make decisions, or take actions (Kooiman, 2003). Because of this complexity, good governance does not just appear but is the culmination of multi-faceted, long-term processes that have to be carefully planned and nurtured (Rhodes, 1996; Kooiman, 2003; Tiihonen, 2004). For good governance to emerge, contextually appropriate conditions must exist and an enabling environment must be cultivated (Tiihonen, 2004), as depicted in Figure 3. Parties concerned must be open to committing to collective decision-making, effective and functional institutions need to be developed, and policy, legal, and political frameworks must be suitable to the goals that are being pursued for the common good (Rhodes, 1996; Kooiman, 2003; Tiihonen, 2004).

Many Arab countries, whether motivated by the many challenges of sustainable water resources management or driven to act under pressure from the donor community or both,

have launched water sector governance reform programs. The reform agenda includes key institutional issues related to the legal, policy, and administrative aspects of water resource development and management. Three major components of governance, namely, public sector reform, stakeholder participation, and public-private partnerships, which are being promoted to improve water management and governance, will be discussed.

### **Public Sector Reform**

Progress in terms of accountability of the public sector is considered particularly important for the successful implementation of an overall governance reform agenda in the region. New water sector strategies and national plans have been formulated since the late 1990s in many countries in the region, including Bahrain, Djibouti, Egypt, Jordan, Lebanon, Libya, Saudi Arabia, Syria, Tunisia, West Bank and Gaza, and Yemen (World Bank, 2007). The new policies integrate supply augmentation

#### **BOX 2: PARTICIPATORY IRRIGATION MANAGEMENT**

The World Bank-supported Irrigation Improvement Project (IIP) in Yemen was articulated around Participatory Irrigation Management (PIM). The project prompted the government to create enabling legal and institutional environments to establish two main irrigation-user organizations: water user associations (WUAs) and irrigation councils (ICs). Each WUA is in charge of implementing PIM in its respective irrigation command area. The WUA is to (1) provide reliable and sustainable irrigation services, (2) perform maintenance and rehabilitation, (3) collect fees from beneficiaries, and (4) develop the capability for self-reliant operation and maintenance (O&M). At later, more advanced stages, ICs were established in both Wadi Zabid and Wadi Tuban with strong representation from the WUAs. The IC acts as the High Executive and Administrative Authority in each wadi (riverbed) representing the local government, WUAs, and the Ministry of Agriculture and Irrigation. The ICs are responsible for (1) applying the IC's by-laws and implementing its executive procedures, (2) coordinating activities between government authorities that continue to be in charge of O&M of head works/primary canals and the WUAs in charge of O&M of the secondary and tertiary systems, (3) protecting water user rights and resolving conflicts and pending issues, and (4) monitoring the

social, financial, and technical performance of WUAs.

In the Nile Delta area, the IWRM action plan has instituted measures that enhance user voice in the O&M of services. The Ministry of Water Resources and Irrigation (MWRI) has delegated responsibilities of O&M to water user associations (WUAs) at the tertiary-canal (mesqa) level. The MWRI plan also entails empowering Branch Canals WUAs to manage irrigation and drainage O&M at the secondary or branch-canal level. Since Branch Canals are also sources for drinking water, members include households, with strong participation of women who oversee the water quality, environmental, and health issues. In a parallel process, Integrated Water Management and Irrigation Districts are being established, to integrate all public services under one entity which works closely with WUAs and Branch canals WUAs. The key measure required is an amendment to Law 12/1984 to empower WUAs. New large scale irrigation projects are now being implemented following an integrated water management approach with the Water User Associations (WUA) taking the lead to maximize economic and social benefits while safeguarding the environment as in the case of the IIIMP project in Egypt.

Source: World Bank, 2009

with demand management. Some countries (Egypt, Jordan, Morocco) have established high-level national planning and coordination entities to combine the voices of those key ministries that have direct and indirect impact on water such as agriculture, housing, finance, and trade. Water ministries in the region are undergoing organizational restructuring in order to introduce flexibility and efficiency in their operations through more decentralization of their functions.

In 2000, the Palestinian Water Authority (PWA) prepared a National Water Plan to set strategic directions for the sector up to 2020. The objective is to achieve sectoral goals, elucidate the role of service providers, and shift the functions of the PWA to regional utilities. The latter is in charge of operations, maintenance, repairs, wastewater collection and treatment, bulk water supply, water reuse, and water allocation for industrial and agriculture use. A Water Council chaired by the President of the PWA is established with representatives from water user associations, ministries, academics, and regional utilities. The government continues to own the regional water utility assets with community representation on their boards. In its drive to strengthen the water sector governance, the PWA developed a new comprehensive water law in 2002. The law covered aspects of water management such as developing and managing resources, increasing capacity, improving quality, and preventing water pollution and depletion.

Public water supply and sanitation institutions in Arab countries are shifting to be more client-oriented with improved institutional capacity to pursue the principles of efficiency, transparency, accountability, and equity in delivering services to their clients. These shifts are designed to address the problems afflicting these institutions “such as unclear lines of responsibility for operations, low tariffs, difficulties retaining qualified personnel, and political interference in staffing policies and other aspects of operations” (World Bank, 2007). In Egypt, the government separated service provision from regulation in the water supply and sanitation sector. The Holding Company (HC), established in 2004, has autonomous authority and is managed by a board consisting of a wide range of stakeholders. The HC operates at the local level through

### **BOX 3: PUBLIC PRIVATE PARTNERSHIP (PPP) IN IRRIGATION**

In Morocco, the Guerdane project includes a 10,000 ha irrigation area serving 600 citrus farmers where the groundwater source was running out. Government was prepared to allocate water from the dam complex of Chakoukane-Aoulouz and to co-finance the development of the 60 mile conveyance pipe and distribution structure. In July 2004, the bid was won by a consortium led by Omnium Nord-Africain (ONA), a Moroccan industrial conglomerate, with participation of French and Austrian companies. The consortium will enter into a 30-year concession for the construction, co-financing, and operation and management of the irrigation network. The project will cost an estimated \$85 million of which the Moroccan government will provide \$50 million, equally split as loans and grants. The water tariff agreed by the consortium is towards the lower limit of the existing cost range of groundwater supply, so farmers will benefit from a cost saving. (World Water Forum, 2004)

The West Delta Irrigation Project in Egypt is another major PPP project involving construction and operation of piped irrigation system to transport Nile water to support high value agricultural development in an area of 100,000 ha located to the west of the Nile delta. The area was initially developed using groundwater which is now showing increasing signs of depletion and deterioration in quality. A Design-Build-Operate (DBO) option with a capital contribution by a private operator and participating farmers was considered as the preferred transaction model for the project area. Water charges will include a flat fee to cover infrastructure cost and a variable fee to cover operation and maintenance cost and operator profit. From the onset, a Water User Organization was established to be fully involved in project preparation and to oversee the performance of the Private Operator together with an independent Regulatory Office. The project preparation started in 2005 with a strategic environmental assessment (SEA) which thoroughly examined the economic, social, and economic cost and benefits of the project following a basin wide consultation with the stakeholders.

(World Water Forum, 2006; Biaetti and Abdel-Dayem, 2008; World Bank, 2009)

companies responsible of service provision and day-to-day operation and maintenance of the networks. Their work is monitored monthly against a set of performance indicators. Along with the Holding Company, the Egyptian Water Regulatory Agency (EWRA) was also created to provide economic regulation for the sector. EWRA links government, society, and the Holding Company to ensure that national policies and regulations are implemented (World Bank, 2007, 2009).



In Tunisia, Société Nationale d'Exploitation et de Distribution des Eaux - SONEDE is following a pricing policy which enables a full cost recovery of operations, with tourist establishments paying the highest rates and households the lowest. Unaccounted for water in Tunis has been reduced below 10%. In 2002, the Moroccan government decentralized responsibility for water supply and sanitation services to the municipalities, and left to them the right to choose how to manage service provision from a menu of several choices. They can manage water services themselves; they can create an independent public provider to delegate water services to; they can delegate water services to the National Office of Potable Water (ONEP); or they can contract out water services to private firms (World Bank, 2007; Louati and Bucknall, 2009). Moreover, Morocco has introduced autonomy and privatization to urban water supply (Saleth and Dinar, 2004). To promote water conservation, the government has introduced a revolving loan fund for urban users to assist them cover the costs of water meters and retrofitting water appliances (Saleth and Dinar, 2004). Another public policy innovative practice has been the creation of River Basin Organizations. According to Saleth and Dinar (2004), "The RBOs in Morocco are unique ... Since they are managed by agricultural agencies, they serve as an organizational means of integrating water delivery with the provision of farm inputs."

### **Stakeholder's Participation**

Participation is central to promoting good governance – creating a climate of accountability and transparency (Abdel-Dayem et al., 2004; WWAR, 2006). Stakeholder participation represents the 'demand side' of good governance. Improvements with regard to more participation of stakeholders are important not only to take into account the needs, values, and opinions of those who are affected by the reforms, but also to ensure that the implications of a new development model are acceptable to communities. Stakeholder participation involves taking part in planning, design, implementation, operation, and maintenance of water works, in setting and administering tariffs, and in supervision and quality control. People's access to relevant water information is an essential precondition for successful participation.

The most structured procedure for participation is that of water users in the irrigation sector. Many countries in the region have made considerable progress passing some responsibility for operating and managing irrigation systems to groups of users known as water user associations (WUA). Egypt, Jordan, Libya, Morocco, Oman, Tunisia, and Yemen promote the involvement of users in the irrigation sector in activities such as management, operation, and maintenance





of local infrastructure (Box 2). Initiatives for establishing water user associations were mostly borne out of the framework of multi-lateral and bilateral financed irrigation projects, which included components for policy and institutional reform. These initiatives are at different levels of implementation and their sustainability beyond the projects' lifetime has not been evaluated yet. Although the objectives for introducing water user organizations are quite similar across the region, the institutional structure and legal status may be quite different (Salman, 1997). In some cases the legal framework that supports and empowers WUAs is not available yet or is undergoing a slow making process (Mohamed and Jagannathan, 2009). It is linked to a great extent with the pace of the on-going political and economic reform in each country. It is important to recognize that "meaningful participation cannot be achieved unless there is greater transfer of responsibility, authority, and resources" to the parties concerned (Mohamed and Jagannathan, 2009).

Effective arrangements and mechanisms are still not available to monitor and evaluate the progress and impact of participatory irrigation management on financial sustainability, natural resource-base sustainability, reduction of avoidable transaction and overhead costs, and piloting, transferring, and scaling up of best practices. Thus, it is too early

to draw conclusions on the quality of irrigation services provided by WUAs, as opposed to those previously provided by corresponding government entities. Indicators and benchmarking to measure progress in participatory irrigation management have been developed and tested in other regions but rarely used in Arab countries (Gonzalez and Salman, 2002).

In this context, the political trend in Tunisia is toward decentralization and participatory management to close gaps in the water management system. Thus, all levels of the administration have made great efforts to help local organizations take control of operating and maintaining their water distribution facilities within the overall framework of IWRM. A key factor of success are the regulations that guide such trend toward greater participation by the beneficiaries/stakeholders. A 2009 UN report has highlighted the central role of increased water users' participation, suggesting the need for Tunisia to "continue implementing policies geared towards sustainable socio-economic development by reconciling user needs with the social and environmental value of water" (WWAP, 2009).

### **Public-private Sector Partnership**

The introduction of public-private partnerships (PPP) has been an important development in water service delivery in Arab countries (AWC, 2008), but it has not displaced public provision as the lead method for delivering these services. Its primary impact has been to mobilize private capital for upstream provision (water treatment, desalination), with only a few cities shifting to private provision of water services at the customer level.

Oman has made substantial efforts to broaden private sector participation and improve the foreign investment climate, with privatization and changes in its foreign capital investment law. PPP has been extended to management of water supply networks in Jordan and Morocco, as well as to construction of new water supply and sanitation systems in Algeria, Egypt, Qatar, Saudi Arabia, and UAE. Management contracts have been signed with the private sector to operate the utilities in Amman and Casablanca. In the irrigation sector, the Guerdane project in

## FUTURE WATER STRATEGY FOR THE UNITED ARAB EMIRATES

**Khalil Ammar and Rachael McDonnell**

The United Arab Emirates is located within the hyper-arid and arid climate zones of the Arabian Peninsula and the limited rainfall leads to natural water scarcity. Against these sparse supply conditions, demand for fresh water has increased with accelerating population growth, higher living standards, and expansion of the agricultural, forestry and industrial sectors. The per capita water consumption is now amongst the highest in the world, creating enormous strains on the water budget. This growing demand was initially met through the pumping of non-renewable water resources but many of these aquifers have now become depleted with resulting declines in levels and deterioration in water quality. Reliance has therefore shifted to non-conventional water resources particularly desalinated and reclaimed water, to bridge the gap between supply and demand although this brings increased stresses on energy supplies and ecological systems.

In addition to these water challenges, water governance in the country has its own challenges. The UAE is a federal nation and its constitution of 1971 defines under Article 23 that natural resources are the property of individual Emirates. As a result, whilst federal ministries hold some strategic and coordinating responsibilities, institutions, legislation, and regulations governing natural, and more recently non-conventional, water resources are to be vested with the individual Emirate level. Day to day operations and management also take place at the local level. In addition, there are increasing inputs to water (and energy) management and regulations from Gulf Cooperative Council agreements.

Against this background research has been undertaken at the International Centre for Biosaline Agriculture (ICBA) in Dubai to develop new strategic policy ideas for the UAE. This work involved developing an updated and integrated assessment of UAE's water resources and their use, from which options have been identified to improve the efficiency of water allocation and use, reduce costs, and improve environmental conditions. The governance of water was also reviewed particularly the responsibilities, laws, and regulations of the various institutions involved.

A number of key initiatives and associated policy instruments have been defined, and are currently under review. Unsurprisingly, a priority area for new water policies is water demand management, particularly in agriculture. This would achieve both sustainable development and significant reductions in related future investments in production capacity and infrastructure. Another key area is the coordination of water governance amongst the different Emirates that would foster increased consistency and transparency in areas such as technical, economic, and environmental regulations and standards. This could bring greater scales of economy in future infrastructure development as well as more effective regulatory control. The key initiatives are as follows:

### **Initiative 1**

Develop legislation, standards, and federal mechanisms for coordinating water resources management for cross-Emirate and cross-sectoral policy development:

- Move to appropriately allocate and effectively use water resources for the benefit of current and future

Morocco is under construction and the West Delta in Egypt is in the bidding phase (Box 3). In 2010, the Egyptian Parliament passed a new law for setting up public-private partnerships in infrastructure development, which is expected to boost the role of the private sector in all economic sectors including water.

### **Case study: PPPs in the urban water sector of Jordan**

Jordan's water supply and sanitation sector provides two insightful lessons about PPPs.

#### **i. The Greater Amman water supply and wastewater service management contract**

In 1999, a Management Contract was signed

between the Water Authority of Jordan (WAJ) and a private consortium, known as LEMA (Suez Lyonnaise des Eaux, Montgomery Watson and a Jordanian company (Arabtech Jardaneh) (LEMA)). The management contract ended on December 31, 2006. LEMA was the operator responsible for managing, operating, and maintaining the facilities in a cost-effective manner with reduced cost and increased profitability in the water and wastewater operations of the service area. The Program Management Unit (PMU), a body within WAJ was created to monitor the progress of the Greater Amman Water Supply Program. The aim of both the management contract and the Capital Investment Program was to restructure and rehabilitate the water supply services in Amman.

- generations;
- Develop regulations, standards, and specifications for benchmarking management;
- Support stakeholder coordination and understanding;
- Integrate the predicted consequences of climate and environmental change;
- Guide and oversee the creation of a national water database;
- Ban water export; and
- Establish a national water council to coordinate activities among stakeholders and provide a forum for dialogue.

### Initiative 2

Enhance natural water resource protection and develop a groundwater strategic reserve:

- Introduce water budgeting at the national, regional, and local levels that accounts of all water supplies and uses;
- Coordinate the merging of Emirate-level activities to form a national water quantity and quality monitoring system;
- Further develop the operation of check dams in the Northern Emirates to improve retention of floodwater and groundwater recharge; and
- Promote zoning and artificial groundwater recharge.

### Initiative 3

Develop national agricultural policy aimed at water conservation and increasing value to the economy:

- Undertake further research to deepen knowledge of the UAE's agricultural economy and its use of water;
- Build on this knowledge to initiate an agricultural plan to better conserve scarce water resources; and

- Promote a new agricultural development model that is water conservative, environmentally benign, and commercially viable.

### Initiative 4

Rationalize water consumption to be within the global daily per capita water consumption rate:

- Save water by limiting the daily per capita consumption to be around the global average of 200 liters per capita per day, through awareness programs and campaigns, and the adoption of modern systems and technologies to save water in various sectors.

### Initiative 5

Review and develop a clear water pricing policy:

- Rationalize the tariff system so that slab pricing is common to all Emirates;
- Reduce subsidies paid by governments to close the gap between actual cost and imposed tariffs; and
- Review possibilities of introducing water pricing for groundwater or reclaimed water.

In the next few months these initiatives will be considered in greater depth and any structural changes to adopt these initiatives will require careful negotiations amongst the various stakeholders. Water security is one of the cornerstones to the future development of the UAE and none of the decisions to be made are going to be easy. However, the challenges cannot be avoided in the UAE, nor can they in any other Arab country.

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The Governorate of Amman service area is the largest domestic water market in the country. The operator's compensation was based on its ability to reduce operating expenditures while increasing revenues from the provision of water and wastewater services. The operator is paid an annual 'performance incentive compensation', which permits the operator to retain a percentage of the gains in profitability over the term of the contract.

The responsibilities of the private operator included transferring water to the water treatment plants and distributing the treated water, maintaining the facilities at specified standards of maintenance and developing a comprehensive

maintenance management program, rehabilitating and repairing the facilities as required, supplying drinking water to subscribers, taking responsibility for billing, collections, and customer service related to subscribers in the service area, and cooperating with WAJ in implementing its Capital Investment Program (WAJ, 1999). LEMA's performance has been evaluated against over 60 measurable targets.

#### ii. The NGWA Managing Consultant contract

In 2004, WAJ conducted through the PMU an open competition to hire an experienced water and wastewater operations firm as a 'Managing Consultant'. The objective was to assist the



Northern Governorates Water Authority (NGWA) increase the efficiency of its water and wastewater services. NGWA is a water utility that provides services to 210,000 customers (residential and commercial) in the four northern governorates (Ajloun, Irbid, Jerash and Mafraq) of the country. Thus, the partnership in this case was a three-year contract between WAJ (specifically the PMU) and the Managing Consultant. The latter is a joint venture of the British water operator Severn Trent Water International and a local engineering firm, Consulting Engineering Center.

WAJ remains responsible for service delivery, general management, custodianship of facilities and personnel matters, all financing requirements of service delivery, asset ownership, as well as legal responsibility for all administrative activities. The Managing Consultant's primary responsibility was to provide advisory services to the new utility - NGWA - and help NGWA breakeven financially to become an operating company (a public water company) within three years.

The Managing Consultant's role included operating the water and wastewater facilities, carrying out leak detection and repair, carrying out day-to-day responsibilities for non-revenue water (NRW) reduction, maintaining the facilities, developing a comprehensive maintenance management

program, carrying out all billings, collections, and customer relations and service functions, reaching the defined objective of an operating ratio (or cost recovery) of 105% and a balanced cash-flow, and meeting all of the criteria necessary for WAJ to ultimately assign responsibility for the management of water and wastewater services to an operating company. The contract value was approximately \$6.5 million and was co-financed with KfW (the German Development Bank). It was monitored by the PMU, which created a performance indicator and benchmarking system for NGWA.

### *iii. Lessons learned*

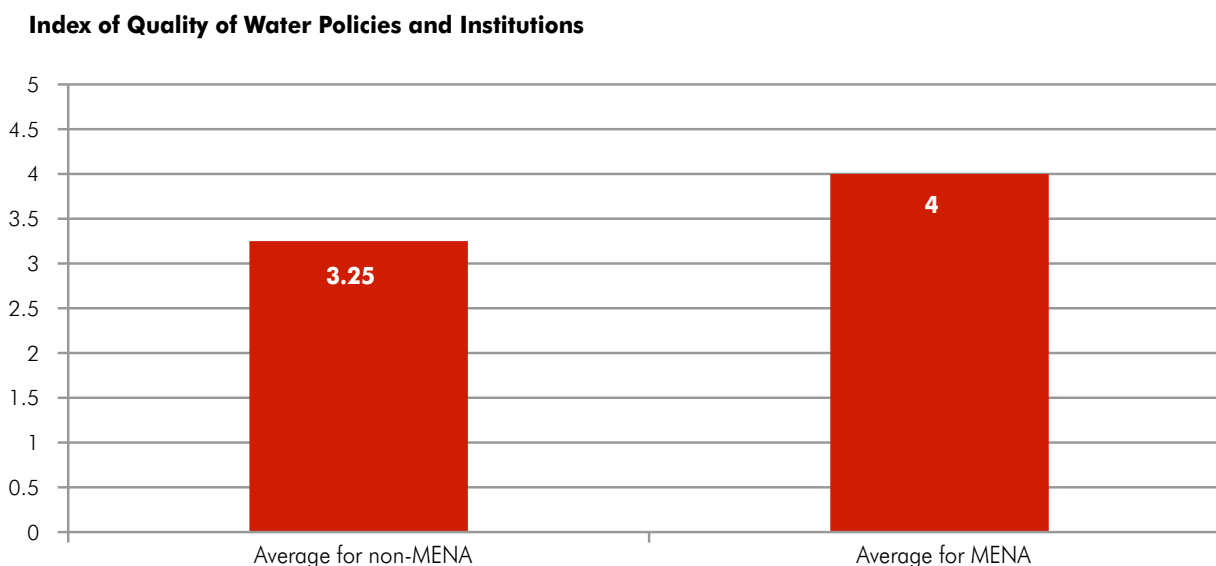
An in-depth study of the two PPPs in Jordan revealed that three institutional factors, namely, contract flexibility and accountability, governance structure, and legal setting, emerged as the most important in determining their effectiveness. First, the Amman management contract offered flexibility in terms of the ability to review and modify the contract. However, both the Amman management contract and the NGWA Management Consultant contract were relatively inflexible in terms of affording the service provider the degree of autonomy it needed in order to be effective. It could also be argued that these two urban contracts fostered accountability to customers and government. The performance standards in both cases were explicit, although as some pointed out were unattainable.

Second, participation was weaker in the Amman management contract mainly because of its internal set-up. Unlike the NGWA Managing Consultant contract, LEMA had not developed a business plan of any description. As a result, there was no vision for the company, and therefore no unifying document around which staff might have coalesced them in finding a common sense of purpose. In sum, both internal and external governance were weakest in LEMA, and this dampened the participatory approach. Another reason for believing that the NGWA Managing Consultant contract was more participatory is that it included an elaborate governance arrangement for decision-making that involved actors from both outside and within the NGWA.

Third, the most constraining laws that confronted both LEMA and the Managing Consultant were:

FIGURE 4

## EVALUATION OF WATER POLICIES AND INSTITUTIONS IN MENA AND COMPARABLE NON-MENA COUNTRIES, 2004



Source: World Bank, 2007

(a) Jordan's government procurement regime is framed by the Government By-Work Regulation No.71 (1986), and the Supplies Regulation No.32 (1993). Both of these are overly bureaucratic and emphasize securing the lowest cost for supplies, which inherently forces a compromise on the quality aspects of nearly any given procurement; (b) the auditing bodies which were numerous and inconsistent in their assessments; (c) the Civil Service Law (2002) which is very rigid and limiting because it does not allow an entity like LEMA to operate on a commercial basis; and (d) the Water and Sewerage Authority Law (1973), which does not provide for any applicable penalties when illegal stormwater connections to the network are discovered. The latter made it very difficult for both LEMA, and the Managing Consultant team to oblige customers to disconnect.

Another adverse effect of the legal setting was, and still is, the lack of consensus on which entity should assume the role of a regulator of Jordan's water sector. This means the lines of responsibility between key organizations are also quite nebulous. However, overall, the various laws and regulations have provided a fairly comprehensive set of 'checks' as to who-does-what, which means the lines of accountability are spelled out. The end effect is that they could not deliver services to their customers as effectively as they might want to.

## V. PROGRESS AND LIMITATIONS

The last two decades have witnessed progress in improving water governance in Arab countries, which can be characterized as slow but steady. It is hard to make generalized conclusions due to the diverse political, social, and economic conditions in the region. According to the World Bank (2007), the averaged index of quality of water management and accountability in 10 MENA countries was above the average score for 27 low- and middle-income countries from outside the region (Figure 4). This index covers the adequacy of what is called a policy mix (legislation, property rights, and allocation mechanisms) as well as instruments and policies to control water pollution (standards, instruments, and stakeholders participation). This is an evidence of the efforts made by the region to improve water management during the past 10-20 years.

The overall evaluation of the World Bank study shows that with respect to the issues of governance and administrative reforms, the MENA region rates high in indicators related to political stability; is fair in terms of service delivery and anticorruption; and rates low on issues of public voice, accountability, and participation. The study identifies as a main constraint the overall size of the public sector.

## OPINION

**RIGHT TO WATER: A PARLIAMENTARIAN VIEW****Adnan Badran**

Right to water is a principle of insuring water for all. Parliamentarians, as a legislative body, should make this right explicit in the law of all countries as a basic human right.

To insure this, countries in the Arab region should look at water as shared commodity and a basic denominator for economic common market. Water networks can be built across borders of the region, whereby water-rich countries charge water-poor countries for their consumption, similar to the currently operational regional power grid for electricity sharing.

The Arab region could establish a common economic market around water and energy as the European Union countries have done for steel and coal.

Parliamentarians need to legislate in the direction of promoting complementarity and distribution of water resources across borders, by creating trans-Mena regional water carries from areas of abundance to areas of water scarcity..

Arab countries are located in arid and semi-arid zones, which are critically at the threshold of water scarcity. Droughts, rising temperatures, seasonal fluctuation of rainfall and rise of the sea level are expected to increase with the predicted climate change. Any reduction of rainfall and rise in temperature will further threaten the fragile ecological system of the Arab countries, destroy the biological diversity and increase desertification, destroying the biodiversity balance. This may lead to the spread of disease and malnutrition, epidemics, poverty and people migration to the North. Parliamentarians need to move, diligently and swiftly, to adopt preventive measures against climate change disasters.

The need for legislation is imperative for good governance, which guarantees better water management and efficient use of water, mainly in agriculture and industry, through reducing loss, better technology in irrigation and recycling.

Transboundary water basins as Euphrates and Tigris between Turkey, Syria and Iraq, should be governed

by a legal framework, and international treaties should be put in place to avoid future conflicts over water basin rights between neighbors. This is the only possible path to avoid conflicts and future wars in the region.

The Nile basin also needs a binding legal framework in the form of international treaty among the 12 African nations which share its water. Transboundary waters may be instrumental in creating stability and economic cooperation among neighboring countries of the shared basins, including rivers, lakes and large underground aquifers. Otherwise, sharing countries may go to wars over water rights.

Jordan, considered the 4th poorest country in the world in water resources, is taking measures to build dams which depend on scarce rainfall to fill, and is also building south-north national carrier to tap underground water. It is also looking to desalination, through Red Sea-Dead Sea project, to overcome shortage of water, and to prevent environmental disaster of the shrinking Dead Sea, similar to that of the Ural Sea, as well as generating power and help moderate the harsh environment of the Wadi Araba Valley.

As parliamentarians of the Arab region, we should tackle the main water issues through appropriate legislation, which helps to find solutions at the national level as well as across borders, particularly to overcome implications of global warming. It is essential to implement overall management of water resources, harnessing science and technology for efficient use of water, including desalination, recycling, efficient irrigation systems and breeding new crops which can withstand increasing drought and tolerate brackish waters.

It is essential to act now for building peace around energy and water for us and for future generations.

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*Dr. Adnan Badran is a former Prime Minister, President of University of Petra and Member of the Senate in Jordan. The text is his opening address on behalf of MENA/Arab states at the Parliamentarian Session during the Fifth World Water Forum on 18-19 March 2009 in Istanbul, Turkey.*

According to the World Bank (2007), “the new policies and organizations are not fully achieving their intended goals in most countries” of the region because: (a) “the existing regime of subsidies does not encourage growth of organizational capacity”, (b) “legislation often lacks the necessary implementing rules and regulations”, and (c) “enforcement tends to be weak”. Further, the World Bank (2007) argues that “potential solutions to the region’s water problems are well known but have often not been implemented because of constraints in the broader political economy” in each country.

Access to reliable data and exchange of information remains a big constraint. Data collection and monitoring programs are conducted by a variety of authorities without co-ordination and integration. When data is available, it is not continuous, comparable, reliable, properly reported, or disclosed to the public. Information on water resources management (quantity and quality) and water sector performance is considered in many instants as classified information not to be disclosed. The drivers could be political motivated by the need to avoid the rise of public pressure or concerns, or economic motivated by the need to protect export and tourism. Sometimes, it is purely bureaucratic succumbing to the adage: ‘Public Authorities Control Information’.

The crucial role of research in creating the knowledge base needed to improve water governance has not yet been sufficiently emphasized. Innovations in science and technology are needed in order to sustainably manage both conventional and nonconventional water resources. Relevant research and development could greatly enhance the institutional capacity, improve governance performance, and reduce associated running costs. Few Arab countries have highly reputed water research centers that conduct research on water resources management. The National Water Research Center (NWRC) in Egypt is one of a few in the region. Its research agenda and products are aligned with the national water plan of the country. Relevant research is emerging today from the Gulf countries, where research and innovations have become central in formulating water strategies and plans. The rewards from this type of research could be reaped quickly as is exemplified by the



international rating of King Saud University of Riyadh, which has been significantly enhanced in a short period due to an aggressive program of academic development (AWC, 2009).

Progress in capacity building, training, and development of the professional skills necessary to meet current and future challenges are receiving increasing attention. Newly established regional organizations such as the Arab Water Council (AWC) and the Arab Water Countries Utilities Association (ACWUA) seek to promote ‘good’ water governance in Arab countries. They implement capacity building and training programs with priority given to policy and institutional reform, water governance, and water management. In 2009, the AWC established the Arab Water Academy (AWA), based in Abu-Dhabi, to be a centre of excellence and agent of change in water management, water service provision, water finance, and water diplomacy. Other examples of regional water governance capacity building programs include the Partner Fora on Water Governance in the Arab Countries started in 2006. This program is implemented by AWC and ACWUA in partnership with the InWEnt - Capacity Building International,

Germany. The program brings world experience, lessons learned, and case studies from around the world and from within the region, and allows water stakeholders from the region to engage in reviews, analyses, discussion, and debate on approaches and applications of 'good' water governance in the region. In 2009, the United Nations Development Program (UNDP) launched the Water Governance Program in the Arab States (WGP-AS), to address regional water challenges resulting from geographic and climatic conditions, lack of peace and security, population growth, increased water demand, inadequate access to clean water and sanitation, insufficient capacity, and limited resources, in addition to deficiencies in data and monitoring tools.

## VI. CONCLUSION

The water sector in Arab countries suffers from a weak governance structure due to inadequate policies and institutions. Institutional limitations and water scarcity are compelling Arab governments to introduce reforms to "create flexible but effective water allocation and management mechanisms" (Saleth and Dinar, 2004). Several Arab countries have been able to achieve progress over the past two decades in reforming their water sector policies, reinforcing institutions, modernizing legal frameworks, and building capacities to improve water management and services. Gradually, but slowly, water beneficiaries are now viewed as water customers or partners (Saleth and Dinar, 2004). In some Arab countries, it is now recognized that non-government groups have to be granted a more enlarged role in water governance.

Policies for sustainable water management have been developed, but they face challenges in their implementation and there is a lack of monitoring tools. Public and private institutions are moving towards greater accountability, transparency, and rule of law. However several policy, financial, and capacity gaps still exist. Participation of stakeholders and civil society groups has improved and private sector participation is growing in water supply and sanitation as well as in building and operating irrigation infrastructure. Legislation and regulation have improved but they still have to

be strengthened and enforced to address current and future changes. In many countries the legal and regulatory framework is still inadequate and there is a need to provide better financial and technical support to water governance.

Overall, ongoing reform processes are geared towards sustainable water management that balances demand (economic instruments) with supply (service delivery). Some Arab countries have realized that fundamental reforms in water management are more likely to result from policy changes in trade, social protection, and economic instruments than from changes under the control of water ministries (World Bank, 2007). Political reforms involving nationwide institutional changes can reduce the transaction costs of water sector reforms directly because the changes within the water sector form only a small part of the overall reform process. Thus the ability of most countries in the region to reform the water sector will critically depend on the speed with which overall political reforms are undertaken to create a new governance structure needed for sustainable water allocation and management.

Positive impacts can be noticed in the region, but more still needs to be done. To date, increased attention to water has not always translated into assigning priority to institutional and regulatory reforms within either the water governance agenda or the broader national governance agenda. Advancing the water reform agenda will be vital to fostering investments, putting in place strategic water policies, and ensuring coherent implementation. The state of the overall national governance will determine how far and how fast water governance can be improved.

## VII. RECOMMENDATIONS

The capacity of institutions participating in drafting and monitoring national and local IWRM plans needs to be improved, particularly at the local level. Improving the legal framework and the rule of law is also needed. To improve water service efficiency and ensure accountability, the public sector has to shape new rules and regulations governing private sector participation in the water sector. It will need to create a more balanced regulatory framework that keeps abreast of public responsibility and private interest and



manages risks adequately in a manner that does not inhibit entrepreneurship and innovation. More experience and institution-strengthening measures are needed to expand public-private partnership (PPP) capacity so that it can make a real contribution to meeting the region's growing urban water service needs.

Participation must not be understood as an end in itself with the rise of organized water user groups as the final objective. Participation has to be a means of achieving joint responsibility at all levels of decision-making processes, where actors form part of the problem as well as the solution.

The Organization for Economic Co-operation and Development (OECD), in a recent unpublished study, defined five major regulatory development gaps which need to be addressed in order to consolidate the progress achieved in improving water governance: (a) the financing gap for meeting the financial cost of setting up regulatory agencies and ensuring their viability; (b) the capacity gap to raise the technical expertise and competences of staff; (c) the policy gap that can establish regulatory agencies' autonomy and independence from the executive power; (d) the information gap to reduce the asymmetry of information between the regulator, the operator, and the user; and (e) the participation gap to allow real citizen involvement in the work of the regulatory agencies. Although these are globally recognized gaps, they aptly apply to most of the Arab countries as discussed in this chapter. More effort should be mobilized to close gaps in policy and institutional reforms, build capacities and skills, disclose information, raise awareness, and allow a broader participation of stakeholders.

In Arab countries today, extraordinary measures of cooperation are required at local, national, and regional levels to improve the existing patterns of water governance in an arena where different interests as well as dissimilar values and norms prevail. Therefore, the way forward in Arab countries is to recognize the importance of planning and implementing frameworks for good water governance that take account of differing social, economic, environmental, and cultural contexts, including the introduction of processes of interaction between state and non-state actors and mechanisms for recognizing mutual responsibilities for governance.

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## NOTES

- IWRM is "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 the ecosystems" (GWP, 2000).
- After the construction of HAD, an annual rice area of 315,000 ha was proposed in the Northern Nile Delta for protection against sea water intrusion and salinization of the soil.
- <http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor>
- This is an important body within the context of the management contract because the PMU was established in 1997 as an entity within WAJ whose task it is to coordinate and monitor the Greater Amman water supply and wastewater service management contract, as well as oversee the Capital Investment Program for Amman and prepare other governorates for commercialization of their water utilities and PSP (PMU, 2007).
- NRW is the metered volume of water that is not producing revenue, so it is the difference between water produced and water billed. NRW has three main components: physical (real) losses (i.e. leaks, overflow at storage tanks); commercial (apparent) losses (i.e. water theft through illegal connections, customer meter under registration, and data-handling errors etc.); and unbilled authorized consumption which is water used by the utility for operational purposes e.g. firefighting and water provided for free to certain customer groups (World Bank, 2006).
- An operating ratio of 105% means operating revenue exceeds operating costs by 5%. Sources of operating revenue include: water sales in the service area, sewerage and drainage fees, meter subscriber fees, water sales to other governorates, water connection fees, sewage connection fees, water sales by NGWA tankers. Operating costs include salaries, electricity, etc. (Interview).
- All countries of the MENA region at the World Bank are Arab Countries except Iran, although the MENA region does not include Sudan, Somalia, and Djibouti, which are part of the Africa Region.
- The Arab Water Council was established in April 2004 as a non-profit independent regional organization open to all water stakeholders to promote improved water management for sustainable development in the Arab countries.
- The Arab Countries Water Utilities Association (ACWUA) was founded in April 2007 as a regional center of excellence, to partner with water supply and wastewater utilities in Arab countries to provide best practice service delivery to their customers.

# Linking Water Research and Policy

HAMMOU LAAMRANI  
ABDIN M.A. SALIH



## I. INTRODUCTION

Given the precarious situation of the water sector in the Arab region, the region should have become, in theory, a water “Silicon Valley”, generating cutting-edge water science, innovative solutions, and new pathways to address the region’s water challenges. Today, this is not the case. Despite some progress, the regional overall knowledge index (including water sciences) remains one of the lowest in the world (World Bank, 2008a). As a result, demand for water research is not yet a systematic component of the water policy cycle even among government agencies that provide funding to research organizations. Underfunded, understaffed, and poorly performing research organizations continue to dominate the regional water research landscape with a few bright spots (Taylor et al., 2008). The weak condition of the region’s water departments at national universities and research centers is compelling some Arab governments to seek the expertise of consultants from outside the region to fulfill the demand for strategic water resources management plans. The high demand for key water policy documents by policy-makers combined with the weak state of water research centers make the debate on linking water research to policy a top priority. Research and innovation are critical to setting the stage for effective water policies that ensure sustainability, efficiency, and equity in access and use of the scarce water resources available to Arab states.

In line with this, in his opening remarks of a Board of Governors’ meeting of the Arab Water Council in the city of Alexandria in June 2007, Sadeq Al Mahdi, the former Prime Minister of Sudan, made a very simple but eloquent statement: “Unless good science is a key demand of the policy-makers in order to choose between policy options, all efforts to reform the water sector in the Arab region will be like flowers in the desert, wasting their perfume.”

Our research has demonstrated that there is little effort to link science to policy in the Arab region particularly in the water sector. The linkage between science and policy can have a significant contribution in improving both water governance “as a process” of decision-making and power sharing and in water management “as a result of that process” (Laamrani et al., 2008). This is evidenced by Carden (2009) in his book devoted



fully to this topic reflecting on linking knowledge to policy based on 23 country case studies across the globe including some from the Arab region: “Research can contribute to better governance in at least three ways: by encouraging open inquiry and debate, by empowering people with the knowledge to hold governments accountable, and by enlarging the array of policy options and solutions available to the policy process.”

The *raison d’être* of research organizations is simply to generate new knowledge that societies can utilize to address socio-economic development challenges. In this sense, the Arab region has excellent individual technical competences in the water sector. The current gap is more about the institutionalization of science and innovation. The Arab region lacks a critical mass of world-class researchers that is needed to build water research organizations. Therefore, the ability to sustainably produce cutting-edge science to influence policy-making is weak. What it needed to address these shortfalls is what this chapter aims to examine. The intention is to shed some light on how research and policy in the Arab region can mutually guide and feed each other in order to work “in series” instead of working “in parallel”. We intend to challenge some taken-for-granted assumptions about research and policy that might not hold true at least in the context of some Arab countries based on recent work pioneered by the Water Demand Initiative for the Middle East and North Africa WaDImena.

## II. RESEARCH AND DEVELOPMENT IN ARAB COUNTRIES: WHERE DO WE STAND?

Water research and scientific innovation in the region is part of a deficient research system. Indeed compared to other regions and countries of the world, excluding Africa (not including South Africa), the Arab region is on the bottom of the world scale in science and technology as reported by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute of Statistics (UNESCO, 2001). As shown in Table 1, Arab states rank low relative to all regions of the world in the global share of research and development (R&D) expenditure, in gross domestic expenditure in research and development (GERD) as a percentage of the gross domestic product (GDP), in the number of researchers per million inhabitants, and in R&D expenditure per researcher. The contribution of Arab states to the world production of science and technology publications, patents, and exports of high-technology products was too insignificant to be detected or reported. In contrast, very high shares of these indicators are scored by countries

from North America, Europe, and Asia which is clearly reflected in their high level of socio-economic development.

The poor position of Arab states in their contribution to science and technology (S&T) has unfortunately continued to appear in all of UNESCO's science reports with minor fluctuations from the indicators shown in Table 1. As an example, Badran (2005) provided a comprehensive report that reviewed the state of science in Arab states. The author stated that the region today exhibits poor performance in science and technology due to political turmoil, low quality education, and inadequate R&D infrastructure. He concluded that the Arab region has failed to deliver the high-quality scientists it needs to build economic self-reliance and capacity for innovation in the region. The indicators quoted for water for the year 2000 in this report showed comparable poor figures to those compiled in table 1 (1996/1997): There is no change in GERD as a % of GDP; the number of researchers per million inhabitants has decreased to 124; and the expenditure per researcher has only increased to US\$48,000 as

TABLE 1

**THE STATE OF SCIENCE AND TECHNOLOGY RESEARCH SYSTEMS IN ARAB STATES COMPARED TO OTHER REGIONS OF THE WORLD**

Region/ Country	Share of world R&D expenditure in 1996/97 (%)	GERD as a % of GDP	Researchers per million inhabitants	R&D expenditure per researcher (10 <sup>3</sup> US\$)	World production of S&T publication (%)	Patent world share (%)	
						EPD	USPTO
USA	36.2	2.6	3698	203	36.6	35.2	51.5
Europe	28.8	1.7	2476	89	37.5	46.3	19.2
Asia	27.8	1.3	537	85	15.2	15.5	27.5
Latin America and Caribbean	3.1	0.5	715	48	1.8	0.2	0.2
Africa (excluding Arab states)	0.5	0.3	113	49	0.7	0.2	0.1
South Africa	0.4	0.7	1031	49	-	-	-
Arab states	0.4	0.2	356	24	-	-	-
World average	100	1.6	946	105	-	100	100

## Key:

R&D: Research and Development  
GERD: Gross Domestic Expenditure in R&D  
GDP: Gross Domestic Product

Source: Adapted from UNESCO (2001)

S&T: Science and Technology  
EPD: European Patent office  
USPTO: United States Patent and Trademarks Office

### **BOX 1: LIMITED HUMAN AND FINANCIAL RESOURCES LEAD TO LIMITED IMPACT**

A study by Taylor et al., (2008) revealed that water research organizations in the Middle East and North Africa (MENA) region are hampered by the following constraints:

- The unavailability of a critical mass of competent researchers in the region.
- The management and leadership of research organizations are ineffective.
- The linkages between research and policy communities are not established.
- Career opportunities in the region for researchers may not be compelling enough to retain them.
- Limited connectivity to international research communities hampers professional growth, learning, and exposure to new ideas, all of which are vital to the success of careers in research.
- Many organizations in the region lack an internal research agenda that is “owned” by the organization itself. Many research organizations feel obliged to follow donors’ agendas, which are not necessarily aligned with community or national needs. Consequently, researchers may feel “sub-contracted” to pursue the agenda of others, leading to frustration and a sense of disempowerment.
- Organizations whose primary goal is to influence policy will often resort to recruiting well-connected and reputable researchers in order to increase policy-makers’ confidence in their research. However, reputation in the Arab region seems to be closely associated with seniority rather than performance in terms of relevant, high quality research. The importance of seniority appears to make it difficult for young researchers to attract funding or support for their own research ideas (Taylor et al., 2008).

compared to US\$238,000 in USA. The report confirmed the same low levels for 2000 in all other indicators and gave more quantitative details about these indicators in different Arab countries. For example, Saudi Arabia showed good progress in registered patents (67) for the period 1995-1999, compared to all other countries in the region. However, the Republic of Korea and Israel registered 9984 and 3076 patents, respectively, in the same period. Furthermore, member countries of the Gulf Cooperation Council (GCC) indicated higher users of Internet in 2003 as a percentage of population, compared to other countries in the region. The report also indicated poor performance by the countries of the region in two other indicators: translation and

publication of scientific papers, and number of cited articles in reputable journals. For example, the number of frequently cited scientific papers per million inhabitants amounted to 0.02 in Egypt, 0.07 in Saudi Arabia, 0.01 in Algeria, and 0.53 in Kuwait compared with 43 in the USA and 80 in Switzerland.

While significant progress in different regions is taking place with regard to the performance of research organizations in different sectors where water resources are used, such as in agricultural research, limited progress in general is witnessed in the Arab world (World Bank, 2008b). A 2008 conference organized by UNESCO, the Arab League Educational, Cultural, and Scientific Organization (ALECSO), and the Arab League of States noted the slow pace of change in the role and capacity of R&D to change realities in the Arab region with water research not being an exception. In his report to the meeting, Saleh (2008) stated that national science and technology policies were lacking, coordination among research organizations was absent, and research data were unavailable.

### **III. WATER RESEARCH INSTITUTIONS: LIMITED ASSETS, LIMITED PERFORMANCE**

In most Arab countries, water science and research organizations are functioning as adjuncts to agricultural research, civil engineering schools, and infrastructure research organizations, and rarely operate as standalone entities. The main mandate for many of them is for higher education with a research agenda left to the will and personal interests of the teaching staff. The low priority given to water research organizations is not commensurate with water’s critical role in securing livelihoods, public health, and development.

A typology of assets and constraints of national water research organizations is elaborated by Taylor et al., (2008) in Box 1. The authors pinpointed a set of key constraints affecting the performance of research organizations and their ability to influence policy formulation, implementation, and evaluation.

The Arab region has to engage strategically in

building a new generation of water researchers. There is an urgent need today for water researchers who are well-trained as engineers and scientists with proven records of performance, but who also possess a very good understanding of the policy environment. Universities and engineering schools in the region could adopt dual degree programs combining doctoral studies in an engineering discipline and a professional graduate study program in public policy. Moreover, research managers need to have sufficient exposure to the business model of “science parks and incubators” emerging in countries like Egypt, Jordan, Morocco, and Tunisia.

Aside from the competence and capacity of researchers and scientists, the capacity of water research organizations to retain talents (see Box 2) and funding mechanisms are key challenges. Core funding often comes from government agencies. But public funding is constrained and often drops off over time. This makes any forward planning typically short term, ad hoc, and uncertain. Unless research is considered central in setting water policy, water challenges are not likely to be addressed soon.

Water research organizations that are able to attract external funding typically perform better. Individuals and organizations that are able to compete for international funding opportunities continue to attract funds that allow them to conduct research that otherwise would not have been possible. Some of this research has generated findings that can be used to influence policy-making with support from donor organizations. For example, international organizations have contributed significantly to making water demand management a central component of water reforms, according to the study on the political economy of water demand management.

However, Taylor et al. (2008) have indicated that some researchers interviewed expressed reservations about the real impact of international funding on public policy considering that the agenda is not set based on national needs but rather on donors’ mandates and requirements.

High quality water research requires a national science and research agenda, political backing, outstanding research managers with a record of proven leadership, sustainable funding mechanisms,

career development incentives to attract and retain young and senior talents, and improved linkages between research and policy communities.

#### **IV. GOVERNMENT DEMAND FOR RESEARCH**

According to Carden (2009), a key element in linking research to policy is the government’s demand and systematic utilization for research findings in formulating policy in any sector. This statement is consistent with findings of the survey by Taylor et al. (2008) conducted in Algeria, Egypt, Jordan, Lebanon, Morocco, Palestine, Sudan, Tunisia, and Yemen with case studies in four countries (Egypt, Jordan, Lebanon, and Morocco) and encompassing 70 research organizations.

The survey has found that government demand for research appears to be extremely limited at present. Where there is government interest, it is most likely to be represented through the actions of specific individuals. Researchers and managers of research organizations need to find strategies and mechanisms to develop personal relationships with these individuals, who tend to privilege the few. Building institutional relationships between research organizations and policy-making bodies is therefore difficult to initiate and sustain. Gate keeping relationships encourage individuals to guard their contacts, their resources, and even their findings with an aim to share them at international events in order to attract prestige

#### **BOX 2: TALENTS ARE NOT ONLY RARE BUT DIFFICULT TO RETAIN UNDER POOR INCENTIVES AND “DISABLING” WORKING ENVIRONMENTS**

In his speech at the Second General Assembly of the Arab Water Council in Cairo in December 2009, the Egyptian Minister of Water Resources and Irrigation made a revealing statement about the real problems facing his Ministry today. He stated that the number one challenge the Ministry has to deal with today is not the lack of funding; it is the movement of talented experts (both senior and junior) outside the Ministry seeking job opportunities in the private sector and international and regional organizations. “Young talents cannot resist attractive packages and a conducive working environment that we simply cannot afford to provide in the Ministry.”

## DEVELOPMENT OF HUMAN AND INSTITUTIONAL CAPACITIES IN THE ARAB WATER SECTOR ARAB WATER ACADEMY: A REGIONAL CENTRE OF EXCELLENCE

**Asma El Kasmi**

The Arab region has a long and distinguished history of hydraulic innovation. In recent decades, leaders have increased access to potable water and sanitation and expanded storage and irrigation networks. Despite these important steps, poor water outcomes remain common in the region. Over-extraction of groundwater has left aquifers depleted and reduced the availability of reliable, lower-cost water resources. Spending on water infrastructure is not always well-directed to the most economically beneficial investments and performance levels of urban water supply and irrigation infrastructures are often low, with water losses of up to 50%.

Where water resources are not managed effectively, there are serious economic, environmental, and social consequences. Fiscal burden and budgetary pressures are increased and negative environmental impacts are accentuated, in addition to adverse public health outcomes, increased poverty, and risk of conflict and local tension.

Put simply, inadequate water management costs the Arab region too much to ignore. From an economic perspective, the facts are compelling: over-extraction of groundwater is undermining national assets at rates equivalent to 1 to 2 percent of GDP every year, environmental problems resulting from poor water management can cost between 0.5 and 2.5 percent of annual GDP, and illness and death related to inappropriate wastewater collection and treatment costs can exceed 2% of GDP in some cases.

The 21<sup>st</sup> century brings yet greater problems for water management in the Arab world. Rising populations, dynamic economic growth, and anticipated negative effects of climate change will further increase pressure on the region's water. Without changes in policy, technology, and behavior, increased water scarcity will reduce agricultural production and threaten regional food security. To further complicate this untenable situation, around 70% of the region's water flows cross international borders and need to be managed fairly and efficiently for all concerned if inter-community antagonisms are to be avoided. Facing and addressing these combined challenges require that high priority be given to investing in the development of human capital and institutional capacities.

It is well-established today that there is a need for more

focus on integrated management of water resources rather than water supply augmentation and service provision. This change in paradigm calls for a radical redefinition of the learning and capacity building programs. The Arab region can be proud to have invested in the training of excellent hydraulic engineers who have ably contributed to building numerous water infrastructure projects, serving cities and irrigation schemes, and helping control flooding. However, water problems are increasingly shifting to institutional and policy issues with a critical impact on both the quality of management and the governance of water. Sharing and managing this scarce resource in the region, while ensuring social equity as well as financial and environmental sustainability, demands skills that go beyond traditional engineering training to include economics, politics, ecology, diplomacy, and democracy.

Moreover, in order for the region to effectively meet the new generation of water challenges, there is a recognized need to focus on strengthening the knowledge and skills of the water sector's decision-makers and professionals.

The Arab Water Academy (AWA) was created to fill the gap in executive education and leadership development. As a unique regional initiative for human and institutional capacity development, the mission of the Academy is to go beyond conventional education and training and act as an "agent for change". Change is inspired by the shift from the hydraulic mission to a mission relating more to water for sustainability and growth.

### **The Academy is established as a regional centre of excellence with the mission to:**

- Equip participants with new skills, ideas, and tools to develop water resource management strategies and policies based on integrated thinking across sectors; and
- Support participants as they work to improve enabling environments, institutional frameworks, policies, and organizational capacity in their countries.

While each country of the Arab region faces its own distinctive water management challenges, a common set of opportunities exists to help achieve integrated water management in the region. The Arab Water Academy focuses on three areas: (1) informed and





visionary leadership to champion strategies for change, (2) management in possession of the latest knowledge and skills, and (3) public awareness of the issues and engagement in finding solutions to water challenges.

**The AWA programs and services include:**

- Leaders' forum, where concepts and ideas are discussed to shape future water policies;
- Executive education to boost knowledge and skills;
- Knowledge communities to share ideas and inspiration; and
- Expert advice to provide practical solutions to pressing problems.

The AWA functions as a regional knowledge hub where the most relevant new thinking from the Arab region and around the world is deposited. This knowledge is provided using cutting-edge learning methods.

The executive education programs of the Academy target senior professionals and policy makers from the public and private sectors. They are designed to bring new perspectives on demand management, institutional reform, cost recovery, integration of the water sector with non-water sector organizations, private sector participation, and environmental sustainability.

The learning programs of AWA for 2010-2011 include

Water Governance and Leadership Development, Designing and Implementing Successful Utility Reform, Private Sector Participation in Water, Water Diplomacy: Sharing the Benefits, and a Non-Conventional Water Resources Traveling Workshop in Abu Dhabi and Australia.

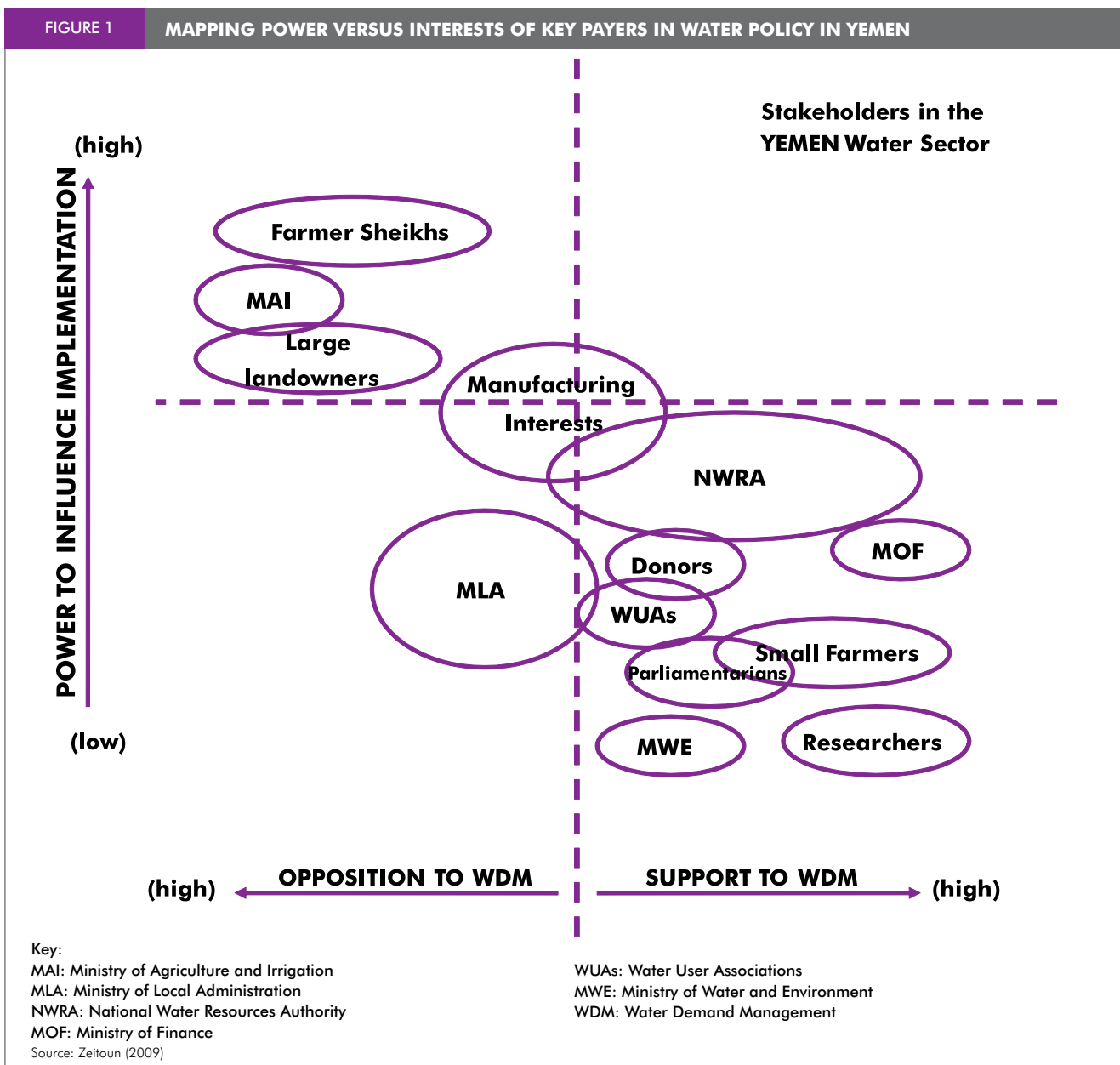
During its first year of existence, AWA has undertaken successful steps towards establishing itself as a regional centre of excellence. The academy is a groundbreaking institution for regional capacity development and has provided high-quality executive education programs to over one hundred professionals from 18 Arab countries. Over 80% of the participants in AWA's main programs were top decisions makers and senior professionals.

By introducing a new momentum for developing the region's knowledge base and advancing its economies, the AWA provides a unique stimulating platform for the Arab world to become a leader in 21<sup>st</sup> century water management.

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*Dr. Asma El Kasmi is Director of the Arab Water Academy, Abu Dhabi, UAE. Initiated by the Arab Water Council (AWC) and developed through consultation with water leaders and experts from the Arab region and around the world, the Arab Water Academy has been based in Abu Dhabi since July 2008. It is hosted by the Environment Agency Abu Dhabi (EAD) in partnership with the International Center for Biosaline Agriculture (ICBA).*

FIGURE 1 MAPPING POWER VERSUS INTERESTS OF KEY PAYERS IN WATER POLICY IN YEMEN



and funding. This seems to reduce opportunities for research organizations to make a contribution to positive change at the national or even regional level (Taylor et al., 2008).

**V. SCIENTIFIC KNOWLEDGE ALONE IS NOT SUFFICIENT TO ENABLE SUSTAINABLE DEVELOPMENT**

How knowledge and politics interact shapes the development of policies for the sustainable management of water resources.

Institutions, interests, and individuals also play a role in promoting or constraining sustainable development. Although the generation of scientific understanding is an exercise in rational thinking and objective analysis, the behavior of stakeholders in many regions of the Arab world is far more driven by existing power asymmetries.

Based on the synthesis work done by Zeitoun (2009), the diagram in Figure 1 demonstrates the power positions of different water stakeholders in Yemen in relation to their stance to reform. Indeed, the most striking element in the graph

is that researchers, who are very supportive of water demand management (WDM) as a way to ensure sustainability of groundwater resources, have limited power to dictate policy formulation and implementation. Stakeholders who stand to benefit from the status quo are opposed to water demand management and will use their more powerful position to prevent reform policies from taking shape or at least from being implemented. Policy-makers are aware of the various alternatives for action, but the political cost of rational action for sustainable water policies is what policy-makers cannot often afford.

The inability of water managers and professionals to adopt practices that reverse unsustainable practices, such as the depletion of water aquifers, is worth reflecting on. The political economy studies conducted in Jordan and Yemen and qualitatively in Morocco by WaDiMena have revealed some preliminary conclusions. Implementing a policy change that threatens deeply-rooted practices and entrenched interests in hierarchical contexts, as in the case of Yemen and Jordan requires a good understanding of the power relations that sustain them. The various forms of power relations between stakeholders in the water sector of both countries are found to fall into either 'hard' or 'soft' forms, but primarily the latter. 'Soft' forms of power include bargaining power and the power to frame issues in such a way that they may not be contested (Zeitoun, 2009).

Therefore, sustainable water policy outcomes in the Arab region depend on processes and institutions that give all stakeholders the right to contestation and permit them to have a role in the formulation of policies regardless of existing power asymmetries. This requires political dialog among all stakeholders. Technical and scientific knowledge, if perceived to be credible and relevant by stakeholders, can provide a common ground on which contesting groups can mediate their differences. Knowledge can also provide an articulate voice to marginalized stakeholders and a means of leveling the playing field.

Another notable example that illustrates the marginal role assigned to technical knowledge is the policy of irrigated agriculture using non-renewable water resources in desert areas in many Arab countries. Scientific understanding of groundwater science has anticipated that

this would be an unsustainable strategy. Yet, the drive to attain food security and the power of agricultural lobbies prevailed. The over-exploitation of groundwater for desert irrigation started in the eighties and continued for 3 decades, although water subsidies have been reduced recently in a gradual policy reversal.

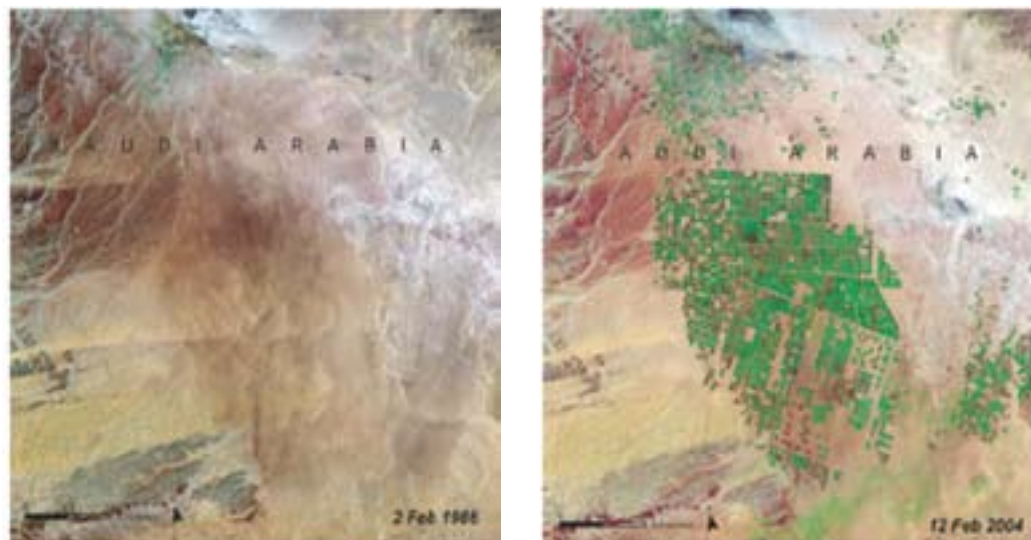
Al-Zubari (2005) remarked that "Over the past three decades, economic policies and generous subsidies in most of the GCC countries supported the expansion of irrigated agriculture in an effort to achieve food security. Irrigation water is often used inefficiently without considering the economic opportunity cost for potable as well as urban and industrial purposes. Agriculture contributes less than two per cent to Gross Domestic Product (GDP) in GCC countries but it over-exploits groundwater resources, most of which are fossil groundwater, resulting in their depletion and quality deterioration due to seawater intrusion and the up-flow of saltwater. No clear "exit strategy" exists to address the question of what happens when the water is gone." Figure 2 demonstrates dramatic changes in the desert landscape in Saudi Arabia as a result of this policy.

The example we borrow from Saudi Arabia is just one of many. The deterioration of groundwater resources in Sana'a and Taiz basins in Yemen as well as in the Saiss Plateau and Souss Mass in Morocco all illustrate the lack of timely impact of science on policy and show that the cost of these delays might be "irreversible and irreparable".

## **VI. HOW IS SCIENCE LINKED TO POLICY?**

Among water scientists, some often see their mandate as being limited to generating scientific knowledge, leaving the task of making the link between knowledge and policy to other professionals. Therefore, the problem at hand goes beyond generating cutting edge knowledge to developing the capacity to utilize knowledge in a timely manner by policy communities. Because systematic mechanisms for linking knowledge to policy are not well established yet in the Arab world, Carden (2009) has suggested, based on an analysis of 23 case studies, to create organizations with capabilities to be knowledge brokers.

FIGURE 2 CHANGES IN DESERT LANDSCAPE AS A RESULT OF IRRIGATED AGRICULTURE IN SAUDI ARABIA



Source: UNEP/GRID-Sioux Falls

Inter-ministerial committees on water, which act more as task forces assigned with specific and time-bound tasks, can play the role of knowledge brokers. However, according to Luzi (2010), the inter-ministerial committees are either not functional or leave little trace due to unclear mandates, lack of permanent supporting structures, and ineffective feedback mechanisms.

Permanent bodies such as the Royal Water Committee of Jordan or the Higher Council for Water and Climate in Morocco could also act as effective knowledge brokers. In other countries this could be part of a multi-task think tank such as the Egyptian Cabinet's Information and Decision Support Center (IDSC).

A unique set-up is the National Water Research Centre of Egypt. This is a consortium of specialized institutes created in 1975 as the research arm of the Ministry of Water Resources and Irrigation. The findings of research projects conducted by the different institutes are used systematically by different departments at the Ministry. Although this is an ideal mechanism to link water research to policy, some structural deficiencies have been reported (IPTRID, 2007).

## VII. CONCLUSION

- In the Arab world today, water research

is not yet a systematic component of the water policy cycle. The Arab region is facing a double challenge in regard to linking water science to public policy. First, the capacity to generate cutting-edge scientific research is lacking. Second, systematic institutional linkages to utilize knowledge in policy-making are not yet well-developed. Hence, the ability to formulate and implement effective water policies is severely constrained;

- The interaction of knowledge and politics within an institutional setting provides a good framework for initiating and advancing water policies. However, the water policy environment in Arab states is far more influenced by the politics of entrenched interests and asymmetric power relations than by a knowledge-based discourse. Institutional mechanisms that give voice to all water stakeholders are not well developed yet;
- Research organizations in Arab countries are hampered by the lack of national science and technology policies and the absence of coordination. Research agendas sometimes reflect the requirements of international funding organizations rather than echo local community needs and national goals;
- Water research organizations in Arab



states lack human and financial assets and do not have the capacity to offer young researchers promising and supportive professional careers. Researchers have limited connectivity to international research communities.

### VIII. RECOMMENDATIONS

- Arab governments should give priority to developing the capacity to generate credible and relevant water research. This requires a national science policy, a locally-accountable research agenda, political commitment, outstanding research management and leadership, sustainable funding mechanisms, and career development incentives to attract and retain young and senior talents;
- Linkages between research and policy communities need to be significantly improved. This would enhance the capacity of governments to utilize knowledge to serve their policy-making needs;
- Water think tanks and water centers of excellence should be established to play an intermediary role in bringing water science to policy;
- Institutional mechanisms and processes need to be established to level the playing field and give voice to all social actors who are affected by water policies. These mechanisms can provide a forum for all stakeholders to engage in political dialog and utilize knowledge in negotiating their differences;
- Universities and water research centers involved in academic endeavours in the Arab world are encouraged to offer innovative graduate-level programs combining engineering education and professional public policy graduate studies;
- Governments should encourage scholars and young water experts to develop an understanding of the policy cycle, where it exists, and to generate scientific knowledge that is perceived by policy-makers to be credible and relevant to their needs;
- Decision-makers should shield strategic decisions in water research and policy from influence by international aid agendas, while keeping high level of scientific cooperation with world class research centers;
- Water research organizations need strong political commitments and mandates to firmly place research at the center of water policy and locate water policy at the heart of overall development policy, rather than the other way around;

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# Remote Sensing: Generating Knowledge about Groundwater

FAROUK EL-BAZ



**FIGURE 1:**  
The Arab Desert Belt  
as photographed  
by the Apollo 11  
astronauts

## I. INTRODUCTION

Arab countries lie in the driest stretch of land on Earth, which encompasses North Africa and the whole of the Arabian Peninsula (Figure 1). Only three major rivers, the Nile, Tigris and Euphrates, supply narrow strips of land with year-round water. The rest of the region must depend on meager resources, where water for human consumption is provided by desalinating seawater, particularly in the Arabian Gulf countries. However, the remaining countries depend largely on groundwater for human consumption and agricultural activities. Thus, groundwater represents a major source of life in the Arab region.

Sparsely populated regions used to depend on water that percolated through rocks at higher topography to exit in the form of springs – called wahat (oases) in North Africa, oyoun in the Middle East, and aflaj in southern Arabia. These resources were sufficient for sparse populations in the past. However, more recently, large amounts of water were pumped from deep wells where water levels subsided giving the impression that the resources were exhausted.

The reasons for the popular perception that groundwater resources are limited include: (a) too many wells were usually drilled within close distances, in most cases to the same depth;

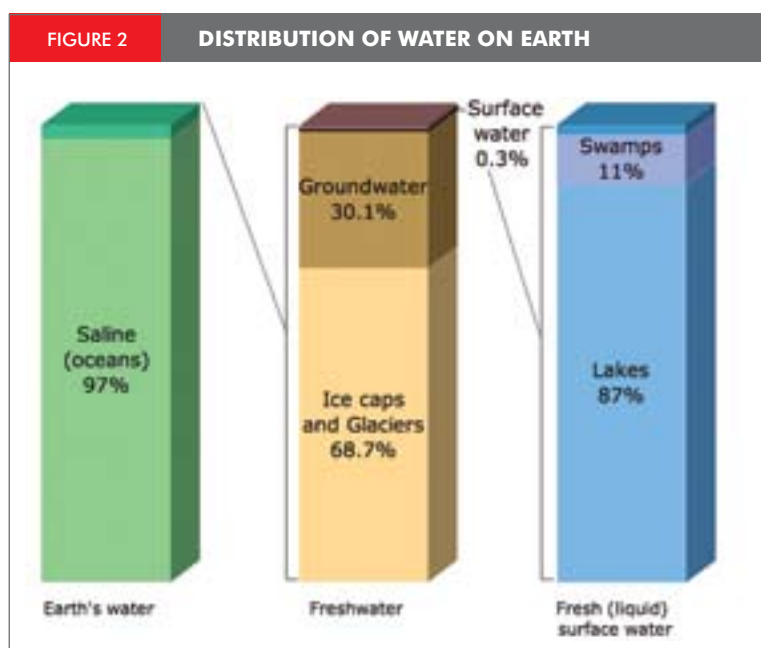
and (b) water was mechanically pumped at rates that were much higher than the mobility rate of water in the pore-spaces of the host rock. These practices resulted from the lack of knowledge of the groundwater environment by both official personnel as well as local farmers. The practices and their results popularized the erroneous notion that groundwater resources are undependable, and that they have been depleted in much of the Arab region. However, the resources are more plentiful if they are mapped thoroughly, used wisely and managed properly.

It is instructive here to consider water distribution on planet Earth (Figure 2). Salt water in the oceans and seas constitutes 97% of all water on our “blue planet”. Tangible and visible fresh water bodies that leave a marked impression upon us constitute a negligible fraction of the store of sweet water in the remaining 3% of water on Earth. Polar ice masses and mountain glaciers contain nearly 70% of all fresh water. Groundwater represents the remaining 30% -- that is more than 30-times all of the fresh water in all the rivers, fresh water lakes and swamps on the surface of the Earth.

These figures require us to ponder how the invisible water resources are distributed and where they are hidden in order to wisely locate, use and manage them. In the Arab region, groundwater is more prevalent and more extensive than generally believed, particularly in sand covered deserts, which are distant from population centers. It is important to note that such water accumulated during wetter climates in the past. Thus, they are not being replenished today and must be properly managed to ensure sustainability.

## II. GROUNDWATER SOURCES

The groundwater story begins as rain water accumulates on the ground surface. The driving force for its movement is gravity where water moves from higher to lower elevations above and within the rock. Water beneath the surface is protected from heating and evaporation by solar radiation and remains locked in the rock fabric for thousands of years. In its journey through the rock, water moves through primary porosity, open spaces between grains of rock,





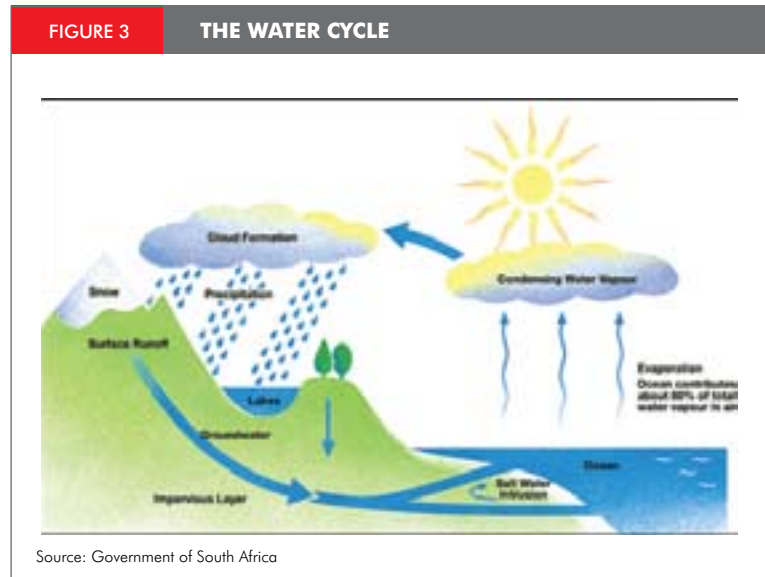
and/or secondary porosity, or permeability that is induced by fractures and faults.

Many people in Arab countries believe that water beneath the surface occurs as lakes or rivers underground. However, water in the ground exists in pore spaces between rock grains or fractures. In the first case, visualize a glass filled with beach sand. The sand fills the glass, but it still has a vast empty volume between the grains. Now fill the glass with water. The latter occupies all the open pore spaces between the sand grains. This explains the nature of the huge aquifers in much of the Arab region.

Rock composed mostly of adjoining sand grains, or sandstone, and others such as limestone have irregular, yet connected pore spaces that allow water passage. In some cases large voids are created by dissolving the host rock to form karsts, caves or dohouls. Water percolates in such rocks to move from a higher to a lower place. Limestone rocks have soluble chemicals and the passing water dissolves the salts. In odd cases, the dissolution of salts within the host rock renders the water saltier than that of the sea.

In addition to pores between grains, surface water passes through fractures in solid rock (El-Baz, 1998a). Although the rock itself may be non-porous, movements of its blocks against each other create porosity. As blocks move along the plain of a fracture, either horizontally or vertically, the rock along that plain of movement is crushed, inducing open and connected pathways that induce secondary or fracture porosity (NRC, 1996). The water can move from higher to lower elevation through these fractures for hundreds of kilometers (Figure 3). It may exist in the form of springs or oases as *oyoun* or *afraj* (Rizk and El-Etr, 1997; Rizk, 1998), and it may pond in the form of a lake, or *sabkha*, on low desert surfaces at great distances from the water source.

Vast amounts of water seep into the ground through natural (in the rock pores) or induced (fracture caused) porosity (El-Baz and Bisson, 1987). The water originates at high altitudes and continues to descend to lower levels by gravity and stops only when it reaches a saturated or non-porous surface. This is how groundwater basins form, up to hundreds of meters in



thickness, such as the “Nubian Aquifer” of North Africa and the Empty Quarter basin of the Arabian Peninsula (El-Baz, 1998a and b). Here and there, this extensive, seemingly horizontal sandstone aquifer is interrupted by non-porous rock masses, including granitic mountains and volcanic rocks. However, in general it extends beneath the dunes of the Great Sahara or the Arabian Peninsula for vast distances.

### III. GROUNDWATER ACCUMULATION

The direction of surface water runoff depends on topography (Figure 3); the greater the degree of tilt the faster the runoff. However, the pattern usually depends on the orientation of faults and fractures in the surface rock. As surface water denudes the rock to establish an easy passageway (Figure 4), a drainage pattern emerges (e.g., Gaber et al., 2010). The pointed tips of the often V-shaped pathways indicate the direction of downward water flow. Such patterns in dry lands indicate the topography at the time of their formation. Thus, analysis of the pattern left on the land surface by running surface water in the past is essential to the prediction of groundwater accumulation.

Similarly, where surface water accumulates in depressed topographic basins, lakes form and may persist for thousands of years. At lake boundaries, terraces form due to the accumulation of rock debris from feeder-rivers

and streams. If the lake level changes, for example due to a reduction in the amount of rainfall, a new terrace forms at a lower level. In multi-terrace borders of former lakes, it is possible to date the various levels of the lake by the remains of the biota in the terraces.

This illustrates that for every feature that we can distinguish in the arid lands of today, there is a story of how, when and what mechanism resulted in the surface characteristics. The variety of such features makes it essential to study details of desert surfaces to be able to understand their history. The study of landforms over vast areas of the Arab region requires a bird's eye view, for example, Figure 4. Satellite images provide the best source of information on desert regions, especially for groundwater exploration (El-Baz, 1988, 1998b).

#### IV. IMAGING SATELLITES

Imaging of the Earth from space has progressively advanced during the past five decades. The first space photographs were those obtained by astronauts from Earth-orbiting spacecraft in the 1960s. Most of these were recorded on color film, which gave us hints as to the nature and composition of the photographed regions. However, more information was provided by the multispectral images.

FIGURE 4

#### BRANCHING DRAINAGE NETWORK AS DEPICTED IN A SPACE IMAGE



#### **Multispectral images**

The more common satellite images were those relayed by digital sensors beginning with NASA's Landsat program in 1972. From the spacecraft altitude of about 900 kilometers above the surface, a sensing instrument looked down at rows of tiny spots, measured the reflected sunlight from each spot, transferred the light intensity values, and beamed the stream of numbers to receiving stations on Earth.

The digital imaging from space allows the use of filters in front of the sensor's lens to separate the reflected light into various wavelengths (Figure 5). It also allows repeat coverage of the same area from the same height by the same instrument for comparisons to detect changes from one time to another. When this is done by overlying the two datasets using computer software, very accurate "change detection" maps are produced (Singh, 1989). This process has been essential to the evaluation of environmental changes, particularly in the increasing use of groundwater in agriculture.

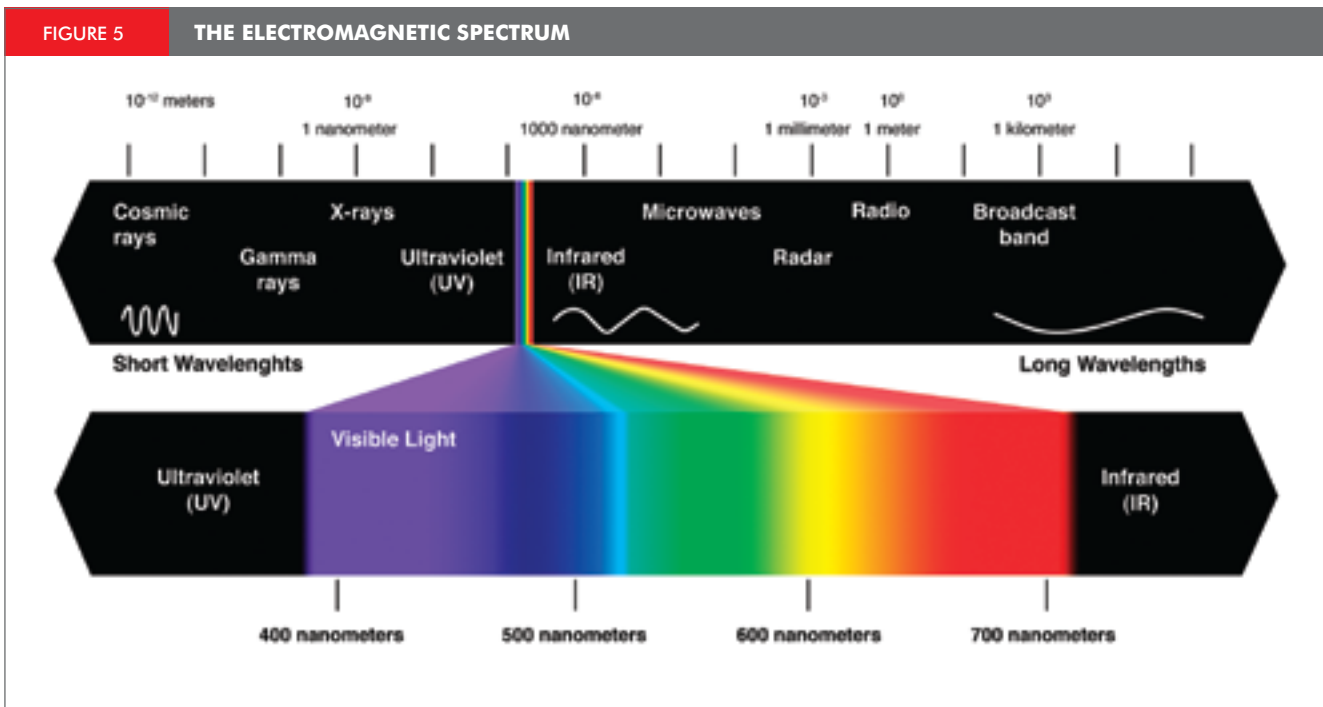
Images acquired by the well known Landsat system, particularly its Enhanced Thematic Mapper (ETM+) sensor, capture data in seven spectral bands. It has a spatial resolution of 30 m in the visible, very near infrared and short wave infrared. It also has a panchromatic band that covers a broad range of the visible with a higher ground resolution of 15 m. In addition, two bands collect data in the thermal infrared region, which are useful in numerous applications; their high spectral resolution makes them suitable for depicting the natural characteristics of the landscape (Lillesand et al., 2004).

The use of multispectral Landsat data is not limited to the physical domain. For example, they can be used to determine the rate of evapotranspiration in irrigated agriculture. Knowledge of evapotranspiration would allow limiting the use of water to specific plant needs.

#### **Thermal data**

Cool anomalies that appear on land in thermal data represent water occurrences at or near the surface. This is because the latent heat content

FIGURE 5 THE ELECTROMAGNETIC SPECTRUM



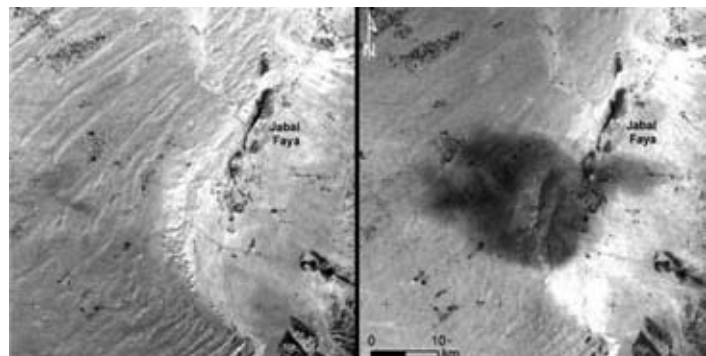
of water (present as moisture in soils) slows the absorbance and emittance of radiation, so that at a given time within the diurnal heating cycle, the warming of the moist soil is retarded (Pratt and Ellyett, 1979). Similarly, cooling during the night is also slowed. Thus, moist soils possess higher thermal inertia, which shows up as cold anomalies in the thermal data collected during daylight hours. Fresh-water seeps into the ocean can also be detected by temperature differences.

Inland thermal anomalies and fresh-water seeps are identified using freely available MODIS data. These data are retrieved for periods after major rainstorm events, the latter being available from the Tropical Rainfall Mapping Mission since 1998. The presence and extent of thermal anomalies are subsequently confirmed using higher spatial resolution Landsat data. Finally, their location and distribution are correlated with the mapped drainage and structural features.

This procedure has been successfully applied to the northern United Arab Emirates (U.A.E.). In this case, a thermal anomaly was identified in the Emirate of Sharjah and linked to rain water passage through a major fault leading to a low region just west of Jabal Faya (Figure 6). Furthermore fresh water seeps into the Gulf of Oman through

FIGURE 6

TWO THERMAL IMAGES OF SHARJAH (U.A.E.) BEFORE AND AFTER RAINFALL ON THE OMAN MOUNTAINS TO THE EAST CAUSING A COOL ANOMALY (DARK AREA) NEAR JABAL FAYA



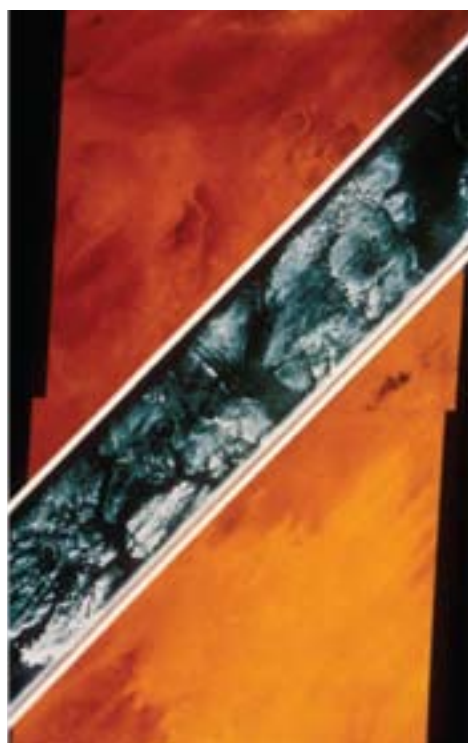
mountain fractures were also identified by thermal data (Ghoneim et al., 2005).

### Imaging radar

The third-generation of satellite images were provided by radar remote sensing (Elachi and Granger, 1982; Elachi et al., 1984). As opposed to the passive sensing of reflected sunlight, a radar sensor emits waves toward the Earth and records the returned beam, or echo. Thus, bedrock surfaces and coarse deposits appear bright, because

FIGURE 7

### RADAR WAVES REVEAL ANCIENT RIVER COURSES UNDER DESERT SANDS



of diffuse reflection. However, smooth soils appear dark owing to reflection of the radar waves away from the receiving antenna on the spacecraft. One most significant aspect is the ability of radar to penetrate dry, fine-grained sand to reveal hidden topography (Figure 7). This principle allows unveiling courses of former rivers beneath desert sand. These courses give hints as to the location of groundwater accumulation sites in arid environments. The principle has been put to the test in several localities in the eastern part of the Great Sahara.

The Shuttle Imaging Radar (SIR) was a series of three radar instruments flown on the U.S. Space Shuttle. The third instrument was part of a joint mission to collect the first multispectral and multi-polarization SIR-C/X SAR data contained two co-registered instruments (Jensen, 2000).

Furthermore, Radarsat systems were commissioned by Canada as commercial Earth observation satellites. The first in the series, Radarsat-1 was launched into a near-polar Sun-

synchronous orbit 798 km above the Earth. Unlike optical satellites that sense reflected Sun light, radar systems transmit microwave energy towards the surface and record the reflections. Thus, radar can image the Earth, day or night, under any atmospheric condition, such as cloud cover, rain, snow, dust or haze.

### High resolution imaging

Ikonos is an example of the commercial high resolution earth observation satellites with a revisit cycle of 11 days. At nadir, its imaging system has a swath width of 11 km and employs linear array technology and collects data in four multispectral bands at a ground resolution of 4 m (Lillesand et al., 2004).

Similarly, QuickBird was launched by Digital Globe, Inc. in a sun-synchronous, relatively low orbit, at an altitude of 450 km, which enables the spacecraft imaging camera to distinguish ground objects 61 cm across. At such high resolutions, details of buildings and other infrastructure are easily visible. Its spectral ranges are equivalent to those of the Ikonos system.

Several other countries launched multispectral imaging satellites, due to their utility in studying the environment of the Earth and its resources. For example France sent a series of SPOT missions, followed by satellites by Russia, India, Japan and China. During the past few years some Arab countries launched imaging satellites. Saudi Arabia began first, followed by Egypt, which now operates a multispectral imaging system with 7.8 meter ground resolution. Algeria is planning one and the U.A.E. is also considering launch and operation of imaging satellites. These systems, although they duplicate area coverage, they bode well for the mapping of resources throughout the Arab region, with particular emphasis on groundwater.

## V. METHODOLOGIES

Modern exploration for groundwater resources requires a combination of image processing and geographic information systems (GIS) analysis. It also requires some supporting field and laboratory work for the verification of the satellite derived information. The following section outlines the methods for such research.

### **Digital data analysis**

Image Preprocessing of satellite images to generate maps of drainage systems (surface and near-surface), geologic structures, thermal anomalies, geologic/geomorphologic units and vegetation distribution. Preprocessing operations are carried out before data analysis and include both radiometric and geometric corrections. In radiometric corrections, images collected at different dates and times, and by different sensors, are normalized to each other so they can be directly compared, except for the case of band ratios, which generate relative, and not absolute, values. Geometric corrections counteract sensor irregularities, terrain relief, curvature and rotation of the Earth. These corrections depend on the data type used.

Image Transformation involves multiple bands of data (a single multispectral image, multi-temporal images or multi-sensor images) to generate a single image that highlights particular features or properties of the land surface. Examples of transformations include image subtraction and image ratios. Image subtraction is applied to identify differences or changes between images of the same area but acquired at different dates. Image ratios are applied to obtain or enhance particular information on the status of the land surface. For example, vegetation indices where healthy vegetation reflects strongly in the near infrared and absorbs strongly in the visible red region of the spectrum, compared with soil and water that show near equal reflectance in the red and near infrared.

Image Enhancement procedures are applied at the end to improve image interpretability. They result in changes to the digital values, thus should be the last step to be applied. They can be stretches that work with the image histogram, or as spatial filters that highlight or suppress features based on their spatial frequency.

Mosaicking of individual satellite scenes might result in providing full coverage of an entire country. This process involves three steps: a) re-sampling images to a finer resolution, b) matching the brightness for all images, and c) blending the overlapping regions. In the case of Egypt, a mosaic (Figure 8) was first used to unravel the groundwater story. It clearly showed

that sand dune lines are oriented north-south (El-Baz, 1979). This is because the wind in Egypt comes normally from the north. The sand, proven to be made of quartz, had no rock source in the north. In the meantime, exposed rocks to the south were largely composed of sandstone. It was theorized that the sand was not transported from its source by wind but by water from the south. Thus, the search for buried courses of ancient rivers began (El-Baz, 1982, 1988 and 2000).

Image Classification is the use of spectral information in a multispectral image to classify each pixel in order to produce thematic maps that denote different kinds of land cover. There are two primary types of classification: the unsupervised and the supervised. Unsupervised classification is useful for preliminary spectral class discrimination. It is considered to be an exploratory procedure where the classification algorithm determines the spectral categories without supervision by the user. A supervised classification involves a priori knowledge of data to “train” the computer to identify categories in an image based on the information provided (Gaber et al., 2010).

Change Detection is the process of identifying differences in the state of an object or phenomenon by observing it at different times (Singh, 1989). There are numerous change detection methods that may relate to groundwater resources in the desert such as determining vegetation differences. Changes between classes in initial and final state images are quantified. Change detection maps are ideal for highlighting the difference in imagery between two times.

### **Geographic Information Systems**

Display and correlation of complex sets of digital information is best done through the use of a structured and relational database. A geographic information system (GIS) offers the basic tools and methodology to create such a database of spatial features with specific properties (attributes) and geo-locations (coordinates).

Data manipulation and analysis in a GIS solve specific research problem. Some data manipulation and analysis tasks are conducted in the raster domain (e.g. surface elevation,

FIGURE 8

MOSAIC OF 65 LANDSAT IMAGES OF EGYPT SHOWING PARALLEL LINES OF SAND DUNES



precipitation, slope) while others in the vector domain (lithology, soil or rock type, land use pattern), depending on parameter characteristics of a particular data set (Gaber et al., 2010).

The GIS output may contain information extracted or derived from a set of map layers by using any combination of analysis operations. The

final outputs are dynamic maps in digital form that represent the characteristics of the study region, as will be shown in the case studies listed below.

## VI. CASE STUDIES

No contribution is broad enough to cover

all possibilities of groundwater occurrences in the Arab region. Below are examples of the eastern part of the Great Sahara of North Africa (Egypt, Libya and Sudan), the Arabian Peninsula (Saudi Arabia and Oman), and the eastern Mediterranean region (Lebanon).

### **East Uweinat (Southwest Egypt)**

The Great Sahara constitutes the largest desert belt on Earth, extending for nearly 6,000 kilometers from east to west. Its eastern part includes some of the driest regions on the planet, where the received solar radiation is capable of evaporating 200-times the amount of rainfall (Henning and Flohn, 1977). This hyper-arid condition necessitates complete dependence on groundwater resources for human consumption and agricultural activities. Increase of populations and the attendant food and fiber needs have exasperated the situation (El-Baz and El-Ashry, 1991).

Although the Sahara is now dry and is subject to the action of strong winds from the north, Archaeological evidence indicate that it hosted much wetter climates in the past (Wendorf et al., 1977; Haynes, 1985; Haynes and Mead, 1987; Haynes et al., 1979 and 1989; Pachur and Hoelzmann, 1991; Pachur and Wunnemann 1996; Pachur and Rottingen, 1997). Surface water during past moist climates led to the formation of lakes in topographic basins. Satellite images represent excellent tools for the study of the desert features (El-Baz, 2000). In addition to the data types described above, use can be made of the Shuttle Radar Topography Mission (SRTM) data that display three-dimensional views of the terrain (El-Baz et al., 2000; Ghoneim and El-Baz, 2007a and b).

In southwest Egypt, a 300 kilometer flat, sand-covered area straddles the border between Egypt and Sudan. This region is called the Great Salima Sand Sheet, after the Salima Oasis on its eastern border. This oasis is a prominent location along the Darb El-Arbain (the 40-day track) of camel caravans from Darfur in northwestern Sudan to the Nile Valley in Egypt. Many drainage lines uphill of the Great Selima Sand Sheet were revealed by SIR-C images with four major lines leading directly to it from the west (Figure 9). The northernmost drainage system trends due

east and measures 150 kilometers in length. The longest and broadest wadi system is aligned in a NE-SW direction. Such broad channels usually develop under sheet flood conditions with plentiful surface water (El-Baz, 2000).

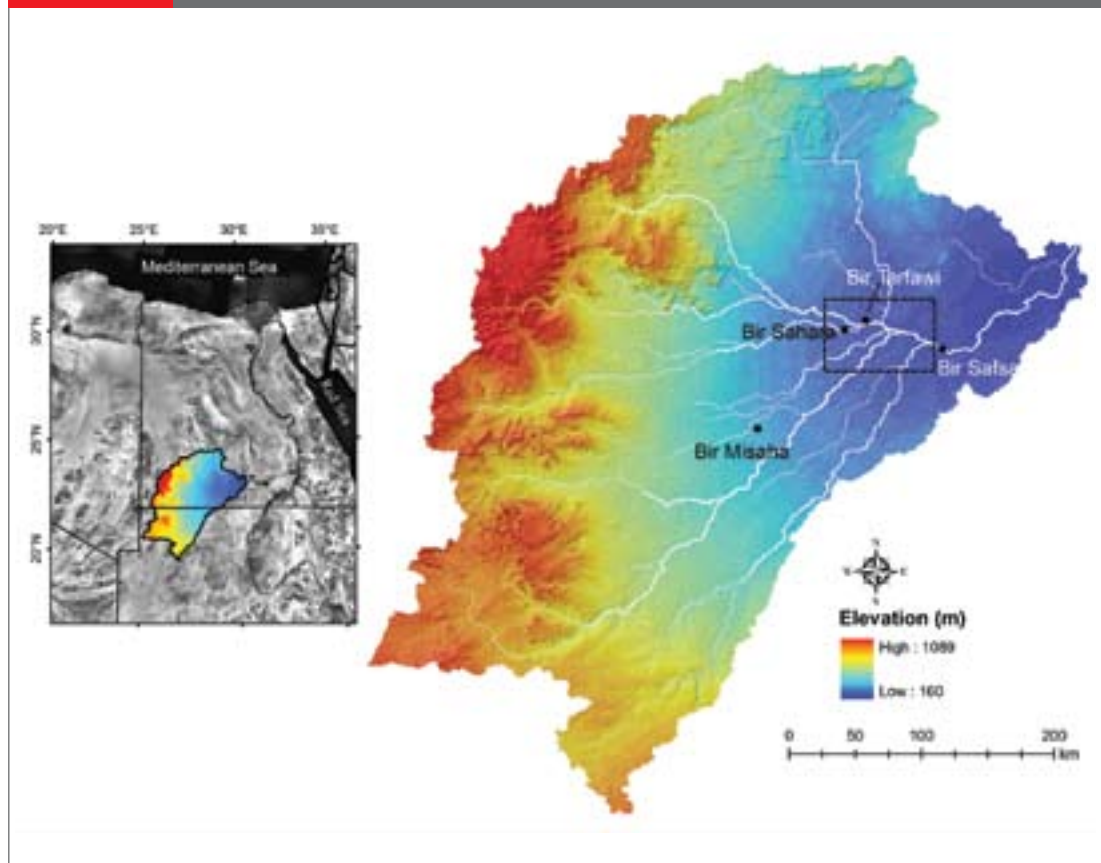
The high resolution, high precision SIR-C data show that several of these broad channels display small braided streams in their floors, indicating several episodes of water flow. Field observations of trenches dug in May 1998 by a joint team of the Egyptian Geological Survey and Mineral Authority and the Desert Institute of Egypt indicate that moisture begins to appear at 25 centimeters depth in the sand cover of shallow channels in the Bir Safsaf region of southern Egypt. This suggests that moisture from occasional rainstorms is carried through, and retained by, the sand fill of the palaeo-channels (El-Baz, 1998b and 2000 and Hoelzmann et al., 2001).

Radar images first revealed the courses of rivers and streams in northwestern Sudan, where the widest channel points toward the region. This setting was interpreted to suggest groundwater accumulation in its eastern, lower-most area. The author made this case repeatedly, starting in 1982, to the Ministry of Agriculture and Land Reclamation of Egypt. Finally, the government of Egypt started in 1995 to drill a few exploratory wells. The latter were monitored for the next five years to assure the presence of large amounts of groundwater. In 2000, plots of 10,000 acres were offered for agricultural development by private sector companies in Egypt.

Today, within this "East Uweinat" region, over 500 wells were drilled to water agricultural fields using circular, spray irrigation. The products include wheat, peanuts and other basic food crops. The wheat, in particular has proven essential for flour production in the mills of Aswan for bread that is distributed in towns of southern Egypt. The proven water resources are capable of supporting agriculture over 150,000 acres for at least 100 years (El-Baz, 1988; Robinson et al., 1999 and 2000). This particular case emphasizes the need to study the desert landscapes in the Arab region to uncover the groundwater potential for the benefit of its people.

FIGURE 9

EAST UWEINAT REGION OF SOUTHWEST EGYPT WHERE RADAR TOPOGRAPHY DATA REVEAL SEVERAL RIVER COURSES LEADING TO A LOW AREA WHERE AGRICULTURAL FARMS AROUND (BOXED AREA)



In such a hot and dry environment drip irrigation is used for trees and spray irrigation is employed for crops, such as cereals. In the case of spray irrigation, measurements of the evapotranspiration during various seasons would be most useful. It would assure limiting spray irrigation to the essential needs of the crops.

### ***Kufra Region (Southeast Libya)***

To the northwest of the East Uweinat region in Egypt, Apollo-Soyuz and Landsat images of southeast Libya show that the Kufra Oasis region is the only inhabited area in this part of the eastern Sahara. The Oasis had been an important stop along the camel caravan route from Chad northward to the Mediterranean Sea. Its circular irrigation farms were developed starting in the 1960s by the Oxidental Oil Company as part of a concession to explore for oil. The farms were visible to Earth-orbiting astronauts due to the contrast between the vegetation and the

FIGURE 10

SHUTTLE RADAR IMAGE OF TWO ANCIENT RIVERS SOUTH OF KUFRA OASIS, SOUTHEASTERN LIBYA





surrounding sandy plain. This contrast was not only depicted in the visible, but also in the near-infra red, as well as in radar data.

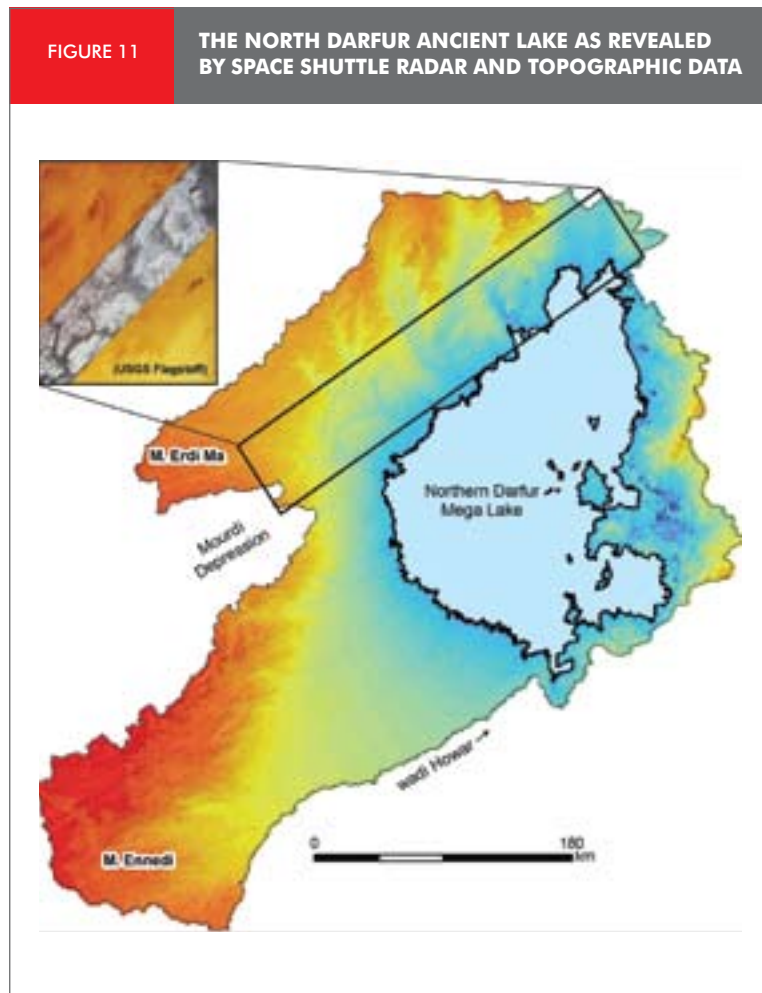
Both SIR-C and Radarsat-1 data revealed courses of two sand-buried palaeo-channels (Figure 10). The longer and narrower western channel, which passed through the Kufra Oasis, originated from the direction of the border with Chad. The wider eastern channel was oriented in a NW-SE direction and originated from highlands west of the Gifl Kebir plateau of southwestern Egypt. Thus, it became clear that the locations of both the Kufra Oasis and the circular irrigation farms were due to the passage of these two former rivers (El-Baz, 2000).

It is notable that the Kufra area is one of five main basins from which water is pumped to supply the Great Man Made River Project of Libya and depends on these two channels. The two rivers that fed the two channels were active during humid phases in the past. Much like the case in Egypt, these channels must have been filled with water during the period from 11,000 to 5,000 years ago. Because some rain clouds occasionally reach the Tebesti Mountain mass, some replenishment of the groundwater occurs in the region through the western channel.

### **North Darfur (Northwest Sudan)**

The Darfur region (home of the Fur tribe) of northwestern Sudan lies to the south of both the Uweinat region of Egypt and the Kufra area of Libya. It is presently divided into three governorates: northern, western and southern (it is now being considered for division into four governorates). The governorate of North Darfur in particular represents an environment typical of the eastern Sahara of North Africa. The farther north one goes, toward Egypt and Libya, the greater the aridity.

Jabal Marra is a massif that straddles the three governorates. It causes some rainfall, but this is characterized by irregularity in both space and time. Particularly severe droughts over the past two decades initiated years of unrest along the fringe of the Sahel belt of North Africa and caused population migrations that were followed by a vicious war in the Darfur region. Water shortages underlie the initiation



of the conflict that had erupted between Darfur's farming communities and nomadic populations. The latter inflicted much damage to numerous farm communities. Thus, there is a need to develop new and innovative techniques to locate additional water resources to satisfy urgent requirements.

In the northern Darfur region, interpretations of space-borne data resulted in the identification of anomalous, arcuate linear features at an elevation of 573 m above present sea level (Ghoneim and El-Baz, 2007b). Detailed geomorphologic analysis of these discontinuous linear features confirmed that they were remnants of shorelines of an ancient mega lake (Figure 11). Hydrologic modeling of the lake's basin showed that at its maximum extent, the lake had occupied an area of about 30,750 square kilometers and would have contained approximately 2530 cubic kilometers of water when filled (Ghoneim and

## THE MIDDLE EAST NORTH AFRICA LAND DATA ASSIMILATION SYSTEM – MENA LDAS

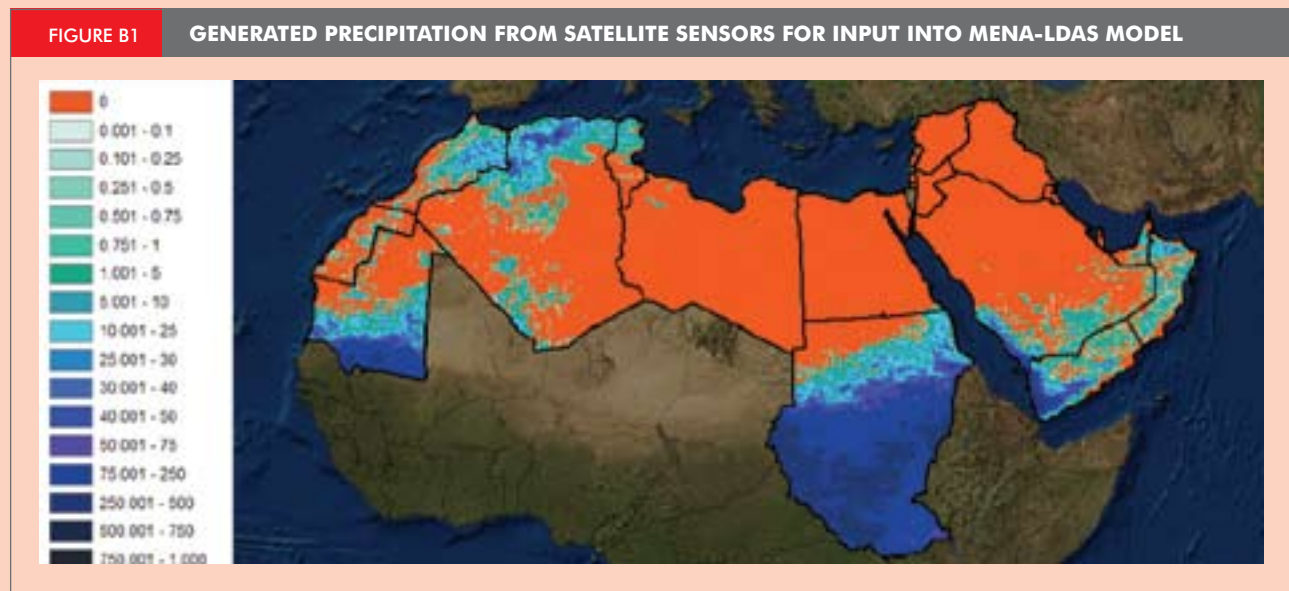
**Rachael A. McDonnell**

The importance of good data for sound decision making cannot be over-emphasized. In water, an understanding of rates and magnitudes of a number of components within any water balance, under various climatic conditions, is needed for sustainable and efficient water policy development and management. Within the MENA region, whilst there are

some data on meteorological variables and surface and groundwater flows, in many countries important data on other key components are either not available or are patchy in time and space coverage. Understanding the dynamics of water use and consumption tends to be limited but is important for many different stakeholders.

To help overcome this problem the National Aeronautics

Static parameters	Meteorological Forcing Fields	State observations	Sample LDAS outputs
<ul style="list-style-type: none"> <li>- Elevation</li> <li>- Vegetation/land use type</li> <li>- Vegetation height</li> <li>- Leaf Area Index</li> <li>- Surface Roughness</li> <li>- Root density and depth</li> <li>- Soil texture</li> <li>- Surface albedo</li> <li>- Thermal inertia</li> <li>- Emissivity</li> </ul>	<ul style="list-style-type: none"> <li>- Precipitation</li> <li>- Downward radiation</li> <li>- Air temperature</li> <li>- Specific humidity</li> <li>- Wind speed and direction</li> <li>- Surface pressure</li> </ul>	<ul style="list-style-type: none"> <li>- Vegetation coverage</li> <li>- Snow coverage</li> <li>- Surface soil moisture</li> <li>- Terrestrial water storage</li> <li>- Surface temperature</li> </ul>	<ul style="list-style-type: none"> <li>- Water balances</li> <li>- Crop types and land use maps</li> <li>- Water consumption by crops and vegetation</li> <li>- Monitoring of reservoir level and - groundwater table fluctuations</li> <li>- Surface and groundwater flows</li> </ul>



El-Baz, 2007b). The enormity of the lake size and the topographic setting of the area suggested that this lake was formed in the Pleistocene wet epochs when rain was plentiful over a protracted period of time.

In the Holocene time, the area experienced frequent wet episodes, but of less rainfall in comparison to the Pleistocene time, and only the central part of the so-called “North Darfur Mega Lake” was inundated with freshwater.

FIGURE B2 THE WATER CYCLE

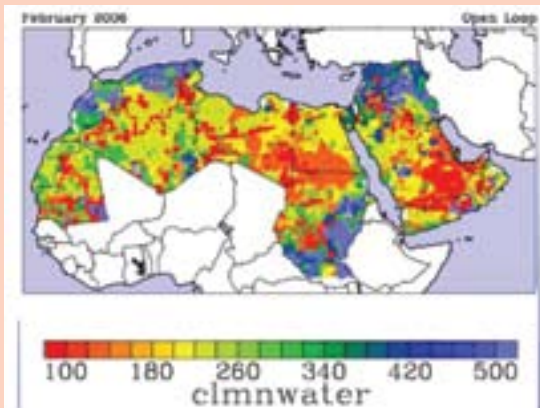
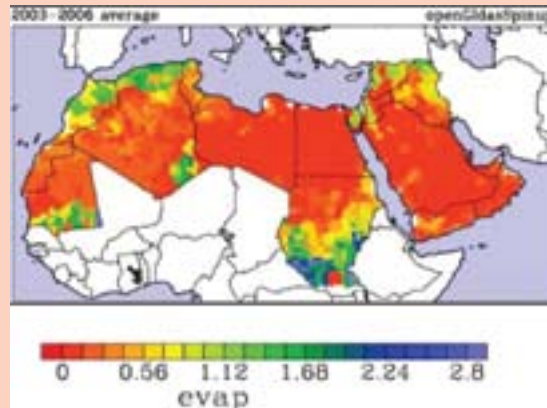


FIGURE B3 THE WATER CYCLE



and Space Administration (NASA) Goddard Space Flight Centre (GSFC), funded by USAID, have developed a regionally specific Land Data Assimilation System (LDAS) model. This complex set of computer programs uses mathematical equations to define the natural processes of water storage and flow, and models have already developed for the regions of North America, South America, and Europe. The modeling system uses NASA satellite data, field observations from MENA countries, and publicly available meteorological analyses from various international research groups. MENA LDAS is particularly useful for the region as it integrates observations from many different sources and is capable of generating data where there are no ground observation points. Special mathematical algorithms in modeling ensure that generated data is rooted firmly to the observed record where it does exist, to limit any errors and inaccuracies.

The data used in modeling are given in Table B1 with a sample input precipitation data set for the region given in Figure B1.

The model will provide estimates of hydrological conditions and flows relevant to water resource management across the region. It will generate time series of maps for important variables such as groundwater fluctuations and storage, soil moisture, surface temperatures, water consumption by

crops and vegetation, river runoff, and snow water storage. Sample outputs are given in Figure B2 and Figure B3. Given the frequent measurements of data of certain key meteorological variables, it will also be possible to provide near-real time monitoring of key hydrological processes.

The initial hub for the MENA-LDAS is being developed at the International Centre for Biosaline Agriculture in Dubai and the focus of the research activities there will be to generate regional datasets which will be made available to water managers and decision-makers through a web portal. In addition, capabilities will be developed at a number of national remote sensing centres within the region whose modeling work will focus on water problems that are particularly important to their countries.

With the development of these capabilities, regional capacities for further research will be enhanced. This research will focus on predicting future water flows and uses based on estimated dynamics in the region of environmental, climate, economic, and social changes. These forecasting capabilities will be able to help decision-makers consider the adaptation policies and initiatives needed to face any future water and food security challenges.

*Dr. Rachael McDonnell is consultant to the International Centre for Biosaline Agriculture (ICBA), Dubai.*

The remnants of the Holocene lake deposits scattered in the central lake area and its oases were precisely identified (Haynes, 1985; Haynes and Mead, 1987; Haynes et al., 1979 and 1989; Pachur and Hoelzmann 1991; Pachur

and Rottingen, 1997; Pachur and Wunnemann, 1996; Hoelzmann et al. 2001).

During the residence time of the water in the northern Darfur depression, for thousands of

years, much of the water would have seeped into the substrate. This seepage would occur through the primary porosity of the underlying sandstone and/or the secondary porosity caused by fractures in the rock. As observed in the Radarsat-1 data, a nearly continuous segment of about 48 km long is well preserved in the northeastern corner of the lake.

This segment is an intact line zone of about 1 km wide. This zone contains four parallel horizontal markers of former shorelines, which demarcate distinct phases and indicate different stages of lake regression. Since they are characterized by dark signals in the radar images, these strandlines are most likely composed of relatively fine-grained sediments.

The shorelines suggest that the lake level was stable for extended periods. The area, where the shoreline segment is located, is characterized by a complex pattern of semi-active chevron-shaped laminated sand dunes (Haynes 1985). In addition to the shoreline zone, several small wadis in the Radarsat-1 data disappear where they join the shoreline zone, which suggests a channel profile adjustment at this particular lake level. Breaching the outer strandlines while the inner remained intact established that the surface runoff became weaker and small wadis could not be maintained to reach the lake as larger wadis did (Ghoneim and El-Baz, 2007b).

On the northeast edge of the lake depression, another well-preserved segment of shoreline, at the same level (573 m above sea level) with a spit-like feature, was detected in both the SRTM and Radarsat-1 data (Ghoneim and El-Baz, 2007a and b). This arch-like segment measured 20 km in length, 1 km in width, and about 3–5 m in height. The parallel barriers characterizing this segment suggested that the ancient lake was stable long enough at this level. The extension of this shoreline at the opposite, western side, could be clearly traced in all examined data.

Upon completion of mapping of the lake boundaries by the space data and publication of the results, the author conveyed the outcome to officials of the government of Sudan, including the President of Sudan and the Minister of Irrigation and Water Resources. These officials adopted the initiative of “1,000 Wells for

Darfur.” The same was done in North Darfur, where local officials welcomed the scientific findings.

These developments were welcomed by the United Nations. The UN recognized the importance of the scientific analysis and the well site selection process. Efforts are being made to place the 1,000 Wells initiative under the auspices of the UN to assure both expediency and accountability. These wells need to be sited within reach of the highly populated areas of Darfur farther south of the ancient lake.

This is possible because yearly rainfall during the monsoon season replenishes the groundwater through numerous channels along the slopes of Jabal Marra. At the present time, Boston University team members are utilizing all available space data to select the best sites for well drilling in search of new water resources. In the final analysis, the planned well drilling program is a tangible illustration of using advanced space technology to resolve a problem of water shortage and alleviate a humanitarian crisis.

### ***Empty Quarter (Arabian Peninsula)***

The Arabian Peninsula is a vast desert separated from the Great Sahara of North Africa by the Red Sea. High mountain ranges bound it from the west and south. These highlands gently grade into a low area in the central-south part of the peninsula. It is within this depression that the endless dunes of the Empty Quarter reside (El-Baz, 1998b). Like the case of western Egypt, the Empty Quarter includes nearly every type of dune form: linear, crescent and star dunes.

North of the Empty Quarter, there exists a perfect example of the concentration of groundwater by fractures. In this case, the fault zone traces the pathway of two former rivers. The one in the west begins with an intricate tree-branch-like pattern of drainage in the Hejaz Mountains that lead to singular channel, Wadi Al Rummah. After an area that had long been covered by avalanches of wind blown sand, another straight segment of a valley emerges from beneath the sands: Wadi Al Batin. The two wadis must have been connected (Figure 12) to form a single system in the past (El-Baz, 1998a).

The area between the courses of the two dry river courses was highly faulted and fractured. It is believed to have been a major source of the groundwater aquifers in Al Qaseem region of central Arabia. In this region numerous wells were drilled down to depths of over a kilometer. Pumping escalated at these wheat farms for over two decades, at very high rates. Soon the level of the aquifer fell to dangerous levels and many of the farms were abandoned.

However, just like the case of the ancient river course that led to the Kufra Oasis of southeast Libya, these wadis defined the locations of three oases towns: Burayda, Uneizah and Hafr Al-Batin (Figure 12). This became an important component of the proof that surface of the State of Kuwait was a delta of the former river that drained the Hijaz Mountains 850 km west of the Arabian Gulf coast (El-Baz, 1998a). This theory was further developed by additional proof from ground based data on the surface of Kuwait (El-Baz and Al-Sarawy (1996).

The fact that rivers used to cross the Arabian Peninsula was later proven by the SRTM data from the Space Shuttle mission. The topographic data showed numerous courses of former rivers that led to the depression, which enclosed the Empty Quarter dunes. It is believed that such

wadis represented defunct rivers, which provided a great deal of water to the depression that is occupied by the dune field. It follows that the substrate of the Empty Quarter dunes would contain the largest accumulation of groundwater in the Arabian Peninsula. It must be stated that all oil wells drilled in the Empty Quarter have encountered water at numerous depth and with varying degrees of salinity.

### **Wahiba Sands Basin (Eastern Oman)**

The Wahiba Sands are rope-like accumulations of particulate matter within a pear-shaped depression along the eastern coast of the Sultanate of Oman. It was studied by the Boston University research team in the course of evaluating the groundwater potential of the country.

The effects of surface drainage and old channels in the development of the Wahiba Sands are clearly displayed in satellite image data. Radar images revealed several palaeo-channels and associated structures. The southeastward extension of fracture lines from the highlands to the north of the Wahiba basin reaches the southwestern termination of the High Sands. It appeared that continued fluvial erosion of the structurally controlled system was the major

FIGURE 12 THE "ARABIA RIVER" MAPPED BY SATELLITE IMAGES

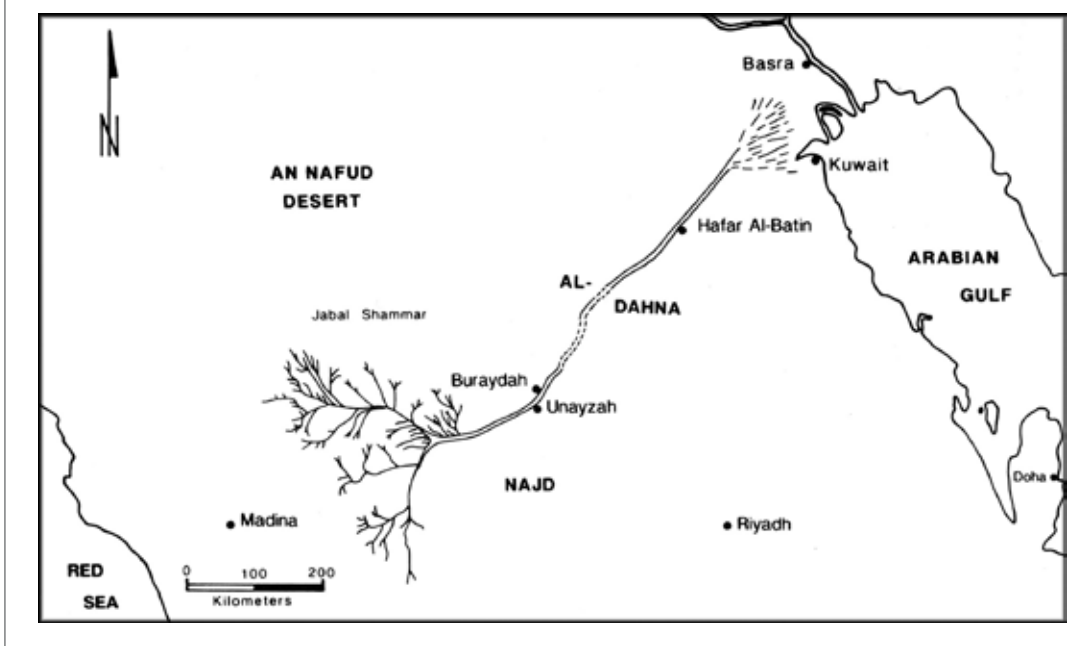
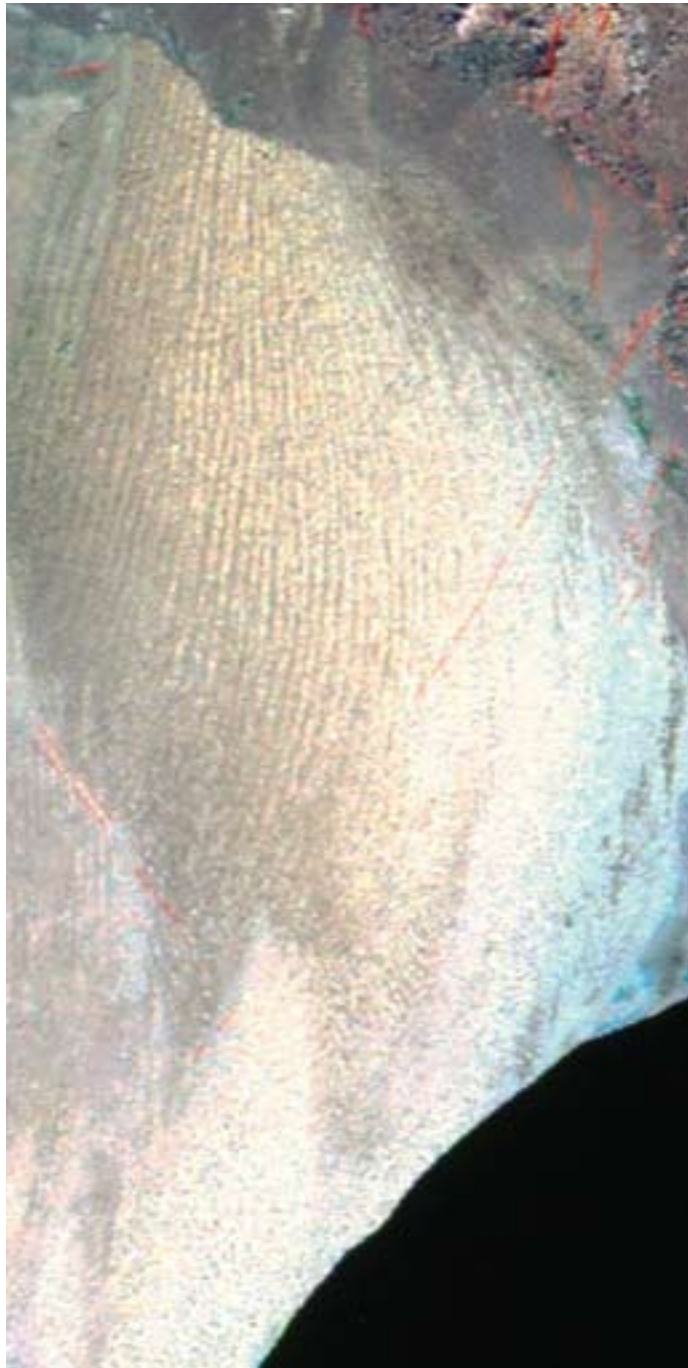


FIGURE 13

## WAHIBA SANDS OF OMAN



cause of the linearity of the southwestern edge of the large dunes. This is reminiscent of other locations, where dune terminations are caused by channel truncations. Similarly, the fault and wadi zones caused the linearity of northeastern margins of the Wahiba Sands (Figure 13).

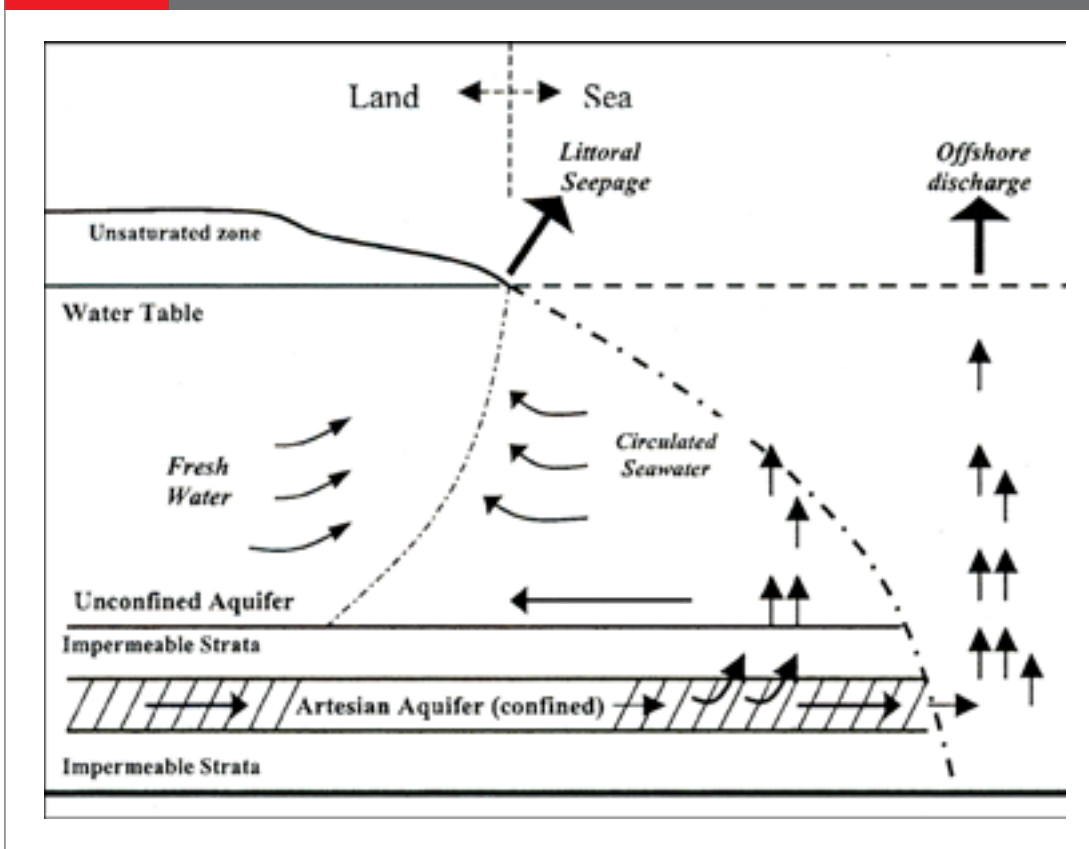
The regional view suggests that structurally controlled fluvial systems, dominant during humid phases of climate, laid down much of the original material of the Wahiba Sands at the mouths of the drainage features. This was also responsible for the extensive volumes of groundwater discharged into the Wahiba basin. Based on these observations, a 100m thick aquifer straddling 1000km<sup>2</sup> has been discovered, which holds approximately 12 billion m<sup>3</sup> of groundwater.

Once the climate changed and dry conditions prevailed, the wind became the principal surface modification agent. It sorted and shaped the water-deposited sand into the dune and sand fields that form today's features, a sequence of events similar to those observed in the Selima Sand Sheet in the eastern Sahara (El-Baz, 1988, 1998a and b, 2000). As is the case in the eastern Sahara, and other arid regions, the change from wet to dry conditions was not simple, with periods of aridity and enhanced wind activity alternating with wetter intervals from at least Tertiary times until the early Holocene.

The thickness of the Wahiba Sands reflects the depth of the basin. The center of the basin is filled with the thickest deposits of the High Sands and hosts the greatest groundwater concentrations. The southern reaches are filled with less sand. The sand thickness is easy to understand when its fluvial origin is considered. The southeast trending, structurally controlled wadis from the Hajar Mountains (observed in both landsat and radar images) are the dominant fluvial trend that provided much of the sand that filled the basin. The wadis would have supplied material to the north to produce the aeolianite that extends offshore; the aeolianite and the sand ridges are rich in carbonates.

It is suggested that the aeolianite may have formed from calcareous lake sediment that mobilized the carbonate and caused cementation of sand deposits at depth. Upper deposits of the same material would have remained loose, leaving them vulnerable to wind action during the dry climates. The more mature, quartz-rich sand that exists in the south can be explained by the greater distance the sand had to travel from the northern mountains (the principal supplier of the sand). Greater transit distance

FIGURE 14 SCHEMATIC OF FRESH WATER SEEPS ALONG COASTAL ZONES



allows more of the carbonate component to dissolve.

This correlation of the dominant sand composition to the surrounding rocks is also clear in the Selima Sand Sheet of southwest Egypt (El-Baz, 1998b). In the latter case, the sand is quartz rich as would be expected if it had originated from the Nubian Sandstone rocks that exist beneath and to the west of the Selima Sand Sheet, compared with limestone rocks to the northeast. This is consistent with a fluvial system working eastward and northward (as observed from palaeo-drainage directions; Robinson et al., 1999 and 2000) during humid phases of climate, followed by a north-south wind system that continues to dominate to this day (El-Baz et al., 2000).

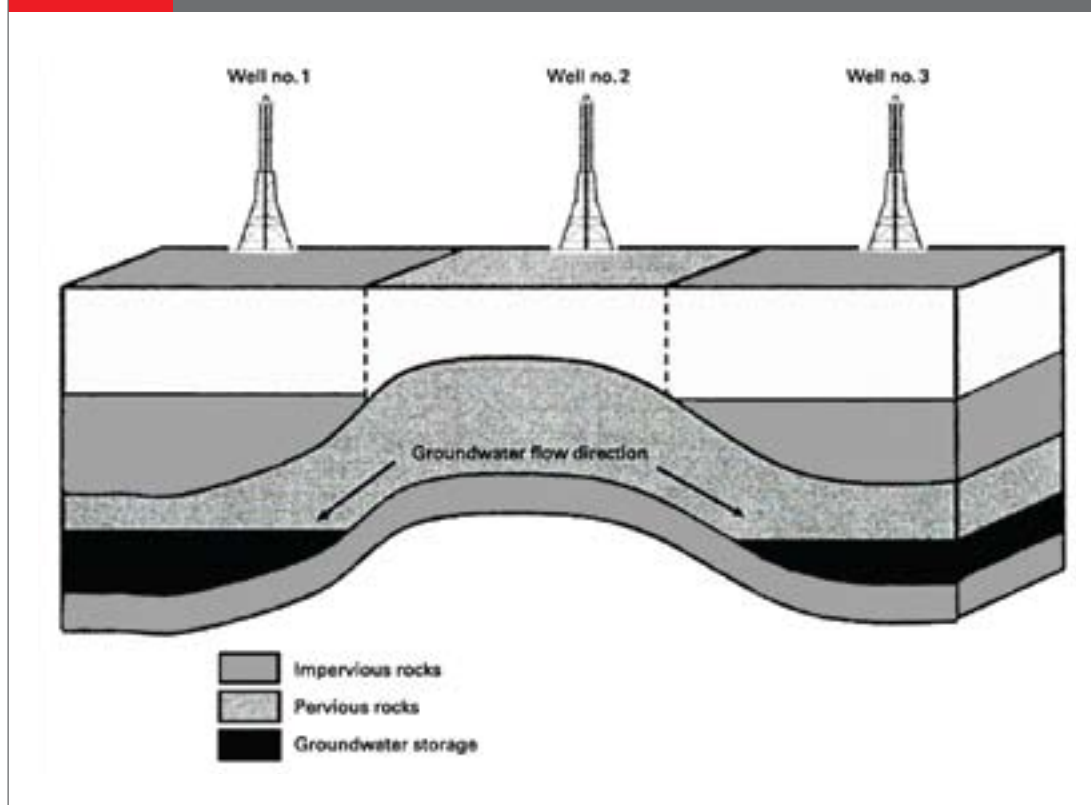
Thus, remote sensing observations suggest that the Wahiba basin encloses vast groundwater resources. It is a smaller version of the sand-filled depressions of the eastern Sahara (the largest known fresh-water mass in the world; El-

Baz, 1998b). The situation is similar to the cases of sandy deserts in the Rajasthan of NW India, the Simpson of Australia and the Taklimakan of China (El-Baz, 1998a). It appears, therefore, that accumulations of large amounts of surface sands in present-day dry areas may be surface indications of the presence of groundwater.

### **Eastern Mediterranean (Lebanon)**

Passage of groundwater within fracture zones has been confirmed in numerous areas. Movement of water within fractures has been established as a potential mechanism for water accumulation in large quantities (El-Baz and Bisson, 1987; NRC, 1996). Furthermore, water runoff into the sea should receive much attention along the coastal zones in the Arab region. Discharged freshwater into the sea occurs either as direct surface runoff (i.e., from rivers and streams), or as groundwater discharge, which is commonly called "submarine springs" and sometime as "invisible rivers". The Eastern Mediterranean is a typical example of this hydrologic phenomenon,

FIGURE 15

**LOCALIZATION OF GROUNDWATER BY SUBSURFACE STRUCTURE WHERE ONE DRY WELL COULD LIE BETWEEN TWO PRODUCTIVE ONES**


particularly off the coast of Lebanon (Shaban et al., 2005).

High precipitation rates (averaging 950-1100 mm) in the region result in large amounts of surface water that rapidly flows toward the sea due to the steepness of the terrain. In addition, groundwater seeps from coastal aquifers to the sea along the bedding planes of rocks (Figure 14) as well as the numerous fracture systems, which increase the flow of groundwater seaward (Shaban et al., 2007).

In Lebanon, there are fourteen small rivers. Three of these are inner ones and originate from the Bekaa plain, which is a depression located between two major mountain chains. The coastal rivers flow directly to the Mediterranean Sea. Recently, remote sensing techniques have been utilized in hydrological studies of the region. As in the aforementioned case of the U.A.E. (Figure 6), MODIS-Terra and TRMM data were used due to their daily acquisition, which permits repeated monitoring. This approach,

if improved, can replace instrumentation techniques, because of low cost and high reliability.

The coastal zone of Lebanon is ideal for such an application, because it encompasses a number of issuing rivers and a variety of climatic conditions. Meanwhile gauging stations and hydrographs are lacking or insufficient. Rainfall in this zone is characterized by high rate and frequency of precipitation peaks. The highland slopes (75-100 m/km) as well as the shortness of rivers (less than 50km) create a high flow energy of water toward the sea. The time is often less than 5 hours. This is reflected by low values of lag time of 2.4 on average (Shaban et al., 2005 and 2007).

The high flow energy of running water from the coastal rivers of Lebanon is tempered by the fracture systems and karst conduits, as well as the high meandering ratio of river courses. The huge loss of freshwater from rivers in this hydrologic regime suggests an urgent need to



implement surface water harvesting in the region. In addition, damming of the river channels for water harvesting would increase the stay time of water on the surface for replenishment of the various groundwater aquifers in the region.

In addition, it is important to take into account the effects of subsurface structure on the localization of groundwater. Subsurface irregularities due to folding and faulting of strata result in confining the water in certain locations. In such cases, a well dug between two productive ones might turn out to be dry (Figure 15). Thus, knowledge of the geologic structure of a given region is essential for groundwater exploration.

## VII. CONCLUSION

Groundwater constitutes one of the most precious resources in the Arab countries. Because of the high aridity and the scarcity of rainfall, it is erroneously perceived that groundwater is scarce or has been depleted in much of the Arab region. In reality, vast tracts in the region have not been explored for their groundwater potential. This includes the extensive, sand covered plains of the Great Sahara and the Empty Quarter. The reason for this is the recent realization that these Arabian sands were rounded, transported and deposited by running surface water during humid climates. The latter alternated with dry phases in the geological past. The last of the wet phases ended about 5,000 years ago. During dry phases, like the present one, the wind acts on the sand deposits to shape desert dunes.

Satellite image data are ideal for investigations of the probability of groundwater concentration in the Arab desert. These data include: (1) multispectral images that clearly depict the surface features and allow the deduction of their geologic history; (2) thermal images that show the location of rain water accumulation just below the surface, which may replenish groundwater aquifers, as well as seepage of groundwater into the sea along coastal zones; (3) radar data that penetrate the sand cover to reveal the underlying topography; and (4) elevation data that depict the direction of surface water flow in the past as well as in the present. Correlations of such data in a GIS allow defining the best way to locate and utilize the groundwater resources.

This contribution exemplifies the use of such data to locate previously unknown groundwater potentials in the eastern Sahara. Two vast ancient lakes were identified in southwest Egypt and northwest Sudan. Furthermore, two ancient river channels were revealed as the cause of the Kufra Oasis and its groundwater resources in southeast Libya. Similarly, the Empty Quarter region of central Arabia and the Wahiba region in eastern Oman were identified as sites of a potential accumulation of vast amounts of groundwater. Some of this water seeps into the sea through fractures beneath the surface.

Based on the results, it is here proposed to initiate a major study of the Arab region with the purpose of identifying regions of potential groundwater accumulation. All available data must be collected for each country or region; using partial data only might be misleading. The data should be processed, analyzed, correlated and updated in an active GIS database. In adjacent countries, such a database should be freely exchanged for planning equitable use of the groundwater resources. This endeavor should be considered of high priority to utilize this valuable resource for the benefit of the Arab people.

For this to be done right, we must adopt a new approach that is distinct from the usual way of doing things. Adherence to outdated theories about groundwater in the Arab region would limit our benefits from this vital resource. We must accept new ideas while applying sound theory to test new propositions along the way. We must be passionate about learning, willing to challenge accepted theories, and able to experiment and test in order to create new knowledge. The created knowledge would allow us to use our resources soundly and efficiently, without harming the environment.

It is evident that much of the Arab region remains not fully charted with regard to groundwater resources. The voluminous literature on groundwater in the region indicates that: (a) current water scarcity will be further exacerbated by rapid population growth and climate change; (b) productive aquifers are being over-drilled and over-pumped with little regulation to assure their sustainability; (c) aquifers shared by multiple nations have

not been quantified for equitable use; and (d) vast areas of the Arab deserts have not yet been studied or explored.

These critical issues belong to the policy domain, where government bodies must collect and analyze the required data to regulate groundwater use. It is also essential that attention of policy makers should be sustained in the long term. For this reason, it is instructive to consider major issues that require institutional regulation by policy makers.

### **Policy Considerations**

For presently exploited groundwater resources, it is essential to build a complete digital database. Such a database should be regularly updated based on new findings or more advanced analysis and modeling methodologies. The data collection is required for all regions where water might be extracted for human consumption, agriculture or industrial uses. The required data include geo-coded locations of the wells, their depth and type of host rock; water salinity; and pumping rates, along with historical illustrations of changes to water levels in space and time.

All such data are essential for the proper assessment of the actively mined resources and the establishment of a proper water extraction rate to assure the longevity of a given aquifer. A glaring example of over-pumping with little or no regulation is that of Al Qaseem region in central Saudi Arabia. The unregulated extraction of groundwater for wheat production resulted in exhausting the resource and the abandonment of numerous fields.

With regard to shared groundwater aquifers that extend beyond national boundaries, a database is required for equitable use of the resource. The case studies listed above illustrate that several areas enclose aquifers that lie across national boundaries. The major shared groundwater aquifers in the Arab region include the Selima basin of Egypt and Sudan; the Siwa-Jaghoub region of Egypt and Libya; the Tabuk fracture zone aquifer of Jordan and Saudi Arabia; the Hamad basin of Syria, Jordan, Palestine and Israel; and the eastern Mediterranean mountain region of Lebanon and Syria. It is advisable to collect the necessary information now to avoid

potential problems when the available resources will be insufficient to satisfy future needs. In this case, policy regulations and governance need to be inter-governmental.

The next important case for the need of data collection, analysis and clear regulation is that of potential resources in the open desert. As discussed earlier in this contribution, there are vast expanses of land that have not been explored. Basic questions to be answered by exploration - and observation - wells in these cases include the following:

1. What are the boundaries of each groundwater basin or aquifer?
2. How far down is the groundwater level(s)?
3. What is the salinity of the aquifer(s)?
4. How much water is contained in each basin?
5. What are the safe pumping rates that would assure sustainability?
6. Would the water be used for in situ agriculture, or transported to where populations reside (as in the case of the Great Man Made River Project of Libya)?

In this specific case of groundwater in desert basins, it is essential for regulators to consider that such resources are “fossil water.” As clearly explained in this contribution, water had accumulated during wet climate episodes that lasted for thousands of years in the geological past. Replenishment may occur in minor locations along the few mountain ranges, while the open desert very rarely receives any rainfall to replenish the groundwater below. From a policy and regulatory perspective, this groundwater must be considered a finite resource that will run out after a given period of time.

In summary, groundwater resources in the Arab region require detailed study and data collection using advanced methodologies, which have been tested and proven in other parts of the world. It is also evident that the use of groundwater requires better and more thoughtful regulations. Neither of these two objectives would be accomplished without sustained attention by policy makers, with emphasis on the long term. Throughout the region, concerted efforts and plans are required at the present time to ameliorate the impacts of water shortages in the future.

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