State of Freshwater Ecosystems

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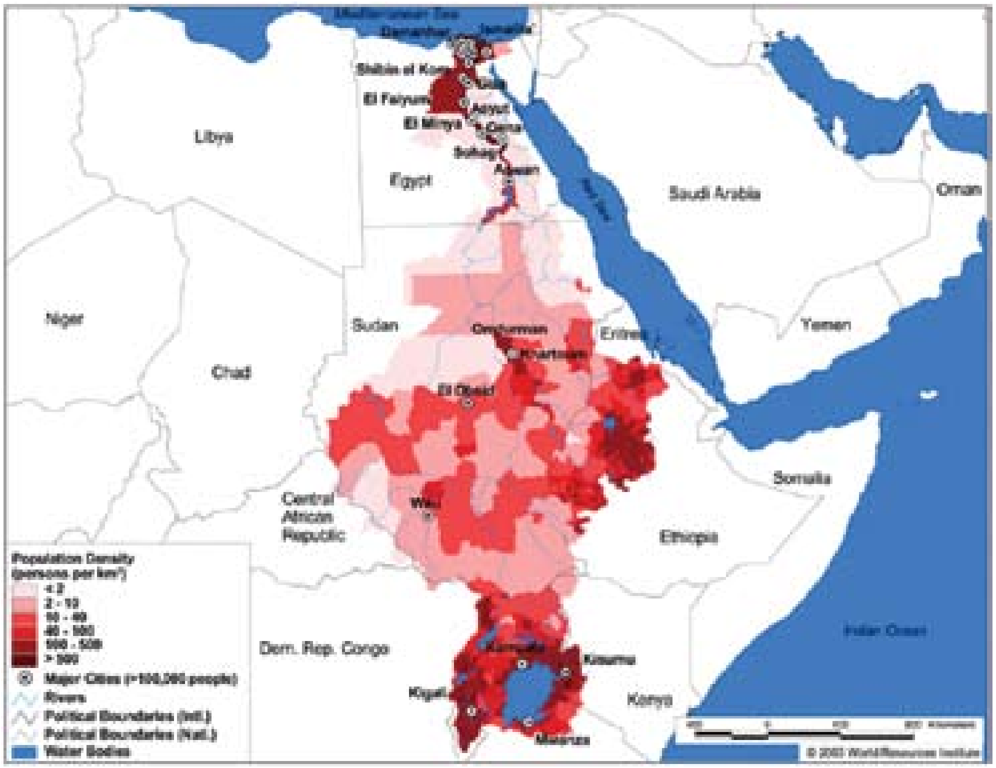
I. INTRODUCTION

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.

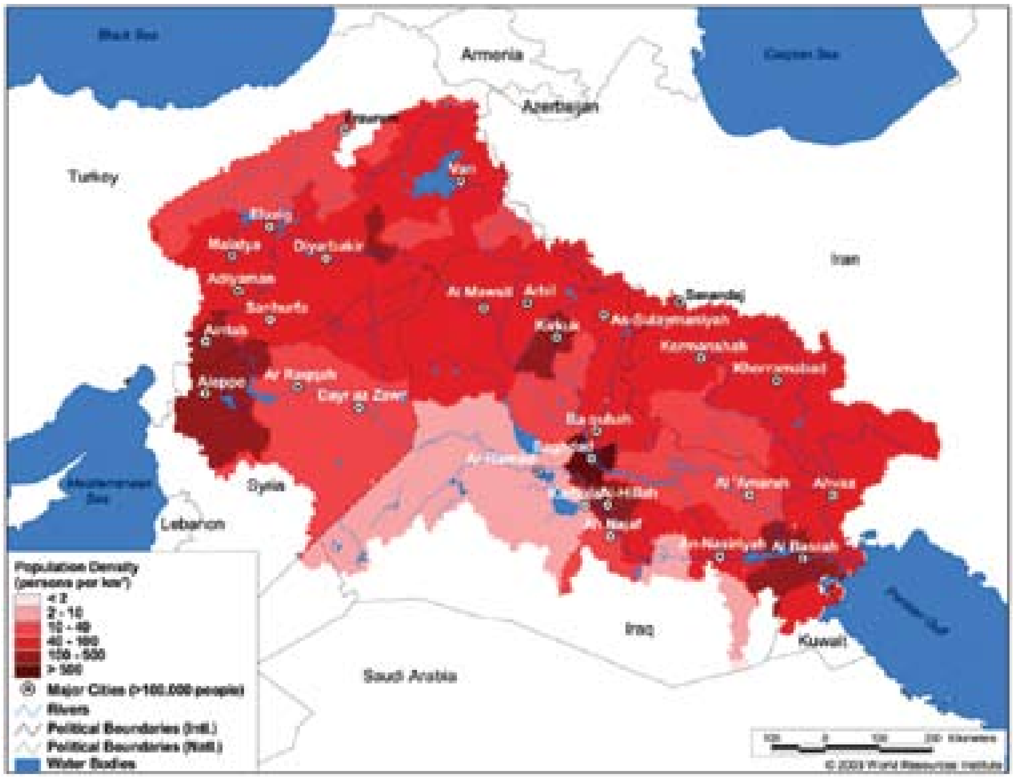
The strained conditions of water resources in the Arab countries have negatively affected the state of freshwater ecosystems as well as species biodiversity significantly. Freshwater ecosystems in Arab countries provide substantial benefits as a source for drinking water, fisheries, and irrigated agriculture. 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:

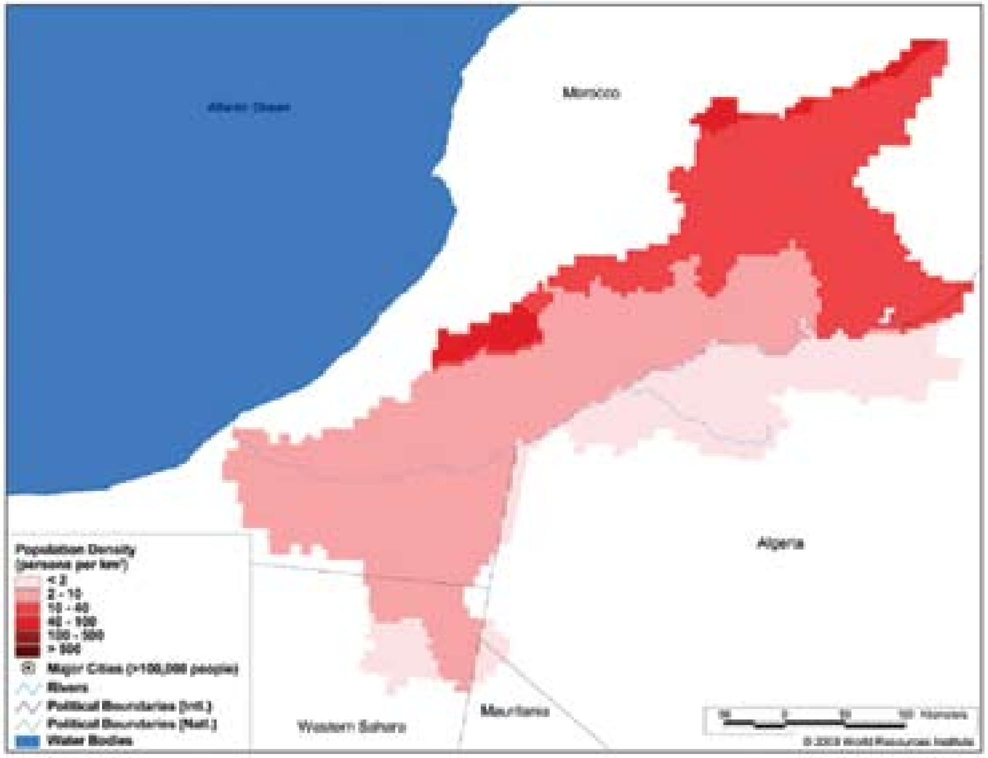
Long rivers: The Nile, Tigris, and Euphrates are the major rivers and contribute almost 80% of the total surface water flow in Arab countries.

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^2 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 Sebkha 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 Swaimeh 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 Toumbos, 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 Sebkha 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^3 considering that the average total abstration equals 150 million m^3 (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[1] 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).

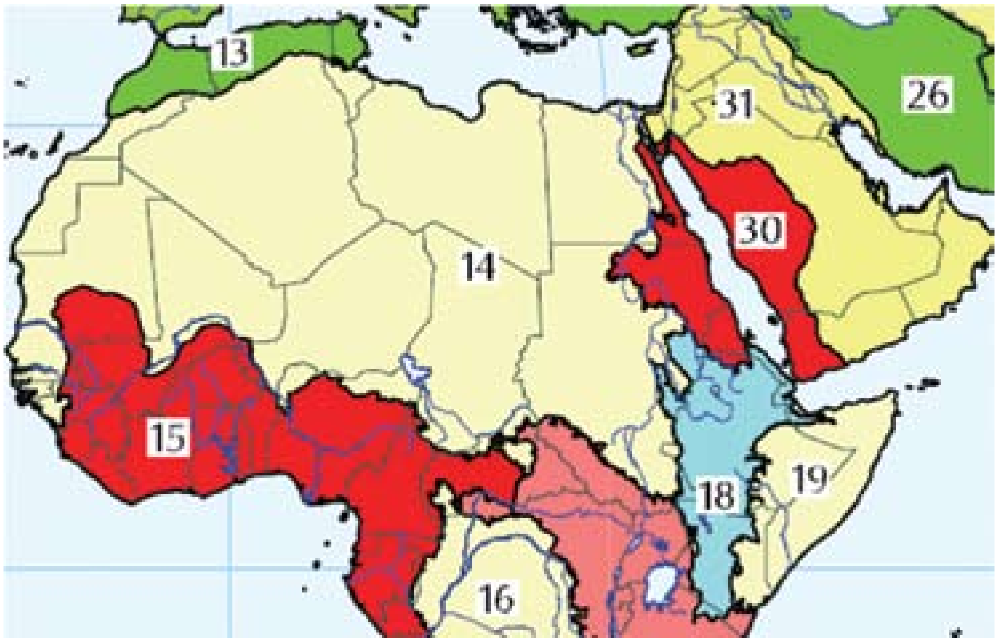
In Jordan, the Al-Azraq Oasis in the Eastern Desert is formerly comprised of a complex of spring-fed marshes and pools. According to Budeiri (2010), "the once extensive wetlands of the Al-Azraq Oasis have been completely destroyed because of over-exploitation of groundwater and dam construction on the 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

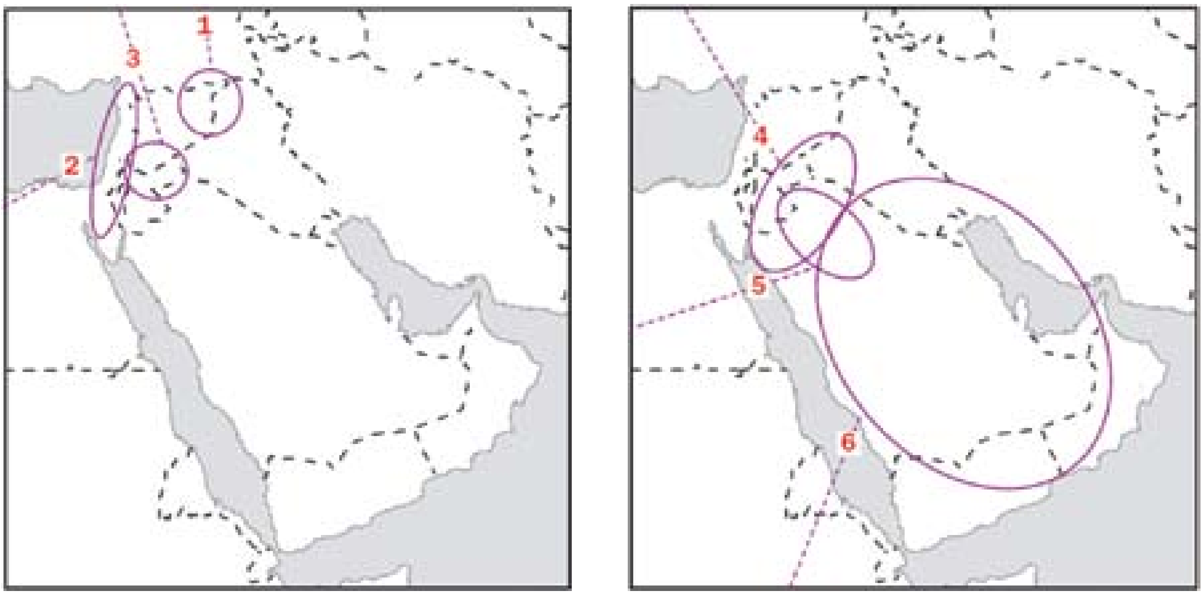
FIGURE 4 **MAP OF GROUNDWATER REGIONS**



Legend:
13. Atlas,
14. North African basins,
18. 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
2	Eastern Mediterranean:	Palestine, Israel, (Jordan), Syria, Lebanon
	Western Mountain Aquifer	Palestine, Israel
	Northern and Southern Jurassic and Cretaceous Aquifers	Lebanon, Syria
	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 Haweija 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.

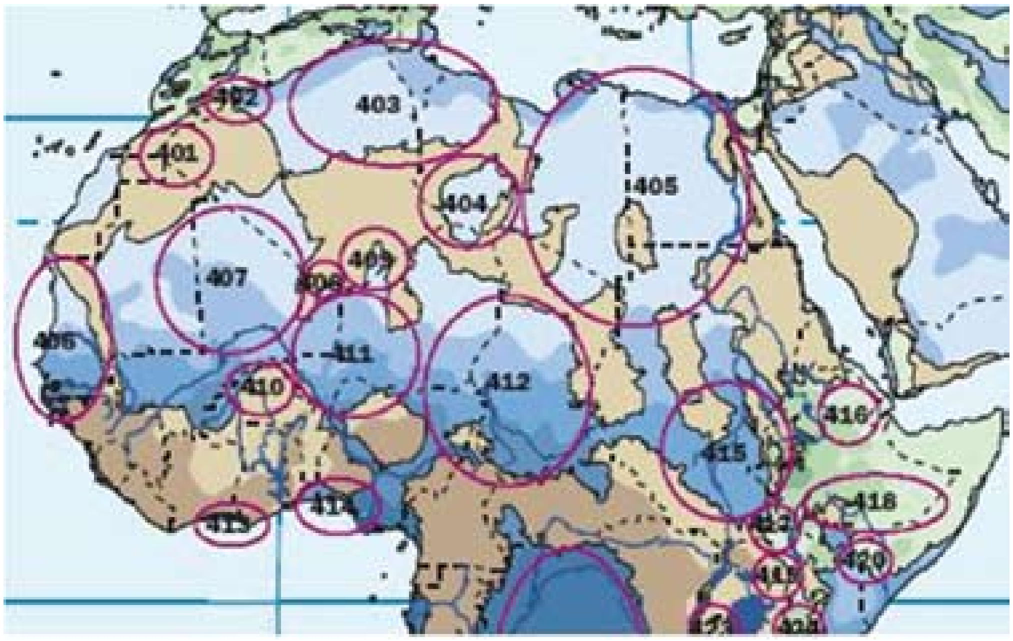
Like other ecosystems, freshwater sources such as groundwater wells, springs, lakes, rivers, and streams provide many services to human society. These services include both market goods and services like drinking water as well as nonmarket goods and services such as biodiversity. Many of the goods and services that may be provided by freshwater sources in the Arab States today are not bought or sold which means that the 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 in 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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TABLE 5 ANNUAL VOLUMES OF GROUNDWATER PRODUCED INTERNALLY, ENTERING THE COUNTRY, AND THE TOTAL RENEWABLE

Country	Produced internally (km³/yr)	Entering the country (km³/yr)	Total renewable (km³/yr)	Total renewable (m³/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 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.

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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NOTES

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