Agricultural Water Management

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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^3 per year. In other words, the per capita share of 889 m^3/year is less than the water scarcity index of 1000 m^3/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 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 piped 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).

BOX 2: WATER DEMAND MANAGEMENT IN EGYPT

Adapted from: A demand driven design for irrigation in Egypt (Baietti 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.

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

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^3 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

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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^2 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^3 in 1995, to about 200 billion m^3 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^3 in 1980 to 20.2 billion m^3 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) assets 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 sustainably 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 scare 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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