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Abstract

Physical water scarcity, in the MENA region, is not the only issue. Conditions of economic scarcity seem to be equally pressing: there are few incentives for wise and efficient use of this critical resource. Jordan is a glaring example of the severity of both sides of this scarcity problem; Jordan is chosen as a case study to explore the complexity and implications of this scarcity and the potential use of incentives, economic instruments and regulation to balance demand growth and supply shortages. Current water availability and uses in Jordan are quantified and profiles of the existing challenges, incentives, instruments and policies in place are analyzed in order to define feasible options for Jordan, focusing on policy change, particularly on the use of more efficient economic incentives and instruments and the building of conservation compatible institutions to manage and optimize water uses.

ملخص

ندرة المياه ، في منطقة الشرق الأوسط ، ليست القضية الوحيدة. فان ظروف الندرة الاقتصادية تبدو هي الاخرى كقضية ضاغطة. هناك حوافز قليلة للاستخدام الحكيم والكفء لهذا المورد الحاسم. الاردن هو مثال صارخ على خطورة من كلا الجانبين لمشكلة الندرة؛ يتم اختيار الأردن كدراسة حالة لاستكشاف مدى تعقيد الآثار المترتبة على هذه الندرة والاستخدام المحتمل للحوافز، والأدوات الاقتصادية والتنظيم لتحقيق التوازن بين نمو الطلب ونقص المعروض . ويتم تحليل ملامح من التحديات القائمة، والحوافز، والأدوات والسياسات في مكان من أجل تحديد الخيارات الممكنة للأردن، مع التركيز على تغيير السياسات، ولا سيما على استخدام مزيد من الحوافز والآليات الاقتصادية بكفاءة وبناء المؤسسات بطريقة متوافقة للحفاظ على ولإدارة وتعظيم استخدامات المياه.

1. Introduction

The MENA region is one of the most water poor and water stressed regions of the world. While the region is home to over 5% of the people of the world, it has less than 1% of its renewable fresh water. Annual per capita availability of fresh water in the region is only one third of its 1960 level (World Bank 1996), falling from 3,300 cubic metres per person in 1960 to less than 1,250 cubic metres in 1995 and to even a low of 545 cubic metres in 2005. This is the lowest per capita water availability in the world. However, Palestine and Jordan, whose annual per capita availability averages are less than 100 cubic metres, fall below the average of most Arab Gulf countries, where the regional average is 545 cubic metres. Of the 22 countries designated by the World Bank as water poor, 15 countries are in the region.

The growth of population and industry are increasing the demand for water everywhere. Global warming is threatening to exacerbate this scarcity and will intensify the tensions and insecurities of supply. This is, however, only one aspect of the problem. Actual physical scarcity, in the MENA region and elsewhere, is not the only issue. Conditions of economic scarcity seem to be equally pressing: there are few incentives for wise and efficient use of this critical resource. Water shortages can be dealt with in a number of ways--increasing supplies and the water system efficiencies and/or through conservation and demand management. The latter are more recent in nature and less used. They are increasingly becoming more urgent and more dependent on using economic instruments, incentives and technology such as efficiency prices, smart metering, water banking, tradable permits and conservation compatible incentive regimes. But for these economic instruments and conservation regimes to work there should exist an understanding of how these instruments work and why? A clear set of objectives and strategies capable of co-ordinating their use and institutions to monitor, guide and implement these incentives are crucial factors for their application. Equally important is to provide a macroeconomic context, which is compatible with micro efficiency while also being consistent with standard notions of equity and justice. A number of questions and complications arise about the efficacy of these instruments and their implication in any particular application. These questions require conclusive and clear answers.

In this paper Jordan is chosen as a case study to explore the complexity and implications of water scarcity and the potential use of incentives, economic instruments and regulation to balance demand growth and supply shortages. While it may not be possible to generalize the experience and lessons that may be learnt from Jordan water practices and policies, the study should serve, however, to highlight issues and modalities of what an efficient and equitable water system may have to contend with.

The paper first describes and quantifies the current water availability and uses in Jordan and profiles the existing challenges, incentives, instruments and policies in place. This is followed by delineating the existing and emerging water scarcity issues facing Jordan and an anatomy of failure of the existing conservation regime and instruments to balance the demand for water with the existing supply. The final section presents some feasible options for Jordan, focusing on policy change, particularly on the use of more efficient economic incentives and instruments and the building of conservation compatible institutions to manage and optimize water uses.

Throughout the Middle East, water shortages, asymmetries in political-military power and water control, consumption and demand interplay to form a complex hydro politico-strategic web. The current allocation arrangements of the region's three major river basins - the Nile, the Euphrates-Tigris and the Jordan - are nascent sources of tension, and potential sources of conflict and violence. Of all the Middle East's river basins, however, it is the Jordan River that hosts the most violence fraught and inflammable dispute rooted deeply in the Arab-

Israeli conflict in the region. This paper will briefly highlight the complex historical hydro-geopolitics in the region stemming from the asymmetry in regional power dynamics (in terms of economic and military might), and illustrates how this affects Jordan and its ability to claim an equitable share of water resources.

2. Features of the Existing Water System in Jordan

A number of dominant characteristics define and shape the existing water system in Jordan. These characteristics are organized by sector and issue.

2.1 Water Abstraction Rates from Underground Aquifer and Surface Water: Are They Sustainable?

Water abstractions from the underground aquifer in Jordan (392 MCM/Year) exceed the average annual safe yield of ground water. The latter is estimated at 275 MCM/year. Furthermore, another 77 MCM/year is being extracted from non-renewable resources. The reverse is true for surface waters, which are being used at the rate of 365 MCM/year which is lower than the average annual sustainable flow of 535 MCM/year. Non-conventional water resources are increasingly being used particularly treated waste -water (80 MCM/yr) and desalinated water (10 MCM/yr) (Ministry of Water and Irrigation 2009).

2.2 The Challenge of Agriculture

The water share of agriculture far exceeds the water shares of households, industries and institutions put together. The industrial and municipal sectors, including the tourist sector, together consume 28% of Jordan's water supply while the agriculture/irrigation sector consumes 72% (Water for Life, Jordan's Water Strategy 2008 - 2022).

While the agricultural sector consumes the largest proportion of water in Jordan it only accounts for 3% of GDP. This share has decreased over time from 6% in 1992 to 3% in 2007 (UN Food and Agricultural Organization 2008). Water consumption in agriculture has declined recently, specifically in the Jordan Rift Valley (JRV) (Figures 1 and 2), due to a number of factors, including loss of irrigated farm area with persistent drought, stiff economic competition in the agricultural sector from neighbouring countries (particularly Turkey, Lebanon and Syria), the aftermath of the Gulf Wars on the Gulf agricultural export market, increased regulation of wells, and the implementation of new water saving technologies (Venot et al. 2007). Water use for irrigation is, however, expected to increase again in the near future (Figure 2) due to the increasing demand for food and the expected rise in the availability of non-conventional water sources such as treated wastewater, rainwater harvesting and desalination of seawater.

Sediment deposits from the Jordan River make the JRV the most fertile area of the country; the JRV also depends almost entirely on irrigation (Department of Statistics, Jordan 2008). The Jordan Valley Authority (JVA) supplies irrigation water to the JRV, using surface water primarily from the Yarmouk River and side *wadis*, as well as some treated wastewater. Groundwater is used to a lesser extent in the JRV, and mostly in the southern part of the valley.

Between 1953 and 1986 the Jordanian government emphasized cropping patterns that it believed would match soil and water availability. Farmers, however, tended to grow crops allegedly based on the highest commercial value, leading to problems in reduced water resources and soil quality depletion (Al-Zabet 2002). There is an obvious trend of overproduction of high water-consuming tree crops irrigated by flooding with open canals. Most of the land is used to produce either vegetables (54% of land area, 99.8% irrigated) or permanent fruit tree crops (33% of land area, 99.2% irrigated). Field crops are produced on

13% of the land area, 89% of which is irrigated. All numbers are averages between 1994 and 2008 (Department of Statistics, Jordan 2008).

In the Uplands, irrigation water is pumped from licensed and unlicensed private wells, tapping both renewable and non-renewable groundwater and, to a lesser extent, from surface water as most agricultural land is in the uplands (88%) (Figure 3). Most agricultural production in this area (57% of land area) is in field crops, with 34% of highland areas producing permanent fruit tree crops and 9% producing vegetables. Vegetables are the most heavily irrigated crop group in the highlands (91% of area), while field crops receive little irrigation water (4% of land area) and tree crops are moderately irrigated (33% of land area). All numbers are averages between 1994 and 2008 (Department of Statistics, Jordan 2008).

The expected increase in the demand for water for irrigation purposes is based on the fact that much of the estimated 888,400 ha of cultivatable land in Jordan (the United Nations Food and Agricultural Organization of the UN 2008) lies outside the zone of sufficient rainwater for rain-fed agriculture. Between 1994 and 2008, 78,501 ha of the 252,680 ha under cultivation were irrigated (Department of Statistics, Jordan 2008). Rain-fed agricultural land is being lost as variable precipitation leads to unreliable production, and as urban expansion increases, with around 88,400 ha of rain-fed land converted to other uses between 1975 and 2000 (Food and Agricultural Organization of the UN 2008). The expected increase in the share of irrigated agriculture will most likely exacerbate the water crisis in Jordan.

It is an undisputed fact that the current irrigation methods are also responsible for significant water wasting, partly due to the continued use of traditional flood irrigation systems, despite the parallel widespread adoption of more efficient drip and sprinkler technologies. Irrigation water loss also arises from leakage in the transport of water, percolation through soil, and evaporation during transport or on the field. In 2007, 32,517 ha (97%) of vegetable crops were irrigated in Jordan. In open fields, 1,768 ha were irrigated with sprinkler systems, 23,529 ha were irrigated with drip irrigation systems, and 2,960 ha were irrigated with flood irrigation methods. Almost all vegetables planted in plastic greenhouses were irrigated using drip irrigation systems (4,260 ha). Only 5,156 hectacres (7%) of field crop area was irrigated in 2007 in Jordan. Most of this was irrigated using flood irrigation methods (3,069 ha), while 1,482 hetacres was irrigated using sprinkler systems and 505 hetacres was irrigated with drip irrigation. Clover (2,156 ha), maize (792 ha) and sorghum (76 ha) were entirely reliant on irrigation. Finally, of the 81,305 hectares of fruit trees planted in Jordan in 2007, 43,327 hectares were under irrigation (Department of Statistics, Jordan 2007). Data between 1994 and 2008 reflect that 88% of agricultural land is situated in the highlands, while only 12% is situated in the JRV (Department of Statistics, Jordan 2008).

There is currently little correlation between the water requirements of crops and crop production in Jordan, indicating how little water prices currently impact crop choices in the country. In Table 1 we present correlation coefficients based on the ranking done in terms of their intensity, efficiency and their values and volumes. The results are very indicative of a major mismatch between water intensity and efficiency with crop prices (a proxy for value) and volumes of production. The correlation coefficients are either negative or fairly low, which shows that current crop prices do not guide scarce water allocations in crop production. Equally relevant is the divergence of volume of production of crops with water intensity. There is a marked divergence between the ranks of crops by volume with water intensity.

2.3 The Threat of Population Growth and Urbanization

Jordan's total municipal and tourist water use has increased significantly during the past decades, from approximately 116 MCM in 1985 to 249 MCM in 2002 (Ministry of Water and

Irrigation, Jordan 2009a). Increased income and changes in lifestyle have contributed to this increased water consumption, especially in the urban areas of Greater Amman, Irbid and Aqaba (Figure 4). The absorption of large refugee numbers from Iraq during this period and the significant rise in the number of tourists visiting Jordan has also contributed to this rapid escalation in water demand. Water consumption in Jordan's industrial sector is limited to nine big industries, located in five governorates. Together they account for about 86% of the total water used by all industries. Both industrial and municipal water uses are expected to rise to meet the demands of a growing and increasingly urbanized population, and the increasing importance of industry in the economy.

The current population growth rate of Jordan is considered to be one of the highest in the world. The already elevated natural population growth rate has been further increased by regional political instability and incessant wars. Approximately three million Palestinian refugees settled in Jordan after the Wars of 1948 and 1967 and half a million Jordanians returned after the First Gulf War in 1990, and an additional half million Iraqi citizens fled to Jordan after the Second Gulf War of 2003. According to the Jordanian Department of Statistics, the population of Jordan is doubling every twenty years. It reached the six million mark in 2008 and is expected to rise to 9.2 million by 2020. This massive increase in population has already strained the limited water resources of Jordan and greatly increased the urban sector water demand.

2.4 Asymmetrical Water Treaties

Jordan has concluded two bilateral water agreements with Israel and Syria to manage shared water resources in the Jordan basin. Jordan has not benefited much from either. This is in part due to its weak strategic position against more powerful interlocutors and Jordan's little success in implementing many of the provisions of the agreements (Table 2 gives water sharing arrangements under different treaties). The Peace Treaty of 1994 between Jordan and Israel calls for desalination projects on the Lower Jordan River but these have yet to be built. Further, diversion of 60 MCM from winter floodwaters of the Yarmouk River to Lake Tiberias for use by Jordan has not materialized either (Haddadin 2006). Jordan also claims that it has been able to access less than half of its share of flow from that river (Haddadin 2006). The Agreement of 1987 focuses on establishing the Al-Wehdah (Unity) Dam on the Yarmouk River. The latter has an annual gross flow of 110 MCM and a capacity to generate 18,800 kWh of power (Ministry of Water and Irrigation, Jordan 2007; 2009a). However, because of excessive depletion of the Yarmouk's surface and groundwater, the water retained in the Dam has been well below its 110 MCM capacity, sitting at little more than 18 MCM since its construction in 2006 (Namrouqa 2009). Even after the 1987 Agreement, the Syrians increased damming of the four recharge springs of the Yarmouk and have increased groundwater drilling in the river basin (Al-Kloub and Shemmeri 1996; Haddadin 2006; Ministry of Water and Irrigation, Jordan 2007b), leading to significant reductions in base flow along the Jordanian/Syrian border (Haddadin 2006; Ministry of Water and Irrigation, Jordan 2007b). Base flow is estimated to have dropped to 2 cubic meter per second in 2000, and to 0.9 cubic meter per second in 2008, compared to 5-7 cubic meter per second in the 1950s (Haddadin 2006; Ministry of Water and Irrigation, Jordan 2007b; Namrouqa 2009).

2.5 Deficient Infrastructure

A large proportion of Jordan's water supply is lost because of inefficient and aging infrastructure (USAID 2006). About 56% of the total production of water for municipal uses in Jordan is unaccounted for (USAID 2006), which includes both administrative losses and physical network losses. Administrative losses result from illegal extraction, unbilled water provided to tankers and fire hydrant points, inaccurate or erroneous meter readings, non-operational meters and/or un-metered connections. Mafraq has the most inefficient system with losses around 78% (Figure 5), with Jerash and Tafilah showing losses on the low end that are still close to 40%. Other reasons for the extensive water losses in places like Mafraq include the lack of law enforcement, very low penalties for use of illegal water, lack of individual responsibility or awareness for water wastage among citizens, low maintenance of the pipes, and poor quality of pipe repair materials.

2.6 Poor Conservation Record

Poor conservation practices occur within all sectors, but are of greatest concern within agriculture due to the overwhelming demand for water in this sector. Poor conservation is linked primarily to the fact that water prices do not reflect the true cost of providing this scarce resource. Currently, the Water Authority of Jordan does not charge farmers anything for pumping from private wells for the first 150,000 cubic meters, and charges only JD0.005 per cubic meter between 150,000 and 200,000 and JD0.060 for every cubic meter over 200,000 cubic meters consumption (Namrouqa 2010). At this time, water prices cover less than 60% of the operation and maintenance costs of water supply for irrigation (Food and Agricultural Organization of the UN 2008). Water tariffs in the JRV have been raised a number of times. The current tariff is designed to accommodate crop water requirements, which are highest for trees. The average collected rate is around $21 USD per 1,000 m^3, but falls short of the marginal cost of around $38 USD per 1,000 m^3 to cover all water supply costs. In the highlands, the average cost of irrigation water is significantly higher at $70-$80 USD per 1,000 m^3 and rises with fuel costs (Food and Agricultural Organization of the UN 2008), but is still below the marginal cost of pumping and delivering the water uplands.

2.7 Paucity of Wastewater and Non-conventional Water Sources

Jordan has made a limited effort to use treated wastewater or to develop other non-conventional water harvesting techniques to augment its dwindling water supplies. Low investment in water infrastructure is a major cause for this, while low water recovery rates have also undermined the incentive to invest in this sector. The current performance of many wastewater treatment plants is inadequate for handling the quantity of water that needs treatment and end up discharging low quality effluent (Ministry of Water and Irrigation, Jordan 2009a). This effluent can adversely impact public health due to pathogen contamination of crops or the accumulation of toxins in irrigated soils. Surface and groundwater are also adversely impacted due to runoff and seepage of polluted water, limiting their use for drinking water purposes. Furthermore, septic water is not regulated and untreated water discharged into the watershed has become a health and environmental issue (Ministry of Water and Irrigation, Jordan 2009a). The salinity of municipal water is around 580 ppm of Total Dissolved Solids (TDS) and the average domestic water consumption is low, which is why wastewater in Jordan, in comparison to other countries, tends to be highly saline and have high organic loads (Ministry of Water and Irrigation, Jordan 2009a). Wastewater treated in waste stabilization ponds aggravates this problem, as water is also lost through evaporation, increasing salinity levels in effluents. Nonetheless, water supplied through wastewater treatment will likely become increasingly important for agricultural and industrial production in Jordan in the near future.

3. Water in Jordan: Anatomy of Failure

Water scarcity in Jordan is a complex problem that is not likely to be resolved or abate with the passage of time. If anything it is likely to intensify and expand in complexity and ramifications under strong pressures from continued population growth, escalation of urbanization, rapid industrialization and climate change. The sooner this problem is confronted and solutions are put in place the more likely it is to contain its implications and limit its many potential difficulties.

The present situation does not augur well for the future. There are many failures, deficiencies and weaknesses that have become ingrained in the water operating system and daily life of Jordanians. Some of these are technological in nature and could be resolved at the technical level. But many are behavioral and institutional and these require longer periods of time and more complex solutions involving social, economic and political restructuring and reform. Being rooted in the institutional and behavioral structures of the society and economy, they require more thorough and pervasive solutions.

It is a well-accepted proposition that a correct diagnosis of the problem is the major part of the solution. A quick review of some of the key issues and deficiencies would include the following:

- High leakages in the water supply network.
- High prices for domestic water use (the smaller component of demand for water) in order to subsidize larger and more profligate agriculture water use (the largest component of water demand).
- Inadequate and limited use of meters, limited monitoring, and repair of existing meters.
- Inadequate administrative and physical infrastructure resulting in large financial and physical loss of water.
- Absence and/or lack of adequate water conservation programs and effective government intervention to encourage conservation.
- Insufficient use of water conserving technologies– for example aerators, low flow flush, water and energy conserving household appliances and limited use of nontraditional and proven irrigation technologies.
- Large amount of water unaccounted for in the system –as high as 60 or 70% in most governorates, 76% in Mafraq
- Inappropriate product structure with several water intensive crops produced for exports, such as citrus fruit and vegetables.
- Sub-optimization in structuring prices and crop structures.
- Asymmetrical regional water shares resulting from poor negotiations and implementation of water treaties.
- Multiplicity in the administrative structures where clear responsibilities and accountability structures are limited and where overlapping responsibilities lead to confusion and inaction.

The realization and recognition of these deficiencies, weaknesses and failures set the stage of designing appropriate responses and developing policies and strategic options for dealing with them.

4. Options, Strategies and Economic Instruments and Incentives

A concerted plan is needed to deal with the many aspects of the water problem in Jordan. This plan would involve all aspects of the hydrologic cycle, land use, climate, geography and pollution, economics, social interactions and institutional aspects relating to water management. It would deal extensively with rationalizing water withdrawal, improving water quality, promoting water conservation and the promulgation of extensive legislation, monitoring procedures and regulatory structures, as well as plans for flood control, building dams and major water and waste treatment engineering works. The confluence of all of these aspects, preferably at the watershed level, is central to the design of a feasible and effective plan. Of course, there are many external factors that would influence the plan over which Jordan may have very limited control such as the effects of global climate change, water transfer between watersheds, and movement of large populations as a result of political events; but some of these events need to be anticipated and adaptation and mitigation strategies could be developed to mitigate and minimize their negative consequences.

It is possible to enumerate a large set of measures to be taken by all segments of the Jordanian economy and society to manage appropriately, efficiently and effectively the water problem in Jordan. Alternatively, it is perhaps more useful to concentrate on a subset of measures and policies that are more likely to be feasible and those that have been tested elsewhere that can afford Jordan a customized plan based for a rational water allocation system.

As part of this plan various measures and reforms will be recommended under different headings. The idea is to have a focused plan with an action sub-plan for its implementation in smaller steps. The recommended set will focus on institutional and economic reforms in the water sector (which include improving infra-structure and water tariffs among other things); involvement and education of all the stakeholders (ministries, industries, farmers, non-governmental sectors, universities, and even the general population) and some technological changes and adjustments to help in instituting the rational water usage plan. The following discussion divides the recommendations into sectors, although in implementation of the general plan a holistic approach is necessary that accounts for diverse interactions between water users, water availability and institutions.

First and foremost there is an immediate need to restructure the water tariffs to account for the full cost of water production. In the short term water tariffs could aim, at minimum, to recover all of the operational and maintenance costs and capital charges (revenue sufficiency), but the long-terms aims should be for a full cost recovery (including economic opportunity costs, economic externalities and environmental costs, Figure 6). The current water tariffs in Jordan are far below the scarcity price for water. This price would include the marginal cost of this water at the particular node plus a scarcity premium and the cost of delivery to the end user. Current tariffs in agriculture are significantly below these shadow prices (Kubursi and Agarwala, 2011). Residential users are charged tariffs that are closer to these scarcity tariffs but the presumption is that the rest of the sectors are to by subsided by the residential sector. In designing these tariffs it is also necessary to recognize that water is not only a desirable commodity, its availability is also critical for life. There are little or no substitutes for it. Furthermore, it is a well-entrenched principle that no matter how scarce water is; every person is entitled to a minimum quantity that is considered consistent with human dignity (Kubursi and Agarwala 2011). But equity considerations need not be dealt with through water tariffs. They can be handled by rebates based on income and not use. There is, however, always the possibility of designing the water tariff using increasing block rates where the lower volumes are charged very low rates that escalate quickly with use. This is based on the confirmed presumption that the poor consume far lower volumes than the rich (Kubursi and Agarwala 2010).

Water is a scarce resource (asset), a scarce commodity and a scarce input. Economics is particularly suited for dealing with such a resource as economics after all is the study of how scarce resources are or should be allocated to various uses and users. It is generally accepted; however, that water is not bought and sold in competitive markets. This is because in the case of water at least five of the basic properties of competitive markets are absent. These five properties include the following: First, free markets lead to an efficient allocation of scarce resources if these markets are characterized by competitive structures, that is, these markets include a large number of independent small sellers and a similarly large number of independent small buyers that no single supplier or buyer is significant enough to influence the price. Each and every buyer and seller in this market is a price-taker. Second, competitive markets require freedom of entry and exit, with no barriers existing to preclude easy entrance or exit. Third, the product must be homogeneous enough that each unit is quite similar to any other unit. Fourth, for a free market to lead to an efficient allocation, externalities must be absent. In economics, an externality or spillover of an economic transaction is an impact on a party that is not directly involved in the transaction. An efficient allocation can emerge from a free market when social costs coincide with private costs. Water production, however, involves many "externalities". In particular, extraction of water in one place reduces the amount available in another. Furthermore, pumping water from an aquifer in one location can affect the cost of pumping elsewhere. Such externalities do not typically enter the private calculations of individual producers and drives a wedge between private cost and social costs. Fifth, in a free market that allocates efficiently scarce resources, social benefits must coincide with private ones. If not, then (as in the case of cost externalities) the pursuit of private ends will not lead to socially optimal results. In the case of water, many uses have social benefits that exceed the private ones. The use of water in agricultural may result in benefits that exceed the private returns to farmers. Among these are food security, border security, and national interest. These conditions are often violated in the case of water, where water sources are relatively few, barriers to entry are real and high (high cost of infrastructure), a large gap exists between private and social costs, and benefits and water units are not homogeneous where a large spectrum of different qualities are observed. This is perhaps why water production facilities are often owned by the State. In many respects water is not a private good; it has, as we alluded to above, many of the characteristics of quasi-public goods.

The presence of externalities and the absence of competitive markets do not, however, absolve policy makers from simulating competitive markets to establish shadow prices based on optimization models and/or restructure prices and tariffs to take into account externalities and opportunity costs. An optimization model has been developed for Jordan as part of the Harvard Water Project by Fisher et al. (2005). The model has many useful applications particularly when appropriate constraints are built in and the objective function is narrowed down to a Jordanian focus. This customization of the Water Allocation Model (WAS) could generate different sectoral and regional shadow prices for Jordan as if competitive conditions prevailed.

Pricing strategies and demand side management are extremely important to meeting increased water demand in Jordan in the face of increasing scarcity. Demand for water is a function of price; it is not fixed and can be modified by changes in prices. Some economists have argued that prices alone can correct behavioral patterns in water use and demand, while others argued that price is only one of several factors that influence demand and use of water. The economic literature has also suggested that domestic and agricultural water use is relatively inelastic (Espey et al. 1997; Hanemann 1998; Renzetti 2002; Garrido 2002) while industrial use is more elastic. Yet, even when the demand is price inelastic, economic instruments can still be used to correct inefficient use of water and to control water demand albeit requiring larger price changes than if the demand is price elastic. There is also the added benefit that revenue that accrues on price changes increase as prices increase in the case of price-inelastic demands.

Second, the crop patterns and the existing agricultural subsidies that support this pattern are at odds with a water conservation regime. In Table 1 the correlation coefficients between water intensity and volumes and values of the different crops are either very low or even negative for Jordan suggesting that crops that require large amounts of water are produced in abundance and that these crops realize lower values per unit of output. This lack of concordance between water intensity and value and volume is at the heart of the problem of excessive use of water in agriculture and the economic waste that results from this misalignment between value and intensity.

The current low correlation between the water requirements of crops and crop production in Jordan shows how little water prices currently impact crop choices in the country. The correlation coefficients in Table 1 are based on ranking products in terms of their intensity, efficiency and their values and volumes. The existing glaring mismatch between water intensity or efficiency with crop prices (a proxy for value) and volumes of production results in excessive use of water with low returns. The weak correlations exhibited in the data show that current crop prices do not guide scarce water allocations in crop production.

The results in Table 1 suggest that increasing water prices could result in less land area being used for crop production, with high-water consuming crops dropping out of production and land-use. For example, the Inter-seasonal Agricultural Water Allocation System (SAWAS) model developed by Water Economics Project (Fisher et al. 2005) shows that certain agricultural activities become unprofitable due to the relationship between their water requirements, cost of production and their market price. Winter crops have been shown to be the most unprofitable in this water scarce region, followed by fishponds, maize, certain orchard fruits, sunflowers, and high water consuming vegetables.

A re-alignment of the Jordanian incentive regime is advisable. There is a need to structure the incentives in such a manner as to prevent overuse of water in all sectors. This would include subsidies for encouraging the use of water-saving appliances in domestic and industrial sectors. Economic incentives and financing opportunities can be advanced to farmers to encourage them to employ new irrigation technologies and new crop patterns that are more consistent with low water intensity. The financing of these incentive programs could be linked to overall higher water prices.

Product substitution is another way the government can seek to align its programs with conservation of water. Moving away from an over emphasis on food self-sufficiency to greater reliance on importing high water-intensity crops from abroad as “virtual water”; using second best Pigovian taxes and tariffs may also provide an important incentive for significantly reducing national water demand in agriculture. There is already credible evidence that restructuring the crop patterns can reduce water consumption and result in higher value added. Wheat and barley are the two main field crops produced in Jordan, with wheat considerably more water intensive than barley (Shatanawi et al. 1998). Increased barley production over wheat may prove a more water-efficient use of field areas. Other water intensive field crops include maize and clover; finding alternatives for both of these crops may prove helpful in increasing the water efficiency of field areas. About 95% of the land-area used for vegetable production in Jordan is irrigated. Tomatoes are the most commonly grown vegetable but they require significantly more water than crops such as potatoes, squash, cauliflower, eggplant and watermelon, highlighting opportunities for water conservation through crop replacements. Tomatoes are currently subsidized for export to the Gulf region. Finding markets for less water-intensive alternatives could open up opportunities for crop-switching and water savings.

Expansion of fruit tree production, particularly citrus, apples, peaches and bananas, should be highly discouraged since these are very water intensive to produce and the ratio of price to cost is not particularly favorable for farmers. Annual crops, already in production in Jordan, that have lower water requirements include barley, vetch, squash, cucumber, sweet peppers, string beans, turnips, radish, and carrots (Shatanawi et al. 1998). Perennial olives also have relatively low water consumption compared to the other tree crops, and are mostly un-irrigated in Jordan.

Third, the experience of many developing countries with successful and efficient agricultural sectors suggests that small changes to management practices in the agricultural sector by local farmers can lead to significant water savings. Some of these practices can and are being implemented at the farm level in Jordan, and can be encouraged to expand through economic incentives and specific subsidies for the acquisition and implementation of new water saving technologies. Implementation also depends on education of local stakeholders about water management options, capacity building for implementation and maintenance of these technologies and extension services. Many water saving technologies are now available for the municipal and industrial sectors, and these can be similarly promoted through economic incentives, education and capacity building. Some specific examples of technological options for improved water management are listed below.

1. Implementing new irrigation technologies and scheduling can improve irrigation wastage. Nighttime irrigation can substantially reduce water losses due to low evaporation. Soil moisture probes can also be helpful in optimizing irrigation through proper scheduling. Sprinkler irrigation systems apply water overhead using high-pressure sprinklers or guns and are much more water efficient than flood irrigation methods. Drip irrigation systems are perhaps the most water-efficient as they deliver water directly to the root zone. Although this is an expensive technology and might require initial government or private investment; these investments will pay off since drip irrigation is very effective at saving water, reducing evaporation and increasing crop yield.

2. Laser leveling and land grading of fields can significantly reduce runoff, particularly in agricultural areas that use flood irrigation, which often results in an uneven distribution of water. Conservation tillage methods in agriculture, which leave a minimum of 30% of crop residue on the soil surface, can be very helpful in reducing water flow rates across the field, improving water infiltration by reducing water loss through runoff, and preventing soil erosion. Greenhouses and natural or plastic mulches are used in agriculture to reduce evaporation, and their use can be expanded, particularly with vegetable production.

3. The central governments and regional governments can improve water conservation in municipal and industrial uses by subsidizing or providing water conservation and water saving technologies such as faucet aerators and low-flow showerheads, dual flush toilets and dry toilets. Rebate programs have provided incentives to customers in places like Canada to invest in efficient appliances like washing machines and toilets and have helped in saving water and energy in many countries around the world.

4. Technical solutions should include maintenance and replacement of many of the water networks in Jordan to achieve the highest possible efficiency in water conveyance, distribution, and use (Abdel Khaleq and Dziegielewski 2006).

5. Detecting and repairing leaks can largely minimize the amount of lost water and reduce the amount of water pumped, saving water and energy. Leak detection and repair is the most practiced conservation activity in the North America (Great Lakes Commission, 2004).

6. Installation of universal water metering is an essential element in conserving waters because it leads to a change in behavior by allowing customers to better track their consumption and thereby reduces water use. As an example, installation of universal water metering in Canada has proven to reduce overall residential, industrial and

commercial water consumption by 15 to 30 percent (Great Lakes St. Lawrence River Cities Initiative 2008).

Fourth, life cycle analyses of different options for domestic water management based on increasing the use of non-conventional water sources and implementing technological solutions, were carried out in order to calculate reductions in use and the environmental and financial implications of the different management options (Tables A1 and A2 in the Appendix). In Table A1 we calculate the annual water and energy savings for domestic water management under different water management options. The results show that increasing the use of non-conventional water sources such as rainwater harvesting and gray-water will save the maximum amount of resources. Nonetheless, the calculations in Table A2 show that the production of rainwater harvesting vessels incurs an environmental cost, but overall this option still appears to be environmentally sound as it reduces the energy cost involved in abstraction and transportation of water from more conventional sources. The production of the tables involved multiple assumptions about the system, but they are still useful for policy makers to weigh different options for combining water and energy savings.

Fifth, treated wastewater is already becoming an extremely important source of water for the continuation of agriculture in Jordan as freshwater sources become more limited and more expensive to provide (Ministry of Water and Irrigation, Jordan 2009a, Food and Agricultural Organization of the UN 2008). This treated wastewater can be used more easily in the JRV due to existing infrastructure, with wastewater generated in urban areas above the JRV, mixed with freshwater, and subsequently released into watercourses that flow into the JRV through gravity. Currently, about 60 MCM per year of treated wastewater is used for JRV irrigation purposes (Ministry of Water and Irrigation, Jordan 2009a).

Wastewater use in food products always involves the risk of contamination, yet the level of consumer exposure to these contaminants depends on the quality of the water used, the irrigation method, the time between irrigation and subsequent consumption, and on how the product is consumed. Sprinkler or spray irrigation should be avoided with treated wastewater as these methods deposit water and microorganisms directly onto the leaves and fruits of a plant and do not conform to Jordan's health standards (Food and Agricultural Organization of the UN 2008). Drip irrigation is the ideal method for depositing treated wastewater. Conversely, drip irrigation can significantly decrease health and environmental risk by depositing water at low pressure directly into the soil.

Treated wastewater has the additional economic benefit of adding effluent nutrients to plants and soil, therefore reducing reliance on synthetic fertilizer, although wastewater also tends to have higher salinity levels than fresh water which needs to be periodically leached from the soil. Gray water reuse systems can be used on a smaller scale to capture untreated household water from showers, washbasins, washing machines etc., and can then be reused for flushing toilets.

Sixth, rainwater-harvesting systems provide a means of increasing the efficiency of rainwater use and reducing water costs. Currently only 5% of rainwater in Jordan is used as 85% is lost through evapotranspiration and 10% is lost through runoff. Rainwater harvesting can be used to collect rainwater on rooftops or off of concrete or rock surfaces. Water can then be stored in cisterns or water storage devices for future use.

For agricultural practices, rainwater can be harvested using terraces, rippers, contour ridges and other type of water collection methods that store water directly in the soil for crop production. However, these methods are not always effective and depend on the infiltration rates of soil and climatic conditions that impact evaporation. Experiments have shown that the best way to harvest rainwater for crop production is to store it deeper in the soil in sand ditches since it also reduces evapotranspiration (Abu-Zreig et al. 2000).

Seventh, improving water management in Jordan will involve reforms at different levels of the management hierarchy. At the utility level, reforms need to improve the performance of both physical and human infrastructure. In terms of physical infrastructure, water losses occur through deteriorating pipes, treatment plants, and metering devices.

Deteriorating infrastructure impacts urban water distribution through leakage problems, and rural/agricultural distribution through wastage in transport of irrigation water. Wastewater treatment plants are also in need of renovation to reach optimal functioning. Investment in aging infrastructure is extremely important in Jordan's water demand management program, but due to the high costs involved in this regard it may not be feasible to achieve except through a public-private partnership. In terms of human infrastructure, utilities will be greatly improved with upgrades to the quality of customer service, human resource management, finance and accounting.

At the sector level, improvements will need to be made by building the competences and capacities of different ministries and regulatory authorities. Education and capacity building will also be necessary to develop a core group of operators for proper management of water resources. Furthermore, the government will need to develop indicators to measure change that allows it to respond to environmental and economic trends impacting water supply or demand. This will require the proper selection of indicators, and the establishment of databases for storing collected information and monitoring data. Some of the key indicators will include the percentage of non-revenue water, water production, meter coverage, meter readings, as well as billing and revenue collection.

Eighth, water management within Jordan is currently undertaken by three different agencies without clear demarcation lines of authority and accountability. It is important that a consolidated institutional and legal framework be established with clearly delineated responsibilities. A coherent regulatory body should be established for controlling and operating water and wastewater systems in Jordan. The responsibilities of this regulating body should include controlling water losses, setting tariff rates, and other reforms that could improve water and wastewater management from the utility level to the governance level.

There are a number of important institutional considerations that should be taken into account. First, there should be a hierarchical context. Stress should be on the systems perspective, which means that while working on a problem at any level or scale, managers must seek the connections between all levels. Management should go beyond the administrative and political boundaries and defining ecological boundaries at appropriate scales, for example basin level or watershed level. The management plan should also consider ecological integrity so as to protect total native diversity and the ecological patterns and processes that maintain that diversity. The use of ecological boundaries necessitates cooperation between national, regional (Governorates) and local (Municipal) management agencies as well as private parties (including NGOs) – thus calling for inter-agency cooperation. Managers must learn to work together and integrate conflicting legal mandates and management goals.

Another consideration for a good water management plan is good data collection. The plan requires more research and data collection on habitat inventories, disturbance regime dynamics, baseline, and population assessment as well as better management and use of existing data. Monitoring is therefore necessary because the data gathered during the monitoring sessions provides feedback to the managers on the progress of the action items and allows the manager to keep track of the changes. Relevant, affordable, and accessible information exchange is the key starting point for integration of activities. Affordable and accessible information encompasses not only the cost of the data and information but also refers to the means and processes that the users already have to fully apply such information. Equitable information access is also critical; users should not be discriminated against because of geography (distance), gender, economic, cultural or social issues. With data collection and monitoring, it is also important for management to be adaptive (especially in the initial stages), which means knowledge is provisional and management is both a learning process and continuous experiment.

In general, implementing the new water management plan in Jordan requires changes in the structure and operation of management agencies. This may range from a simple change such as forming an interagency committee, to complex changes such as modifying professional norms and altering power relations. Regardless of the role of scientific knowledge, human values play a dominant role in setting goals, so people (stakeholders) should be an integral part of the plan (Grover et al. 2005).

5. Summary and Conclusions

A more rational water allocation system of scarce water is needed in Jordan. This is primarily necessary for the agricultural sector where moving to more economically viable and low water consuming crops and varieties can accomplish reducing the production of high water-intensive crops.

The over emphasis on food security in Jordan is perhaps not justified in the context of escalating water scarcity. Jordan may wish to explore the possibility of trade in "virtual water" through importation of high water consuming crops and products from countries that are more water-endowed and producing and exporting crops that are less water intensive with higher value added components.

Fresh water use in agriculture can be reduced by implementing incentives that encourage more efficient water applications through adopting water-saving irrigation technologies, expanding the exploitation of non-conventional water and more effective wastewater treatment and use. The increased reliance on treated wastewater in some specific agricultural products will free up fresh water for use in other sectors.

There is an obvious need for more efficient and effective water policies, metering and monitoring of water use, and the design of economic instruments and incentives through carefully structured water tariffs and other conservation incentives to balance expected increases in demand for water with reduced availability.

Four different economic instruments/approaches are tendered in this paper to help manage the demand for water and perhaps even the supply of water. The first one is structuring water tariffs to reflect full cost prices using increasing block rates. The second approach involves estimating the correlations between water efficiency, production and value added in order to rebalance and match the ranks and structures of crops with water intensity and value. The third approach is to calculate shadow prices using competitive general equilibrium models. Finally, the fourth approach is to use a life cycle assessment tool to determine the best options (high present value of net benefits) for domestic water conservation methods. Essentially, all of the suggested instruments highlight the importance of full cost accounting in the development of efficient water prices. Full cost accounting should reflect all the costs associated with operation, maintenance, replacing the infrastructure, opportunity costs and cost of economic and even environmental externalities.

It is also argued that the enforcement of the Water Strategy Policy of 1997, Groundwater Policies and Bylaw # 85 of 2002 are particularly critical for achieving rational water allocations over sectors and time.

Stakeholder and civil society participation in water management and water conservation efforts can and must be encouraged through education and capacity building, and through making the political process more transparent, coherent and cooperative.

Finally, another serious challenge to implementing economic instruments/approaches in water demand management is the need to clearly establish and define property rights to resolve the issue of common property rights embedded into the tragedy of commons associated with water being a public good. Other challenges include the impact of water markets on equity and the environment, and also the impact that high costs of water can have on other market functions. This calls for a comprehensive and nuanced approach to water management that abstracts from partial equilibrium solutions and microeconomic prescriptions.

In conclusion, Jordan needs to shift towards a fully integrated and coherent policy for water management inclusive of all sectors (i.e. domestic, industrial and agricultural), where the focus is on the watershed or catchment scale, and where Jordan can persuade regional parties to define more equitable and efficient shares.

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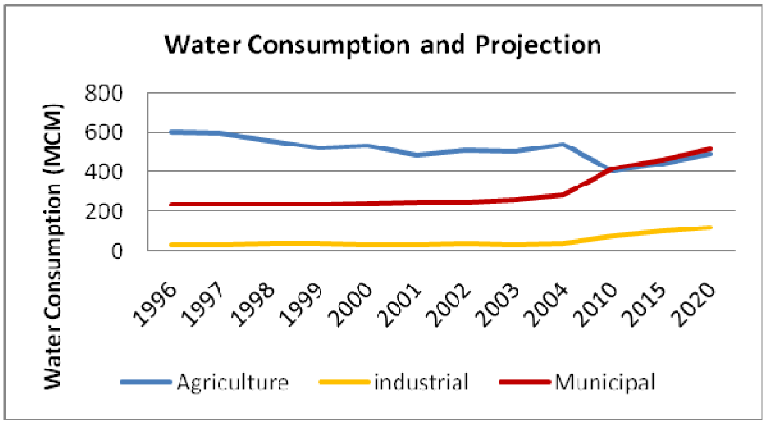
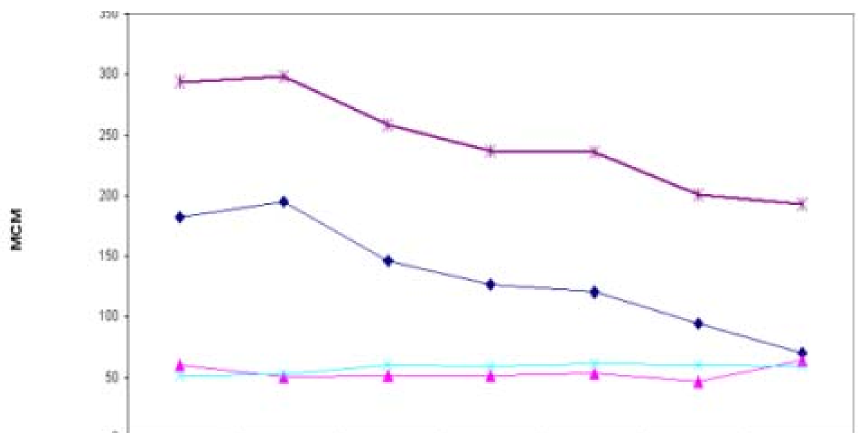
Figure 1: Water Consumption in Agriculture, Industry and Municipal Sectors 1996-2020



Source: National Water Master Plan- Ministry of Water and Irrigation 2007

Figure 2: Water Use for Irrigation in the Jordan Valley 1996 - 2002

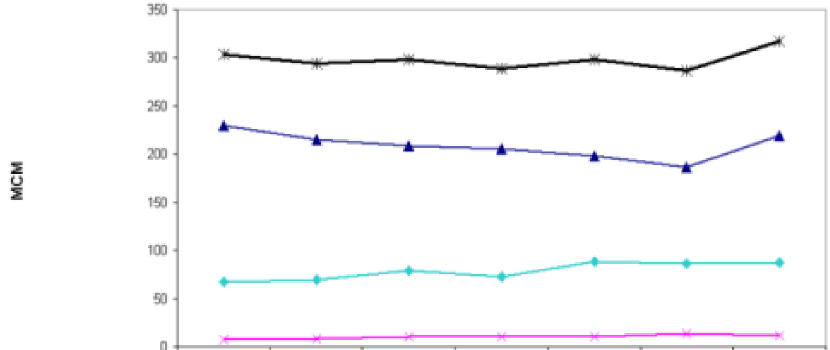


	1996	1997	1998	1999	2000	2001	2002
Surface water	182	195	146	127	121	94	70
Groundwater	60	51	52	51	54	47	64
Treated Wastewater	52	53	60	59	61	60	59
Total JRV	294	298	258	237	236	201	194

Year

Source: National Water Master Plan- Ministry of Water and Irrigation 2007

Figure 3: Water Use for Irrigation in the Uplands 1992 - 2002

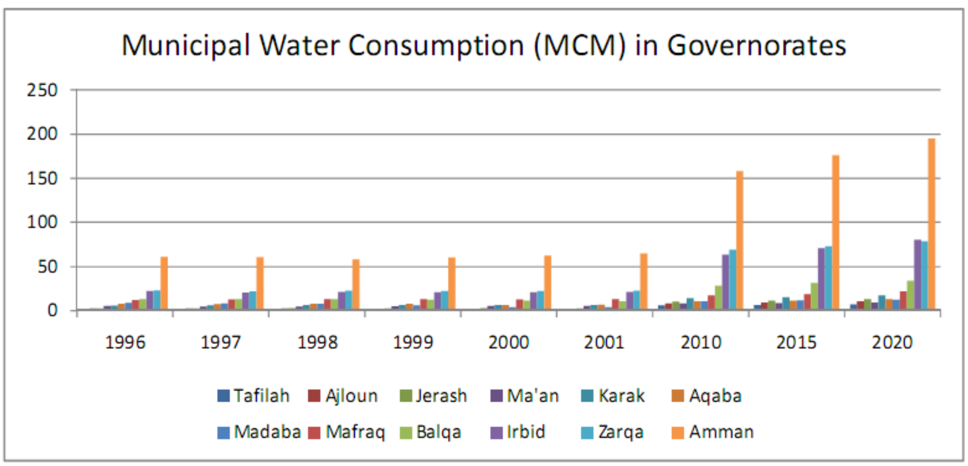


	1996	1997	1998	1999	2000	2001	2002
Surfacewater	67	70	79	73	89	87	87
Groundwater	230	216	208	205	199	186	219
Direct Treated Wastewater	7	8	11	11	11	13	11
Total Uplds	304	294	299	289	298	286	317

Year

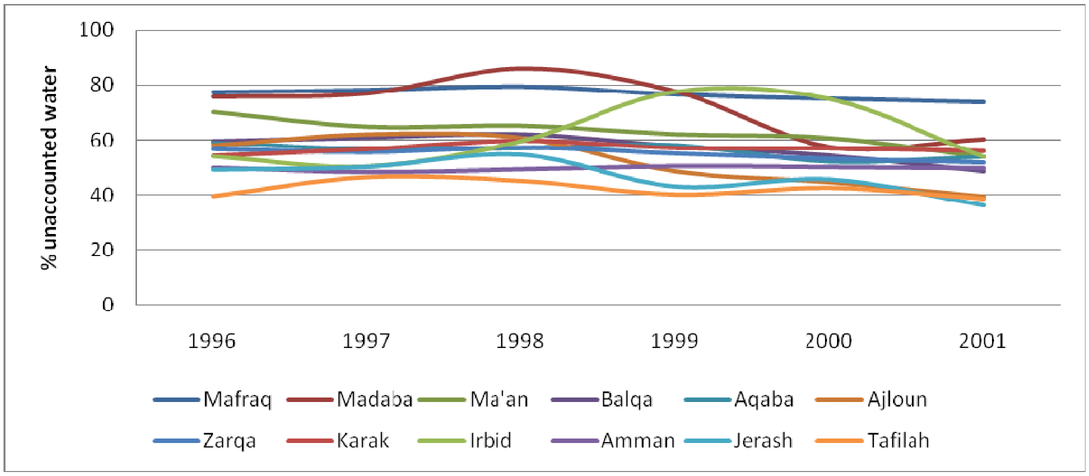
Source: National Water Master Plan- Ministry of Water and Irrigation 2007

Figure 4: Past and Projected Municipal Water Consumption by Governorate



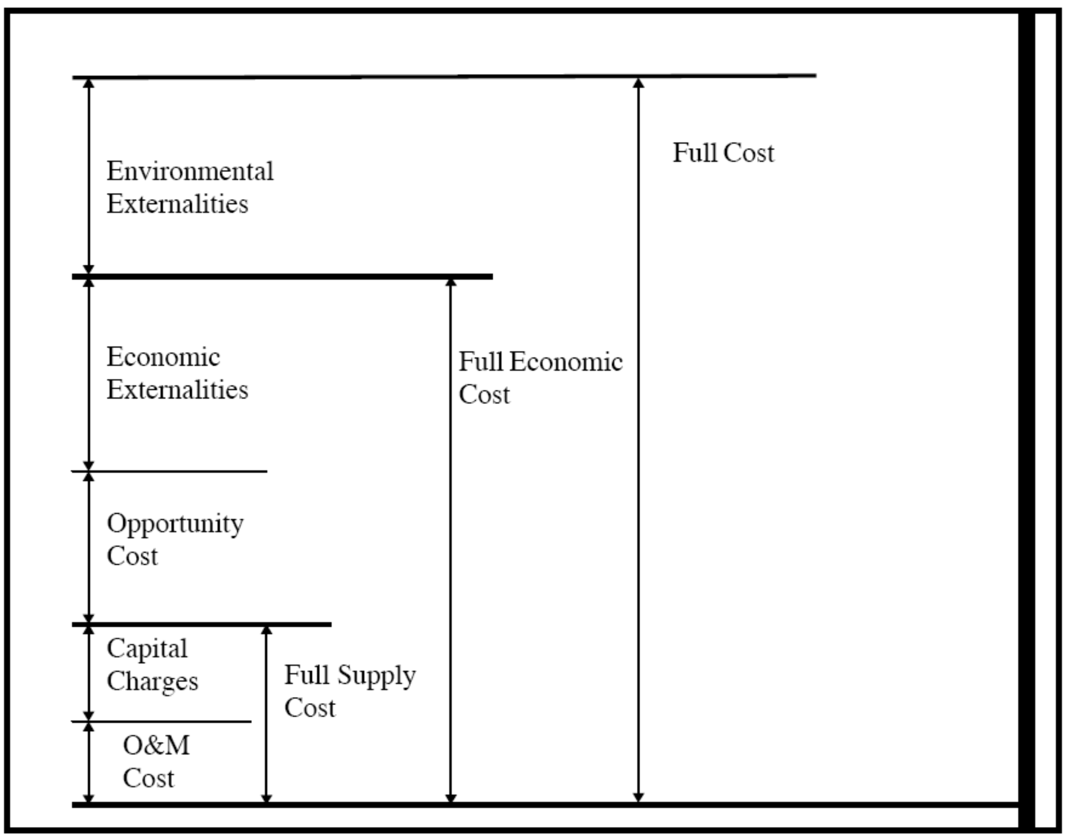
Source: National Water Master Plan- Ministry of Water and Irrigation 2007

Figure 5: Percentage Unaccounted Water per Governorate



Source: National Water Master Plan- Ministry of Water and Irrigation 2007

Figure 6: Full Cost Price of Water



Source: Rogers, Bhatia, and Huber. A. 1998.

Table 1: Correlation Coefficients of Water Intensity, Efficiency, Crop Production and Prices

	Drip Irrigation	Surface Irrigation
Intensity and Productivity	-0.102	-0.087
Efficiency and Productivity	-0.102	-0.082
Value and Productivity	-0.030	NA
Intensity and Value	0.015	0.024

Table 2: Summary of Water Shares for Jordan, Syria and Israel Under Different Plans

<table>
<tr><td colspan="3">Water allocated to Jordan, Syria, and Israel from the Jordan and the Yarmouk Rivers according to the Johnston Plan of 1953 (Mm^3/yr)</td><td colspan="2">Water used by Jordan, Syria, and Israel from the Jordan River basin after refusal of the Johnston Plan and before signing the Agreement of 1987 between Jordan and Syria and before signing the Water Agreement of 1994</td><td colspan="2">Water that should be allocated to Jordan, Syria, and Israel from the Jordan and the Yarmouk Rivers after signing the Water Treaty between Jordan and Israel and after assuming that the provisions of the Agreement of 1987 have been implemented (i.e. Al-Wehda Dam was filled with water)</td></tr>
<tr><td></td><td>Jordan River</td><td>Yarmouk River</td><td>Jordan River</td><td>Yarmouk River</td><td>Jordan River</td><td>Yarmouk River</td></tr>
<tr><td>Jordan</td><td>343*</td><td>377</td><td>243</td><td>120</td><td>273**</td><td>305***</td></tr>
<tr><td>Israel</td><td>375</td><td>25</td><td>552</td><td>100</td><td>522</td><td>25</td></tr>
<tr><td>Syria</td><td>42</td><td>90</td><td>0</td><td>170</td><td>0</td><td>160****</td></tr>
</table>

Notes: * The Jordan water share from the Jordan River is divided as follows: 100 MCM/yr from the Lower Jordan River, and 243 MCM/yr from the side wadis that feed the river from the Jordanian territories (Elmusa 1998). ** Before signing the Agreement of 1994, Jordan received nothing from the Lower Jordan River but after signing the Agreement, Jordan was able to get 30 MCM/yr from the Lower Jordan. *** 305 MCM/yr includes the amounts of water, 75 MCM/yr, that returned to Jordan because of signing the Water Agreement with Israel in 1994 and also includes the amounts of water that should be provided to Jordan if Al-Wehda (the Unity) Dam has been filled. **** 160 MCM/yr represents the approximate storage capacity of 26 dams that Syria was allowed to build on the tributaries of the Yarmouk River according to Jordan-Syria Agreement of 1987.
Source: Elmusa, 1998.

Appendix

Table A1: Annual reduction per capita in resources uses due to the implementation of domestic water management options

Option type			New Resource	Water Saving Options					Reuse Option
Option		**Do nothing alternative**	**Rainwater harvesting system**	**Low Flow shower head**	**Faucet aerator**	**Leakage Prevention**	**Dual Flush Toilet**	**Dry Toilet**	**Gray-water reuse system**
Resource use after using the option	groundwater use (m3/capita/year)	9.69	0.97	5.81	3.88	6.78	7.52	5.02	3.69
	surface water (m3/capita/year)	36.97	3.70	22.18	14.79	25.88	28.84	19.22	14.05
	Desalination*	1.78							
	Energy Consumption (KWh/capita/year)	54.72	6.85	33.45	22.81	38.76	42.91	29.14	21.77
Reduction in use due to using the option	groundwater use (m3/capita/year)		8.72	3.88	5.81	2.91	2.17	4.67	6.00
	surface water (m3/capita/year)		33.27	14.79	22.18	11.09	8.13	17.75	22.92
	Desalination	1.78							
	Energy Consumption (KWh/year)		47.87	21.28	31.91	15.96	11.81	25.58	32.95

Notes: Assumptions: Family Size = 5, Energy consumption = energy used for water abstraction and transportation = 3.2KWh/m3 + energy needed for treatment (in case of chlorination = 0) + energy used for desalination (0.86Kwh/m3)+energy used to transfer surface water (0.6). Desalination water is only used for drinking, so all these options will not change consumption. Reduction in water use has been distributed equally under different options from groundwater and surface water. rainwater harvesting - using a cistern to collect 80m3 and can save 30 - 90% of the water from other sources - for calculations here 90% is used. Low flow shower head use reduces water usage by 40% than using normal shower heads (EPA 1995). Faucet aerator reduces water usage by 60% (EPA 1995). Leakage prevention can go up to 75% and it is expected that due to system improvements and education water savings can be up to 30%. Dual flush toilet = reduction of 22%. Dry toilet savings are 48%. Gray water reuse saves 62%.

Source: JWU, 2007 (from thesis) and for desal http://www.desware.net/Energy-Requirements-Desalination-Processes.aspx and for transportation
http://www.uni- hamburg.de/Wiss/FB/15/Sustainability/DesalinationFNU41_revised.pdf

Table A2: Annual benefits, costs and the present worth of net benefits for the different water management options relative to the "do-nothing" alternative

Option type	New Resource	Water Saving Options					Reuse Option
Option	Rainwater harvesting system	Low Flow shower head	Faucet aerator	Leakage Prevention	Dual Flush Toilet	Dry Toilet	Gray-water reuse system
Investment							
Initial investment (cost and installation)	800	3	9	2	40	180	140
Expected life of equipment	50	10	10		20	20	10
Investment for 10 years (I0)	160	3	9	20	20	90	140
Annual Operational Benefits							
From water savings ($)	50.39	22.40	33.60	16.80	12.36	26.90	34.71
From energy savings ($)	6.70	2.98	4.47	2.23	1.65	3.58	4.61
From using compost as a fertilizer ($)	0.00	0.00	0.00	0.00	0.00	3.60	0.00
Total annual benefits ($)	57.09	25.38	38.06	19.03	14.01	34.08	39.32
Annual Operations Cost							
Operation and Maintenance cost ($)	-0.80	-0.02	-0.05	0.00	-0.10	-0.45	-0.70
Net annual benefits ($) = Total benefits - total costs	56.29	25.36	38.02	19.03	13.91	33.63	38.62
Present Worth (PW)	274.69	192.83	284.57	126.96	87.44	169.65	158.21

Notes: Assumptions: Average cost for water for domestic use is 1.2US$/m3. Average cost of energy 0.14 US$/KWh. Annual operations and maintenance cost 5% of investment cost. Annually US $ 2 per capita will be spent on leakage prevention. PW is calculated based on equation PW = (A((1+k)^n)-1)/(k((1+k)^n))-I0. Where: PW is present worth. A represents net annual benefits (US$/year). k discount rate (taken as 5% in this case). n is number of years. I0 is investment in year zero (US$).

Source: JWU, 2007 (from thesis) and for desalinization http://www.desware.net/Energy-Requirements-Desalination-Processes.aspx and for transportation
http://www.uni- hamburg.de/Wiss/FB/15/Sustainability/DesalinationFNU41_revised.pdf