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An Economic Analysis of Water Status in Jordan

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Abstract: This study aims to describe and identify with some details the water status in Jordan, its sources and the various usages using selected econometric models. Variables for analysis will include rainfall, population, water distribution, water sources (surface, ground and treated and waste water) and also the various demands for water uses including from the municipal, industrial and agricultural sectors. Results of the analysis should give a clearer overview of the status in Jordan. It is hoped that the issues, the problems identified and discussed will also be useful to some other Middle Eastern countries or any country having similar water problems. Jordan, a small Arab country with population of about 5 million in the Middle East is one country that has very limited water supply for competing uses in agriculture and human consumption. In fact, Jordan is also poor of other natural resources such as oil. The water consumption per person in Jordan for household use is about 126.5 L day^{-1} in 2002, this figure will increase to 155 L day^{-1} by 2020, as a result of the higher living standard. The water sector in Jordan has witnessed many stages of development in spite of the many challenges it has to face particularly beginning the 1990s. Today, the problem is even more serious because of population increase, improved living standards and many other social and economic developments in the country. Water is now given a top priority by the Jordanian government due to its vital importance and in particular because it is a basic need for the survival and development of life, as well as the economic growth and development of Jordan.

Key words: Economic analysis, water resources, demand and supply, simple econometric model, forecasting

INTRODUCTION

Jordan is about 89,320 square kilometers in area and is located between latitudes of 29.0 and 33.5 degrees north and longitudes of 35.0 to 39.5 degrees east. It lies within the semi-arid climatic zone and has a typical Mediterranean short, wet winter and a long, dry summer. Annual precipitation varies with location and topography, but ranges from 50 mm in the desert to 600 mm in the northwest highlands. Jordan is said to be one of the most water scarce countries in the world (Hamdy and Lacirignola, 1999).

The climate is generally arid, with more than 90% of Jordan's total area receiving less than 200 millimeters of rainfall per year and more than 70% of the country receiving less than 100 mm of precipitation in a year. The rest of Jordan receives higher average rainfall with the Humid zone, which constitute about one percent of total area getting an average of more than 500 mm year^{-1}. The 100,000 ha representing the Jordan Valley gets between 100 to 350 mm year^{-1} (Table 1).

Table 1: Agro-climatological zones of Jordan

Zone	Average rainfall	Area ('000 ha)	Percent
Arid desert	<100	6925	77.53
Desert	100-200	1130	12.65
Marginal	200-300	389	4.36
Semi-arid	300-400	169	1.89
Semi-humid	400-500	125	1.40
Humid	>500	94	1.05
Jordan Valley	100-350	100	1.12

Source: Haddad (1991)

Water is the basis of the life and is the driving force for economic and social development and for poverty eradication. Yet, it is generally agreed that rapid population growth and urbanization, spread of more water intensive life style and agriculture is leading to over utilization of limited an in some cases diminishing fresh water supplies which will lead to growing water shortage especially in certain parts of the world where water resources are already are scarce (Baris and Karadag, 2007).

The pattern of rainfall is characterized by an uneven distribution over the various regions and fluctuates considerably, in terms of quantity and timing, from year to

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year. Jordan has three quite distinct physiographic regions with unique climates. (1) The Central Highlands consisting of the hilly to mountainous region of the country, which ranges from 600 to 1600 m in elevation, receives the most rainfall at an average of 582 mm year^{-1}. The capital city of Amman is located in this region. (2) The Rift Valley runs along the entire length of Jordan's western border and descends to 400 m below sea level at the Dead Sea. And the zone is relatively rich in subsurface water resources. Rainfall occurs from November until mid-April and decreases from 377 mm year^{-1} in the north to 87 mm year^{-1} in the south (Department of Meteorology, 1999). Finally, (3) the Desert region of east Jordan, which accounts for nearly two-thirds of the total land area of the country, is the home of the Bedouins, whose ability to prosper in this harsh environment is legendary. Rainfall average in this zone is less than 100 mm (DOS, 1984).

Water consumption per person in Jordan for household use amounted to about 126.5 liters/person/day in 2002 (MWI, 1991). It is expected that this figure will increase to 155 liters/person/day by 2020, as a result of the higher living standards (World Bank, 2001). Jordan's water consumption is one of the lowest in the world. Eastern European, for example, consume between 150-300 liters/person/day (Krinner *et al*., 1999), while people in the Unites States consume about 700 liters/person/day. (World Resources Institute, 1993). According to a United Nations study, the individual needs of water to meet all his/her daily activities in a civilized manner should not be less than 1000 m^3/person/year (Frey, 1993).

This study aims to describe and identify with some details the water status in Jordan, its sources and its various usages. Some of the factors to be analyzed will include rainfall, population, water distribution, water sources (surface, ground and treated and waste water) and the various demands for water uses, which include from the municipal, industrial and agricultural sectors. It is hoped that the issues, the problems to be identified and discussed will be useful to some other Middle Eastern countries or any country having similar water problems.

WATER STATUS IN JORDAN

The population growth has increased the demand for fresh water for drinking and farming use. Nowadays, water is considered a valuable commodity. The identification of its resources and proper exploitation has become a fundamental necessity. If surface and underground water resources are not properly managed, water crisis will be created with social, political and economical consequences (Farajzadeh *et al*., 2007).

Jordan, a small Arab country with population of about 5.3 million in the Middle East (CBJ, 1990), is one country that has very limited water supply for competing uses. In fact, Jordan is also poor of other natural resources, particularly of oil unlike many other Middle Eastern countries.

Jordan's population growth is high with an annual rate of 3.6%, which can be expected to double the population in about 22 years. About 25% of the total population and one third of the poor live in rural areas. Jordanian authorities stated that 21.3% of the Jordanian households were below the absolute poverty line of an annual per capita income of 140 JD in 1995. The poverty rate in rural areas is higher by almost 30% while about 20% of Jordanians living under the poverty line in urban areas. In 2000, the average annual income per capita was US$1,655 (CBJ, 1990).

The majority (78%) of the population is concentrated in urban areas located in the northern governorates of Amman (Capital of Jordan), Zarqa, Irbid and Balqa. These areas are situated more than 1000 m above Jordan's primary surface water resources coming from the Yarmouk and Jordan River Basins (MWI, 1999). Jordan's population has been augmented by three population influxes: (1) Arab-Israeli war of 1948 (then 450,000 Palestinian refugees); (2) Arab-Israeli war of 1967 (then 400,000 displaced Palestinians) and (3) the returnees during the 1990 Gulf Crisis (then 300,000) (El-Naser and Elias, 1993). The sudden waves of refugees and displaced persons provided no time for organized population settlement planning and they all settled in or nearby these urban areas.

RAINFALL

According to a Ministry of Water and Irrigation report, total rainfall in Jordan averages about 8330.7 million cubic meters per year. Normally, about 85 percent of this quantity is lost by evaporation to the atmosphere, with the rest flowing to the rivers and valleys (11%) and the remainder (4%) contributes to Jordan's ground water. There are several other water sources not yet completely explored and utilized, such as the historical underground water, non-renewable water and the low quality surface or ground (Ministry of Planning, 1999).

Table 2 presents the frequency of a given range of rainfall occurring over 65 years beginning 1937 to 2002. Based on the statistics available, 13 intervals of rainfall from the lowest (2001-3000 million cubic meters) to the highest (>14,001 million cubic meters) were observed and their frequencies noted. It is clear from the table that the median range (8001-9000) occurred the greatest number of times (13 of 65) during that period and this gives a likelihood of that happening at 0.2. The likelihood of a rainfall below the median level is 0.43 and similarly, likelihood of a higher than median rainfall is calculated to be 0.368.

Extrapolating the above statistics collected, in a given 100-year period, Jordan can expect to get 20 years of average yearly rainfall of between 8001-9000 million cubic meters. Similarly, the drier years will occur 43 times and the over average amount of rain will occur about 37 times in the same 100-year period. Given the high variation of rainfall and given that the number of years Jordan can expect to have lower than average rainfall, it is therefore very crucial that the issue of water be looked very critically.

Table 3 shows total rainfall over the period 1994 to 2002, the long-range average rainfall as recorded by the relevant authorities. Finally, the last row of the table shows the percentage of rainfall for the year against the average recorded. Even over this eight year period (1994-2002), the variation of total rainfall when compared to its long-term average varied significantly, from a low of 35.2% in 1998/1999 to a higher than average of 107% in 1997/1998. In fact, over this period, Jordan received lower than average rainfall more times (6 times) than it received higher than average (2 times). Jordan is therefore more likely to experience draught in any given year based on this rainfall statistics.

Table 4 below looks at rainfall statistics by month for the years 1994 to 2002. It is obvious that January is the wettest month with an average rainfall of 1940.8 mm^3 giving its seasonal index at 0.278. Based on the same statistics, December is the next wettest month at 1339.6 mm^3 with an index of 0.192. The rainfall is very much lower in most of the other months and in particular, it was almost dry in May, June, July and August.

Table 2: Average annual rainfall and frequency, 1937-2002

Rainfall intervals ($m\ m^{-3}$)	Frequency (f)	Accumulative frequency (fm)	Likelihood
(2001-3000)	1	1	0.015
(3001-4000)	2	3	0.031
(4001-5000)	3	6	0.047
(5001-6000)	8	14	0.123
(6001-7000)	6	20	0.092
(7001-8000)	8	28	0.123
(8001-9000)	13	41	0.200
(9001-10000)	8	49	0.123
(10001-11000)	9	58	0.138
(11001-12000)	4	62	0.062
(12001-13000)	1	63	0.015
(13001-14000)	1	64	0.015
(>14001)	1	65	0.015
Total	65	65	1.00

Jordan's water sources: Jordan's available water sources per capita are declining due to population growth. They are projected to decline from more than 170 m^3/capita/year (for all uses) from 1997 to only 91 m^3/capita/year by 2025, thus putting Jordan in the category of having an absolute water shortage. Current water use already exceeds the renewable water supply. The annual Water deficit has been satisfied by the unsustainable practice of overdrawing from highland aquifers resulting in lowered water tables and declining water quality.

Table 3: Total rainfall, average rainfall and percentage (%) of average rainfall, 1994-2002

	Years							
Rainfall/Years	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Total of rainfall (mm^3)	8524	6046	8746	9110	2972.8	3651.1	7375.3	7545
Long-range average ($m\ m^{-3}$)	8561.3	8519	8519	8529	8441.4	8453.7	8436	8330.7
Percentage of average	99.6	71	103	107	35.2	43.2	87.4	90.6

Source: GSD (1995), MWI (1998)

Table 4: Monthly rainfall (mm^3), average rainfall and seasonal rainfall index, 1994-2002

	Years										
Months	1994	1995	1996	1997	1998	1999	2000	2001	2002	Average	Seasonal rainfall index
Jan.	2907.1	169.6	2298	2125	1978.2	930.6	2845.7	1222.6	2990.3	1940.8	0.278
Feb.	1211.2	1516.1	445.4	2490.3	1004.9	1276.7	806.6	1174.2	919.6	1205	0.172
Mar.	1267	449.3	2202.1	1523.8	1706	378.3	893	260.8	1273.7	1106	0.158
Apr.	90.5	309.1	193	157.9	145.2	189.7	10.8	492.3	685.4	202.7	0.036
May	13.2	23.1	1.4	101	75.3	0.6	....	505.4	35.4	83.9	0.012
Jun.	2.5	....	....	....	....	....	....	....	....	0.28	0.0000
Jul.	....	....	3.8	....	....	....	0.1	....	....	0.42	0.0001
Aug.	....	....	....	....	....	....	....	....	....	....	....
Sep.	64.3	0.2	....	24.4	6.8	....	4.9	....	11.8	12.5	0.002
Oct.	536.1	14.6	367.4	514.7	12.8	32.8	536.9	100.7	268.4	264.9	0.038
Nov.	3716.6	549.2	542.7	604.2	29.7	37.5	98.9	856.3	593	780.9	0.112
Dec.	2401.9	438.6	850.2	1739.6	239.7	216.8	1671.1	1410.3	3088.5	1339.6	0.192
Total	12210.4	3469.8	6904	9280.9	5198.6	3063	6868	6022.6	9866.1	6987.03	1.000

Source: Meteorology Department (1994)

Table 5: Water sources and water uses in 2000

Source	Uses in Million Cubic Meters (MCM)				Total
	Municipal	Industrial	Irrigation	Livestock	Uses
Surface water	53.309	2.537	209.670	6.000	271.516
Jordan rift valley	38.464	2.537	121.180	0.000	162.181
Springs	14.845	0.000	38.000	0.000	52.845
Base and flood	0.000	0.000	50.490	6.000	56.490
Ground water	185.735	34.156	252.300	1.413	473.604
Renewable	176.362	29.586	204.644	1.409	412.001
Nonrenewable	9.373	4.570	47.656	0.004	61.603
Treated wastewater	0.000	0.000	72.033	0.000	72.033
Registered	0.000	0.000	66.933	0.000	66.933
Not registered	0.000	0.000	5.100	0.000	5.100
Total	239.004	36.693	534.003	7.413	817.153

Source: Ministry of Water and Irrigation

Jordan's primary water sources consist of surface and ground water. Renewable water sources are estimated at about 80 million cubic meters (MCM) per annum, including ground water (275 MCM year^{-1} distributed among 11 basins) and usable surface water (505 MCM year^{-1} distributed among 15 catchments basins). An additional 143 MCM year^{-1} of ground water is estimated to be available from fossil aquifers. Brackish aquifers are not yet fully explored, but at least 50 MCM year^{-1} is expected to be available for urban uses after desalination (JICA, 1995). Treated wastewaters are being used on an increasing scale for irrigation, primarily in the Jordan River Valley and can provide at least an additional 80 MCM year^{-1} until the year 2010 (El-Naser and Elias, 1993).

Ground water is the major source of water supply in the country. Jordan's water allocation for 2000 was approximately 817 MCM, of which more than 474 MCM was provided from ground water sources (412 MCM from renewable; 62 MCM from non-renewable) (Table 5). The total annual recharge of ground water in Jordan is approximately 275 MCM; consequently, about 138 MCM year^{-1} was over pumped from ground water resources in 1997 and more in 2000.

Surface waters contributed approximately 33 percent (272 MCM) to the 2000 water budget. Approximately 72 MCM of wastewaters were reused in 2000 (9% of the water allocated). In the last decade, treated wastewater has become an important water resource for restricted uses and has been actively incorporated into the strategic planning of water policy makers in the country.

Surface water: Jordan is divided into 15 surface water drainage basins (Fig. 1 and Table 6). Surface water discharges vary greatly between seasons and from year to year. The overall long-term average base flow for all basins is about 519 MCM year^{-1} and the flood flow is about 327 MCM year^{-1} and the total flow about 846 MCM year^{-1}. The Yarmouk River Basin is Jordan's greatest source of surface water and contributes

Table 6: Long-term average flows for jordan's surface water basins*

Surface water basin	Base flow	Flood flow	Total flow
	(MCM year^{-1})		
Yarmouk river (at Adasiya) 1500 km^2	273	147	420
Jordan river valley 775 km^2	19.3	2.4	21.7
North rift side wadis 975 km^2	36.1	13.9	50
South rift side wadis 725 km^2	24.8	8.5	33.3
Zarqa river 3725 km^2	33.5	25.7	59.2
Dead sea side wadis 1525 km^2	54	7.2	61.2
Wadi Mujib and Wala 6675 km^2	38.1	45.5	83.6
Wadi Hasa 2600 km^2	24.4	9	33.4
Wadi Araba North	15.6	2.6	18.2
Wadi Araba South 3725 km^2	0	3.2	3.2
Southern Desert 6300 km^2	0	2.2	2.2
Azraq 12200 km^2	0	26.8	26.8
Sirhan 15700 km^2	0	10	10
Hammad 18150 km^2	0	13	13
Jafer 12450 km^2	0	10	10
Total	518.8	327	845.8

*Data computed from the Ministry of Water and Irrigation Statistics in 2000

Table 7: Jordan's ground water basins*

Ground water basin	Safe yield (MCM year^{-1})	Ground water aquifers
Yarmouk Basin	40	B4, B2/A7, A2
Jordan river side wadis	15	A7, A1-6, Kurnub
Jordan valley basin	21	Alluvium
Amman-Zarqa basin	87.5	Basalt, B2/A7, A4, A2, Kurnub
Dead sea basin	57	B2/A7, A4, A2
Disi	0	Ram (non-renewable)
Wadi Araba North Basin	3.5	Alluvium, B2/A7, Kurnub, Ram
Red Sea Basin	5.5	Alluvium, Ram
Jafer Basin	9	B4, B2/A7
Azraq Basin	24	Basalt, B4, B2/A7, Kurnub
Wadi Sirhan Basin	5	B5/4, B2/A7/A1-6, Kurnub
Hammad Basin	8	B4
Total	275.5	

Table computed from Ministry of Water and Irrigation Statistics in 2000

approximately 40% of the annual total. This includes water flowing from Syrian territories within the Yarmouk Basin.

Ground water: Ground water is the major water source in Jordan; and it is the only water source in some areas of the country. These water sources may be renewable or nonrenewable and to date 12 around water basins have been identified in Jordan (Fig. 2, Table 7).

Most basins comprised of several ground water aquifer systems, as listed in Table 7. Approximately 80% of Jordan's known ground water reserves are from the three main aquifer systems namely: (1) Amman / Wadi El Sir (B2/A7); (2) Basalt (Ba); and, (3) Ram (formerly Disi). The total annual recharge to the ground water aquifers in Jordan is approximately 276 MCM.

Currently, most of the renewable ground water sources are already exploited to the maximum. In some cases extraction exceeds the safe yield level of the aquifer system. It was estimated that about 138 MCM year^{-1} was over-pumped from ground water sources in 1997. In recent years, over pumping has exceeded 200 MCM year^{-1}.

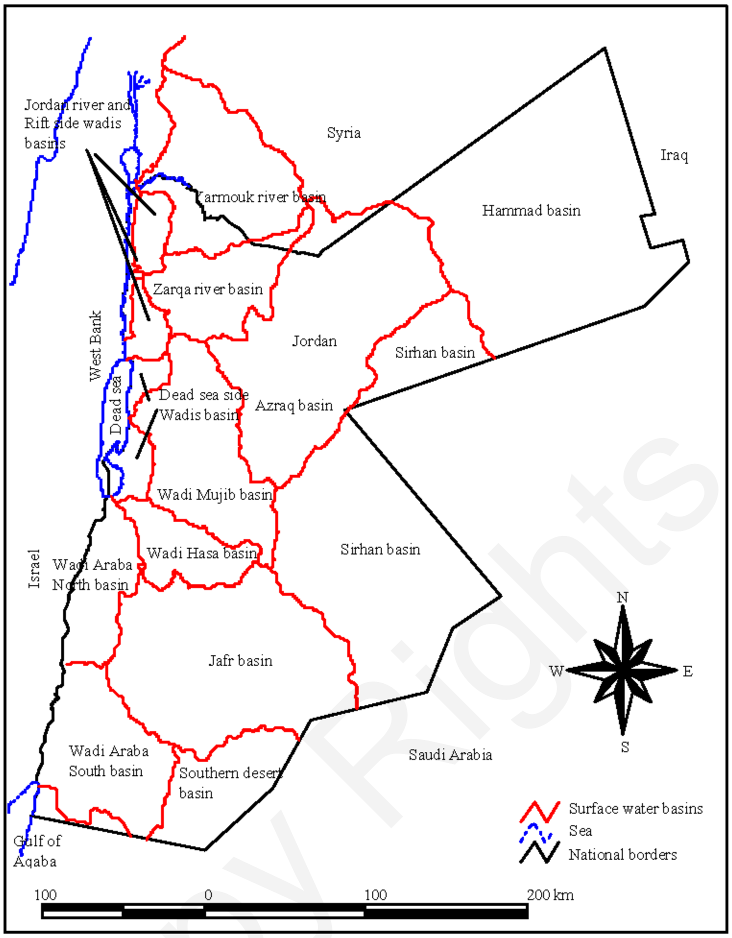

Fig. 1: Jordan’s surface water basins

Today, aquifers in seven ground water basins are being over-pumped with extractions ranging from 135 to 225% of the safe level yields (El-Naser *et al*., 1998). In four basins extraction equals the safe yield.

Wastewater: Jordan's ambitious water infrastructure development campaign during the 1980s has resulted in about 75% of the urban population and 52% of the total population currently connected to wastewater collection and treatment systems. The first wastewater collection network and treatment plant was built in Amman and was operational in 1968. Presently, there are 14 major wastewater treatment plants servicing the country. These plants processed more than 63 MCM of raw wastewater in 1997 and reached about 83 MCM in 2000. From this quantity 73 MCM is used for irrigation.

Approximately 95% of treated wastewater in the Kingdom is used for irrigation. These treated effluent from major urban areas constituted more than 10% of irrigation water in 1997. Furthermore, treated wastewater may be diverted to meet municipal water demands.

At present, the planned direct use of treated wastewater in Jordan is rather limited. A small portion is used to irrigate trees in the vicinity of the treatment plants, while the major portion is discharged to the wadis after treatment and reaches water reservoirs used for restricted irrigation. The largest wastewater treatment plant (Al-Samra) contributes approximately 75% of the wastewater in Jordan. Treated effluent from the Al-Samra plant is discharged into the Wadi Zarqa Basin system and flows to the King Talal Reservoir located about 42 km from the plant. In the reservoir, the treated wastewater is mixed with water from the Zarqa River Basin in a ratio of approximately 1:1. Water from this reservoir is used to irrigate lands within the middle and southern sections of the Jordan Valley. (MWI, 1998). It is expected

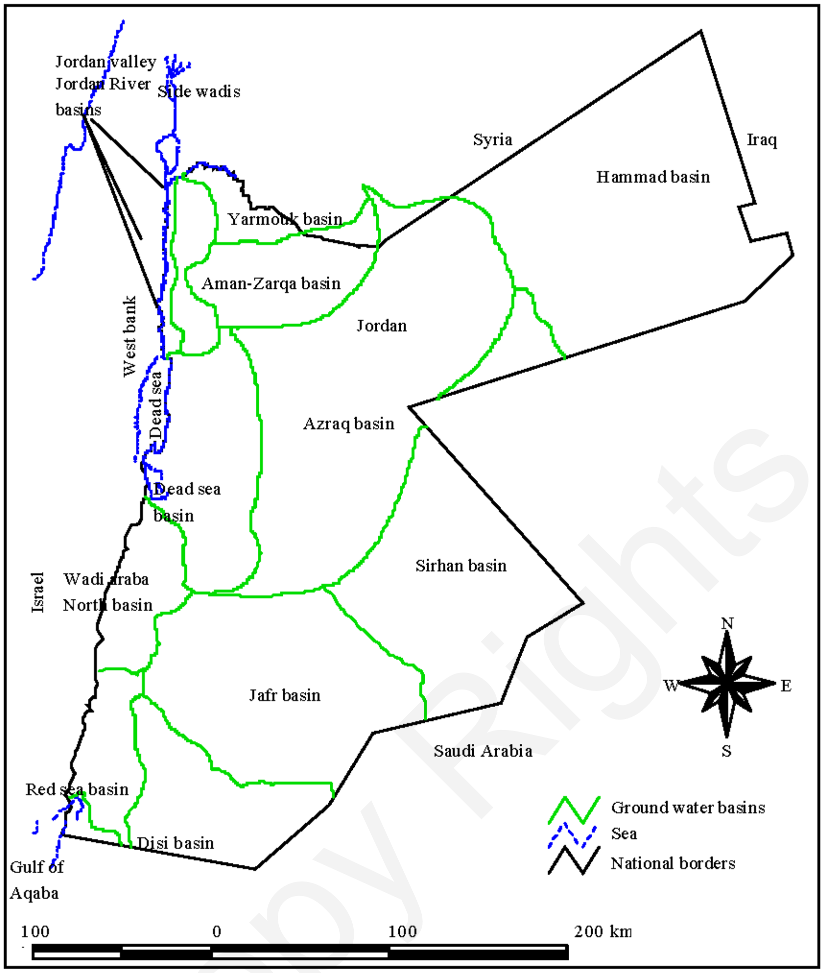

Fig. 2: Jordans's ground water basins

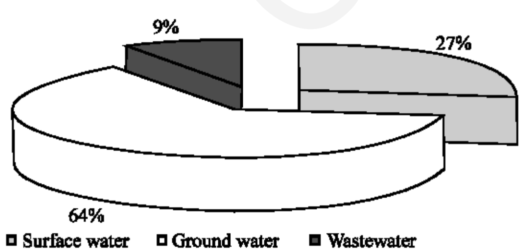

Fig. 3: Water resources in Jordan 2002

that the treated wastewater volume will reach 220 MCM year^{-1}, which will cover a large portion of the water demand for plant irrigation.

Ninety-eight percent of Jordan's total population has access to the municipal water network. As noted previously, about 75% of the urban population and 52% of the total population currently are connected to wastewater collection and treatment systems.

The total quantity of water sources in 2002 is about 810 MCM comprising of 215 MCM surface water (27%), 522 MCM ground water (renewable and non renewable) (64%) and 72 MCM of wastewater (9%) (Fig. 3).

REGIONAL WATER SOURCES

The Yarmouk River is Jordan's principal source of surface water. The Yarmouk River Basin and the Jordan River Basin also are shared with adjacent countries. For decades, Jordan has not been able to receive its full-rights share of the surface water from the Yarmouk River primarily due to the lack of adequate storage and distribution systems. Of the approximately 260 MCM year^{-1} of Yarmouk River waters flowing at

Adasiya, Jordan only approximately 124 MCM year^{-1} had been able to be diverted (El-Naser, 1997).

In recent years, Jordan has been able to increase the amount of water it receives from the Yarmouk River with the construction of the Karameh Reservoir (total storage capacity of 55 MCM). Under provisions of the Israel-Jordan Peace Treaty, Jordan will receive 10 MCM year^{-1} from desalination of saline springs (provided from Lake Tiberias until the desalination works are completed), 50 MCM year^{-1} of water from Israel (source undefined, but generally from Lake Tiberias; Jordan currently is receiving about 25-30 MCM year^{-1} of this amount) and 20 MCM year^{-1} of Jordan River water is exchanged with Israel for an equal quantity of Yarmouk River waters that are stored temporarily in Lake Tiberias. In the absence of an extensive desalination projects, regional waters will become increasingly important to Jordan's water resources management planning (El-Naser, 1998).

To date, there has been a net increase of approximately 115 MCM of surface water obtained from the Yarmouk and Jordan Rivers. Through other development projects such as the Adasiya diversion dam and two low storage dams on the Jordan River, Jordan plans to capture all surface waters from the Yarmouk River (less 25 MCM for Israel) and the Jordan River to which it is entitled to.

A second major water source is the Ram (formerly Disi) aquifer system that was developed only in the Disi/Mudawwara area of southeastern Jordan. Geohydologic studies and numerical modeling conducted by the Ministry of Water and Irrigation indicate that Jordan can realize approximately 100 MCM year^{-1} for 100 years from this aquifer system.

VARIOUS USES OF WATER

The total water consumption in Jordan increased by more than 28%, from 639 MCM in 1985 to 849 MCM in 2000, or an average of 807 MCM over the same period. However, strong yearly fluctuations can be observed due to high variation in rainfall. For example, Jordan's water budget in 2000 as shown in (Table 8) was approximately 817 MCM or about 16 percent less than the peak year of 1993. In 2000, approximately 534 MCM of water used for agriculture, 239 MCM was used for municipal purpose, 37 was used for industrial purposes and 7.4 MCM for livestock purposes, or about 65, 29, 5 and 1% of the budget, respectively.

Water for municipal uses showed the highest increase in average annual water consumption (153-216 MCM) and with 5% the highest increase in share of total average water consumption was between the period 1985-1990 and 1991-2000 as shown in (Table 9). The share of total average consumption 1985-2000 amounts to almost 23%. Water use for the industry stagnated at around 33 MCM, which compares to a 4% share of the total average water consumption during the entire time period.

Irrigation water for agriculture makes up the largest part of total average water consumption with 70% over the time period 1985-2000. The average annual water consumption between 1985-1990 and 1991-2000 has increased by a total of 34 MCM. However, the average share of irrigation water in total water use has decreased by 5% between 1985-1990 and 1991-2000. (Table 9). Water consumption for livestock production has increased slightly but constitutes only 0.9 percent of the total average water consumption between 1985 and 2000. It has to be noted that annual water uses for the agricultural sector vary considerably due to variations in climate.

The amount of water supplied for agricultural purposes in 2000 was 541 MCM. Approximately 330 MCM was supplied to the Jordan Rift Valley, including the south Ghors and Wadi Araba, to irrigate approximately 28,000 ha. There are an additional 6,000 ha in the southern part of the Jordan River Valley that have been laid out but

Table 8: Jordan's annual utilizations of water and total allocation (1985-2000)

	Municipal		Industrial		Irrigation*		Total
Year	MCM	Percent	MCM	Percent	MCM	Percent	MCM
1985	116.00	18.2	22.00	3.4	496.85	77.8	638.85
1986	134.70	21.8	23.00	3.7	456.24	73.7	618.94
1987	150.40	20.2	23.50	3.2	565.46	76.0	744.36
1988	164.70	20.2	39.22	4.8	607.91	74.4	816.60
1989	169.77	20.4	36.30	4.4	618.35	74.5	830.34
1990	175.57	20.2	36.64	4.2	652.03	75.0	869.49
1991	173.23	20.8	41.83	5.0	613.19	73.6	833.05
1992	206.64	21.7	34.78	3.7	700.47	73.7	950.73
1993	213.54	21.7	33.25	3.4	726.44	73.9	983.58
1994	215.82	23.7	24.45	2.7	655.25	72.1	908.84
1995	239.85	27.3	32.57	3.7	596.33	67.9	878.21
1996	236.36	26.8	35.76	4.1	597.87	67.8	881.77
1997	235.63	26.9	37.24	4.3	591.68	67.6	875.66
1998	236.20	25.5	38.10	4.1	622.70	67.2	926.60
1999	237.30	28.3	38.30	4.6	530.40	63.2	838.90
2000	239.10	28.1	36.70	4.3	541.40	63.7	849.70

Ministry of Water and Irrigation in 2002, Department of Statistics in 2000. *Irrigation's share in water budget included livestock because the low percentage of livestock

Table 9: Water consumption by sectors

	Average annual water consumption (MCM)		Share of total average water consumption (%)	
Sector	1985-1990	1991-2000	1985-1990	1991-2000
Municipal	153	223.0	20.2	25.1
Industrial	31	35.3	4.1	3.9
Irrigation	566	614.0	75.0	69.9
Livestock	5	9.9	0.7	1.1
Total	755	883.0	100.0	100.0

Own estimate from data in MWI (1998)

not farmed because water is not available. With the Karameh Reservoir now in place, these areas will soon start to receive water. The cropping pattern of these areas is different from other locations in the Jordan River Valley due to the relatively high salinity of water in the Karameh Reservoir and the increased salinity of the soils. The remainder of the supplied water for irrigation (approximately 262 MCM) was used to irrigate about 37,000 ha in the upland areas. Most of this water was pumped from privately owned ground water wells and surface water resources.

Major industrial water consumers in Jordan include: Arab Potash Company; Phosphate Mining Company including fertilizer industries; Jordan Petroleum Refinery; Al Hussein Thermal Power Station; cement factories; and various chemical and pharmaceutical companies. In 2000, approximately 95% (36.7 MCM) of the water used by industry was derived from ground water sources. As industrial water demand increases in the near future, more reliable sources of water must be secured to support this sector of the economy

DISCUSSION AND CONCLUSIONS

In 1995, the total renewable water source available to Jordan was estimated at 657 MCM. This quantity gradually will increase as new development programs are implemented. By 2020, Jordan will have developed an estimated 1,112 MCM of renewable water sources. In addition, Jordan will be utilizing about 140 MCM of non-renewable ground water sources for a total water supply of approximately 1,252 MCM year^{-1}. During the period 1995 through 2020, over-extraction of ground waters from renewable aquifers will be reduced to within the safe yield of the aquifers. Development of these water resources is planned over a period of 20 years. In each year of these projections, available water resources will be less than the water demand as discussed below (El-Naser, 1999) and (MWI).

Studies of projected water supply from all sources have shown that the water deficit is increasing over time. Despite a proposed investment program of US$5 billion from 1997 to 2010, Jordan will continue to face water deficit every year. According to El-Naser (1999) and sources from MWI and WB, water deficit for all uses is expected to increase from about 224 MCM in 1995 to 398 MCM by the year 2020. This is in spite of the huge investment envisaged under the investment program of the sector. These deficits will continue to be covered partially by mining ground water, according to the same source. Where additional naturally occurring fresh water is not available, then domestic and industrial demands eventually must be met by desalination of brackish and saline ground waters, or seawater (El-Naser 1999) and (MWI) and (WB).

The population of Jordan is expected to increase from approximately 4.4 million in 1996, to 5.1 million in 2000, 7.0 million in 2010 and 9.3 million in 2020. Assuming a modest increase in the per capita water use to 155 L day^{-1} during this period, then the municipal water demand is expected to grow from approximately 275 MCM in 1995, to 388 MCM in 2000, 438 MCM in 2010 and 616 MCM in 2020.

Industrial water demand will depend on future development programs. Prior to 1989, the industrial water demand was estimated to grow from 43 MCM in 1990 to 96 MCM in 2005. Current projections based on an increasing industrial contribution to overall economic development have industrial water uses increasing from 38 MCM in 1995, to 119 MCM in 2010 and 142 MCM in 2020 (El-Naser, 1995). This remains a very ambitious development program based on current economic conditions, but is absolutely critical to Jordan's economic stability. Projected irrigation water demand in Jordan is expected to grow from approximately 600 MCM in 1995 to a stable 900 MCM by the year 2005. The increase is related to the completion of on-going projects (i.e., dams in the south, Wadi Araba, development of the Yarmouk River waters and peace waters) and utilizing treated wastewaters that otherwise would be lost (El-Naser, 1999) and (MWI) and (WB).

The Water Authority Law No. 18 of 1988 states that All water resources within the boundaries of the Kingdom, whether they are surface or groundwater, river or internal seas, are considered to be state-owned property and shall not be used or transported except in compliance with law.

Three generally independent, but organizationally related, public agencies are responsible for management of Jordan's water sector. The Ministry of Water and Irrigation (MWI) was established in 1992 by a by-law issued by the Executive Branch of the Government under the Constitution. The MWI's main responsibilities include water resources policy and strategy development, water resources planning, research and development, information systems and procuring financial resources. The Water Authority of Jordan (WAJ) was established by Law 18 of 1988 and is responsible for water and sewerage services throughout Jordan and for water resources management. The Jordan Valley Authority (JVA) was established by Law 19 of 1988 and primarily is responsible for development of the Jordan Rift Valley including water resources, primarily for agriculture in the Jordan River Valley. JVA also manages all dams/reservoirs in Jordan.

Several other Jordanian agencies also have programs relating to water resources and water quality. The Ministry of Health monitors the water quality of drinking water supplies including source areas (e.g., springs) and the distribution network. The Ministry of Agriculture establishes agricultural policies and provides services primarily to farmers in the upland (non-Jordan Rift Valley) areas of the country. The Ministry of Municipal, Rural Affairs and the Environment are responsible for water quality monitoring of water resources and for protecting these resources from pollution.

The future of Jordan's water woes will depend on how well the country can manage its limited supply sources. There is definitely some potential for saving water in the agricultural sector by improving efficiency of water use and improving the irrigation management. Technologies are now available to grow crops under controlled conditions utilizing very minimal water (example hydroponics), although this approach may not be cost effective at the moment.

In addition to the more efficient use of water, wastewater recycling, which is good for conservation as well limiting potential impacts to the environment, should be promoted. Wastewater recycling generally has been expensive and probably beyond the economic capabilities of small industries. But, as a national policy and undertaken as the Kingdom's long-term program, this may prove to be a viable alternative.

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