The Jordan River Basin in Jordan:
Impacts of Support for Irrigation and Rural Development

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MREA Mission Regionale Eau-Agriculture

Comprehensive Assessment of water management in agriculture

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Impacts of Support for Irrigation and Rural Development

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Locations, terms, and a caveat

The Jordan River Basin in Jordan consists of (from east to west) the plateau and mountains of the Highlands, which drop sharply into the Valley. Tributaries of the Jordan River flow out of the Highlands to the Valley. A major tributary of the Jordan River is the Yarmouk River flowing between Syria and Jordan. The Jordan River Basin in Jordan contains the Jordanian part of the Yarmouk River's surface water basin, the north and south side wadis (river basins) and the Jordanian part of the Amman-Zarqa river basin. The Basin is bounded in the north and in the east by Syria, in the west by the Jordan River, and in the south by the Dead Sea. Most water used in the Valley is surface water and most water used in the Highlands is groundwater.

The Jordan Valley Authority and the Department of Statistics both divide Jordan Valley into three sections: north, middle, and south. These agencies use slightly different boundaries. I use the Department of Statistics boundaries. In this paper the Highlands include the governorates of Amman, Zarqa, Balqa, Jarash, and Ajlun, and also a small part of Mafraq. The Mafraq governorate is mostly not over the Amman-Zarqa river basin but is included in calculations since approximately sixty-five percent of the irrigated land in Mafraq is in the Basin.

One Jordanian Dinar (JD) is 1.4 U.S. Dollars (USD). Ten dunums (du) are 1 hectare (ha) or 2.471 acres. MCM means million cubic meters. Wadi is Arabic for river or riverbed.

Lack of figures for costs is the most important weakness of this paper.

Overview

Irrigation in the Jordan River Basin in Jordan has contributed to many governmental goals. Jordan's agricultural development succeeded in part because water was relatively plentiful. As water has become scarcer and as the Jordanian economy has developed, national water allocation priorities have shifted slowly. The social returns on water use in different economic sectors are important, though difficult to measure. As fresh water is reallocated for drinking water or water for business use (and as new water sources are developed), water costs in agriculture may become more expensive (due to pumping costs, treatment costs or competition). Thus farmers may oppose water reallocation. One major management lesson to be drawn from the Jordan River Basin in Jordan is that success of farming support programs at one time may contribute to difficulties in water allocation later.

Since the 1950s, the government policy of supporting irrigated farming and rural development helped Jordan economically and socially. Development included land reform and provision of community services. Large projects in the Valley include dams, canals and irrigation projects. Subsidies of electricity and diesel used to run pumps supported extensive private well use in the Highlands. Bedouin agriculture and settlement were also supported. Support for irrigated farming now includes the use of import tariffs or quotas during certain periods to protect farmers from competition with imported crops. One important tariff is on bananas. Banana farmers benefit from a high tariff even though bananas require a large amount of high-quality water.

Investments and subsidies were designed to (in no particular order) (1) increase the welfare of farmers, (2) increase food production, (3) increase the value of farming to the national economy, (4) settle the significant numbers of Palestinians who moved to the Jordan Valley after 1948, (5) address the risk of further Israeli expansion by populating the land with Jordanians, and (6) reduce migration to cities. The positive impacts of investments have been large.

These positive impacts could perhaps have been greater if the government had been more active in crop selection and the marketing of produce, and if there had been a better agricultural extension system to educate farmers. In the Valley, forming water users associations now is difficult because development did not foster local control of water allocation. In the Highlands, reducing groundwater use now is difficult due to the historic lack of enforcement of well abstraction limits.

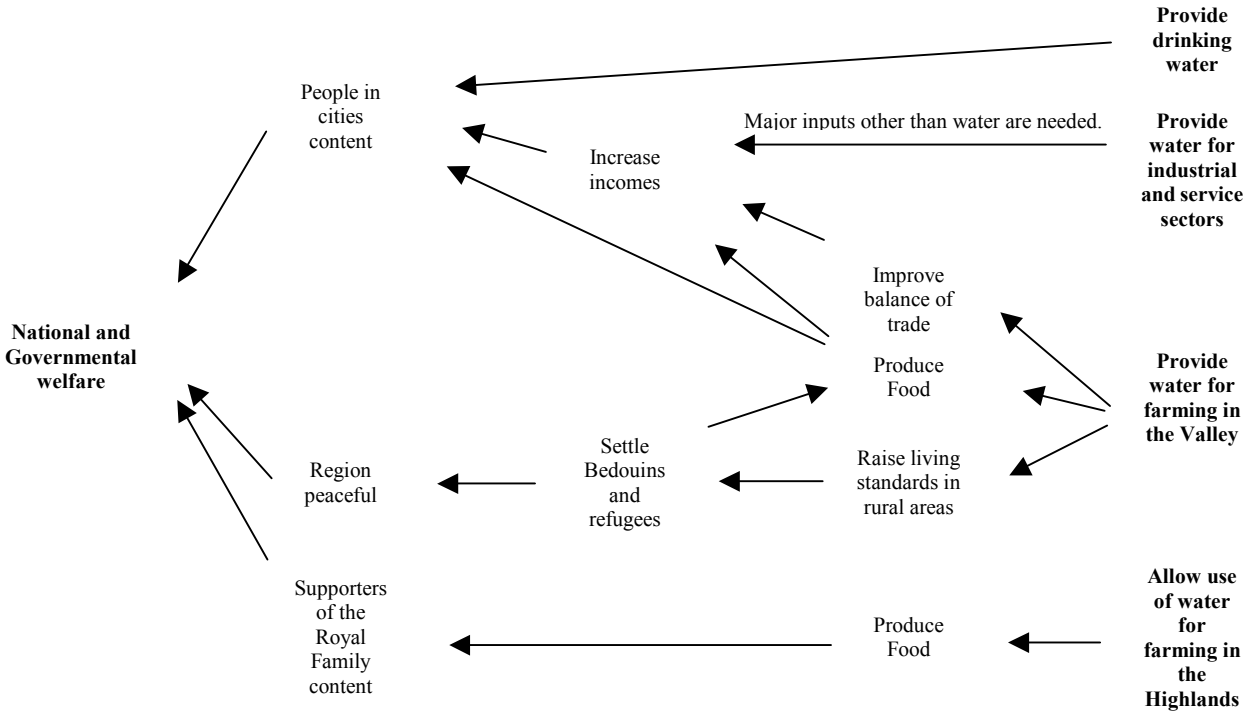
The costs of supporting irrigation include forgone economic growth, the cost of developing other drinking water supplies, and harm to aquifers. The costs of supporting irrigation are mounting. Also, support for irrigation has strengthened politically powerful groups who want irrigation support to continue.

Between 1982 and 1998, Jordan experienced (1) a drop in vegetable prices due to oversupply, (2) a drought, (3) a large immigration following the Gulf War in 1990-1991, (4) another drought, and (5) a water quality scare in Amman. The oversupply issues and the droughts contributed to a lack of growth in agricultural revenue. The need for economic growth and the development of the industrial and service sectors (which are also water users) made

water use outside of agriculture a high social priority. The increase in urban population and the water quality scare made affordable municipal drinking water a high social priority. Water allocation in the future will be challenging.

This paper briefly presents two hypothetical future scenarios: the provision of a greater portion treated wastewater for irrigation in the Valley, and nearly eliminating irrigation with groundwater in the Highlands. The greater use of treated city wastewater in the Valley would free up freshwater to be pumped up to the cities in the Highlands. In contrast, reduction in Highlands' irrigation would not provide a sustainable source of freshwater since non-irrigation use of groundwater currently exceeds the aquifers' recharge capacity. Lower water quality in the Valley would reduce the cultivation of bananas, citrus, string beans, and other salt-intolerant crops. More sustainable water use in the Highlands may involve reducing irrigated farming of olives and other crops such as tomatoes and apples.

Schematic flow of some benefits from water allocation.
For water used in the industrial and service sectors to increase incomes, investments are needed. These investments, including factories, have grown over time. Now that investments have been made, providing water to industry increases incomes more than providing that water to farming does. Also, as the urban population of Jordan has increased, the welfare of people in cities has become quite important. Most water used in the Valley is surface water and most water used in the Highlands is groundwater.



How Jordan supported irrigation and rural development

The policy of supporting irrigation and rural development in the Basin

The population of Jordan was less than half a million people until the late 1940s. In the Jordan Valley approximately four hundred families owned large plots of land where they grew mostly rainfed field crops. There was limited irrigation near small tributaries of the Jordan River but no large dams or canals. Farmers did not draw water directly from the Jordan River on a large scale. These families were mostly Bedouin and some were connected to Jordan's ruling family.[1]

The government of Jordan (and foreign donors led by the United States and Britain) encouraged developing the Valley in a planned way.[2, 3] Investments and subsidies were designed to (in no particular order) (1) increase the welfare of farmers, (2) increase food production, (3) increase the value of farming to the national economy, (4) settle the significant numbers of Palestinians who moved to the Jordan Valley after 1948, (5) address the risk of further Israeli expansion by populating the land with Jordanians, and (6) reduce migration to cities.

In 1951, Jordan announced its intention to divert water from the Yarmouk River, a tributary of the Jordan River, to irrigate the Valley to support agriculture and the population.[4] The government planned irrigation canals on both the West Bank and the East Bank. On the East Bank the first section of the King Abdullah Canal was begun in 1957 with financial assistance from the United States.[5] The canal on the West Bank was never built because the West Bank was occupied by Israel following the 1967 War. The King Abdullah Canal would be the foundation of the Valley irrigation and development scheme. Details on the irrigation scheme and the effects of the 1967 War are presented later.

The overall governmental support for irrigation and rural development took many forms in the Valley. The Jordan Valley Authority (created as the Jordan Valley Commission in 1973 by King Hussein) had the mandate for all development and service provision in the Valley. Projects included schools, hospitals, domestic water, electricity, telephone service, roads, and land reforms, in addition to irrigation projects. Public construction for irrigation included dams, pumps, pipes and concrete-lined canals. Housing and wells for irrigation have been private.[6]

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1 DuCros, Marine and Benjamin Vallin. 2001. *Agricultural diagnosis on the Northern half of the Jordan Valley.* INAPG-MREA.

2 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC.

3 Invoking the value of stability, the United States Senate Foreign Relations Committee said: "The United States has an interest in doing what it can to help solve the refugee problem because of its direct relationship to the economic and political stability of the Middle East. The United States does not wish to see the internal order and independence of the countries of the Near East threatened by economic chaos, communist penetration, or military hostilities." Shadid, Mohammed K. 1981. *The United States and the Palestinians.* London, Croom Helm. Page 55.

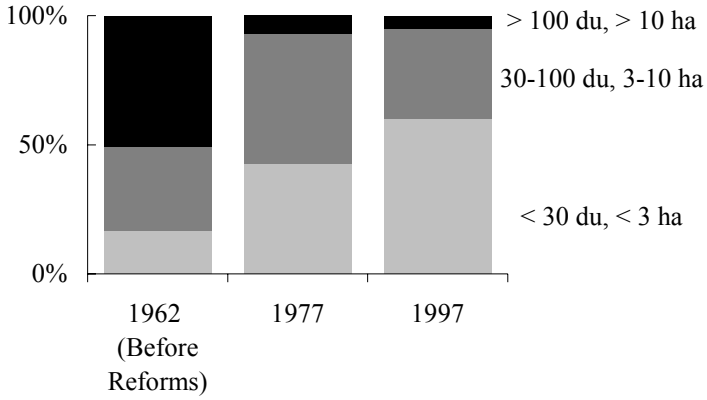
4 Farinelli, Xavier. 1997. Freshwater conflicts in the Jordan River Basin. Green Cross International. Online at <http://www.gci.ch/GreenCrossPrograms/waterres/gcwater/jordan.html>

5 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.

6 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.

Land reforms occurred as the irrigation projects were built. The land reforms were intended to build a class of landowners with small and medium sized farms and to reduce the number of landless people. In each location, land was appropriated, the irrigation system was built, and licenses to farm the land were distributed by the government. Figure 1 shows how land reform increased the percentage of small land holdings. Unfortunately, because multiple holdings may belong to members of one extended family and people may own multiple holdings, figure 1 is not ideal to examine the distribution of land across landowners. Most holdings in the valley now are in the five to fifty dunum range (one-half to five hectares). Land reforms increased the percent of poor farmers who held productive-sized farms.[7]

Figure 1. Sizes of holdings before and after the land reforms in the Jordan Valley.



Sources: Sharif Elmusa, 1994. Gert Soer, 1998 (GTZ).

Another aspect of land reform allowed Palestinian refugees to buy land licenses. Although the United Nations subsidized purchases, few Palestinian refugees bought land licenses. The refugees did not want to settle since they hoped to return home.[8] To some Palestinians, settlement seemed like giving up their claims to land now controlled by Israel.

Historically Bedouins had herded animals in the Highlands. The first government attempts to settle Bedouins were in the 1960s.[9] To encourage settlement, the government subsidized irrigation with groundwater and set up schools. The first subsidized farms were small farms of 25 dunums (2.5 hectares). The Zarqa governorate was settled first, followed by Mafraq.[10] The first farmers grew mostly fodder and olives.

7 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.
8 DuCros, Marine and Benjamin Vallin. 2001. *Agricultural diagnosis on the Northern half of the Jordan Valley.* INAPG-MREA.
9 Jabarin, Amer. 2001. "Curtailment of Groundwater Use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: A Socio-Economic Analysis." *Water Resource Policy Support, Groundwater Management Component.* For USAID, ARD.
10 Jabarin, Amer. 2001. "Curtailment of Groundwater use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: A Socio-Economic Analysis." *Water Resource Policy Support, Groundwater Management Component.* For USAID, ARD.

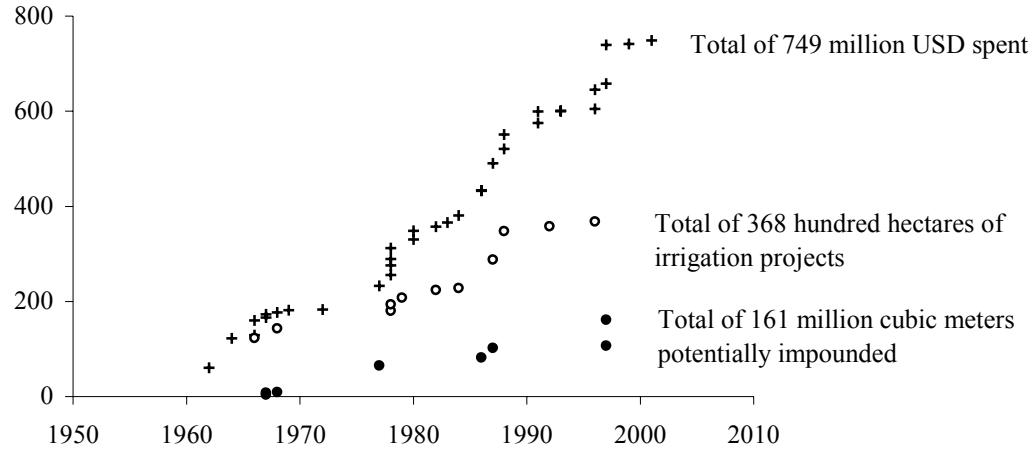
Support for irrigated farming has included import tariffs and subsidies in the Valley and the Highlands

The tariffs and subsidies related to farming helped Jordan's agricultural sector grow, encouraged food production in Jordan, and protected some farmers' profit margins. Tariffs and subsidies are also part of politics in Jordan. The most important supports historically have been the subsidized water prices in the Valley, the subsidized electricity and diesel used to run well pumps in the Highlands, subsidies for some field crops, and an import tariff on bananas.[11] Stone fruits such as peaches are also subsidized, but to a lesser degree than bananas. The government has also been tolerant of Highland pumping, consistent with interpreting groundwater as a private good. The end of subsidies on power for pumping in the Highlands is now proposed.[12, 13]

Support for irrigation included investments of more than 535 million Dinars in the Valley.

Figure 2 summarizes government projects for water storage and irrigation in the Valley. In the Valley now there is a water storage capacity of 161 million cubic meters, less volume lost to sedimentation. The irrigation projects[14] can potentially irrigate 304 thousand dunums but fewer are irrigated at this time.

Figure 2. Progress in the Jordan Valley



Sources: The irrigated areas from communications with Nayif Sider (JVA) and from Ministry of Water and Irrigation, 1993: Study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan. The dam live storage volumes are from communications with Raja Nasser (JVA).

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11 Schiffler, Manuel. 1998. *The Economics of Groundwater Management in Arid Countries. Theory, International Experience and a Case Study of Jordan*. German Development Institute Book Series No. 11. London.

12 Siegfried Holtkemper *et at.* 2003. Draft of *National Water Master Plan Volume VIII Water Sector Economics*. Water Sector Planning Support. GTZ, MWI.

13 Schiffler, Manuel. 1998. *The Economics of Groundwater Management in Arid Countries. Theory, International Experience and a Case Study of Jordan.* German Development Institute Book Series No. 11. London.

14 An irrigation project may include the water distribution system, the linkage to the main canal, drainage, roads, and fences.

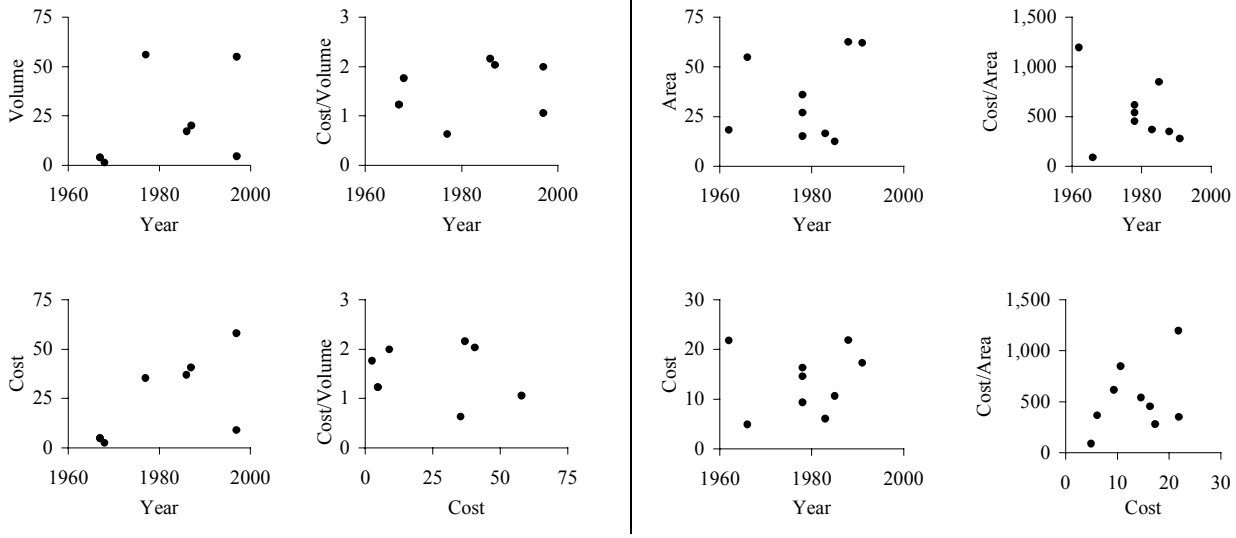
Support for irrigation included investments of more than 535 million Dinars in the Valley.

There is no clear trend in the sizes and costs of investments over time. Figure 3 shows earlier projects were not cheaper or bigger. The larger investments do not seem to have lower per unit costs.

Figure 3. Costs, unit costs, and completion dates for projects in the Valley

Dams: Volumes are in MCM; costs are in year 2000 Dinars.

Irrigation Projects: Areas are in thousand dunums; costs are in year 2000 Dinars.



Sources: The irrigated areas from communications with Nayif Sider (JVA) and from Ministry of Water and Irrigation, 1993: Study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan. The dam live storage volumes are from communications with Raja Nasser (JVA).

Table 1 shows the costs of the infrastructure supporting irrigation in the Valley. Note that the irrigation projects cost more than the dams or canals. I have not factored in depreciation or operations and maintenance costs. These costs should not be ignored but were unavailable.

Table 1. Costs of public investments for irrigation in the Jordan Valley, constant year 2000 million Dinars
Excluding operations and maintenance and depreciation, and also excluding the estimated investments for Amman's drinking water. "Other investments" includes such things as roads and drainage systems. Repairs and the conversion of some irrigation projects to pressure are included.

	Million JD year 2000	Million USD year 2000
Canals	72.0	101
Dams	180	252
Irrigation Projects	219	306
Total including other investments	535	749
Cost of Dams and Canals above Deir Allah	94.0	132
The portion of that cost for Amman's drinking water (assumed to be one third)	31.3	43.9
Total from above, less costs for Amman's drinking water	504	705

Sources: See appendix for details.

Private wells and the public investments mentioned above bring water to the farms. There have been additional private investments in on-farm irrigation systems and holding pools. Holding pools are necessary for a regular irrigation water supply, since the Jordan Valley Authority does not deliver water with perfect reliability. Other private investments include fences, orchards, tractors, greenhouses, operations and maintenance.

In the Highlands investments have been mostly private

There is very little surface water flow in the Highlands. Although most of the wells for irrigation in the Highland are private, the Government of Jordan dug a few of the early wells. These government wells provided subsidized water to the Bedouin, who the government was encouraging to settle and adopt agriculture. Table 2 shows the numbers of wells in the Amman-Zarqa basin and in the Yarmouk Basin.

Table 2. Highlands' wells for irrigation
The small number of government wells were dug when the Water Authority of Jordan and the Ministry of Agriculture were first attempting to settle Bedouins by subsidizing irrigation.

	Number of private wells	Number of government wells
Amman-Zarqa Basin	629	11
Yarmouk Basin	138	8
Subtotals	767	19
Total wells	786	

Source: Communications with Suzan Taha (MWI).

Comparison of Valley and Highlands

Table 3 compares the Valley and the Highlands. The Valley is estimated to have received significantly more investment per unit area than the Highlands. Also, the Valley on average produces more revenue per unit area. Cost figures needed for computations of profit

were unavailable. The investments listed here are *public* for the Valley and *private* for the Highlands.

Table 3. Comparison of the Valley and the Highlands
All Dinars are year 2000 Dinars. Note there are two listed Highland areas since some, but not all, of the areas planted with grapes and olives are irrigated. The large Highland areas assume all grapes and olives are irrigated and the small areas assume none were. Investment in the Valley is an underestimate since operations and maintenance costs were not included.

	Irrigated Area ha	Investment Million JD	Investment per unit area JD/du	Investment per unit area USD/ha
Valley	25498	535	2010	28,100
Highlands	40,392 to 98,478	64.3	65.2 to 159	913 to 2,230

	2002 Value of production Million JD	Revenue per unit area JD/du	Revenue per unit area USD/ha
Valley	107.8	422	5,910
Highlands	127.7	129 to 316	1,810 to 4,420

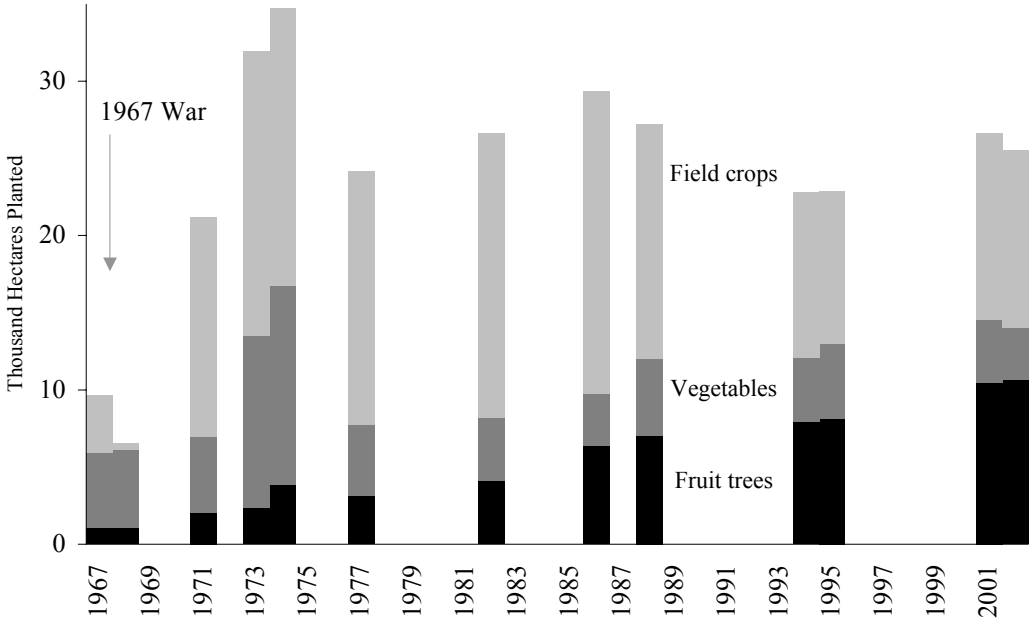
Source: Data from the *Agricultural Statistics 2002* (DOS), an appendix to "Curtailment of Groundwater Use..." by James Fitch, 2001, and calculations.

Positive Impacts of supporting irrigation

The positive impacts of supporting irrigation included the production of valuable food crops

A large social benefit of support for irrigation was increased food security. Figure 4 shows how extensive agriculture had become by 1967 (almost 10,000 ha), the disruption in labor-intensive vegetable farming due to the War in June 1967, and the increase in agriculture after 1968. Increased production had both local value and export value and supported both Jordan's growing population and economic development. Since 1968, fruit trees take up more area and vegetables take up less.

Figure 4. Cropping patterns in the Jordan Valley
Blank spaces indicate missing data. The agricultural statistics books do not distinguish between irrigated land and rainfed land. In recent years, almost all crops grown in the Valley are irrigated. Vegetables are planted in the summer and the winter and the areas planted in each season may be different. The larger of the two planted areas are used for this figure. The bar for 1967 represents farming before the War since the War was in June. Figures for 1967 only include the East Bank. Note the low area planted with vegetables in 1968. Fruit trees and field crops needed less management and so did better as farmers left the Valley during the conflict.



Sources: Volumes of *Agricultural Statistics* for all years listed (DOS).

The switch from vegetables to fruit trees is one of the important stories of this study. The switch has been one response to the volatility of vegetable prices in Jordan. Volatile vegetable prices are in part due to the poor system for marketing produce nationally and regionally. More on marketing and price changes is presented later. Changes in Valley cropping patterns have been slow. Not all farmers could switch to fruit trees since orchards have large initial costs and one needs a license to grow fruit trees in the Valley.

Compared to vegetables, fruit trees require less labor, less management, and fewer day-to-day investments, despite larger initial investments. Rich and politically powerful absentee farmers prefer to grow fruit trees because they are more convenient and profitable than vegetables. Due to their political strength, fruit producers get priority in the distribution of water. (Note that for a given amount of fruit trees, it may be efficient to give fruit trees priority since trees killed by droughts are more expensive to replace than other crops are.) It is important that the high value fruit trees such as apples, peaches, and bananas require relatively large amounts of high quality water per ton of fruit produced.[15] The Jordan Valley Authority delivers water that would reach a daily total water depth of 2 mm for vegetables, 4 mm for fruit trees, and 8 mm for bananas over each farm.[16] Thus the politically powerful farmers use large amounts of high quality water.

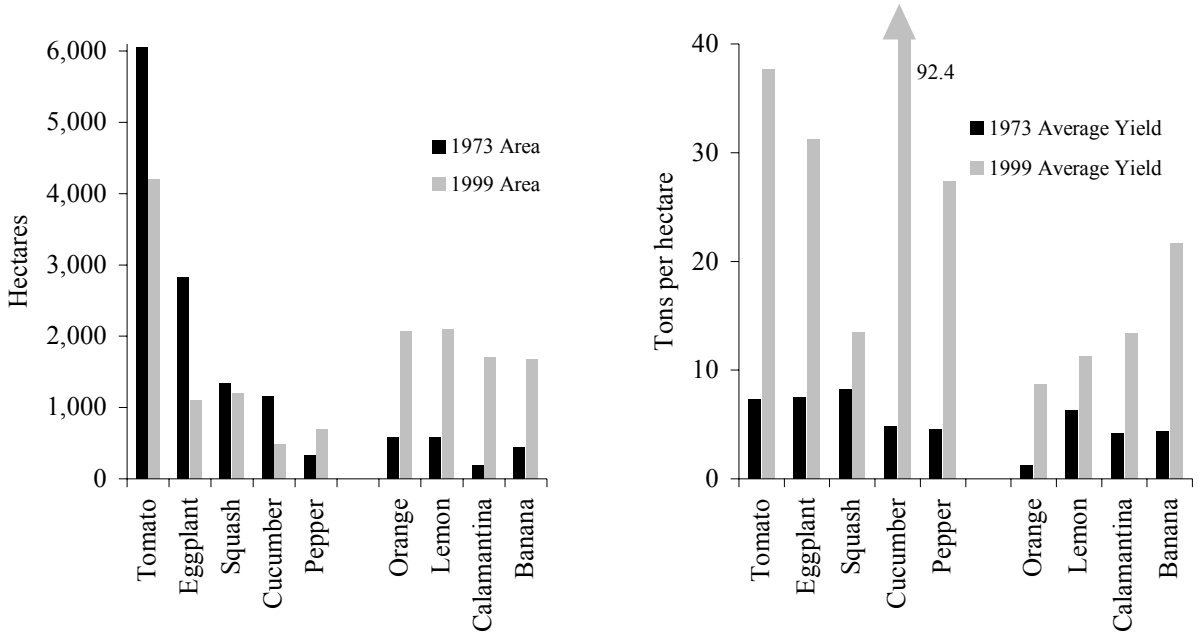
Economically, fruit trees may be a good use of water. As water quality and availability falls, however, fruit tree farmers may try to use political pressure and private wells to maintain ongoing access to high quality water. It may not have been clear that establishing a class of fruit tree farmers might make future water allocation difficult.

The left panel of figure 5 shows the areas planted for major fruits and vegetables in 1973 and 1999. The area planted with all the major vegetables except peppers decreased and the area planted with fruit trees increased. The right panel of figure 5 shows how farming became more productive between 1973 and 1999. This productivity growth is due in part to the increased use of drip irrigation, plastic mulch, fertilizer, and plastic greenhouses or tunnels to keep plants warm in the winter.[17] The replacement of bulls with tractors and land laws that stopped farm fragmentation due to division of land before inheritance also increased productivity.[18] The total tons produced of all crops listed here increased between 1973 and 1999.

15 Olive trees and vegetables such as tomatoes and eggplant do not require high quality water.
16 This may change in the future. Since the amount of water a farmer receives depends on the crop rather than the area, there is little incentive to switch to a less water-demanding crop, all else equal.
17 Hagan, Ross and Suzan Taha. 1998. "Irrigated Agriculture in Jordan: Background paper." Water Quality Improvement and Conservation Project. JVA.
18 FAO, DOS 2002. *Analysis of the structure of Agriculture in Jordan: using data from 1997 Agricultural Census.* Page 100.

The positive impacts of supporting irrigation included the production of valuable food crops

Figure 5. Comparisons of 1973 and 1999 in the Valley
Cropped areas, 1973 and 1999, in the Jordan Valley Average yields, 1973 and 1999, in the Jordan Valley.



Source: *Jordan Rift Valley Improvement Project Phase A.* Section 5 (MWI, JVA).

Governmental support for irrigation and rural development increased revenues from farming. Figure 6 shows different estimated of the values of production in the Valley. The vastly different estimates are probably due to using different levels of aggregated prices.[19]

Over time the value of production tended to increase, except following the 1967 War and a period of overproduction and low prices after 1982. The King Abdullah Canal 18 Kilometer Extension, the North East Ghor Irrigation Project, and the Zarqa Triangle Irrigation Project increased irrigated area by more than 15 percent by 1979.[20] This coincides with the increase in revenue after 1967. Additional revenue growth came from increases in productivity. The growth in revenue from vegetables was due more to improvements in productivity and the growth in revenue from fruits was due more to the increase in area farmed.[21]

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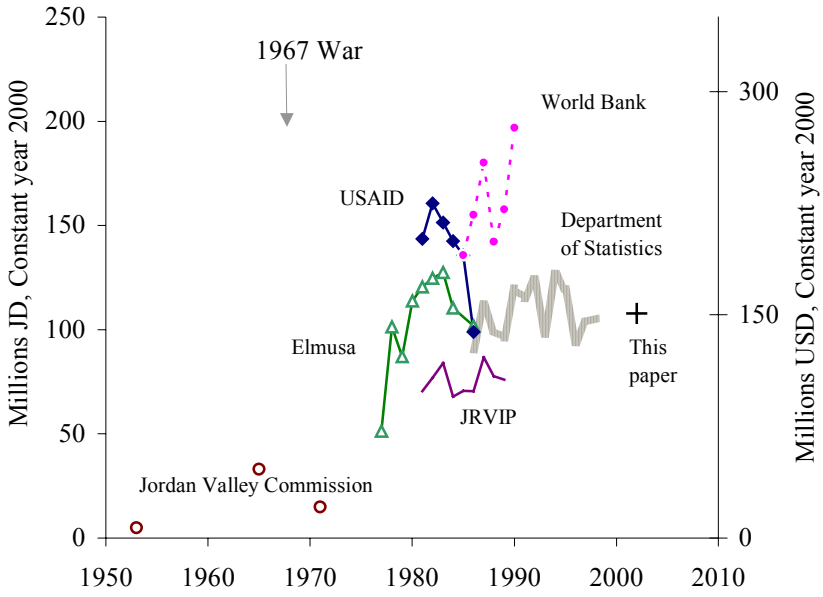
19 For example, I used seasonal prices for squash but one annual price for apricots, the only price available to me.
20 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC. Page 129.
21 Elmusa writes,

> Of total vegetable output growth between 1977 and 1986, we estimate that 80 percent was brought about by drip irrigation and plasticulture, and 20 percent by the increase in the cropped area. The estimate is based on the assumption that without drip irrigation and plasticulture, yields would have been constant and growth proportion to the additional cropped area.
> By the same token, 63 percent of the increase in fruit output was from the expansion of the cropped area and 27 percent from drip irrigation. These estimates should be taken only as rough indications of trends, because output still fluctuated and the selection of years is necessarily arbitrary. Still, the indisputable conclusion is that drip irrigation and plasticulture brought about a remarkable increase in vegetable output and, and a lesser but still significant increase in that of fruits. [Page 129]

The conveyance efficiency of canals in the Jordan Valley increased over time. Since the 1990s, water in the Jordan Valley has been delivered to farms in pressurized pipes as an incentive for farmers to use drip irrigation. Drip irrigation is now standard for banana and vegetable farming.

Figure 6. Valley's value of production
Constant year 2000 million Dinars. The Jordan Valley Commission, Department of Statistics, and JRVIP figures are published by the Jordanian government.

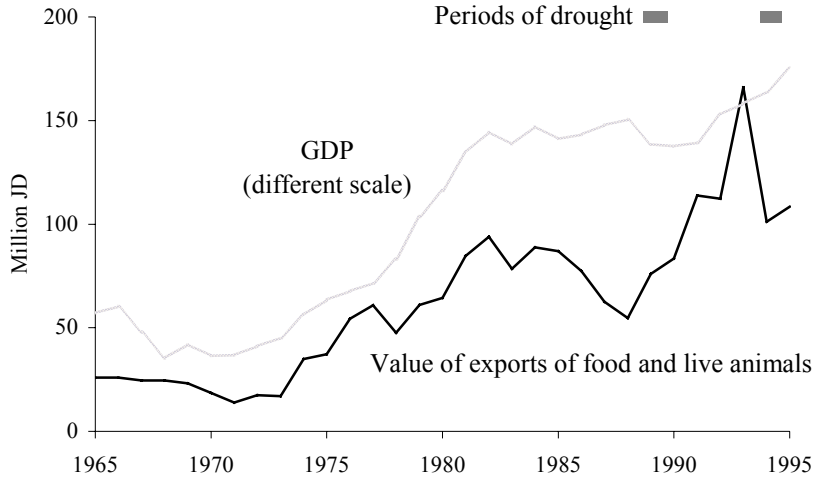


Sources: Different data sources are different lines. Jordan Valley Commission, Elmusa = Sharif Elmusa, 1993, USAID = Steven Shepley, *et at.* 1987, JRVIP = *Jordan Rift Valley Improvement Project Phase A.* (MWI, JVA), World Bank = World Bank 1997. This paper = calculated from *Agricultural Statistics 2002* (DOS).

The increased value of produce exports is an impact of the support for irrigation in Jordan. Figure 7 shows the value of exports peaks in the early 1980s, drops, and then peaks again in the early 1990s. Gross Domestic Product is included for comparison. The Valley's exports were a large portion of total export value for agricultural goods, in part because regional prices were higher in the winter when only the Jordan Valley was producing on a large scale. Eventually, Turkey, Cyprus, and Greece began to compete with Jordan.[22, 23]

22 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC.
23 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986.* Tech International, Inc. for USAID.

Figure 7. Value of exports of food and live animals
Constant year 2000 million Dinars. A time series for produce alone was unavailable.



Source: Central Bank of Jordan, 1996. Communications with Omar Hakouz (DOS) for the GDP figures.

The positive impacts of supporting irrigation included increases in the standard of living in the Basin

The following are good sources for social changes reflecting the impacts of support for irrigation and rural development in Jordan. Full citations are in the references.

1. Sharif Elmusa: *A Harvest of Technology: the super-green revolution in the Jordan Valley,*
2. Ministry of Water and Irrigation: *The Jordan Rift Valley Improvement Project, Phase A*, Sections 5, 7, 8, and especially Section 9,
3. Munther Haddadin: "The Socio-Economic Role of the King Talal Dam in the Kingdom of Jordan,"
4. Jordan Valley Commission: *Rehabilitation and Development Plan of Jordan Valley (East Bank) (1973-1975),*
5. Ministry of Water and Irrigation: "Strategic Issues Facing the Jordan Valley Authority,"
6. Marine DuCros and Benjamin Vallin: *Agricultural diagnosis on the Northern half of the Jordan Valley*, and
7. Rami Khouri: *The Jordan Valley: Life and Society Below Sea Level.*

Reports of positive outcomes in the Basin relate mostly to the Valley because development occurred there earlier. Public projects have directly increased positive social outcomes in the Valley. One indication of development is greater employment. Employment in agriculture rose strongly since 1950. Building the dams, canals, and irrigation projects directly

provided jobs in the Valley.[24] Over time, demand for farm labor increased mostly because of the increase in the area under cultivation and not from the spread of plasticulture which mostly created field manager jobs.[25] As the national economy grows, the agricultural sector contributes a smaller percentage to national employment each year.

Incomes in the Valley have been higher than rural incomes in places that did not receive public investments in irrigation.[26] It is a sign of good progress that national per capita income and Valley per capita income were nearly the same by 1987.[27] Irrigation from wells led to increased profits from farming relatively far from the Jordan's tributaries and from the canal system.

In the Valley from the 1970s on, greater education of women led to higher career goals, a higher age of marriage, and higher bride prices. There has also been more marriage outside of one's immediate social group and greater use of contraceptives. Infant mortality and general morbidity have decreased. Life expectancies rose.[28] In the Highlands, permanent residence and school enrollment both have increased significantly.[29]

National positive impacts of rural development increased as agency roles were redefined. In 1988, the Jordan Valley Authority became part of the Ministry of Water and Irrigation. Centralized control of Jordan's water helped simplify national water allocation issues such as responses to droughts.[30]

The positive impacts of supporting irrigation included reducing migration to Amman and other urban areas

Rural development successfully caused a net migration of people to the Valley.[31] Immigration of people led to demand for goods and services that led to further economic growth.[32] In the middle section of the Valley where the largest dam, the King Talal Dam, was completed in 1977, population growth rates were higher than in other parts of the Valley.[33]

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24 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.
25 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC.
26 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986*. Tech International, Inc. for USAID.
27 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.
28 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986.* Tech International, Inc. for USAID.
29 Jabarin, Amer. 2001. "Curtailment of Groundwater Use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: A Socio-Economic Analysis." Water Resource Policy Support, Groundwater Management Component. For USAID, ARD.
30 Charkasi, Dana. May 31, 1999. "Government plans to stop water supply to Jordan Valley vegetable farms." *Jordan Times*.
31 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986.* Tech International, Inc. for USAID.
32 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986.* Tech International, Inc. for USAID.
33 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.

Movement to the Valley is good since high-density urban poverty may contribute to national and regional instability. The values of migrations to or from the Valley are hard to quantify.

Support for irrigated agriculture and rural development helped Jordan cope with immigration and a Civil War

A basic management lesson from the Basin is that the capacity to deal with political changes is valuable. Having supported irrigation and rural development in the 1950s, Jordan was able to accept refugee immigration in 1967. During the 1967 War, many people fled the valley. Following the War, Israel controlled the West Bank, which had been Jordanian farmland. Palestinians from the West Bank entered Jordan and some of these refugees moved to rural areas.

Jordan's Civil War began. The Palestine Liberation Organization took advantage of the lack of governmental controls in Jordan. In 1970, there were Fedayeen attacks in the occupied West Bank and other terrorist actions, including threats against King Hussein and an airplane hijacking. King Hussein used the army, largely made up of Bedouins, to force the Palestinian armed groups to leave Jordan. Support for the King during this Civil War was strong in part because of prior governmental support for Bedouins in the Highlands and for the old land-holding Bedouin farming families in the Valley.

Some would argue more progressive land reforms (as part of development) would have been better.[34] Large landowners kept some control of their land by dividing ownership across their families. Families thwarted the complete breakup of lands especially in the south of the Jordan Valley. It is interesting to consider how the government's success in the Civil War may have been due in part to the support of old land-holding families.

During the 1990-1991 Gulf War, many Jordanian Palestinians, who were living in Kuwait and other places since leaving Palestine, moved to Jordan.[35] Jordan's post-1948 and post-1967 experiences in settling the Palestinians helped new immigrants assimilate after 1990. The effects of the 1990-1991 Gulf War, including the economic growth following the immigration, will be covered in more detail later.

Positive impacts could have been greater if managed differently

A management lesson from the Basin is that opportunities for additional positive impacts may have been lost due to governance issues. Marketing and education systems to support agriculture could have been better. Until the early 1980s farming in the Highlands was not generally profitable. Only in the mid 1980s when private investors from the cities established farms in the Highlands did the stone fruits, drip irrigation, and greenhouses for vegetables

34 According to a 1980 USAID report, "Foreign donors have been especially concerned that a handful of powerful farmers will capture a disproportionate share of the windfall of the [land reform] project. This concern has persisted in part because the JVA [Jordan Valley Authority] has administered the land reform program without foreign assistance, and therefore its reporting on this aspect of the project has been minimal." [Frankel, Richard. 1980. *Social Soundness Analysis-Maqarin Dam Project (Jordan)*. Washington DC, USAID. Page 22.]
35 The 1990-1991 immigrants had picked up Jordanian citizenship before going to the Gulf States.

appear on a large scale. Bedouin farmers (whom the government had attempted to settle) lacked experience with agriculture and instruction on how and what to farm.[36]

In the Valley as well, the lack of training and education, the lack of credit, and insufficient support for the marketing of produce have been important. According to a 2002 Canadian International Development Research Centre study by Tareq Al-Zabet,

> Marketing is the weakest point in the system. Jordan has no real forecasting system or marketing policy, and political problems also play a great role in blocking agricultural production. The farmers also refuse to trust government statements and insist on farming the typical crops, with a great risk of financial losses. Jordan needs to organize the market processes and monitor the domestic and export markets. A dynamic early feedback system for farmers on supply and demand information would be very important to make the farmers aware of what crops are in demand and help avoid overproduction.[37]

Perhaps supporting new crops and the spread of technology would have further increased productivity and rural incomes. Lack of educational opportunities and unsophisticated marketing together make it difficult for farmers to grow or export non-traditional crops such as cut flowers.[38]

In the Valley, there is no history of local control of projects or planning for the reduction of government involvement in water allocation. The lack of precedent has made attempts at forming water users associations difficult. Only now are participatory water management projects beginning. Such projects will reduce the cost to the government of determining, recording, and charging for water use.

In the Highlands, rather than too much governmental involvement, there has been too little. There are several unenforced limits on abstraction from private wells. The lack of enforcement established a pattern of farmers ignoring legal limits. The possible future enforcement of limits may be difficult due to the pattern of farmers ignoring legal limits.

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36 Jabarin, Amer. 2001. "Curtailment of Groundwater Use for Irrigated Agriculture in the Amman-Zarqa Basin Uplands: A Socio-Economic Analysis." Water Resource Policy Support, Groundwater Management Component. For USAID, ARD.

37 Al-Zabet, Tareq G. 2002. "Integrated Agricultural and Water Management in the Jordan Valley." In Modern And Traditional Irrigation Technologies In The Eastern Mediterranean, Edited by Özay Mehmet and Hasan Ali Biçak. International Development Research Centre. Ottawa, Canada.

38 Soer, Gert. 1998. *Study on Strategical Aspects of Irrigation Water Management in the Jordan Valley.* GTZ, JVA.

Negative impacts of support for irrigation and rural development

The negative impacts of support for irrigation have included environmental problems

According to a 2002 study by the Department of Statistics,

> Jordan is experiencing significant and widespread environmental degradation. A primary result of this degradation is the erosion of biodiversity, desertification, [soil] salination, [and] water logging, reduc[ing] productivity and jeopardiz[ing] long-term sustainability.[39]

In some aquifers in the Dulayl area of the Highlands, the groundwater has become too saline to use directly for irrigation. Outside of the Basin, highland oases have been greatly reduced. In the Jordan's tributary basins, heavy abstraction has lowered the groundwater level enough to strongly reduce the base flow of some tributaries. The lowering of base flow has negative environmental impacts on local ecosystems. Clearly, lower groundwater levels mean higher pumping costs for farmers.

Other environmental problems relate to soil. Irrigating without enough water to wash away salt leads to salt buildup in the soil. Soil water logging is also a problem. Some crops are excessively watered since some farmers think more water always leads to greater production. Excessive watering also occurs when drip irrigation emitters are not working properly.

In Jordan, an area with a visible environmental problem is the Dead Sea. The level of water reaching the Dead Sea has decreased due to almost complete use of surface water in the Valley. Dropping water levels threaten the unique Dead Sea ecosystem and tourism.

Developing and changing the distribution of water in the Valley has presented some public health issues. Diseases found in the Valley due to the presence of water include infectious hepatitis, dysentery, typhoid, and diarrhea.[40]

A negative impact has been the growth of powerful interest groups who want irrigation support to continue

In the Valley and in the Highlands, there are groups resistant to change since the status quo benefits them. As mentioned for the Valley, if the government ever wants to reduce support for irrigation, especially of fruit trees, this will be politically difficult. In the Highlands where water quality remains high, reducing support for irrigation may be more difficult due to extensive political ties between farmers and the government. Farming in the Highlands has been and still is quite profitable for some investors. These investors want to continue to make profits by irrigating with groundwater.[41]

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39 FAO, DOS 2002. *Analysis of the structure of Agriculture in Jordan: using data from 1997 Agricultural Census.* Page 9.

40 MWI, JVA. *Jordan Rift Valley Improvement Project*, Section 8.

41 Richards, Alan. 1993. "Bananas and Bedouins: Political Economy Issues in Agricultural Sector Reform in Jordan." Democratic Institutions Support Project, USAID.

Comparison of positive and negative impacts

Ideally, I could show the net social value of using water in different economic sectors over time as political events and water availability changed. Unfortunately, I can only suggest how the social value of water has changed sector for the agricultural, industrial and service sectors. First, I argue that social returns on water in agriculture have been large. Next I argue that the economic returns on water in agriculture are far below the returns of water in other uses. Finally, I argue needed drinking water can come from new sources and from existing sources, and that the existing sources (now in use by farmers) are less expensive.

Historically, the social returns on water in agriculture have been large. Benefits are impossible to quantify since they have included (1) increased welfare of farmers, (2) increased production, (3) increased value of farming to the national economy, (4) settlement of the significant numbers of Palestinians who moved to the Jordan Valley after 1948, (5) population of land adjacent to Israel, and (6) reduced migration to cities.

The social costs of supporting irrigation on a large scale have included forgone economic growth. According to Jamal Jaber and Mousa Mohsen's article in *Desalination*,

> Almost all local industries have suffered from shortages in water supplies during the last two decades. Hence, they have usually improved water-usage effectiveness by recycling their wastewater streams wherever feasible. The water shortage is also the limiting factor for the establishment of new industries as well as the expansion of certain high rate-of-water-consumption processes… and paper manufacture as well as the utilization of fertile land for food production.[42]

Table 4 shows the water productivities (private economic returns) on water are now much higher outside of agriculture. Some of the water productivities (Total revenue per volume of water *minus* variable cost) of water in agriculture, such as those for eggplants and squash, are negative. In these crops with negative gross margins of water, the variable costs exceed the revenue per volume of water.

42 Jaber, Jamal O., Mousa S. Mohsen. "Evaluation of non-conventional water resources supply in Jordan." *Desalination* **136** (2001) 83–92.

A negative impact has been the growth of powerful interest groups who want irrigation support to continue

Table 4. Water productivities in the agricultural, industrial, and service sectors

Gross margin is the revenue from the crop divided by the volume of water used. Value added is profit divided by the volume of water used. Because it ignores costs, the gross margin for produce is less than the value added for produce. The middle and south of the Valley are similar to the north.

Crop	Water Productivity (Gross Margin of water) JD/m^3	Activity	Water Productivity (Value added of water) JD/m^3
Major crops in the Highlands		**Industrial Sector**	
Olive	0.05	Mining & quarrying	20.0
Tomatoes	0.11	Extraction of crude petroleum & natural gas (including service activities)	36.3
Cauliflower	0.12		
Apple	0.14	Food products & beverages	53.6
Peach	0.24	Medical, precision & optical instruments, watches & clocks	78.4
Grapes	0.39		
Watermelon	0.46	Electrical machinery & apparatus	121.0
Sweet melon	0.49	Tanning & dressing of leather; manufacture of luggage, handbags, saddles, harness & footwear	132.0
Major crops in the north of the Valley			
Eggplants	-0.13		
Summer Squash	-0.13	Paper & paper products	187.0
Autumn Squash	-0.13	Machinery & equipment	280.3
Potatoes	-0.01	Textiles	362.0
Tomatoes	0.08	Basic metal	377.0
Citrus	0.13	Radio, TV & communication equipment & apparatus	384.4
Banana	0.13		
Wheat	0.15	Publishing, printing & reproduction of recorded media	399.5
Fava Beans	0.31		
Peppers	0.74	Apparel, dressing & dyeing of fur	540.0
String Beans	0.87	**Service Sector**	
Cucumbers	1.00	Construction sector	0.3
		Health activities	73.4
		Recreational & cultural activities	101.9
		Educational services	197.7

Sources: James Fitch (USAID, 2001), Siegfried Holtkemper *et at.* (MWI, 2003).

It is true table 4 shows only private economic returns and says nothing about effects on the income distribution of allocating water away from the agricultural sector. Table 4 also says nothing about the social benefits or social costs of water use in any sector. Despite uncertainty about how allocating water away from the agricultural sector might affect income distributions or social welfare, it is clear private economic returns on water are higher outside of agriculture.

A negative impact has been the growth of powerful interest groups who want irrigation support to continue

Demand for drinking water in Amman is growing. It is important that water in Amman not be too expensive for people to afford. As table 5 shows, developing new sources of drinking water for Amman will be expensive. Note two options, which decrease water for farmers, are among the least expensive options. The Zai-Dabouq conveyor carries surface water from the Jordan Valley to Amman. The source listed as "From groundwater currently serving farms" would involve reducing Highland farmers' well use and increasing use of the Highlands municipal water supply wells.

Table 5. Approximate costs of drinking water supply

These costs are approximate since political situations have changed since these figures were estimated, especially in Iraq, and not all figures include all of production, conveyance, treatment and distribution of the water.
A dam on the Yarmouk would supply freshwater to the King Abdullah Canal and allow better control of flow in the canal. The Zai-Dabouq conveyor pumps water from Deir Allah in the Valley to Amman in the Highlands. Desalination of water from both the Red Sea and the Mediterranean Sea are under consideration. The Disi aquifer is in the south of Jordan. There have been a few instances of farmers with wells close to the city selling their water to urban domestic users via private tanker trucks, so getting water from Highland farmers on a large scale is possible.

Water Source	Cost Year 2000 JD/m^3	Cost Year 2000 USD/m^3	Water for use annually MCM
For Amman and Highlands			
Amman network rehabilitation[♠] (low)	0.026	0.036	83 to 394 per project
Amman network rehabilitation[♠] (high)	0.247	0.346	
From groundwater currently serving farms[∇] (low)	0.061	0.086	
From groundwater currently serving farms[∇] (high)	0.075	0.105	20
Wehda dam (on Yarmouk)[♠]	0.119	0.166	85
Zai-Dabouq conveyor[♠]	0.297	0.415	45 (45 now in use)
Pipe from Litani in Lebanon[∂]	0.484	0.678	150
Sea water desalination Mediterranean-Dead[∂]	0.504	0.706	800
Disi fossil aquifer[♠]	0.561	0.786	100
Import by sea in bags[∂]	0.594	0.831	200
Sea water desalination reverse osmosis plant[∂]	0.682	0.955	50
Sea water desalination Red-Dead[∂]	0.713	0.998	850
Import by sea in used tankers[∂]	0.792	1.108	200
Pipe from Euphrates in Iraq[∂]	0.792	1.108	150
Import by sea in new tankers[∂]	0.990	1.386	200
Pipe from Seyhan-Ceyhan in Turkey[∂]	1.168	1.635	150
Not for Highlands or not for drinking			
Wastewater collection in Northern Governorates[♠]	0.221	0.310	8,700
Aqaba desalination[♠]	0.495	0.693	30
Wastewater treatment plant in Salt[♠]	0.532	0.744	1,300
Wastewater treatment plant in Irbid[♠]	0.695	0.973	1,850
Wastewater treatment plant in Fuhais[♠]	1.429	2.001	440

Sources: [♠]*National water master plan, Volume viii: Water sector economics* (MWI, year 2003 Dinars).
[∂]*Middle East regional study on water supply and demand development,* page 27 (GTZ, year 1998 Dinars).
[∇]James Fitch. (USAID, year 2001 Dinars).

At some point between the beginning of irrigation and development in Jordan and now, use of fresh water has become more socially valuable outside of agriculture. The turning point is impossible to identify, but probably occurred in the 1980s. I will now explain some of the events in Jordan since 1980.

In the early 1980s Jordan suffered from oversupply of vegetables

Until the 1980s, development and agriculture were successful in part because regional demand for produce exceeded Jordan's output. The value added to the national economy of agriculture was growing. Then, for a variety of reasons, the prices for Jordanian vegetables crashed in the early 1980s. The use of plastic tunnels and greenhouses and the favoring of traditional crops such as tomatoes and eggplants contributed to overproduction of some crops. Twenty years after the crash, the United Nations Food and Agriculture Organization and the Department of Statistics say:

> Jordan's production of fresh horticultural produce is not based on a well-established and clear knowledge of market demand in terms of quantity, quality, and timing. For most products, Jordan does not produce the appropriate varieties, with the right production technologies, at the most profitable season, since most producers do not receive any advice or information in these areas.[43]

Leading up to the crash, both oversupply and low demand were problems. During the 1979 the Iran-Iraq War, Iran and Iraq's demand for produce dropped.[44] In that war Syria backed Iran and Jordan backed Iraq, so Syria also reduced their import of Jordanian vegetables.[45] Civil War in Lebanon in 1982 reduced Lebanese and Syrian markets.[46] Meanwhile, Saudi Arabia and the United Arab Emirates increased their production of food.[47]

In 1982 oil prices dropped and demand for food by oil-producing Gulf States fell. Remittances from Jordanians working in oil-producing Gulf States fell also. With less income, Jordanian demand for produce decreased.[48] For many countries, imports from Turkey replaced imports from Jordan.

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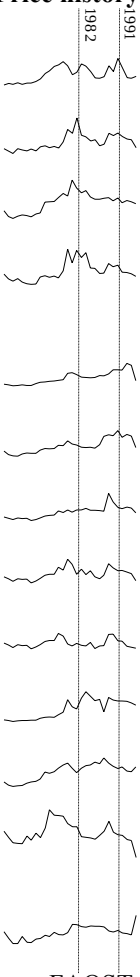
43 FAO, DOS 2002. *Analysis of the structure of Agriculture in Jordan: using data from 1997 Agricultural Census.* Page 10.
44 Shepley, Steven *et at.* Probably 1987. *The Jordan Valley: Dynamic Transformation 1973-1986.* Tech International, Inc. for USAID. Page 65.
45 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC.
46 Haddadin, Munther. "The Socio-Economic Role of The King Talal dam in the Kingdom of Jordan." Part of the World Commission on Dams Knowledge Base.
47 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC.
48 Hagan, Ross and Suzan Taha. 1998. "Irrigated Agriculture in Jordan: Background paper." Water Quality Improvement and Conservation Project. JVA.

The crash can be seen in annual average price histories in table 6. Note day-to-day prices fluctuated more. Increased quality and demand led to increased prices. The first vertical line marks 1982. Following 1982, for the reasons listed above, oversupply led to a drop in prices. Eggplants, watermelons, cucumbers show the most pronounced price changes. The farmers who could switched to tree crops, including olives, which are very low maintenance. Now, however due to extensive rainfed and irrigated olive orchards, there is an oversupply of olives.

Table 6. On-farm prices and the oversupply of produce in Jordan 1966-1995
Prices are inflation adjusted and indexed on 1990 prices. There is no scale because prices are indexed.

1966 to 1995 Price history	Crop	Notes
	**Vegetables**	
	Tomatoes	The prices of the vegetables have more spikes than the prices of bananas, apples, and oranges.
	Eggplants	
	Watermelons	
	Cucumbers	
	Fruits	
	Bananas	Bananas are subsidized.
	Apples	
	Oranges	
	Lemons and Limes	
	Grapefruit and Pomelos	
	Peaches and Nectarines	New varieties were introduced and consumption increased but later there was oversupply.
	Grapes	
	Olives	Olive prices have gone down due to oversupply. Once planted, olive trees require little maintenance.
	Field crop	
	Wheat	Wheat is subsidized.

Source: FAOSTAT website.

The government took action. The import of some crops was banned.[49] According to the U. S. Country Guide for Jordan,

> Rationalization started with a controversial 1985 government decision to regulate cropping and production, primarily in the Jordan River valley. Farmers there had repeatedly produced surpluses of tomatoes, cucumbers, eggplants, and squashes because they were reliable and traditional crops. At the same time, underproduction of crops such as potatoes, onions, broccoli, celery, garlic, and spices led to unnecessary imports.
>
> The government offered incentives to farmers to experiment with new crops and cut subsidy payments to those who continued to produce surplus crops. In 1986 cucumber production dropped by 25 percent to about 50,000 tons and tomato harvests dropped by more than 33 percent to 160,000 tons, while self-sufficiency was achieved in potatoes and onions.[50]

Following the crash, the rate of growth of use of drip irrigation, plastic mulch, greenhouses and plastic tunnels fell. One important impact from the produce market crash is that revenues from agriculture dropped and stayed down. Refer back to figure 6 and note in the early 1980s the peak in revenues from agriculture. Another important impact from the produce market crash is the spread of fruit tree orchard planting and the creation of politically powerful fruit tree farmers, as mentioned before.

Two droughts, a massive immigration, and a water quality scare

In the 1989-1990 season, there was not enough water in the Jordan Valley to irrigate the crops planted the previous fall. The government paid farmers in the middle and south of the Valley not to plant some of their land. This reduced planting reduced production and increased the import of food, as shown in figure 8. Figure 8 also shows imports of food had been low since the vegetable overproduction in the early 1980s. In 1999 the government again paid farmers not to irrigate their land due to drought.[51]

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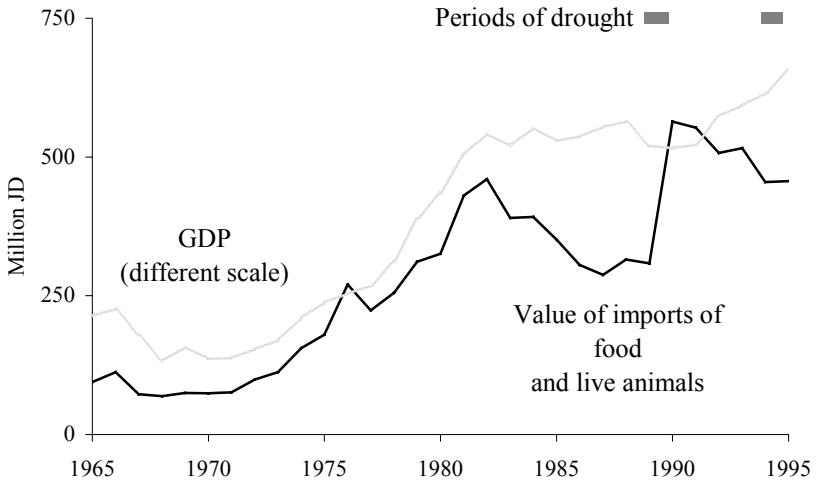
49 Elmusa, Sharif. 1994. *A Harvest of Technology: the super-green revolution in the Jordan Valley.* Center for Contemporary Arab Studies, Georgetown University, Washington DC. Page 70.

50 The United States Library of Congress Country Studies, Jordan. 1998. Online at <http://countrystudies.us/jordan/51.htm>

51 Charkasi, Dana. May 31, 1999. "Government plans to stop water supply to Jordan Valley vegetable farms." *Jordan Times.*

Figure 8. Value of imports of food and live animals



Source: Central Bank of Jordan, 1996. Communications with Omar Hakouz for the GDP figures.

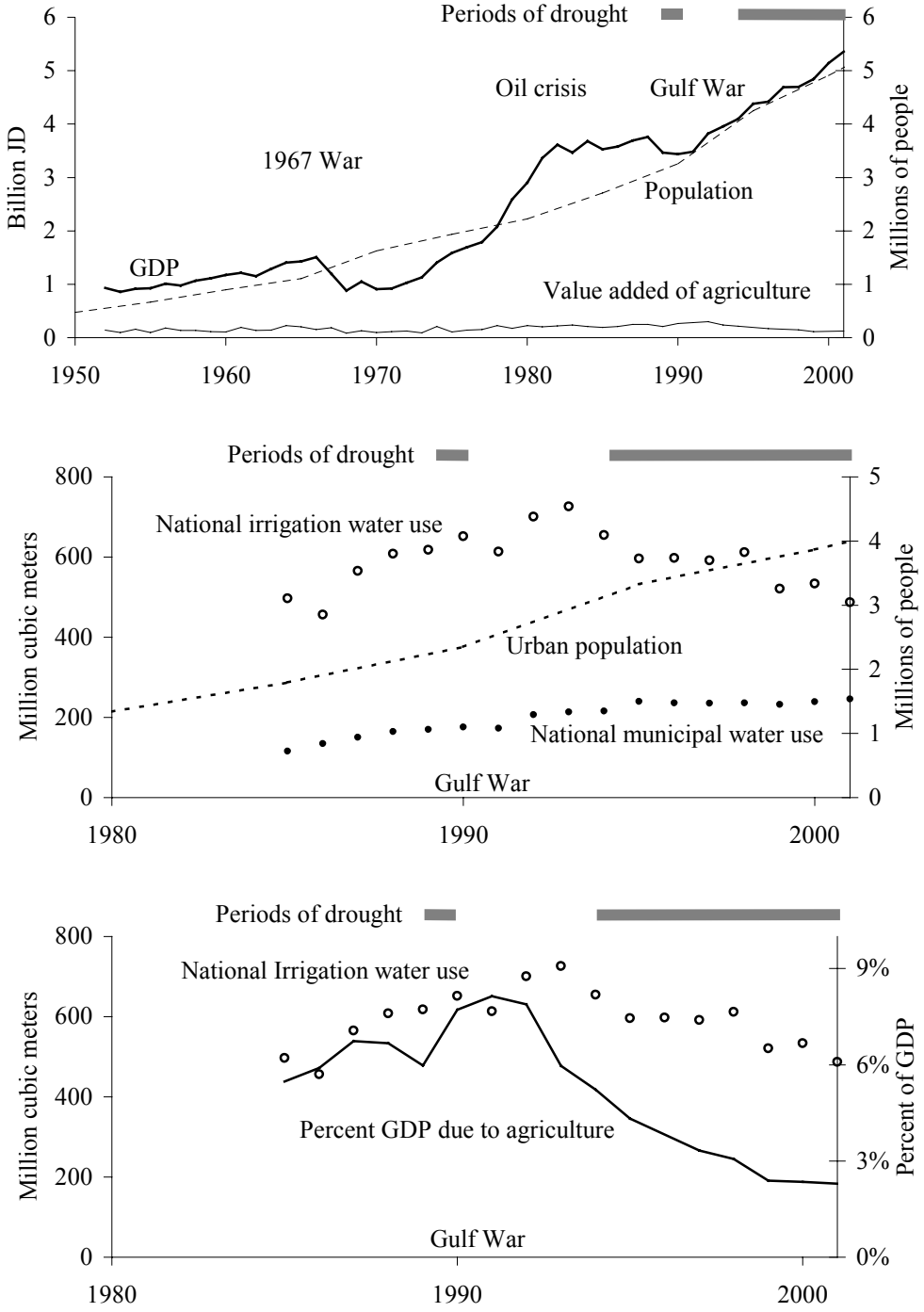
In 1990 more than 300,000 Jordanian Palestinians living in Kuwait at the time were expelled because Iraq, Jordan's ally, was attacking Kuwait. Those Jordanians moved to Jordan since they had become Jordanian citizens after leaving Palestine. This one-time influx of people was an approximately ten percent increase in Jordan's population. Demographically, the refugees tended to be educated. They were generally wealthy and came back with savings that they invested in housing and local businesses.

Especially when considered with tables 4 and 5, Figure 9 is important. Figure 9 suggests connections between the diminished fraction of agriculture in national income and events outside of Jordan and outside of Jordan's control, such as droughts, wars, immigration. The panels in figure 9 show the following:

1. The GDP grew by 16.1 percent in 1992 in part due to entrepreneurial returnees and a macroeconomic restructuring program.[52] The growth in GDP continued.
2. Municipal water use increased because many returning Palestinians moved to the cities. Note total water use declines. This is due to the long drought from 1994 to 2001.[53] During this period, industrial and livestock use of water held constant around 33 and 8 million cubic meters per year respectively.
3. From 1993 on, one year after the GDP grew so rapidly, water use for irrigation has fallen and the relative value of agriculture to the national economy dropped. This water drop may be due to a general reduction in agricultural development and from actions to decrease the use and increase the efficiency of irrigation.

52 Akel, Mufleh M. "The Jordanian Economy: Revival Amid Regional Uncertainty" The Arab Bank Review, Vol. 5, No. 1 April 2003.
53 Dalal, Khalid. May 8, 2001. "Eighth successive year of drought qualifies Jordan for international aid, experts say." *Jordan Times.*

Figure 9. Recent events. (1) Changes in population and GDP, (2) Changes in urban population and water use by sector, (3) Percent GDP due to agriculture and water use in irrigation.



Sources: Suzan Taha (MWI) for the water use figures. Omar Hakouz (DOS) for the GDP figures after 1976. For GDP before 1976, data is from DOS website. For this period, the agricultural figures include hunting, fishing and forestry, but there was very little hunting fishing, or forestry. FAOSTAT for the population figures. The droughts are 1989-1990 and 1994-2001.

In the summer of 1998 there was a major water quality scare in Amman. According to a BBC report, "High summer temperatures… led to an excessive concentration of algae in the capital's Zai treatment plant reservoir. Tests showed the presence of worms and weeds which a main treatment plant had been unable to handle."[54] This water quality scare increased general awareness of the value and scarcity of water in Jordan and of the importance of an affordable urban water supply.

Although I cannot present historical private water productivities, the private water productivities outside of agriculture *now* are higher on average than those in agriculture. This demonstrates there is generally more income to be made from use of water outside of agriculture (refer to table 4).[55] The high urban population now (refer to figure 9), the high importance of an affordable urban water supply (especially following the scare in 1998), and the need for economic growth suggest the social productivity of water is now highest outside of agriculture.

Historically, Jordan's prudent water management in the Valley responded successfully to the need for rural development and food security. As non-irrigation water needs expand, water allocation challenges will increase. As the population grows and water scarcity becomes more widely acknowledged, reallocating water will be a major political, economic, social, and management problem. Current management plans seem to center on complex drinking water development schemes, such as piping water from the Disi Aquifer in the far south of Jordan or desalinating brackish or sea water and piping it from the Valley to Amman. These projects will be expensive to develop and difficult to coordinate. New strategies, requiring political accommodations, will have to be developed and implemented.

54 *BBC News, World Edition*. September 15, 1998. "World: Middle East: Something fishy in Jordan's water."
55 Directly comparing water productivities ignores the costs of getting water to the different sectors, which are in different places in Jordan.

Two future scenarios

Now I will briefly examine two hypothetical and severe future scenarios, one in the Valley and one in the Highlands. Be aware these two scenarios are extreme and are not policy recommendations or predictions. However, as extreme scenarios, they both have been considered in detail by official studies and are useful to think about.

In the Jordan Valley, it seems likely that surface water quality and ground water availability will change. These changes may be extreme or moderate. My scenario for the Valley looks at the hypothetical case of using a greater portion of wastewater for irrigation.

In the Highlands, irrigation and other uses are depleting the aquifers. If depletion continues, at some point water will be too expensive to use for farming on a large scale, due to the depth of pumping and the costs of treating the water if treatment is necessary. To save the groundwater for long-term sustainable domestic and industrial use, groundwater use would have to be curtailed strongly. My scenario for the Highlands looks at the hypothetical case of almost eliminating irrigated agriculture.

In the Valley: hypothetically using a mix of fresh water and treated wastewater for irrigation

Recall that the King Abdullah Canal delivers water from the Yarmouk River to the north, middle, and south of the Valley. South of Deir Allah, water from behind the King Talal Dam, which is a mix of fresh water from the Zarqa River and treated city wastewater, is added to the canal. Table 7 lists water quality in the Valley from north to south.

Table 7. Quality of water in the Valley, north to south

North end of the Valley	Fresh water from the Yarmouk River via the King Abdullah Canal
↓	Fresh water from the Yarmouk River via the King Abdullah Canal mixed with treated waste water
South end of the Valley	Fresh water from the Yarmouk River via the King Abdullah Canal mixed with treated waste water, or low quality groundwater from private wells

Suppose the Jordan Valley Authority distributed mostly treated wastewater to farmers and stopped the use of groundwater for irrigation. Treated wastewater would be pumped to the north of the Valley from the King Talal Dam. Calculations from a MWI-USAID study suggest treated wastewater could replace 57 MCM of fresh water that would then be available for pumping up to Amman and the rest of the Highlands.[56] The pipeline from Wadi Zarqa to the Valley's Northern Directorate was projected to cost 87 million JD in 2001.[57] New drainage systems would be required in some places as part of the switch to treated wastewater, an

56 ARD. 2001. "Plan for Managing Water Reuse in the Amman-Zarqa Basin and the Jordan Valley." Water Resource Policy Support. Water Reuse Component. USAID, ARD.
57 Ibid.

additional expense.[58] Leaching will be more effective in the north than in the south because soils in the north have better drainage than soils in the south do.[59] Because irregular and unpredictable water supplies exacerbates the problems of using treated wastewater, the Jordan Valley Authority would have to upgrade the distribution system to provide a more constant water supply.[60]

Irrigation water everywhere in the valley would be of almost the same quality. Currently, areas in the south of the Valley not irrigated with groundwater receive the lowest quality water. If the water is treated only as well as it currently is, it will be too saline for most fruit trees and some other crops. Farmers with very saline water will have to switch to salt-tolerant crops such as asparagus or accept reduced yields. Water unusable for vegetable farming might still be usable for salt-tolerant grasses for use as fodder and for trees such as date palms.[61] Future cropping patterns for the whole Valley are likely to resemble the cropping patterns currently using the low quality water in the south and no groundwater from private wells. Other than citrus, banana, and string beans, which are all sensitive to salt, these are the crops currently in the top ten by revenue in the south and not in the top ten by revenue in the north: eggplant, melokhia, broad beans, cauliflower, grapes, and sweet peppers.[62]

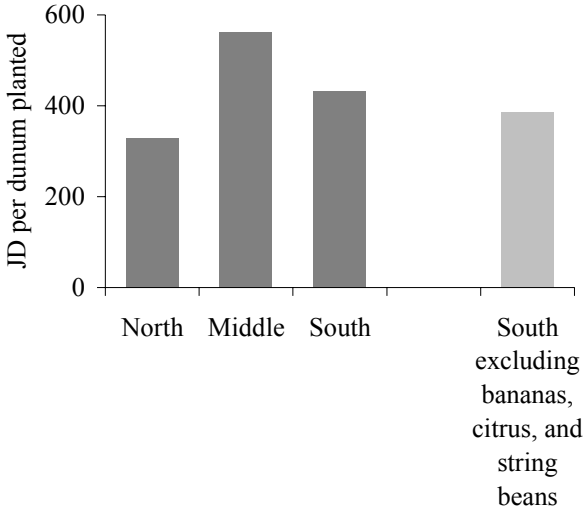
Average revenue per unit farmed by region of the Valley for 2002 are in figure 10. Also included is the average revenue per unit farmed for the south of the Valley, excluding the area planted with, and the revenue from, highly salt-intolerant crops. Figure 10 suggests the value of production in the middle of the Valley will fall the most if irrigation were only with treated wastewater. The north, middle and south are currently different for historical and physical reasons. Greenhouses reached the middle of the Valley first and so are more widespread there. Also, the weather in the north is colder in the winter and in the summer.

Figure 10. 2002 Valley value of production, per unit area
The column on the right side is the same as the column labeled "South," but without the revenue due to bananas, citrus, and string beans, which are all highly salt-intolerant crops.

Farmers will have to modify their methods of irrigating, fertilizing, and leaching. Assistance with crop selection and general farming with treated wastewater would be required. As the amount of solids in the water increases the cost to maintain a drip irrigation system increases. Clogging of filters and emitters is mostly caused by high levels of algae (due to the nitrogen and phosphorus in the water) and by lime precipitating out of the water (due to the high pH of the water). Although difficult and expensive, chlorination would remove algal slime and acids added to the water can reduce precipitation in pipes.[63]

58 Grattan, Stephen. 2000. *Impact of increasing supplies of recycled water on crops, soils and irrigation management in the Jordan Valley.* For USAID, ARD. Section 2.3.
59 Ibid.
60 Ibid.
61 Ibid.
62 Salt tolerances are from World Bank. Rural Development Water and Environment Department Middle East and North Africa Region. 1997. *The Hashemite Kingdom of Jordan Water Sector Review.*
63 Grattan, Stephen. 2000. *Impact of increasing supplies of recycled water on crops, soils and irrigation management in the Jordan Valley.* For USAID, ARD. Section 3.7.1.

In the Valley: hypothetically using a mix of fresh water and treated wastewater for irrigation



Source: Calculations based on data from the *Agricultural Statistics 2002* book (DOS).

Treated wastewater can substitute for some fertilizer use since phosphorus and nitrogen exist in treated wastewater. However, nitrogen may be harmful to mature plants. Tomato, grape, and olive crops are delayed or reduced by nitrogen application near harvest time.[64]

More crops would be feasible if the water could be desalinated but desalination is expensive.[65] The government may opt to desalinate water for farming use to lessen the harm to farmers of distributing treated wastewater.

To assess the economic impacts of switching to mostly treated wastewater, information on production costs is needed. Farm models exist but using them presented various problems for me.[66] I did not create farm models of production costs. An additional difficulty in doing economic impact analysis is that some of Jordan's current trade partners may not wish to import produce grown with treated wastewater. For example, the Gulf Sates currently refuse produce grown with treated wastewater because of sanitation concerns. Europe may accept crops grown with treated wastewater but with conditions on how the crop is grown and marketed. These conditions may be difficult for farmers to meet without support services.

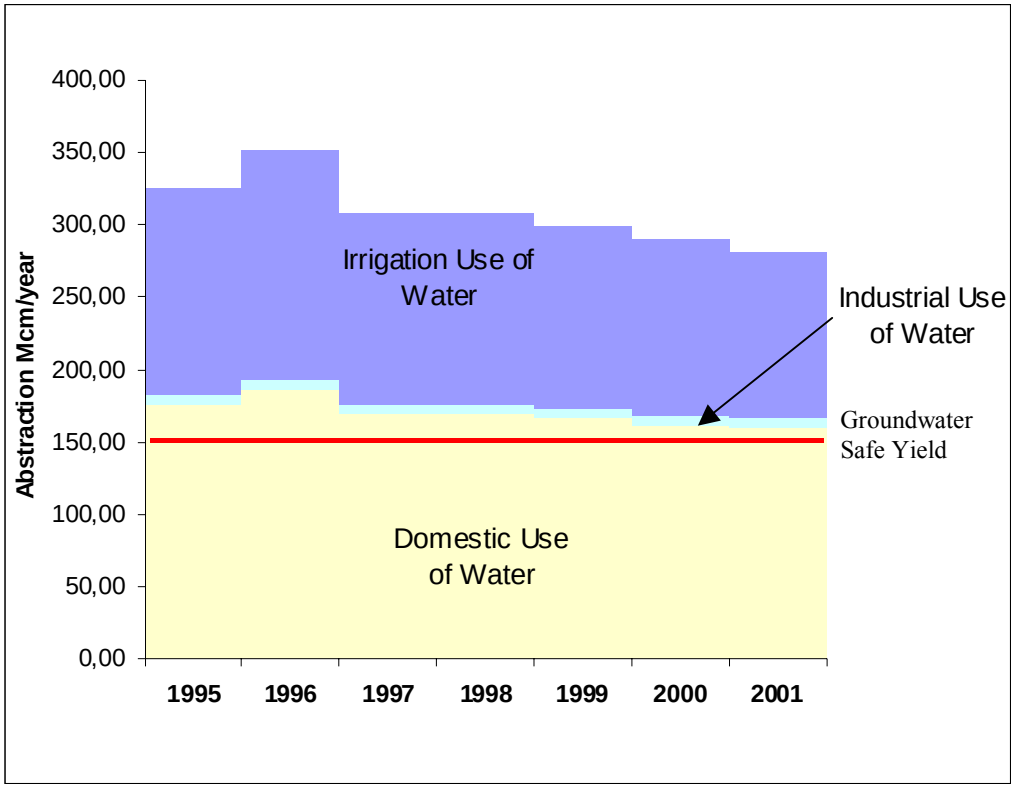
In summary, if the Valley were irrigated with only treated wastewater, 57 million cubic meters of water per year on average would be available to be pumped to the Highlands. Long-term environmental effects depend very strongly on the quality of the water and how the water is used. Sufficient leaching is essential for sustainable farming.[67] It is likely that further environmental degradation will accompany the heavy use of wastewater in the Valley. Effluent leaving the Valley for the Dead Sea will be more saline than it currently is.

64 Ibid.
65 Additionally, wastewater is becoming increasingly saline due to urban water supplies becoming increasingly saline.
66 I lacked the time to use the farm models. Some of the models were a decade old or incomplete or for the Valley as a whole.
67 Grattan, Stephen. 2000. *Impact of increasing supplies of recycled water on crops, soils and irrigation management in the Jordan Valley.* For USAID, ARD.

In the Highlands: hypothetically allowing much less irrigation

In the Highlands, currently abstraction for *non*-irrigation use exceeds sustainable levels in parts of the Highlands, as shown in figure 11. If abstraction continues unchecked, many wells will eventually become saline and dry up. Assuming industrial, domestic, and governmental use does not change, even hypothetically ending all irrigation immediately would not save the Highland aquifers from eventually running dry nor would it provide Amman with a sustainable water supply.

Figure 11. Recent groundwater abstraction the Highlands



Sources: Communication with Suzan Taha (MWI).

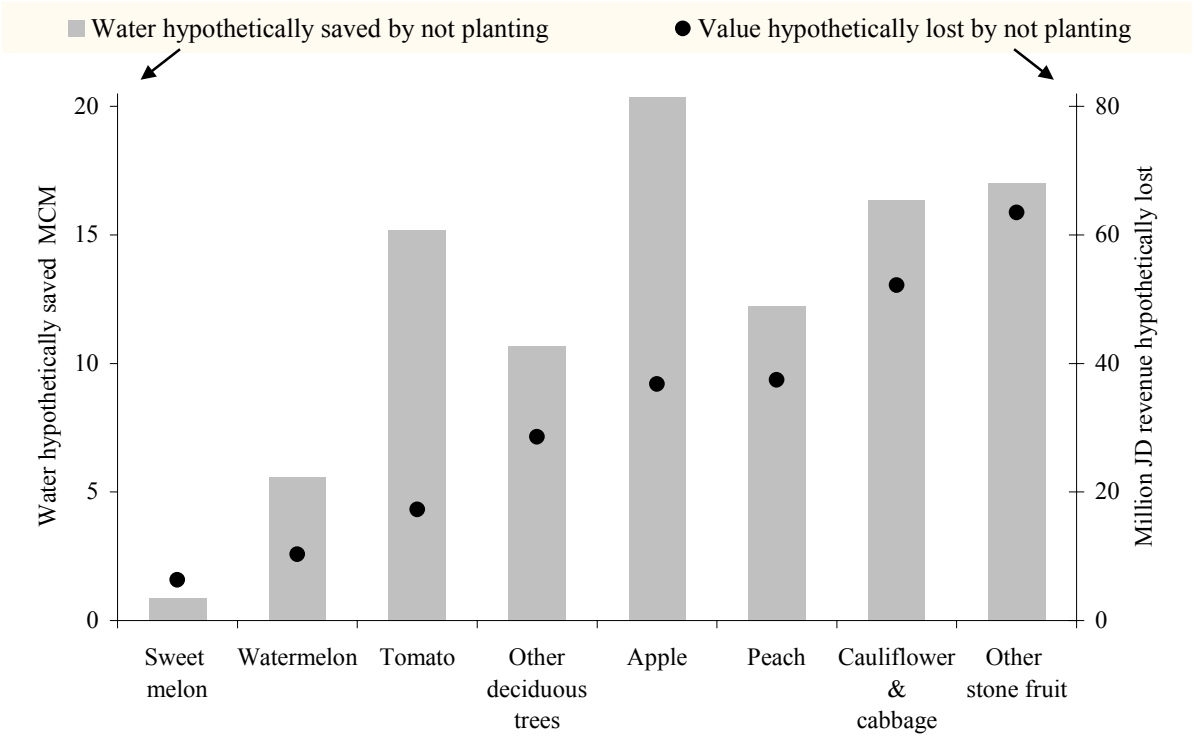
If abstraction for irrigation ceases, life in the highlands will change dramatically. Farming will end. Some farm workers will find new jobs in the Highlands, some will move to other parts of Jordan, and some foreign workers will leave Jordan.

The larger the curtailment of groundwater use, the larger the political opposition from the farmers will be. However, investors would have to accept that large profits are no longer possible. If abstraction is reduced by ninety percent, for example, farmers may focus on growing high-value fruit crops and grow fewer vegetables. See the paper by Amer Salman, Khamis Raddad, *et at.* for a linear programming model of optimal crop selection in the Highlands.[68]

68 Amer Salman. Khamis Raddad, Mohammad Shatanawi, and Hussein Al-Qudah. "The Economics of Groundwater Use in Agriculture Under Different Water Prices and Supply Regimes in the Upland Area of Jordan." Personal communication.

Consider figure 12. A chart like this would a useful policy aid. Crops are lined up across the bottom in order of their estimated value in 2002. These values are represented by the black dots. The estimated amount of water saved if all the land planted with each crop had been left fallow is also shown. Tomatoes are near the left, which means the value of tomatoes in 2002 was low compared with some other crops. However, the amount of water estimated to have been used to grow those tomatoes is high. Thus, if a possible policy tool were the strong reduction in specific crops in the Highlands, tomatoes would be a good choice since tomatoes contributed around twice as much value as watermelons did but used thee times the water. Olives and grapes are omitted because it difficult to assess how much water is needed to grow these crops since many are rainfed. To calculate this chart with lost profits instead of revenue, a farm model to calculate costs with is needed.

Figure 12. Revenue lost and water saved if the area set for various crops had been left fallow in the Highlands in 2002
Based on a general farm model for the Amman-Zarqa Highlands.



Sources: Values are from *Agricultural statistics 2002* (DOS). Water uses are from Fitch, 2001, appendix.

In summary, the near-elimination of irrigation in the Highlands will not significantly affect Jordan's short-term water budget since the non-irrigation abstraction in the Highlands will still exceed the aquifers' rates of recharge. However, reducing abstraction would improve the status of Highland aquifers.

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Abbreviations:

MREA	French Regional Mission for Water and Agriculture in Jordan
USAID	United States Agency for International Development
DOS	Jordanian Department Of Statistics
MWI	Jordanian Ministry of Water and Irrigation
JVA	Jordan Valley Authority
GTZ	Gesellschaft für Technische Zusammenarbeit
ARD	Associates in Rural Development, Inc. (A USAID contractor)
FAO	United Nations Food and Agriculture Organization

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Appendix: Details of dams and irrigation projects in the Valley

Here are the basics of water flow in the Valley. Farmers in the Valley receive water from many sources. Currently, water from the Yarmouk River enters the King Abdullah Canal and is delivered to irrigation projects in the Valley. Water from the King Talal dam (built in 1977) is added to the King Abdullah Canal. The water behind the King Talal Dam is a mix of water from the Zarqa River and treated wastewater, mostly from Amman. Upstream of the King Talal Dam, drinking water is pumped from the station at Deir Allah up to Amman. Roughly one third of the flow of water upstream of Deir Allah goes to Amman. Thus two thirds of the investments in water supply upstream of Deir Allah may be considered as just for irrigation. Canals and dams upstream of Deir Allah are the Wadi Arab Dam, the Wadi Zeqlab Dam, and sections one and two of the King Abdullah Canal. Downstream of Deir Allah, almost all water goes to irrigation. Some other dams in the Valley connect to the King Abdullah Canal and all dams irrigate land.

This table lists some information about the dams and irrigation projects. In the Valley now there is a storage capacity of 162 million cubic meters, less volume lost to sedimentation. The irrigation projects can potentially irrigate 304 thousand dunums but fewer are irrigated at this time.

Dams and irrigation projects

The dams. The storage volumes are reservoir capacities, not volumes impounded.

	Year	Live storage volume MCM	Cost year 2000 million JD	Cost JD/m3	Cost USD/m3
Kafrain Dam	1967	3.9	4.8	1.2	1.7
Wadi Zeqlab Dam	1967	3.9	4.8	1.2	1.7
Wadi Shueib Dam	1968	1.4	2.5	1.8	2.5
King Talal Dam	1977	56.0	35.3	0.6	0.9
Wadi Arab Dam	1986	17.1	36.9	2.2	3.0
King Talal Dam Raising (additonal storage and cost)	1987	20.0	40.6	2.0	2.8
Kafrein Dam Raising (additional storage and cost)	1997	4.5	9.0	2.0	2.8
Karama Dam	1997	55.0	58.0	1.1	1.5
Totals		162	190		

The irrigation projects. The areas are those potentially served by the projects.

	Year	Area thousand dunums	Cost year 2000 million JD	Cost per unit area JD/du	Cost per unit area USD/ha
North Ghor Phase 1	1962	18.2	21.8	1,195	16,724
North Ghor Phase 2	1966	54.8	4.9	90	1,261
KAC 18 Km Extension	1978	36.0	16.3	453	6,345
NE Ghor	1978	27.0	14.6	540	7,553
Zarqa Triangle	1978	15.1	9.3	616	8,627
Hisban-Kafrein	1983	16.5	6.1	367	5,141
Wadi Arab Dam	1985	12.5	10.6	849	11,880
KAC 14.5 Km Extension	1988	62.5	21.9	350	4,899
Middle Ghor	1991	62.0	17.3	279	3,904
Totals		305	120		

Source: The irrigated areas from communications with Nayif Sider (JVA) and from Ministry of Water and Irrigation, 1993: Study for the Recovery of Operation and Maintenance Costs of Irrigation Water in Jordan. The dam live storage volumes are from communications with Raja Nasser (JVA).

Appendix: Historic price deflator

The Jordanian Dinar deflator I used to bring historic costs and prices to inflation-adjusted value:

Year	Index Number (1974 = 1)	Year	Index Number (1974 = 1)
1950	0.329	1977	1.237
1951	0.361	1978	1.250
1952	0.380	1979	1.266
1953	0.388	1980	1.329
1954	0.395	1981	1.420
1955	0.410	1982	1.519
1956	0.429	1983	1.683
1957	0.442	1984	1.712
1958	0.455	1985	1.824
1959	0.459	1986	1.971
1960	0.463	1987	1.971
1961	0.476	1988	1.998
1962	0.495	1989	2.332
1963	0.503	1990	2.608
1964	0.521	1991	2.752
1965	0.546	1992	2.985
1966	0.568	1993	3.070
1967	0.686	1994	3.280
1968	0.827	1995	3.343
1969	0.866	1996	3.412
1970	0.913	1997	3.454
1971	0.961	1998	3.661
1972	1.000	1999	3.651
1973	1.000	2000	3.641
1974	1.000	2001	3.684
1975	1.000		
1976	1.096		

Calculation and rationale:

"Basic currency unit consisting of 1,000 fils; created in 1950 as replacement for the Palestinian pound. Dinar's value was established at parity with the British pound sterling, or a value of US$2.80 equal to JD1. Jordan, as a member of the sterling area, maintained parity with the British pound until 1967 when the British devalued their currency. Jordan did not follow the pound, retaining the Dinar at US$2.80 equal to JD1 through 1972. When United States currency was devalued in 1973, the Dinar was unlinked from the dollar, since which time the rate has fluctuated. Beginning in February 1975, the Dinar was pegged to the special drawing right. According to International Monetary Fund data, the average conversion rate of the Dinar for trade and other purposes was US$3.04 in 1987, US$2.1 in 1988, and US$1.54 in 1989."
Source: The United States Library of Congress Country Studies, Jordan, Glossary, online at <http://memory.loc.gov/frd/cs/jordan/jo_glos.html>, accessed 15 September 2003.

I used the British Pound to derive the Dinar deflator, 1950 to 1967. Source: Twigger, Robert. Inflation: the value of the pound 1750-1998. British House of Commons Library, Research Paper 9/20. Online at <http://www.parliament.uk/commons/lib/research/rp99/rp99-020.pdf> accessed 15 September 2003.

I used the U. S. Dollar to derive the Dinar deflator, 1967 to 1972.

U.S. Dollar Deflator: 1959 – 1997

Year	**Index Number (1992=100)**
1959	22.9
1960	22.3
1961	23.6
1962	23.9
1963	24.2
1964	24.5
1965	25.0
1966	25.7
1967	26.5
1968	27.7
1969	29.0
1970	30.6
1971	32.2
1972	33.5
1973	35.4
1974	38.5
1975	42.2

Source: U. S. Department of Commerce, Bureau of Economic Analysis, reproduced at <http://www.owlriver.com/pie.mhsc.org/DataPages/sd-079.htm> accessed 15 September 2003.

For the years 1972 to 1975, I had no data and assumed no deflation. For the years 1976 to 2001, I have a deflator directly for the Dinar from communication with Omar Hakouz, head of National Account Division at the Department of Statistics.

Appendix: Some major public investments in irrigation in the Valley

Project	Completed	Cost at time, million JD	year 2000 cost, million JD	Year 2000 cost, million USD	Used for Total?*	Upstream of Deir Allah?	Notes	Sources (Refer to references section)
CANALS								
KAC Sec. 1	1962	5.900	43.395	60.753	Yes Yes			Shepley, Steven et. al.
KAC Sec. 2	1969	0.900	3.786	5.300	Yes Yes			Shepley, Steven et. al.
KAC Sec. 3 (18 km Extension)	1978	5.600	16.315	22.841				Shepley, Steven et. al.
	1978	5.600	16.315	22.841	Yes No		Published	Serpekian, Avedis.
	1978	5.600	16.315	22.841				MWI, GTZ 1993
	1978	5.300	15.441	21.617				Isfahan report (MREA)
KAC Sec. 4 (14.5 km Extension)	1988	11.937	21.757	30.460	Yes No		Published	Serpekian, Avedis.
	1988	11.946	21.773	30.483				MWI, GTZ 1993
	1988	11.500	20.961	29.345				Isfahan report (MREA)
Repairs to KAC after 1967	1972	0.272	0.989	1.385	Yes Yes			Jodan Valley Commission 1972
Tiberias-KAC Connection	1996	2.5	2.668	3.736	Yes Yes			Yousef Assan
		Total	88.910	124.474	*Total upstream of Deir Allah*			
					JOD 50.838		*$71.173 (Millions)*	
DAMS								
Kafrain Dam	1967	0.900	4.776	6.686	Yes No			Raja Nasser
	1967							Isfahan report (MREA)
	1968	0.600	2.642	3.699				Serpekian, Avedis.
Kafrein Dam Raising	1996							Raja Nasser
	1997	8.500	8.960	12.544	Yes No			Raja Nasser
	1997							Isfahan report (MREA)
Karama Dam	1997	56.000	59.031	82.644				Isfahan report (MREA)

	1997	55.000	57.977	81.168	Yes No		Raja Nasser
King Talal Dam	1977	12.000	35.332	49.464			MWI, GTZ 1993
	1977						Isfahan report (MREA)
	1979	16.200	46.585	65.220			Shepley, Steven et. al.
	1977	12.000	35.332	49.464	Yes No	Published	Serpekian, Avedis.
	1977	12.000	35.332	49.464			Raja Nasser
King Talal Dam Raising	1987	18.348	33.888	47.443			MWI, GTZ 1993
	1987						Isfahan report (MREA)
	1987	18.348	33.888	47.443			Serpekian, Avedis.
	1987						Raja Nasser
	1987	22.000	40.632	56.885	Yes No		Raja Nasser
Wadi Arab Dam	1986	20.000	36.938	51.714	Yes Yes		Raja Nasser
	1986	20.000	36.938	51.714			Isfahan report (MREA)
	1986	18.267	33.737	47.232			MWI, GTZ 1993
	1986	18.267	33.737	47.232			Serpekian, Avedis.
	1985	17.000	33.939	47.514			Shepley, Steven et. al.
Wadi Kufranja Weir	1993	0.369	0.437	0.612			MWI, GTZ 1993
	1993	0.369	0.437	0.612	Yes No	Published	Serpekian, Avedis.
Wadi Shueid Dam	1969	0.300	1.262	1.767			Isfahan report (MREA)
	1968	0.300	1.321	1.849			Isfahan report (MREA)
	1969						Raja Nasser
	1968	0.560	2.466	3.452			German document iv, JVA dams dept, 1993
	1968	0.560	2.466	3.452	Yes No	Published	Serpekian, Avedis.
	1967	0.560	2.971	4.160			Raja Nasser
Wadi Yabes Weir	1993	0.408	0.484	0.678			MWI, GTZ 1993
	1993	0.406	0.482	0.675	Yes No	Published	Serpekian, Avedis.
Wadi Zeqlab Dam	1967	0.900	4.776	6.686			Raja Nasser
	1967	0.900	4.776	6.686			Isfahan report (MREA)
	1967	0.900	4.776	6.686	Yes Yes	Published	Serpekian, Avedis.
	1968	0.600	2.642	3.699			MWI, GTZ 1993
Yarmouk Weir	1999	1.500	1.496	2.094	Yes Yes		Raja Nasser
		Total	194.272	271.981	*Total upstream of Deir Allah*		

JOD 43.210 *$60.494 (Millions)*

IRRIGATION PROJECTS							
Hisban Kafrein IP 1983	1983	2.800	6.058	8.482			Nayif Seder
	1983	2.800	6.058	8.482	Yes	Published	Serpekian, Avedis.
	1983	2.800	6.058	8.482			MWI, GTZ 1993
Middle Ghor IP	1991	13.070	17.291	24.208			MWI, GTZ 1993
	1992	8.800	10.734	15.028			Isfahan report (MREA)
	1991	13.070	17.291	24.208	Yes	Published	Serpekian, Avedis.
Middle Ghors Conversion To Pressure	1991	13.050	17.265	24.171	Yes		Nayif Seder
N. Ghors Conversion Project	1996	27.300	29.137	40.792	Yes	More recnent	Nayif Seder
	1996	23.781	25.381	35.534			MWI, GTZ 1993
	1996	23.781	25.381	35.534			Serpekian, Avedis.
	1996	12.000	12.808	17.931			Isfahan report (MREA)
N Ghor, Kac (70 IP)	1964	6.300	44.043	61.660	Yes		Serpekian, Avedis.
N. Ghor 1-17	1966	0.770	4.934	6.908			MWI, GTZ 1993
N Ghor 1-17 IP	1966	0.770	4.934	6.908	Yes		Serpekian, Avedis.
N Ghor 18-24 IP	1966	3.400	21.789	30.504	Yes		Serpekian, Avedis.
N. Ghor 18-21	1966	3.400	21.789	30.504			MWI, GTZ 1993
N. Ghor KAC	1964	6.300	44.043	61.660			MWI, GTZ 1993
N.E. Ghor IP	1978	5.000	14.567	20.394			MWI, GTZ 1993
	1978	5.000	14.567	20.394			Nayif Seder
	1978	5.000	14.567	20.394	Yes	Published	Serpekian, Avedis.
Wadi Arab IP	1984	5.000	10.632	14.885			MWI, GTZ 1993
	1985	5.000	9.982	13.975			Isfahan report (MREA)
	1985	4.500	8.984	12.577			Shepley, Steven et. al.
	1984	5.000	10.632	14.885	Yes	Published	Serpekian, Avedis.
	1984	5.000	10.632	14.885			Nayif Seder
Zarqa Triangle IP	1978	1.500	4.370	6.118			Isfahan report (MREA)
	1978	3.200	9.323	13.052			MWI, GTZ 1993
	1978	3.200	9.323	13.052	Yes		Serpekian, Avedis.

	1978	3.200	9.323	13.052		Nayif Seder
KAC 14.5 km Extension IP	1988	12.000	21.872	30.621	Yes	Nayif Seder
KAC 18 Km Ex IP	1978	5.600	16.315	22.841	Yes	Nayif Seder
FTA rehab for 18-km, Zarqa Triangle, and N.E. Ghor projects	2001	5.480	5.417	7.583	Yes	World Bank internal document report 22227, ag sector tech support project
		Total	218.644	306.101		
OTHER						
Jordan Valley Subsurface Drainage	1980	4.800	13.156	18.418	Yes	Serpekian, Avedis.
Roads	1982	2.582	6.189	8.665	Yes	MWI, GTZ 1993
Subsurface Drainage	1980	4.800	13.156	18.418	Yes	MWI, GTZ 1993
Subsurface Drainage	1986	0.307	0.567	0.794	Yes	MWI, GTZ 1993
		Total	33.067	46.294		
		Grand Total	**535**	**749**	**(Millions, year 2000)**	
			JD	**USD**		