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Note: This paper is an enhanced and longer version of the book chapter "Wells and Canals in Jordan: Can Pricing Policies Regulate Irrigation Water Use" (Venot et al. 2007).

Cover photograph courtesy of the MREA shows the greenhouses in Deir Allah, Jordan Valley.

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Contents

List of Acronyms

ARD   Associate in Rural Development
AZB   Amman-Zarqa Basin
CWR   Crop Water Requirements
DoS   Department of Statistics
FORWARD   Fostering Resolution of Water Disputes Project
GTZ   Deutsche Gesellshaft für Technische Zusammenarbeit
JVA   Jordan Valley Authority
KAC   King Abdullah Canal
KfW   Kreditanstalt Für Wiederaufbau (German Bank)
LJRB   Lower Jordan River Basin
MWI   Ministry of Water and Irrigation
O&M   Operation and Maintenance
USAID   United States Agency for International Development
WAJ   Water Authority of Jordan
WP   Water Productivity
WTO   World Trade Organization

Note: One fils equals 1/1,000 of a Jordanian dinar (JD)
           One JD is equivalent to US$0.7

Summary

In the Hashemite Kingdom of Jordan, which is an arid country, the per capita availability of water is low and declining. Moreover, in the Lower Jordan River basin the annual water withdrawal stands at 585 million m^3 (Mm^3), roughly half of which is pumped from aquifers. The development of both public irrigation systems in the 'Jordan Rift Valley' and private groundwater abstraction in the 'Highlands' has committed most of the surface water and groundwater, respectively. With the growth of urban demand and the evidence of serious overdraft of aquifers, many policy instruments have been used in the last 10 years to reallocate water to nonagricultural uses; encourage improvements in efficiency throughout the water sector; use increasing volumes of treated wastewater for agricultural purposes and curb groundwater abstraction.

Emphasis has been placed on demand management—a plan to reform the agriculture sector (ASAL 1994) and a new national water strategy (1997) have vested much hope in economic instruments and reforms. Pricing of irrigation water at adequate levels was seen as a crucial lever to elicit water savings, raise water productivity, ensure financial sustainability, and allocate water economically. In 2002, the 'Groundwater Control Bylaw No. (85)' was passed with the objective of controlling groundwater abstraction in the Highlands by taxing abstraction above a limit of 150,000 m^3/ well/yr. In the Jordan Valley, a block-rate tariff system associated with crop-based quotas had been in place for some time and the debate revolved on the possibility of increasing water charges to cover costs and promote water-saving behaviors among the water users.

This report examines both contexts, the Highlands and the Jordan Valley, and establishes farming system typologies that illustrate the diversity of farms and farmers. Their respective strategies in the face of rising prices are assessed based on crop budgets and farm constraints and strategies. Options include reducing cropping areas, shifting cropping patterns, improving irrigation efficiency, renting wells or plots to other farmers, discontinuing agriculture or just paying the relevant charges. By using regional farm and crop data, these strategies are aggregated to describe the likelihood of success of water pricing policies in terms of recovering operation and maintenance (O&M) costs, saving water and improving economic efficiency. Finally, this study explores some of the alternatives available for meeting these objectives.

The analysis shows that increased charges alone are unlikely to bring about significant water savings and that, beyond certain levels, they will reinforce dynamics towards more capital-intensive farming in both the Highlands and the Jordan Valley. Water productivity could be increased but this would take place to the detriment of poorer and more extensive farmers and would transfer a growing share of the value added to major entrepreneurs and state agencies. In addition, in the Highlands, it might eventually increase the amount of water depleted. Hence, farmers should not be made to bear price incentives unless these are accompanied with positive incentives that reduce capital and risk constraints, offer attractive cropping alternatives, and exit options with appropriate compensation.

In the Highlands, water abstraction cannot be brought to sustainable levels merely through price revisions. Nevertheless, it can be done through the implementation of drastic measures such as setting a maximum limit on annual well abstraction (fixed quota), offering subsidies to encourage the buy-out of wells, and uprooting of olive trees.

In the Jordan Valley, recovery of operation and maintenance (O&M) costs of the public irrigation system is desirable and achievable without imposing too much of a burden on farmers. Higher prices, however, have limited

potential for achieving gains in irrigation efficiency. The current system of quotas (strict limitations when demand exceeds supply), the lack of storage and the technical difficulties experienced in the collective and individual pressurized networks indicate that little water can be saved. The new dam on the Yarmouk River, however, could allow monthly quotas to be transformed into a yearly quota, with the possibility of fine-tuning supply and saving water in the excess periods. In the Jordan Valley, on-farm losses are not merely the result of low water prices but reflect the high costs of adopting better technology without subsidies and intensifying production. Capital-intensive farmers have shifted to high-quality products for specific market niches, despite low water prices, but such strategies remain out of the reach of small and frequently indebted farmers. Savings could be obtained through reconsideration of higher quotas granted to citrus and banana farms, and being more flexible by allowing trading of water rights. This latter option, however, might lead to a concentration of rights in the hands of major entrepreneurs, an evolution that is currently seen as undesirable by the decision makers.

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Introduction

One of the countries with the scarcest water resources in the world is the Hashemite Kingdom of Jordan. Due to both physical water scarcity and a high demographic growth during most of the second half of the twentieth century it has been estimated that the per capita endowment of renewable blue water (i.e., surface runoff and groundwater recharge) is now only 163 m³/yr, while the average domestic consumption is 94 liters per capita and per day nationwide (THKJ 2004). The water resources available in the Jordanian part of the Lower Jordan River Basin (LJRB: see figure 1) are currently being renewed at a rate of 705 million cubic meters per year (Mm³/yr), including 155 Mm³/yr of groundwater and 550 Mm³/yr of surface water. The total water withdrawn within the basin amounts to 585 Mm³/yr, i.e., 83 percent of the renewable surface water and groundwater, but this value obscures the critical overdraft of the main aquifers (Courcier et al. 2005).

The LJRB is a region of prime importance for the country: it includes 83 percent of the total population, most of the main industries, and 80 percent of irrigated agriculture of the country; it is endowed with 80 percent of the country's water resources and uses 75 percent of these (Venot 2004b). With the exception of some rain-fed agriculture in the mountain range (pasture, wheat, olive trees etc.), the bulk of agriculture is irrigated and can be found in two contrasting environments—the Jordan Valley, where a public

scheme supplies approximately 23,000 hectares, and the Highlands, which includes two groundwater basins of major importance, the Amman-Zarqa (AZB) and the Yarmouk[1] (figure 1), where most of the private tube-well-based irrigation (that has developed over 14,000 hectares over the last 30 years) takes place.

This report focuses on the debate revolving around the pricing of water as a means to regulate water use in irrigation, in these two contrasting environments. In both the Highlands and the Jordan Valley, a typology of farming systems has been established to discriminate the impact of pricing policies on different types of farms, and to assess what could be farmers' adjustments and responses in each case. Regional data aggregation then provides a wider picture of the water savings achieved, and of the financial impacts on both the farmers and the state.

The first section (The Policy Context) presents the water policy context of Jordan, in which different pricing policies have been recently implemented. The following section (The Farming Sytems in the Two Study Areas) sets the context of the study and describes the LJRB and the irrigated farming systems of the two regions. Section 3 (Pricing Water to Control Groundwater Overabstraction in the Highlands) and section 4 (Water Pricing in the Jordan Valley) investigate the efficiency of pricing water in reducing groundwater abstraction in the Jordanian Highlands, and in reducing agricultural freshwater

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[1] The Amman-Zarqa and Yarmouk groundwater basins are roughly coterminous with the river basins bearing the same names.

FIGURE 1.
Main water uses; water flows and agricultural zoning in the Lower Jordan River Basin.
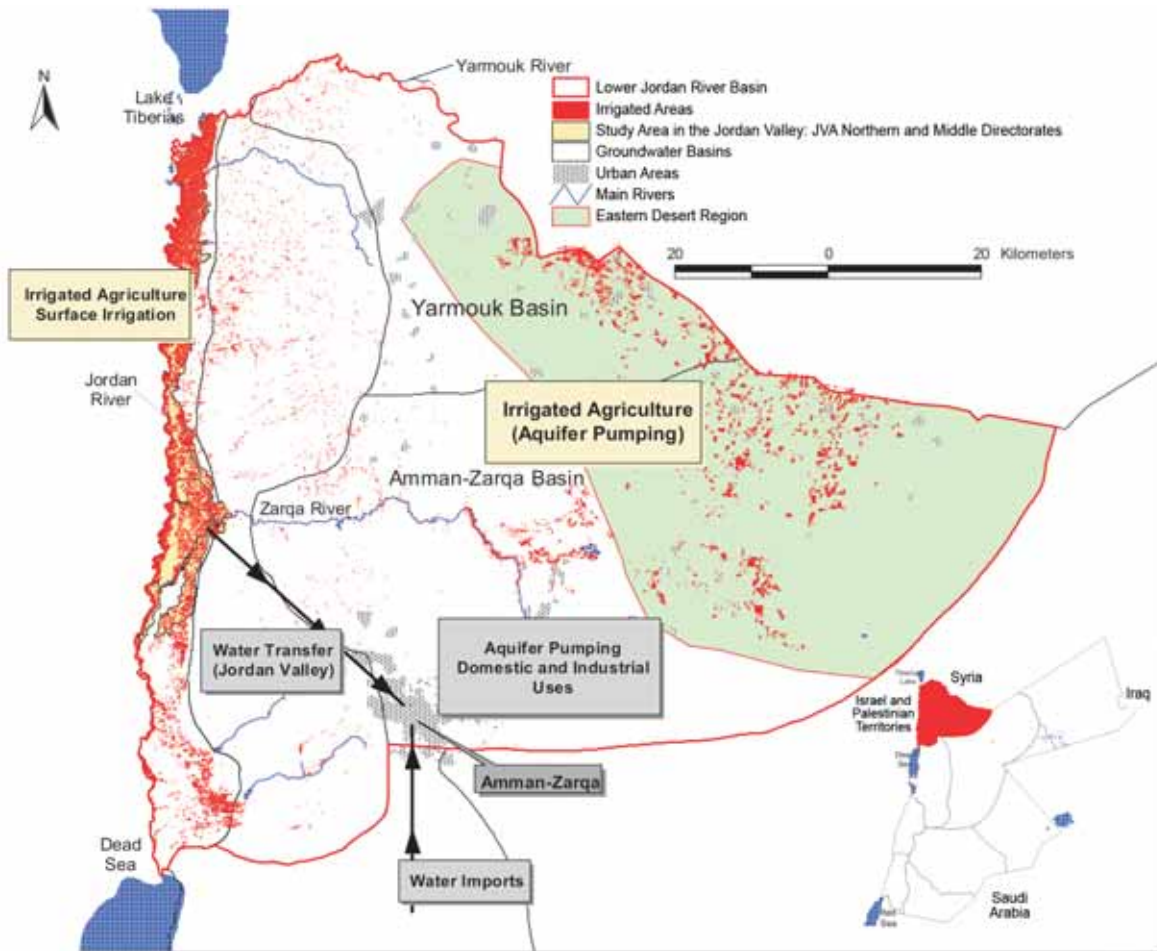
Note: The land-use classification is from the Ministry of Water and Irrigation (MWI) and the GTZ

diversion in the Jordan Valley, respectively. Section 5 (Discussion and Prospects) expands the discussion to the wider socio-political and economic context, in which water policies, in general, and pricing policy, in particular, are embedded—it discusses the disjuncture between expected and actual or estimated outcomes, points to commonalities and discrepancies between the two regions, and identifies measures that can improve water management in Jordan. Finally, the last section (Conclusion) provides conclusions made by the study.

The Policy Context: Debating Allocation and Pricing of Water in Jordan

The main water use areas, water flows and water allocation problems in the LJRB are schematized in figure 1. Amman receives water from the Jordan Valley, local aquifers, and from the southern and eastern outer basins. To meet the increasing domestic water demand, available options include: a) improving inflow from the Yarmouk River (with the newly built Wehdah Dam [Al-Jayyousi 2001]); b) transferring more water from the Jordan Valley to Amman (and hence reducing freshwater supply to agriculture, although treated wastewater [TWW] is sent back to the Jordan Valley); c) reducing abstraction from aquifers by highland agriculture in order to preserve water quality, avoid overdraft and reallocate water to cities (ARD and USAID 2001a; Chebaane et al. 2004); and d) relying on (costly) imports (THKJ 2004).

In the early 1990s, Jordan's officials evaluated the coming water crisis and began shifting their policy focus from supply augmentation towards demand management (Al-Jayyousi 2001). The World Bank and other development agencies emphasized the unsustainable use of water and were influential in calling for an agenda that would include demand-management instruments to encourage efficient water use, transfer water to nonagricultural higher-value uses (agriculture only generated 3.6 percent of the country's GDP in 2005 [Central Bank of Jordan 2005]), and reduce groundwater overdraft (Pitman 2004). The expectations were high and it was anticipated that this policy shift would reconcile the different goals central to the definition of 'Integrated Water Resources Management' e.g., economic efficiency, equity and environmental sustainability. Pricing of irrigation water was chosen as an instrument to reduce the demand for water (World Bank 2003a).

In the Highlands, the development of groundwater resources had been "exacerbated by relaxed controls on drilling operations, and the near absence of controls on licensed abstraction rates" (THKJ and MWI 1997b, 1998a). High rates of abstraction (up to 215% of the mean annual recharge in the AZB) prompted the government to react by designing a new water strategy in 1997 (THKJ and MWI 1997b). Pricing policies were deemed to assist in controlling groundwater abstraction with the ambitious task of taking abstraction rates "close to the annual recharge by the year 2005"[2] and to elicit shifts towards higher-value crops. The Groundwater Control Bylaw No.85, passed in 2002 and further amended in 2004, was designed to regulate groundwater abstraction through the establishment of a quota of 150,000 m^3/yr/well and a block-rate tariff system to be operative beyond the quota.

In the Jordan Valley, a block-rate tariff system associated with crop-based quotas had been in place for some time and the debate revolved on the possibility of increasing water charges—more expensive water was expected to bring about efficiency improvements and a switch to less water-intensive crops, thus making water available for Amman (World Bank 2003b). The block-rate tariff system would also assist in recovering state expenditures in public irrigation schemes: "The water price shall at least cover the cost of operation and maintenance (O&M) and, subject to some other economic constraints, it should also recover part of the capital cost of the irrigation water project. The ultimate objective being the full recovery of cost subject to economic, social and political constraints" (THKJ and MWI 1997a, 1998b, 2004c and JRVIP 2001).

Some of these reforms were to be embedded in the 1994 Agriculture Sector Structural Adjustment Loan (ASAL) jointly funded by the World Bank and the German KfW and designed with the prime objective of "supporting a transition to an optimal use of water and land resources" and addressing key problems in the sector: "the lack of

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[2] This target was revised in 2004 and shifted to 2020 (Pitman 2004).

a national water policy, competing sector institutions, and insufficient attention to demand management" (ASAL-JORDAN 1994; Berkoff 1994 and World Bank 2003a). The implementation of these policies proved to be problematic: according to Pitman (2004), Jordan had not asked for such lending and there was much doubt within the bank on the potential efficiency of pricing policies for allocating water, as well as conflicting views on the social and political impacts of the market-based measures that were being discussed. Pitman (2004) reports that "the Government was upset by the Bank's unwillingness to take account of the political realities of water and the difficulties increased agricultural water tariffs would cause" and argued that administrative allocation coupled with efficiency improvement would be more effective in saving water. These policies, whether embedded in the ASAL or in the 1997 Water Strategy, generated a substantial debate as shown by the occupation of Parliament in opposition to higher water tariffs, requiring further intervention by His Majesty the King (Pitman, 2004).

Jordan provides an interesting case where two different types of irrigation have developed: one controlled by the state (public management of a pressurized irrigation system in the Jordan Valley) and the other developed privately (albeit initially with state support: tube-well-irrigation in the Highlands). Because of the necessity for intersectoral reallocation, state policies and regulation are needed to effectively reduce the water use. This report examines the rationale, the potential and the current impact of two water-pricing policies. It attempts to answer the following questions:

- What will be the likely impacts of the application of the bylaw in the Highlands?

- What will be the financial impact of increasing water prices in the Jordan Valley, to cover O&M or capital costs?

- What is the likelihood of success of such policies in terms of water saving and raising economic efficiency, and what alternatives are available to meet these objectives?

Farming Systems in the Two Study Areas

Physical Features of the Lower Jordan River Basin (LJRB)

The Jordan River is an international river, which flows through a total area of about 18,000 km² pertaining to five countries namely, Jordan, Syria, Lebanon, Israel and Palestine (the West Bank). Its three headwater tributaries originate from the slopes of Mount Hermon (Lebanon) and flow southward into Lake Tiberias. With the outflow of the Jordan River from Lake Tiberias blocked by Israel, the Lower Jordan River receives the water chiefly from its main tributary, the Yarmouk River. Several temporary streams of lesser importance named 'side-wadis', as well as the larger Zarqa River, also incise the two mountainous banks and feed the Lower Jordan River.

The LJRB represents 40 percent of the entire Jordan River Basin, but only 7.8 percent of Jordan's total territory (figure 1). The basin thus defined is nevertheless the wettest area in Jordan and is endowed with 80 percent of the country's water resources. Figure 2 shows a cross section of the LJRB from west (the Jordan River) to east (the eastern desert area). The LJRB is divided into two main areas: the Jordan Valley and the remaining part referred to by the term 'Highlands'.

The Highlands are composed of a mountain range (uplands) running alongside the Jordan Valley and of a desert plateau (Badia) extending easterly to Syria and Iraq. The mountains are mostly composed of rangelands, with occasional olive trees and stone-fruit trees. The plateau has an average altitude of 600 m and is mainly used

FIGURE 2.
Cross section (west-east) of the Lower Jordan River Basin.
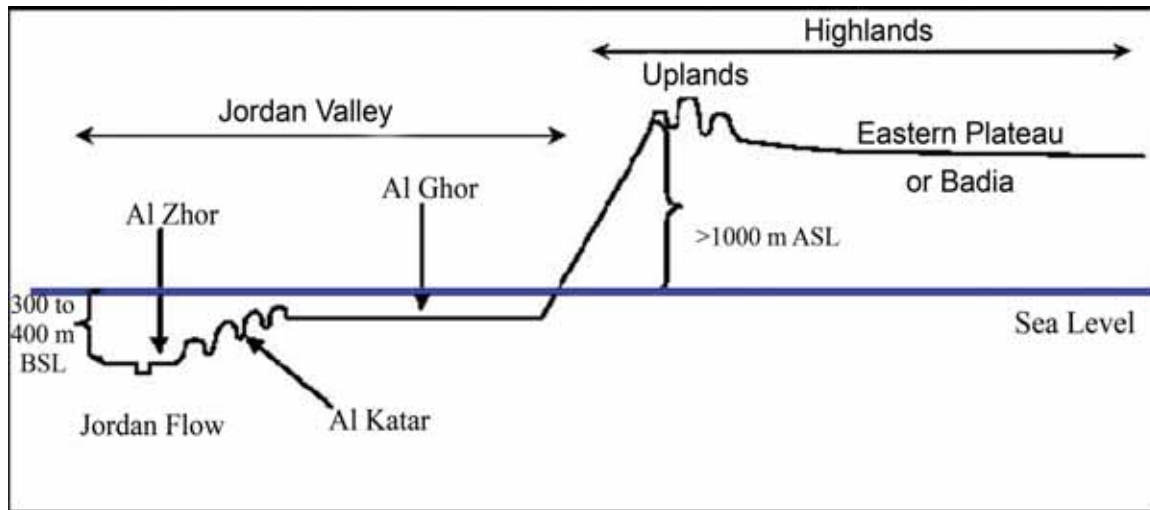
to grow cereals near the mountains, where main urban areas are concentrated and the rainfall is still sufficient for rain-fed agriculture. Eastward, precipitations become scarcer and only nomadic Bedouin livestock farming can be found, with a few localized plots of groundwater-based irrigated agriculture.

The Jordan Valley is a 110-km stretch between the Yarmouk River in the north and the Dead Sea in the south; it is the northern part of the Jordan Rift Valley, extending from Lake Tiberias in the north to the Red Sea in the south. Its altitude varies from 200 m (in the north) to 400 m (in the south) below sea level. The climate is semi-arid in the north and arid in the south. The Jordan River flows in a 30–60 m deep gorge through a narrow alluvial, fertile plain that is locally called Al Zhor (figure 2), which can be flooded during exceptional hydrologic events, as occurred in 2003. The rest of the valley, called Al Ghor, is a fertile area where irrigation schemes have been built.

This report focuses on two main regions of the LJRB: a) the eastern desert area, which is the only region of the LJRB Highlands that will be affected by the bylaw;[3] and b) the Jordan Valley. The eastern desert overlaps the Amman-Zarqa and the Yarmouk groundwater basins (figure 1). These basins represent 57 and 20 percent of the LJRB area, respectively, and include 38 percent of all irrigated areas in the LJRB.

History of Agricultural Development in the Highlands and in the Jordan Valley

Over the years, irrigation in the Jordan Valley has developed along the side-wadi valleys and on their alluvial fans, and wherever springs were available (Khouri 1981). Large-scale public irrigation dates back to the establishment of the Jordan Valley Authority (JVA) and to the construction, between 1958 and 1966, of a main 69-km concrete canal—the King Abdullah Canal (KAC)—which parallels the Jordan River on its eastern bank. In 1962, a land reform led to the formation of thousands of small intensive farms (3.5 ha on average), and the settlement of numerous families, including Palestinian refugees (Khouri 1981; Van Aken 2004). During the same

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[3] Some located in the south of the Jordan Valley which are using groundwater, as well as farmers located in the surroundings of the Azraq oasis (in the east of the country) and in the plateaus south of Amman will be affected by the bylaw (Venot 2004a). They, however, are not considered in the present study.

period, several governmental projects aiming at settling Bedouins were implemented in the Highlands (and notably in the eastern desert area). Land was irrigated by the public, while deep wells were managed by the Water Authority of Jordan (WAJ). Although these projects focused on subsistence and fodder crops, and seemed to have failed in most cases, many Bedouins adopted the idea and began to drill their own wells and engage in private irrigation, often keeping part of their herd too. This was the origin of a modern market-oriented agriculture developed by small to medium entrepreneurial farmers, supplying growing cities and exporting their surplus produce around the Middle East (Elmusa 1994; Nachbaur 2004; Venot 2004a).

Irrigated agriculture thrived in the late 1970s and 1980s. In the Jordan Valley, irrigation facilities were improved and expanded by the government, and modern irrigation and cropping techniques (greenhouses, drip irrigation, plastic mulch, fertilizer, new varieties, etc.), together with cheap labor from Egypt, became widely available. In the Highlands, energy costs decreased, well-drilling techniques improved, and land was cheap, fertile and immune to diseases. During this period, agricultural revenues increased tenfold for vegetables and more than doubled for fruits: irrigated agriculture in Jordan enjoyed a boom in production and economic profitability, which was described by Elmusa (1994) as the "Super Green Revolution."

With increasing economic competition from the surrounding countries (Turkey, Lebanon and Syria) and the loss of the Gulf export market (due to both fears of the impact of the use of wastewater in vegetable production and the first Gulf war) in the 1990s, the profitability of Jordanian agriculture decreased, strongly affecting farm revenues (GTZ 1995; Fitch 2001; Jabarin 2001). The sector's contribution to Jordan's Gross Domestic Product declined from 8.1 percent in 1991 to 3.6 percent in 2005 (Nachbaur 2004 and Central Bank of Jordan 2005). Competition for water also increased. Freshwater has been increasingly transferred from irrigated agriculture (in the Jordan Valley) to urban uses (in the Highlands)—(figure 1 and Courcier et al. 2005),

affecting the agriculture sector, which receives ever-decreasing quantities of water and becomes more vulnerable to droughts. In exchange, agriculture in the southern part of the Jordan Valley is increasingly supplied with treated wastewater blended with freshwater coming from the Zarqa River (see McCornick et al. 2001, 2002; THKJ et al. 2002; Scott et al. 2003; THKJ and MWI 2004b; JICA 2004).

Farming System Characterization

Methodology

Farming systems were analyzed in order to identify the different types of farms found in the Jordan Valley and in the Highlands. Understanding the socioeconomic processes occurring at this micro-scale will facilitate us to better foresee the adjustments and the strategies developed by farmers in a changing context, and to assess the impact of water-pricing policies on farmers. By complementing this micro-level analysis with regional data (statistic data, satellite image analysis, etc.), we can assess the possible evolution of regional irrigated agriculture as a whole.

Extensive farm surveys were carried out in the Highlands by ARD/USAID in 2000/2001 (ARD and USAID 2001a; Fitch 2001; Chebaane et al. 2004), but economic analyses were mainly based on cropping patterns. This makes it difficult to discriminate responses by type of farmer. In order to sketch out farming systems that combine typical cropping patterns with socioeconomic characterization (profile of the farmer, land tenure, labor use, costs, etc.), 30 farm surveys were carried out during the spring of 2003. Farming systems were then modeled in economic terms based on crop budgets, the consistencies of which were checked with ARD/USAID data. Likewise, the main farming systems in the Jordan Valley were identified and their economics were modeled on 50 farm surveys carried out during the spring of 2003, the consistencies of which were checked against other studies (Salman 2001b; ARD and USAID 2001c).

Farming Systems in the Highlands

This section focuses on the eastern desert region, which totals an irrigated area of 11,835 ha; 50 percent of which is planted with olive trees, 34 percent with stone-fruit trees (peach and nectarine trees essentially) and 16 percent with vegetables (see appendix 3). The Highland surveys led to the identification of three main categories of farming systems (see table 1; a detailed description can be found in appendix 1). They include settled Bedouins who have taken up vegetable (and sometimes fruit-tree) cultivation, and urban-based entrepreneurs involved in high-value fruit production and closely managing their farm, although they often reside in Amman. Both Bedouins and entrepreneurs, at times, also maintain olive orchards. Other absentee-owners adopt more extensive agricultural systems (with open-field vegetables or olive trees) and employ a manager. The main differences between these farming systems are the degree of capital use and intensification, the type of land tenure and the direct/indirect type of management. All farms are equipped with a pressurized irrigation network and crops are watered by drippers.

Farming Systems in the Jordan Valley

We focus here on the northern and middle directorates of the Jordan Valley where JVA's allocation rules apply. The irrigated area is 19,345 hectares, with 43 percent of the area for vegetables (both in open field and under greenhouses), 42 percent for citrus, and the remaining area for banana and cereals (cf. appendix 3). A conversion from the earlier open channel irrigation network to pressurized systems was completed in the mid-1990s. Irrigation water is now provided to farmers through pumping stations that draw water directly from the King Abdullah Canal and supply collective pressurized networks that serve areas of approximately 400 to 500 ha.

Just like in the Highlands, farming systems in the Jordan Valley are very diverse. Generally, farming systems in the Jordan Valley are more intensive than in the Highlands: farms are smaller (3.5 ha on average against 20–25 ha in the Highlands) and net benefit per hectare (for similar crops and/or farming systems) is higher. The Jordan Valley survey identified five main categories of farming systems (see table 2 and appendix 1 for more details). They include:

TABLE 1.
Profile of main farming systems (eastern desert region; LJRB Highlands).*

	Settled Bedouins			Stone-fruit tree entrepreneurs		Absentee-owners	
	Family vegetable farm	Mixed farm-vegetables and olive trees	Family fruit-tree farms	Intensive entrepreneurial farmer	Intensive absentee-owner—stone-fruit trees and olive trees	Prestige olive tree farm	Extensive open-field vegetables
Land tenure/water access	Rent	Ownership	Ownership	Ownership	Ownership	Ownership	Ownership/Rent
Farm area range (ha)	20–25	'20–25'+'10–15'	10–20	25–35	40–80	15–35	20–25
Net revenue (US$/ha/yr)**	1,100	621	6,900	16,000	14,850	300	600
Net revenue (US$/farm/yr)	24,750	21,750	103,500	480,000	891,000	7,500	13,500
Number of wells	1	1	1	1	2	1	1

Notes: * The data represent mean values obtained during a survey of 30 farmers in the eastern desert of the LJRB Highlands during 2003
** The net revenue is the gross income minus all production costs (the latter includes amortization of capital, financial costs, and hired labor valued on the basis of daily wages observed in the Highlands)

1) family farmers, who either own or rent the land and grow vegetables in open fields; 2) entrepreneurial farmers, who adopt capital- and labor-intensive techniques such as greenhouses, and earn high return on investments; 3) citrus orchards in the north of the Jordan Valley, managed either by the family who owns the land or by absentee-investors interested in the social rather than the economical value of their farm; 4) highly profitable bananas grown in the extreme north of the Jordan Valley; and 5) mixed farms with more extensive vegetable cultivation, associated with small orchards (the poorest category of farmers). The same features mentioned above, for the Highlands, differentiate farming systems in the Jordan Valley. In addition, irrigation technology is also very important to characterize each farming system in the Jordan Valley as it determines the different strategies that farmers may develop to adjust to an increase in water prices.

TABLE 2.
Profile of the main farming systems (Jordan Valley, northern and middle directorates).*

			Citrus farms		Banana farms		Mixed farms
	Open-field vegetable family farms	Entrepreneurial greenhouse farms	Family farms***	Absentee-owner and family farms	Family farms	Entrepreneurial farms	Poor family farmers
Land tenure	Rent/Ownership	Rent/Ownership	Ownership	Ownership	Ownership	Ownership/Rent	Rent/Share cropping
Farm area range (ha)	3–6	6–10	3–6	1–20	1–5	1–5	1–3
Number of family workers	2–5	1–2	3–5	1	3–5	1–2	4–10
Water quota (m³/ha/yr)	5,050	5,050	10,100	10,100	15,000	15,000	5,050
Main irrigation system	Micro-irrigation	Micro-irrigation	Micro-irrigation	Gravity irrigation	Gravity and micro-irrigation	Micro-irrigation	Gravity irrigation
Net revenue (US$/ha/yr)**	3,800	7,500	1,250	400	7,000	12,500	1,050
Net revenue (US$/farm/yr)	17,100	60,000	5,625	4,000	21,000	37,500	2,100

Notes: * The data represent mean values obtained during a survey of 50 farmers in the Jordan Valley during 2003

     ** As in table 1

     *** Data for absentee-owners using micro-irrigation systems (less than 10% of all citrus farms) are not shown here

Pricing Water to Control Groundwater Overabstraction in the Highlands

The Problem of Groundwater Overdraft

In Jordan, the first wells were dug during the 1930s in the Azraq oasis, and water for both local agriculture and domestic uses in Amman was pumped from them. Wells also existed along side-wadis and tapped groundwater from neighboring shallow aquifers. In the Highlands and notably in the eastern desert region, the shift from animal husbandry to agricultural activities (based on the exploitation of groundwater resources) was a state policy that existed as far back as the 1960s (when diesel motor pumps were first introduced). Groundwater exploitation was further developed in the 1970s and 1980s with the introduction of new drilling techniques and the establishment of a new electric network that allowed the use of electric pumps. Groundwater development also enabled to meet the domestic and industrial water needs in Jordan.

Recent records from the Ministry of Water and Irrigation (MWI) show that, between 1996 and 2003, overall groundwater abstraction in the LJRB has continuously increased. Domestic use has steadily risen and industrial use has remained stable. However, agricultural groundwater abstraction in the LJRB has continuously decreased from 158 to 109 Mm^3/yr despite an increase in irrigated areas. This increase in irrigated areas is in part due to policies that support olive oil production and subsidize the planting of olive trees, although ensuring an increase in rain-fed production was their main objective (World Bank 1999; WTO 2001). Reasons for this decrease in groundwater abstraction are not clear yet.[4]

According to the official figures of the MWI, total groundwater abstraction in the LJRB in 2004 reached 248 Mm^3, about half of which was used in agriculture. Of the 2,804 wells registered by the WAJ in Jordan, 1,412 wells were located in the LJRB.[5] The total abstraction corresponds to 157 percent of the annual recharge evaluated at 158 Mm^3/yr (THKJ 2004). In 2004, at the subbasin level, local groundwater abstraction reached 215 percent and 125 percent of the annual recharge in the AZB and Yarmouk basins, respectively. Taking into account the return flows from municipal/industrial and irrigation uses, brings down the overall net depletion of aquifers of the LJRB to 119 percent of their annual recharge. Net depletion in the AZB and Yarmouk basins averages 159 and 98 percent of their annual recharge, respectively.[6]

The resulting drawdown of the aquifer is paralleled with a decline in water quality (due to increasing salinity and use of fertilizers and pesticides), and it is feared that both domestic and agricultural uses could be jeopardized, resulting in further costly investments in water treatment (ARD and USAID 2001a; Chebaane et al. 2004; JICA 2004; Venot 2004a). In addition to these salinity problems, aquifer overdraft incurs growing pumping costs to all users and contributes, in some instances, to the abandoning of wells (Chebaane et al. 2004).

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[4] Possible reasons for this trend include: a decreasing pumping capacity of wells as the water table drops; under-reporting due to the tampering or destruction of water meters; shifts from vegetables to fruits and from fruits to olive trees (Chebaane et al. 2004), and from furrow to drip irrigation, which may have lessened water abstraction.

[5] Out of these 1,412 wells, most are agricultural wells (1,009), while 325 wells are used for domestic purposes and only 78 wells are used by the industrial sector.

[6] Net values are obtained by considering all uses in the LJRB (as recorded by the MWI) and efficiencies of 80 percent for agricultural uses and 70 percent for industrial and domestic uses. After accounting for return flows, Courcier et al. 2005 found higher values, with net abstraction at 161 percent and 135 percent of the annual recharge of the AZB and the Yarmouk basins, respectively. The difference observed for the Yarmouk Basin is due to the fact that abstraction from the governmental Mucheibeh wells (about 20 Mm^3/yr), in the north of the country, is not accounted for here (they were considered as depleting the Yarmouk Basin in Courcier et al. 2005).

Groundwater Policies and Bylaw No. 85 of 2002

Faced with such problems and the evidence of a growing overall scarcity of water, the Government of Jordan has tried to reorient its water policy through the 'Water Strategy Policy' of 1997 (THKJ and MWI 1997b). Several measures have been taken to decrease groundwater abstraction, including: a) freezing of well-drilling authorizations in 1992; b) implementation of a tax of US$0.35 (hereafter noted $) per cubic meter for any water pumped and sold/used for industrial or aesthetic purposes (since 1994) as well as for domestic purposes (since 2002); c) promulgation of the 'Groundwater Management Policy' in 1998 (THKJ and MWI 1998a) d) a campaign to equip private wells with water meters; e) reduction of losses in urban networks; f) promotion of less water-intensive/high-value crops, and finally g) promulgation of the 'Groundwater Bylaw No. 85 of 2002' (Chebaane et al. 2004). Government policies called for a massive reduction in groundwater abstractions (by 86 Mm^3/yr until 2010, and by a further 36 Mm^3/yr until 2020) by 'pumpers' in the Highlands (World Bank 2001b). Water savings elicited by the new water charges were expected to reach 40 to 50 Mm^3 over the next 3 to 5 years (Checchi and Devtech 2003).

From 1962 to 1992[7] licenses to drill agricultural wells were granted by the government. Two-thirds of the licenses granted specified the maximum amount of water that each farmer could pump (most commonly 50,000 or 75,000 m^3/yr/ well, and sometimes 100,000 after 1990; Fitch 2001), but these limits were never enforced (THKJ and MWI 1997b, 1998a). Farmers, in the eastern desert area do not feel concerned by these limits, as they rarely mention them during interviews and often pump water in excess of the specified amount. Wells that do not have an abstraction license are considered 'illegal'.

In 2002, the groundwater bylaw introduced a system of quotas combined with taxation of any use exceeding the quota. This bylaw was officially presented as a conservation tool to preserve the quality of the main Jordanian aquifers (THKJ and MWI 2002b; THKJ 2004). It introduced effective metering and fee collection on water use, and constituted an important first step in the direction of limiting agricultural groundwater abstraction. However, instead of endorsing the previous license quotas, the bylaw raised the maximum limit of abstraction up to 150,000 m^3 per year and per well—a volume much higher than the limits mentioned in the licenses. Rules for the taxation of water pumped above this limit are detailed in table 3.

TABLE 3.
Water prices according to the volume abstracted in private agricultural wells.

Quantity of water pumped	Water prices in wells with former abstraction license —2002 bylaw	Water prices in wells with former abstraction license —2004 amendment	Water prices in wells without former abstraction license
0–100,000 m^3	Free	Free	$0.035/$m^3$ (JD 0.025)
101,000 –150,000 m^3			$0.042/$m^3$ (JD 0.03)
151,000–200,000 m^3	$0.035 m^3 (JD 0.025)	$0.007/$m^3$ (JD 0.005)	$0.05/$m^3$ (JD 0.035)
More than 200,000 m^3	$0.085/$m^3$ (JD 0.06)	$0.085/$m^3$ (JD 0.06)	$0.098/$m^3$ (JD 0.07)

Source: THKJ and MWI 2002b, 2004a: as mentioned in bylaw No.85 of 2002

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[7] No drilling license has been delivered after 1992. However, the number of operating wells is continuously increasing as illustrated by WAJ records of 2004. This may be due to the development of well metering.

It is reported that farmer-interest groups have obtained the canceling of the former licenses against the acceptance of the principle of taxing volumes abstracted above a certain limit (Pitman 2004) — technical, institutional and political difficulties have been impediments to the effective implementation of the reforms.

Compared with other water fees (notably on industrial and municipal groundwater use charged at $0.35/m^3$), the fees summarized in table 3 are very low. Lower quotas and higher tariffs have been designed for unlicensed wells.[8] In April 2004, the first bills, corresponding to water consumption between 01/04/2003 and 31/03/2004, were sent to farmers. Until November 2005, no employee of the MWI had been entrusted with the task of collecting fees. Because of this slackness in the regulation, farmers have not yet paid these bills. However, fees are cumulative and could still be collected later.

Between May and August 2004, the regulation has been modified by introducing two amendments: the first one being a lowering of the already low fees for the volumes abstracted in licensed wells between 150,000 and 200,000 m^3/yr. Volumes of water abstracted are to be charged at $0.007/m^3$ instead of $0.035/m^3$ (cf. table 3). The second amendment relates to abstraction from brackish aquifers: the higher the water salinity, the lower the fee would be (not shown in the table). This will greatly reduce the impact of the bylaw in the south of the Jordan Valley and, as such, banana farmers in the area will continue to deplete the valley aquifer (Venot 2004a). In the Highlands, the second amendment will not have much impact since the two main aquifers, in general, have a salinity level lower than 1,350 ppm (ARD and USAID 2001b), which is below the limit where this amendment becomes applicable.

Implementing the bylaw is now possible since most of the wells are equipped with water meters (94% according to Al-Hadidi [2002]). However, several more problems must be underlined. First of all, in 2001 only 61 percent of the meters were functioning properly (Fitch 2001) and, although major replacement campaigns have been conducted, this problem is likely to recur. Moreover, there is a significant lack of material and human resources since controls are done by a small number of employees of the Water Authority of Jordan (WAJ). In 2006, there were, for example, only three teams to control the entire LJRB which is inadequate to effectively control farmers' abstractions.[9]

Another problem is that the meters are still not protected. Experience in the Jordan Valley has shown that if water meters are not protected in a box closed with a padlock, they are likely to be broken or at least fiddled with (Courcier and Guérin 2004). As the meter is paid for by the farmer, the risks of deterioration are reduced but, on the other hand, tampering is quite easy and could become a common practice.[10]

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[8] Unlicensed wells in Jordan are mainly located near the Azraq oasis out of the LJRB limits and in the south of the Jordan Valley, where they tap the brackish aquifer. For the sake of simplification, we will consider that all wells in the Highlands of the LJRB have a license.

[9] According to the head of one of these teams, each team is made up of two engineers in charge of water meter reading, one technician in charge of meter maintenance and two drivers. The team in charge of the surroundings of Amman is supposed to control around 400 wells monthly. This means about 10 wells per working day and per group of readers (the team can be divided into two groups, if cars are available). Wells are very widely scattered and vehicles are not always available. These conditions impede frequent controls.

[10] On an anecdotal plan, during one survey in the Highlands, a farmer told us that he telephoned the WAJ in Amman and managed to have the controller come to his farm to read the meter again, two days after he had received his water bill. The first time, the water bill indicated fees to be paid based on a consumption of 270,000 cubic meters. After this visit and a new reading of the meter, the WAJ employee agreed that the bill was not accurate since the consumption of the well 'only' reached 148,000 cubic meters. Thanks to a phone call, the farmer managed to save about $4,200 either because the first evaluation was really inaccurate, or because the farmer tampered with the meter, bribed the government official, etc.

Financial Impacts and Expected Adjustments in the Eastern Desert's Farming Systems

Based on the description of farming systems presented earlier, this section explores the financial impact of the bylaw on each type of farming system, and how farmers could mitigate or minimize it by adopting appropriate strategies.

Financial Impacts of the Bylaw on Farming Systems

Table 4 summarizes these financial impacts (before [scenario A] and after [scenario B] the 2004-amendment) on farms with licensed wells, assuming that actual withdrawals remain unchanged and that farmers squarely foot the extra water bill.

Settled Bedouins with their fruit-tree farms and absentee-owners with their 'prestige' olive-tree farms will not be affected by the bylaw since their current annual water consumption is lower than 150,000 m^3 per well. Fruit-tree farmers will be very slightly affected by the bylaw. Table 4 illustrates that the amendment considerably softened the financial impact of the bylaw on settled Bedouins (with vegetables or mixed farms) and on absentee-owners (with vegetables).[11]

To assess possible behaviors by farmers, it is necessary to know what the present irrigation

TABLE 4.
Bylaw impact on farm income in the eastern desert.[12]

		Settled Bedouins			Stone-fruit tree entrepreneurs		Absentee-owners	
		Family vegetable farm	Mixed farm—vegetables and olive trees	Family fruit-tree farms	Intensive entrepreneurial farmer	Intensive absentee-owner—stone-fruit trees and olive trees	Prestige olive tree farm	Extensive open-field vegetables
Net revenue (US$/ha/yr)		1,100	621	6,900	16,000	14,850	300	600
Water use (m³/farm/yr)		216,000	284,750	150,000	300,000	435,000	137,500	216,000
Actual water abstraction costs	US$/ha/yr	2,181	1,513	1,373	1,310	1,310	432	1,875
	US$/farm/yr	49,072	52,955	20,595	39,300	78,600	10,800	42,187
	% of current revenue	198	243	19.3	8.2	8.8	144	312
Scenario A—Extra water costs bylaw	US$/ha/yr	138	259	-	342	108	-	138
	US$/farm/yr	3,110	9,050	-	10,250	6,475	-	3,110
Scenario B—Extra water costs bylaw and amendment	US$/ha/yr	76	217	-	295	61	-	76
	US$/farm/yr	1,710	7,621	-	8,850	3,675	-	1,710
Revenue decrease (% of current revenue)	Scenario A	12.6	41.6	-	2.1	0.7	-	23.0
	Scenario B	6.9	35	-	1.8	0.4	-	12.7

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[11] For mixed farms owned by settled Bedouins, we have presented a case where farmers have only one well. In these conditions, impacts of the bylaw are expected to be high. However, many of these farmers have two separate wells that they use alternatively to irrigate two different plots. As such, the bylaw will not have any impact on them and, therefore, no changes are expected to occur.

[12] Water abstraction costs can be divided into operational costs of the wells (diesel or electricity) and renting costs for tenants or maintenance/depreciation costs for owners (Venot 2004a).

efficiency in the eastern desert is, and to what extent the quantity of water supplied to crops matches their water requirements. Table 5 indicates that orchards (especially olive trees)[13] are under-irrigated with regard to full agronomic requirements: further water savings are thus unlikely. On the other hand, vegetable farmers seem to over-irrigate their crops: they abstract nearly 160 percent of the net crop water requirements, as evaluated by Fitch (2001). In this condition, the overall efficiency of water use only reaches 62 percent and can be improved without affecting production. If we assume that on-farm irrigation efficiency can reach a maximum of 75 percent, vegetable farmers could decrease the amount of water they pump from 216,000 m^3 to 179,700 m^3, while still meeting net crop water requirements.

area as well (water use efficiency remains constant); 3) strategy C is like strategy B (pumping of 150,000 m^3/well/yr), but farmers also improve their irrigation efficiency up to 75 percent and so reduce their cultivated area to a lesser extent; 4) strategy D expects farmers to increase irrigation efficiency up to 75 percent (still meeting crop water requirements): they keep the same cultivated area and reduce water abstraction accordingly; and 5) strategy E is like strategy D (irrigation efficiency increase up to 75%) but farmers do not reduce abstraction and use the water saved to increase the cultivated area.

We hypothesize that irrigation efficiency can be improved up to a maximum of 75 percent through: a) a better design of farm network; b) the use of higher-quality emitters; c) better on-farm

TABLE 5.
Evaluation of gross water abstraction and net water requirements in the eastern deserts of the LJRB (m^3/ha).

	Vegetables	Olive trees	Other fruit trees
Net water requirement (adapted from Fitch 2001, cf. appendix 2)	5,990	6,880	10,320
Gross water abstraction (based on interviews with farmers)	9,600	5,500	10,000

The financial impacts at the farm level of five different strategies are presented below:
1) strategy A assumes that farmers pay their water bills without changing their water consumption pattern (business as usual, see table 6);
2) strategy B assumes a maximization of water savings by decreasing the use of water to 150,000 m^3/well/yr (so that no fee needs to be paid), and a proportional reduction in the cultivated

operations; d) use of skilled labor; and e) a better monitoring of soil water reserves that would allow fine-tuning of irrigation. We consider that such changes in the open field vegetable farming systems require similar investments than in the Jordan Valley ($970/ha; see section on Water Pricing in the Jordan Valley). Improving irrigation efficiency also induces additional running costs ($370/ha/yr; Courcier [2006][14] and an increase in

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[13] Only 56 percent of olive orchard water requirements are met: this very low satisfaction of the demand of olive trees (also observed by Hanson 2000) illustrates their drought-tolerance quality and also their very low profitability. Deficit irrigation highlights also that these orchards have a high social value and that their conventional economic profitability is not of prime importance to farmers. Farmer strategies do not boil down here to profit maximization.

[14] The incremental cost for increasing efficiency up to 75 percent in open field vegetable farms can be broken down into $90/ha/year of incremental wages and $280/ha/year for dripper lines as well as for primary and secondary pipes, filters and tensiometers. Due to an increase in the value of the production, increasing efficiency is cost effective. Moreover, the cost is also lower than the extra revenue that farmers would derive from expanding their fields and using saved water. In spite of the availability of this option, there are other constraints that deter 'farmer-maximizers' from increasing irrigation efficiency in their systems. These include aversion to risk or to incremental labor and time to be spent on the farm, as well as a low investment capacity, especially in a situation where most Bedouin farmers are already indebted (Chebaane et al. 2004)—(see Molle and Berkoff [2007] for a detailed description of the reasons that hinder intensification and see the section on 'Water Pricing in the Jordan Valley', where this argument is further developed). To increase efficiency above 75 percent, there is an additional need for skilled engineers as well as computerized systems: this would induce high costs (compared to farmer's revenue: $1,400/ha/yr [Courcier 2006]) that make such an evolution unlikely.

the value of the production by 10 to 15 percent. The net financial result is positive with an additional revenue of about $150/ha/yr ($100/ha/yr in absentee-owner systems). Contrary to common assumptions that farmers can easily save substantial amounts of water by just being 'more careful', improvements demand better knowledge and material and thus have a cost involved, especially in a situation where micro-irrigation is already in use. In spite of the cost incurred, these improvements can also generate benefits due to increase in yields. The willingness/ability of farmers to achieve these improvements will depend on their relative costs and benefits which are difficult to assess.

Adjustments to be Observed in Open-field Vegetable and Mixed Farms

Table 6 summarizes the impacts of the five strategies on vegetable farms run by settled Bedouins or absentee-owners.

For settled Bedouins who cultivate vegetables in open fields, paying the water fee (strategy A) entails a decrease in revenue of 6.9 percent, even though farmers already face water costs that are higher than their net income (cf. table 4). This impact remains modest and it is unlikely that it will alter the perception of the farmers on the constraints to intensification. In comparison, reducing the land area until water abstraction is curtailed down to 150,000 m^3/well/yr entails a decrease in income of 31 percent (strategy B) and 5 percent (strategy C), respectively. Improving efficiency without increasing cropping area (strategy D) induces an increase in revenue by 13 percent (depending on the yield responses to better irrigation uniformity). Finally, strategy E appears as the best option with a 29 percent increase in farm revenue, following an expansion of the irrigated area and higher yields.

In general, technology costs are higher than the savings in the water bill unless prices are

TABLE 6.
Financial effects of the bylaw (with amendment) on settled Bedouins' farms and absentee-owner vegetable farms according to five response strategies.

		Settled Bedouins		Absentee-owner
		Open-field vegetable family farm	Mixed farm— vegetables and olive trees	Open-field farm
Strategy A (business as usual)	Volume abstracted (m^3/well/yr)	216,000	284,750	216,000
	Change in revenue—US$/ha/yr and % of current revenue	$ -76 (-6.9%)	$ -217 (-35%)	$ -76 (-12.7%)
Strategy B	Volume abstracted (m^3/well/yr)	150,000	150,000	150,000
	Change in revenue—US$/ha/yr and % of current revenue	$ -341 (-31%)	$ -264 (-43%)	$ -186 (-31%)
Strategy C	Volume abstracted (m^3/well/yr)	150,000	150,000	150,000
	Change in revenue—US$/ha/yr and % of current revenue	$ -57 (-5%)	$ -174 (-28%)	$ -16 (-3%)
Strategy D	Volume abstracted (m^3/well/yr)	179,700	248,450	179,700
	Change in revenue—US$/ha/yr and % of current revenue	$ +141 (+13%)	$ -31 (+5%)*	$ +91 (+8%)
Strategy E	Volume abstracted (m^3/well/yr)	216,000	284,750	216,000
	Change in revenue—US$/ha/yr and % of current revenue	$+326 (+29%)	$+4 (<+1%)*	$+165 (+15%)

Note: * Water abstraction for olive trees has been considered constant. The low profitability of the orchard is not modified

taken at very high levels (improving irrigation systems in open field vegetable farms would cost five times as much as the maximum resulting savings in the water bill, the cropping area being considered constant). Furthermore, the existing incentives to intensification (i.e., higher revenue and yields due to better uniformity of irrigation) would be reduced by water price increases, since relative gains would be lower than at current water prices. Finally, in regions with abundant land, savings derived from improved irrigation efficiency can be used to expand the cropping area in a cost-effective way (strategy E): this defeats the conservation objective of pricing mechanisms, but is economically interesting. Since they deplete incomes, notably in the less productive farming systems, high water costs may also trigger adoption of higher-value crops and thereby, enhance water productivity (see below).

Conclusions for absentee-owners are similar: strategy E is the best option (+15%) and strategy B, the worst. Another possible strategy for well-owners would be to rent out their wells to major entrepreneurial fruit-tree farmers or to cities (cf. below). It is noteworthy that these conclusions would not have been significantly different with the pre-amendment price of water.

To avoid paying any water fee (like in strategy B), settled Bedouins with mixed farms would have to decrease their current abstraction of 284,750 m^3/well/yr by 47 percent. This, however, will result in a drop in the income by 43 percent (as the farmer would first have to abandon his olive orchard and then shrink its vegetable area). The average income is so low that paying the fees (strategy A) would entail a 35 percent decrease in revenue (pre-amendment water prices would have sent a stronger signal but at the cost of more than half the current income). Strategy C would be slightly better with an expected decrease in revenue of about 28 percent. Finally, as in the case of vegetables in the open field, keeping or expanding the cropping area (or changing crops) and improving efficiency (strategies D and E) would offset the financial loss due to the bylaw. The last two strategies (D and E) entail a 5 and 1 percent increase in farmers' revenue, respectively. Benefits derived

from strategies D and E are lower in mixed farms than in open-field vegetable farms, because of the much higher water abstraction that reaches the high tariff-block (table 3).

Adjustments to be Observed in Entrepreneurial Fruit-tree Farms

Intensive stone-fruit tree entrepreneurs will be slightly affected by the bylaw. In line with their large water abstraction, farmers will have to pay high water fees (between $3,675 and $8,850 per farm according to the farming system, cf. table 4). However, due to the high profitability of these farming systems, this increase in water costs will have a negligible impact on farmers' revenue, which would decrease by less than 2 percent.

In all likelihood, therefore, strategy A (business as usual) will prevail, i.e., farmers will squarely foot the bill. In systems where trees are under-irrigated (cf. table 5) and efficiency is already high (stone fruit orchards are closely managed and irrigation networks operate at their optimum), adoption of strategies C and D (increasing irrigation efficiency) are very unlikely. Strategies B and E, however, might also be feasible if farmers have the possibility to rent an additional nearby well. This new well would provide for both the shortfall of water for the old orchard (strategy B) and the additional water needed for expansion (strategies B and E). The availability of vast expanses of flat desert would make this option quite easy to adopt (although it is illegal, because areas attached to a particular well are normally specified), and economic calculations show that such an expansion would be profitable, even with the additional cost of renting a well (about $18,000/well/year). This rent is higher than the total revenue generated by extensive open-field farms managed by absentee-owners (cf. table 4). Renting out their wells would thus provide them with a regular income, higher than the one they already have (or that they could have if they adopted any of the strategies from A to E), which can be attractive if they can also find other means of employment. This could accentuate the current increase in stone-fruit production by entrepreneurial farmers in the

Highlands. In such a case, there will not be any water savings. Nevertheless, a higher productivity will be achieved through the shift from vegetables to fruit trees.

Water Savings at a Regional Scale

Evaluation of Agricultural Water Abstraction in the Highlands

In 2004, the MWI and the GTZ carried out a land-use mapping based on two mosaics of LandSat images, dated August 1999 and May 2000, respectively. These data were used to estimate irrigated areas within the Amman-Zarqa and Yarmouk groundwater basins, and are summarized in appendix 3. Of the 14,460 hectares cultivated in the two groundwater basins mentioned above, 82 percent is located in the eastern desert area, i.e., a total area of 11,835 hectares.

Based on these estimates of irrigated areas and data on crop water use, we can approximate the groundwater abstraction in the Amman-Zarqa and the Yarmouk basins (cf. table 7). These evaluations are compared with earlier estimates obtained from other sources. Annual recharge values are drawn from THKJ (2004).

Table 7 indicates that the gross agricultural abstraction records of the MWI are 20 percent less than other evaluations. The MWI may underestimate present agricultural abstraction partly because of the problems surrounding water metering that have been mentioned above. In "our estimate," gross abstraction rates are presently reaching 249 and 195 percent of the annual recharge in the Amman-Zarqa and Yarmouk basins, respectively. By computing return flows of irrigation and municipal/industrial uses, the exploitation rates decreased to 179 and 168 percent of the annual recharges of the Amman-Zarqa and Yarmouk basins, respectively (net abstraction of 121 and 63 Mm^3/yr).[15] These estimates will be used as a baseline situation in the following sections to assess the amount of possible water savings in the two groundwater basins considered here.

TABLE 7.
Different evaluations of agricultural groundwater abstraction in the Amman-Zarqa and Yarmouk basins.[16]

	Amman-Zarqa Basin (Annual recharge: 67.5 Mm³/yr)			Yarmouk Basin (Annual recharge:37.5 Mm³/yr)		
	Total abstraction		Agricultural abstraction (Mm³/yr)	Total abstraction		Agricultural abstraction (Mm³/yr)
	Volume (Mm³/yr)	% of annual recharge		Volume (Mm³/yr)	% of annual recharge	
Earlier estimates						
MWI—gross abstraction records for the year 2004	145	216	60	47	100	37
Total gross abstraction according to ARD (2001)—provision for the year 2002	155	230	80		No Data	
Our estimate						
Gross abstraction	168	249	83	73	195	63
Net abstraction	121	179	60	63	168	55

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[15] These values are slightly higher than those presented in the section on 'The Problem of Groundwater Overdraft' that were calculated on the basis of official values of groundwater abstraction presented by the MWI.

[16] We used average gross abstraction rates as follows: 8,500 and 11,400 m³/ha for vegetables and fruit trees, respectively (average between Fitch 2001 and our surveys; cf. table 5) and 5,500 m³/ha for olive trees. Crops also receive between 100 and 200 mm of rainfall each year. Municipal and Industrial (M&I) groundwater abstraction has been computed according to MWI records for the year 2004. The net abstraction is based on efficiencies of 70 percent in vegetables and olive-tree agriculture, 80 percent for other fruit trees, and 70 percent in the domestic and industrial sectors. We assumed that all the water not used by crops infiltrates back to the aquifer.

Evaluation of Possible Water Savings in the Highlands

Table 8 presents the different classes of agricultural wells according to their yearly production in the two groundwater basins of Amman-Zarqa and Yarmouk. Out of the 606 wells located in the Amman-Zarqa and Yarmouk basins, only 182 yield more than 150,000 m³/yr and will be impacted by the bylaw.[17] Discounting wells producing more than 500,000 m³/yr,[18] this figure further drops to 166 wells, which in turn represent 62 percent and 7 percent of the water abstracted in the Amman-Zarqa and Yarmouk basins, respectively. In addition, as mentioned earlier, only settled Bedouins with vegetables or mixed farms and absentee-owners with vegetable farms are likely to be affected by the bylaw. Eventually, only 83 wells (90% of these in the Amman-Zarqa Basin) will be affected by the bylaw in the eastern desert of the LJRB.

We focus here on possible short-term impacts of the bylaw at a regional scale in terms of water savings, agricultural area reduction, and WAJ-revenue increase. Long-term impacts in terms of employment losses, migration, increase in energy costs, and yield decrease due to aquifer degradation, etc., are not discussed here (see Fitch 2001; ARD and USAID 2001a and Chebaane et al. 2004 for quantification on the Amman-Zarqa Basin). Regional water savings can be assessed based on the five strategies considered earlier by aggregating responses expected for each type of farm.

Table 9 shows that the maximum gross water savings to be expected in vegetable plots in the eastern deserts are about 5.5 Mm³/yr (90% of these in the Amman-Zarqa Basin: strategies B and C). The highest net savings would be obtained if all vegetable farmers decreased their water application and the irrigated area by

TABLE 8.
Structure of agricultural groundwater exploitation in the Highlands.

Classes of water abstraction (Mm³/well/yr)	Amman-Zarqa Basin		Yarmouk Basin	
	Number of wells	Total production (Mm³/yr)	Number of wells	Total production (Mm³/yr)
0–50	157	3.4	37	0.8
50–100	84	6.0	31	2.3
100–150	92	11.6	23	2.8
150–200	71	12.4	12	2.0
200–300	54	12.7	2	0.4
300–400	20	6.9	1	0.3
400–500	6	2.7	0	0.0
>500	7	4.1	9	28.7
Total	491	59.8	115	37.3

Source: MWI records for the year 2004

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[17] That is, 38 percent of all wells likely to be affected by the bylaw in Jordan.

[18] These wells are governmental wells. Water is either used locally (Amman-Zarqa Basin) or pumped to be transferred and used in the Jordan Valley (Mucheibeh wells in the Yarmouk Basin). They will not be affected by the bylaw although limiting this water transfer could lead to substantial water savings at the regional scale. Ensuring that wells producing more than 500,000 m³/yr would decrease production to 150,000 m³/yr would allow savings of 3.1 and 27.4 Mm³ in the Amman-Zarqa and the Yarmouk basins (i.e., 70 percent of the maximum expected water savings in the two groundwater basins) but will have dramatic impacts on Jordan valley agriculture.

TABLE 9.
Impact of the bylaw on vegetable farms at the basin level (eastern desert zone).[19]

	Abstraction (m³/well/yr)	Gross water savings (Mm³/year)		Net water savings (Mm³/year)		Depleted fraction in vegetables (Mm³/year)	Government revenue from vegetable farms (Million US$/yr)	Overall government revenue (Million US$/yr)
		(Mm³/year)	% of current gross overdraft	(Mm³/year)	% of current net overdraft			
Present situation	216,000	-	-	-	-	11.1	-	-
Strategy A: Payment of water fees	216,000	-	-	-	-	11.1	0.21	0.84
Strategy B: Maximizing water savings and maintaining constant efficiency	150,000	5.5	4.0	3.4	4.2	7.7	-	-
Strategy C: Maximizing water savings and improving efficiency	150,000	5.5	4.0	1.7	2.1	7.7	-	-
Strategy D: Improving efficiency with constant area	179,700	3.0	2.2	-	-	11.1	0.012	0.63
Strategy E: Improving efficiency with increased area	216,000	-	-	-2.3	-2.9	13.4	0.21	0.84

one-third on an average basis, while maintaining their actual water use efficiency (strategy B). This would lead to high agricultural losses ($2.5 million, not shown in the table). This response, however, is not the one that the incentives in place are likely to prompt.

In strategy A, nothing is changed except for a transfer of $0.21 million in revenue from vegetable farmers to the state coffers, or a total of $0.84 million when all farm payments are considered. Improving efficiency without increasing cropping area (strategy D) would reduce abstracted volumes to around 179,700 m³/well/yr in vegetable farms. In such conditions, gross water savings would reach 3.0 Mm³/yr and the regional gross overdraft would be decreased by about 2.2 percent. However, net abstraction would not be affected by this change.

Finally, strategy E would lead to increasing the depleted fraction by about 2.3 Mm³/yr (as cropping area and efficiency increase, and return flows are reduced), which defeats the objective of the bylaw. In general, encouraging higher efficiency in conditions where land is not a constraint is counterproductive to the objective of reducing the depletion of water resources. The fact, however, that expanding cultivation by using saved water is—on paper—financially profitable, but not observed in practice, suggests that the real costs of increasing efficiency may be higher than what is shown, and that farmers face other constraints to developing their agricultural activity, notably higher opportunity costs for entrepreneurs with multiple economic activities (Van Aken 2004).

In conclusion, we can say that the implementation of the bylaw in its current

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[19] For scenarios C and to E, all calculations have been done considering an achievable irrigation efficiency of 75 percent (in vegetable farms). For scenarios A and B we considered the present efficiency in vegetable farms (62%). System efficiencies in olive and other orchards have been considered homogeneous at 70 percent and 80 percent, respectively in the five scenarios. Gross and net overdrafts indicate the gaps between gross or net abstraction and annual recharge, respectively.

version will not lead to significant water savings. Because of the threshold of 150,000 m^3 and the public wells that are not targeted by the by-law, 72 percent of the wells in the Amman-Zarqa and Yarmouk basins will not be affected by the bylaw (a threshold of 100,000 m^3 would take this proportion down to 53%). Olive orchards, for example, which represent 32 percent of the total agricultural water abstraction in the Highlands and qualify as the prime target of policies because of their low water productivity (WP=$0.05/m^3), will not be affected. If we add to this the facts that high-value crops such as fruit-trees (WP=$1.1/m^3) will be financially little affected and farmers' behavior unlikely to change, then the wells concerned correspond to only 11 percent of the total water abstraction (16.1 and 1.8 Mm^3/yr in the Amman-Zarqa and Yarmouk basins, respectively).

Vegetable and mixed farms are the most vulnerable to hikes in water charges. Their income being so low that any additional production cost will depress them further. However, whether substantial water savings will be achieved in these farms remain uncertain and depends on the balance between costs and benefits of improving irrigation efficiency. Investments in technology and qualified labor are: a) beyond the capacity of most of these farmers, many of whom are indebted, and b) higher than gains resulting from a reduced water bill, unless yields and products quality positively respond to a better uniformity of irrigation. Upper (optimistic) estimates of reduction in gross water abstraction (strategy B for vegetable and mixed farms) point to a decrease of 4 percent, i.e., 5.5 Mm^3/yr, a drop in an ocean of overabstraction, and quite short of the 40–50 Mm^3 expected.[20] Revenue to the government is expected to vary between $0.63 and 0.84 million/year, not considering the costs of collection and enforcement.

Would higher tariffs (like in the pre-amendment price table, for example), or a lower threshold for the first block, be more effective? Was the bylaw

nullified by the downward revision of the charges in 2004? With higher charges, olive orchards and fruit-tree farms would remain insulated, but the pressure would be borne by the most vulnerable vegetable and mixed farms. With a lower threshold, however, olive orchards too would be under pressure. In all likelihood, only a few of these farms would be in a position to invest in order to achieve better efficiency (and existing potential gains from intensification [due to higher yields] would be negated by higher water costs). Affected farmers might just opt to decrease their cultivated area and thereby, the amount of water abstracted (incurring a loss in their income) until they reach the threshold and can avoid water charges completely.

They might as well sell their water to neighboring fruit farmers, rent out their wells (if they own them), and move out of agriculture altogether. This would amount to a shift in production from vegetable farming and olive trees to higher-value fruit production, and would definitely raise the productivity of water, but a) benefits would accrue to wealthier entrepreneurs; b) this would defeat earlier social policies aimed at settling Bedouins by providing them opportunities in the agriculture sector (Chebaane et al. 2004), unless these are able to find equivalent or better job opportunities; c) the amount of water used would not be radically altered; d) water demand would become extremely inelastic because of the high crop return. Finally, the shift to higher efficiency fruit (or other) production could have the perverse consequence of allowing expansion of orchards, with lower return flow to the aquifer, greater depletion of water, and thus worsening the status of the aquifer (strategy E).

Because of the large percentage of unaffected farmers and likely impacts in terms of crop shifts rather than of improvements in efficiency, a substantial drop in water abstraction can be achieved only through the diminution of either the cultivated area or the number of wells

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[20] If abstraction of all private wells was to be reduced to 150,000 m^3/yr, total gross water savings would reach 12.5 Mm^3/yr.

in use. As demonstrated above, negative incentives (reduced thresholds, higher tariffs, petrol taxation, stricter enforcement, etc.,) cannot achieve this without displacing financially weaker farmers and strictly prohibiting the selling of wells. Recent political crises suggest that such extreme measures are unlikely to be accepted. Attendant positive incentives that are more promising include:, 1) buying-out of wells (a measure envisaged by the government and received positively by 50 % of farmers [Chebaane et al. 2004]); 2) paying adequate compensation for the uprooting of olive trees in the eastern desert (Fitch 2001); and 3) substituting treated wastewater for groundwater (ARD and USAID, 2001c). Additional measures that may assist in decreasing groundwater abstraction include: 1) reduction of losses in urban networks; and 2) having educational and public awareness programs for water users. Allowing the transfer of water to neighboring orchards or the possibility of having vegetable farmers renting out their wells would provide them a financial compensation but would not contribute towards the conservation objectives [Chebaane et al. 2004]). Finally, the removal of petrol subsidies for well operation or imposing higher taxation of water must be accompanied by measures that provide alternatives to people moving out of low-value agriculture, as for example, subsidies or secure market opportunities to help viable farms to intensify production.

Water Pricing in the Jordan Valley

Current System of Allocation: Quotas and Water Prices

A Historical System of Water Allocation

From the beginning of large-scale irrigation in the Jordan Valley, in the 1960s, water has been allocated through a system of crop-based water quotas. Volumetric pricing was also initiated in 1961, with a cost of 1 fils/m^3 (Hussein 2002; one fils is equivalent to 0.001 JD or $0.0014). The official quota system has undergone several changes since the 1960s and has been primarily used as a guideline, with adaptations made according to circumstances and national priorities (THKJ and JVA 1988 and 2001).

Between the 1960s and the 1980s, quotas were based on crop water requirements as calculated by Baker and Harza in 1955 (and summarized in appendix 4).[21] 'The Jordan Valley Development Law No.19 of 1988' defined new quotas (THKJ and JVA 1988)—until the end of the 1990s, each plot of vegetable grown between mid-April and mid-December received 2 mm of water per day (during the rest of the year water was allocated on demand). Citrus and bananas were supplied with 4 and 8 mm per day, respectively, from the beginning of May to the end of October (and on demand during the rest of the year, when demand is low).

Bananas and citrus, which were traditionally cultivated in the northern part of the Jordan Valley, are highly water-consuming crops (Khouri 1981; Elmusa 1994; Jridi 2002; Suleiman 2004). In the early 1990s, the government decided to 'freeze' cropping patterns in the Jordan Valley and to grant 'vegetable allowances' to all areas not covered by orchards at the time, with the intent of limiting the expansion of bananas and citrus. This has institutionalized some inequity in the access to water in the Jordan Valley: major

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[21] Quotas used at that time are not precisely known. Crop water requirements as calculated in 1955 were certainly used as rough guidelines for water allocation although at that time water problems were not yet experienced in the Jordan Valley and fields were supplied by gravity canals.

landowners (mainly citrus owners) as well as entrepreneurial farmers (with highly profitable banana plantations, although profitability is partly enhanced by import tariffs) are the main beneficiaries of the quota system.

Banana orchards planted before 1991 are the only areas to be entitled 'banana allowances': any area planted with bananas after the specified date is considered 'illegal'—even if no sanctions have been taken—and do not receive the corresponding quota. In 2004, however, in contradiction to its policy to reduce demand, the JVA legalized citrus orchards planted between 1991 and 2001; granting them citrus allowance instead of the vegetable allowance they were receiving earlier. All other areas were afforded the vegetable allowance, subject to an assurance given by the farmer to the JVA that he is cultivating his plot of land.[22]

The 1997–1999 period was marked by a severe drought, which strained the resources of the Kingdom and compelled the administrators to make ad-hoc reductions in the allowances of water to the farms. In 1999, vegetable and citrus farmers were granted 75 percent of their entitled water allocation, while banana farmers received 85 percent of their quota. Allocations were reduced by 25 percent in 2000 and 2003, and by 50 and 40 percent during the summers of 2001 and 2002, respectively (MREA and JVA 2006). Some areas were left fallow and yields were significantly impacted, notably in citrus and banana plantations. Lower quotas have been maintained ever since (except in the south of the Jordan Valley, where treated wastewater is used).

In 2004, the JVA established new quotas to better match supply of water and crop water requirements (THKJ and JVA 2004; see table 10). The annual values of these revised quotas are almost similar to the reduced quotas of 1999. Before 1999, official allowances between April and November totaled 4,800, 9,500 and 17,200 m^3/ha for vegetables, citrus and bananas, respectively. The new quotas correspond to 3,600, 7,650 and 12,550 m^3/ha for vegetables, citrus and bananas, respectively, i.e., a cut by about 20 to 25 percent.[23] At a regional scale, this generated total freshwater savings in the northern and middle directorates (where the rules apply) of approximately 20.2 Mm^3/yr (between April and November).[24] The water saved was subsequently reallocated to domestic use in Amman.

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[22] It is not rare to see some farmers 'hiding' some trees (either bananas for their high profitability or citrus for their relatively easy management) on a small share of their farm although they are only eligible to the vegetable allotment. This kind of adjustment reveals that the farmer prefers to cultivate a smaller area of high water-consuming crops than his entire farm with vegetables, especially when other economic activities are available (daily wage labor in other farms or in the construction sector) — (Bourdin 2001; Petitguyot 2003). The farmer is running only a limited risk by adopting this approach since there are very few controls of cropping pattern by the Ministry of Agriculture, and even fewer sanctions taken by the JVA.

[23] In this section, economic calculations are based on theoretical volumes supplied to farmers (we tried to collect bills from farmers in order to assess individual and effective consumption, but it proved to be unviable because most of them did not have bills for one year on hand —bills are issued every month—and most had paid the full quota because water meters were broken or consumption lower than 75 percent of their allocation [see below]). Because of conveyance losses the effective quantity of water supplied to the crops is lower than these theoretical volumes. On the other hand, many farmers also use water coming from the side-wadis and, sometimes, wells (Refer to THKJ et al. 2001; Guérin and Courcier 2004 for further information on irrigation efficiency and potential improvement in the Jordan Valley).
Extra hours are not considered in this allocation. Extra hours are requested by farmers for exceptional needs and, subject to decisions by the JVA, granted in the same amounts to every farmer of a network at specific periods (for example, at the time of land preparation, or 'solarization', or during exceptionally hot periods). This system is the main source of flexibility in an otherwise, quite rigid allocation system. Petitguyot (2003) has shown, for one pumping station in the middle of the Jordan Valley that, on a yearly basis (in 2003), the required amount of extra hours average to 23 percent of the quota allocation.

[24] This 8-month period is particularly crucial since water availability is low and water requirements are high. Trees need high supply during the entire period. Vegetables do not require water during the entire period (very few vegetables are grown between May and July) but requirements are high in April (harvest) and in September/October (for solarization, soil preparation and plantation) — (cf. appendix 7).

TABLE 10.
Current quota system (implemented from 2004 onwards).

Period of the year	Quotas (m³/ha/day)		
	Vegetables	Citrus	Bananas
16/3–31/3	15	On-demand but ≤ 20	
1/4–15/4	15	20	30
16/4–30/4	20	20	30
1/5–15/6	20	30	50
16/6–15/8	On-demand but ≤ 10	40	70
16/8–15/9	10	40	70
16/9–15/10	15	30	50
16/10–31/10	20	30	50
01/11–15/12	20	On-demand but ≤ 20	
16/12–15/03	10	On-demand but ≤ 20	

Source: THKJ and JVA (2004)

Operation and Maintenance Costs Recovery

JVA's revenues from irrigation water have gradually increased with time, as water charges established at 1 fils/m³ (0.14 cent/m³) in 1961 being increased to 0.42 cent/m³, then to 0.84 cent/m³ in 1989, and to an average of 2.1 cent/m³ in 1996 (GTZ 1993; FORWARD 1998; the planned increase up to 25 fils has been put off).

Revenues from charges covered one-sixth of operation and maintenance (O&M) costs during the 1988–1992 period (GTZ 1993; Hussein 2002), implying an average annual subsidy of $3.4 million. In 1995, revenues accounted for less than a quarter of O&M costs. Water charges were then increased more than twofold in 1996. In 1997, with a rate of non-payment of 20 percent, average revenues amounted to 1.7 cent/m³, against 2.5 cent/m³ of O&M costs (i.e., a recovery rate of 68%)—(FORWARD 1998; World Bank 2001b).

Calculations made over the 1988–1992 period show that fixed asset depreciation and financing costs were twice as large as proper O&M costs (total costs were thus three times higher than

O&M costs)—(GTZ 1993). Likewise, THJK (2004) indicates that the ratio of average capital costs to O&M was 2.07 during the 1997–2002 period.

Based on the current block tariff system (in place since 1995; cf. appendix 5; the proposed increase for freshwater has been postponed) and on the current quota system (cf. table 10), we have estimated the yearly cost of water per cubic meter and per hectare for three types of crop (vegetable, citrus and banana; see appendix 6). We assume that farmers use their full (new) quotas when supply is restricted and consider average water consumption for the on-demand period.[25] Total water costs for the farmers are higher in banana plantations ($350/ha/yr) than in citrus orchards ($138/ha/yr). They are lowest in vegetable farms where the water consumption is also low ($67/ha/yr). Differences in water charges for each crop are lower than they were in the past, since uses have been capped—the main beneficiaries of this evolution are banana farmers whose consumption reaches expensive tariff blocks less frequently than before. Implementing the new quotas led to lower water use and consequently to a lower overall recovery of O&M

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[25] Annual allotments average at 5,050, 10,100 and 15,000 m³/ha for vegetables, citrus and bananas, respectively. Extra hours are not accounted for.

costs (fees are volumetric, fixed costs such as salaries do not vary with effective supply; and maintenance costs—canals, pumping stations—do not decrease proportionally to volumes of water). Water is now charged at an average of 1.8 cent/m^3 (against 2.1 cent/m^3 in 1997; see above).[26] In line with these recent evaluations and despite substantial differences between sources, we will consider here that current charges cover 72 percent of O&M costs and that full costs are three times higher than O&M costs (THKJ 2004).[27]

Possible Responses to Increased Water Costs

Farmers may respond to the drop in income resulting from higher water prices in several ways, including: a) saving water by improving on-farm water management practices; b) adopting improved irrigation technology; c) shifting cropping patterns; d) renting out land, or discontinuing agriculture in the case of a tenant; e) other secondary responses such as illegal water use, bribery, and tampering of structures; and f) doing nothing (and paying the higher water charges). The response selected depends on the relative costs and benefits of the different options available to the farmer. Beyond their economic impact the first four options above are constrained by technical, financial and human factors that need to be made explicit.

On-farm Management

By improving on-farm water application farmers may reduce water losses and, thereby possibly decrease farm water requirements and corresponding water costs. Yet, there are several constraints to increasing on-farm irrigation efficiency (whose evaluation remains a difficult task; see box 1) under current conditions, for example:

- Despite being conceived as a demand-based system, subject to the limitation of quotas, the actual mode of operation of the JVA and the uncontrolled nature of the inflow from the Yarmouk River do not allow a reliable supply of water (Courcier and Guerin 2004). Farmers experience many difficulties because of deficiencies in collective pressurized networks that result in variable pressure and substantial variation in water distribution (with deficits observed in higher parts, on sandy soils, or at the ends of water distribution lines). For example, secondary irrigation networks were designed for 6 l/s flows, but 9 or 12 l/s flow limiters were eventually installed, after farmers complained. The importance of stable pressure is illustrated by farmers in the extreme north of the Jordan Valley. Most of them shifted to micro-irrigation systems after pressurization of the network by the JVA in 1996 but they quickly reverted to their previous system as the delivery service did not match the design of the collective network or their expectations (Bourdin 2001). Finally, rotations are difficult to establish and not adhered to; and water theft and tampering of equipment are rampant (GTZ 2004; MREA and JVA 2006). Farmers relying on the same pumping stations are extremely heterogeneous in terms of socioeconomic status and low social cohesion among them hinders collective management (Van Aken 2004).

- Farmers also experience many technical problems at the farm level that come from microirrigation systems, such as installation without technical guidance (in 70% of the cases), direct connection of old pressurized

Box 1: Difficulties to Evaluate Irrigation Efficiency in the Jordan Valley

Because of the high diversity of situations, it is extremely complex to evaluate water use efficiency in the Jordan Valley. Available data are inconsistent (World Bank 2002; Al-Zabet 2002; Petitguyot 2003, etc.), and evaluations are variable, as they notably depend on features such as the ones given below:

- The volume of water supplied in the Jordan Valley: aggregated JVA's evaluations at the pumping station, the Development Area (an administrative subunit), or the directorate levels often differ from the centralized data obtained in Deir Allah (where the control centre of the Jordan Valley network is located) or in Amman; the degree of consideration of other sources of water, such as uncontrolled side-wadis, groundwater, etc.
- The values of ET and of Kc coefficients: uncertainties are high, notably when crops face water stress (appendix 7) and when cropping techniques (drip and mulch, greenhouses) vary.
- The evaluation of rainfall and the degree of consideration of effective rainfall.
- The 'unit of study': a farm, an irrigation network, a pumping station, a Development Area, a directorate, the whole Jordan Valley, etc.
- The evaluation of cultivated areas (different sets of data are available from the Ministry of Agriculture; the JVA: at the farm, the pumping station, the directorate and the valley levels; and satellite imagery analysis).
- The period considered: before or after 1999 (when quota reductions were initially implemented); the whole year (lumping together periods when demand exceeds supply with periods when supply exceeds demand); the period when water abstraction is effectively sealed (see quotas in table 10); the cropping season, etc.
- The type of farm and the degree of intensification of farming.
- The type of crop cultivated and of irrigation technology used (surface irrigation or microirrigation with microsprinklers, drippers or open tubes) by the farmers.
- The degree of consideration of special water requirements for specific operations such as land preparation and 'solarization' and of occasional periods of deficit irrigation (Petitguyot 2003).

All these factors combined preclude a clear idea of what the actual irrigation efficiency is. USAID (2006) cites studies that indicate that only 50 percent of the water received is effectively applied and that "overall irrigation efficiencies might be as low as 40 percent." A World Bank report (2002) cites "evidence that over-irrigation takes place and water application practices are out-dated," while another report (World Bank 2001a) specifies that "irrigation conveyance and distribution efficiency in the pressurized network in the Jordan Valley is high" and sees "a considerable range to improve on-farm irrigation efficiency." Other estimates at the country level put irrigation efficiency at approximately 75 percent in areas irrigated with sprinklers and 85 percent in areas using drip irrigation techniques (Ghezawi and Dajani 1995). Furthermore, Shatanawi et al. (2005) found that overall efficiency in the Jordan Valley was 65 percent.

Our macro-calculations based on land-use statistics (appendix 3), rainfall data (THKJ and Meteorological Department 2002), assumption of a full ET, and volumes of water diverted by the JVA to irrigated areas in the northern and middle directorates (calculations according to the new quotas [see table 10] are consistent with volumes supplied as presented by the JVA-water resources department in Amman), give the following annual efficiencies (defined as the ratio of crop water requirements to water supply): 64, 62 and 82 percent for vegetables, citrus and bananas, respectively. If the April–November period is considered, efficiencies rise to 88, 75 and 84 percent for the same crops. Overall efficiency in the Jordan Valley is included between 69 percent (if the whole year is considered) and 81 percent (if figures are only computed for the April-November period).

lines to the JVA's pressurized network, poor design of blocks and rotations, problems of filtration and clogging, (Wolf et al. 1996; Courcier and Guérin 2004; Shatanawi et al. 2005).

- Unless saved water can be traded, the economic incentive for the farmer to conserve water will be insignificant (Development Alternative 2004)—because the farmer cannot use the water saved to expand cultivated land, and more crucially, because of the system of monthly quotas that defines a ceiling to the abstraction of canal water by the pumping stations. No savings are possible during critical periods in spring and autumn, because demand exceeds supply (Petitguyot 2003; appendix 7) and the marginal value of water far exceeds its marginal cost (see the section 'Economic Impacts and Adjustments at the Farm level'). During the rest of the year (November to March), efficiency is lower as supply exceeds demand, but this occurs at times when there is no alternative use for water (and no possibility of storage). Therefore, there is little rationale or prospect for saving water. In addition, the desirability of further water savings is not fully established, as it is feared that lower salt leaching would raise salinity problems in the Jordan Valley (McCornick et al. 2001). In the early 1990s, for example, the JVA encouraged farmers to take water free of charge in the winter months for leaching purposes (Wolf et al. 1996). Furthermore, detailed observations in citrus farms showed that trees could abstract water from as deep as 1.50–2.50 m, thus tapping part of the 'excess' supply that has been stored in the ground during this surplus period (Arrighi de Casanova 2007a).

- In most instances farmers are now billed based on their quota and not on effective use, either because the meter has been broken or because the actual use indicated is suspiciously low (i.e., under 75% of the quota, in which case, the full quota is charged).

Adoption of Technology

Technological improvements can improve irrigation efficiency. If pressure in the main network is stabilized, or intermediate storage (farm ponds) and individual pumps are available, better on-farm irrigation is possible. Hence, internal rotations can be redefined to better balance pressure in the network, but this requires technical assistance and capital. Farmers who already adopted microirrigation in the past can improve irrigation uniformity, but need to redesign their network (mainly by installing larger secondary pipes). In addition, they also need improved filtration, more frequent renewal of drippers and skilled operators. MREA and JVA (2006) experiments have shown that improving existing microirrigation systems would, on average, cost $1,075, $1,330, $970, $1,435 per hectare of citrus, bananas and vegetables in open fields and under greenhouses, respectively (e.g., annualized investments of about $205, $224, $147 and $185 per year given the average lifetime of the material). Investments could yield added net revenues for these four crops of $430, $1,460, $820, $650 per hectare (these average values vary depending on the type of irrigation technology—gravity, open tubes, micro-sprinklers and drippers). These values were observed in pilot projects under relatively controlled conditions and, therefore, should be taken as upper limits. Redesigning needs technical assistance (and computer software to define blocks with a uniform pressure), stressing the knowledge-intensive nature of improving irrigation.

In citrus and banana orchards, a shift from gravity irrigation (which still represents 30% of the area and is mostly found in absentee-owner and mixed farms) to microirrigation costs $1,400-2,400 and $2,900/ha for citrus and banana, respectively (e.g., annualized investments of $263-462 and $615/ha/yr), depending on the specifications, but may yield additional average net revenues of $850 and $425/ha/yr (amortization of investments deducted)—(MREA and JVA 2006). If pressure is not stabilized (in general, it will be too low for the collective network to supply the amount of water needed and as a result drippers will clog up more

easily), farmers will have to invest an additional $410/ha in a farm pond and a pump (especially if they use microsprinklers; open tubes are less sensitive to variation in pressure).

Three important points must be emphasized here. First, this technological shift was financially attractive (on paper) both before and after an increase in water costs was made (and even more so before than after). Therefore, increasing water prices may push farmers to invest in technology, with the possibility of increasing income instead of incurring higher costs. However, adoption is constrained by lack of capital or credit as the costs of investing in technology are sometimes higher than the average annual net revenue (as shown for citrus farms in table 5). Smaller, indebted farmers, or ones without collateral, cannot easily access credit and, therefore, stick to older simpler production methods, or rent out their land to commercial growers. Some urban absentee-owners also have strategies adverse to intensification (see later). Second, the increases in net revenue, despite the investment costs, stem from improved quality and better yield due to better irrigation scheduling and uniformity, and better control of nutrient status by 'fertigation' (applying fertilizer through drippers). As evidenced in the gradual adoption of microirrigation from the 1970s to the 1990s,[28] it is the whole package of intensification and higher-quality crop marketing that pays for the technology and not the savings in the water bill (since farmers use the same quotas, regardless of the technology). Third, better irrigation technology improves irrigation efficiency (ET = [evapotranspiration]/farm supply), not because the denominator (supply) is reduced (quotas remain fully used: see above) but because the numerator (ET) is increased, due to a more homogenous distribution of water.

Crop Choice

Higher water charges, while reducing farmer net revenues may also prompt shifts towards low-water consuming crops and/or higher-value crops (Pitman 2004; THKJ 2004). Economic data (see next section) suggest that, as far as net revenue per hectare is concerned, citrus (low productivity) appear as undesirable when compared with more profitable trees (mangoes, guava, grapes and dates, which are becoming more common in certain places of the Jordan Valley), or with vegetables. Banana crops, although they yield fair revenues could be replaced by other crops with lower water requirements such as grapes and dates. Yet, these options are already available and, despite their apparent economic attractiveness, farmers have opted for extensive and less profitable systems.

Reasons that hinder intensification and explain as to why everybody does not grow the most profitable crops typically include environmental constraints (soil type, salinity, temperature, etc.), lack of skill or capital, indebtedness, alternative economic activities, ageing of the farm-holder, aversion to risk or drudgery, etc., (for a review see Molle and Berkoff [2007]). It is difficult for many farmers to shift to riskier, more intensive, and time-/input-consuming crops, unless relatively stable market opportunities are available to them. Identification of, and adaptation to, market demand and requirements are key bottlenecks associated with agriculture in Jordan (Salman 2001b; DOS and FAO 2002; Al-Zabet 2002; Nachbaur 2004). Palm trees, for example, are attractive because they are salt-resistant and, in addition, their yield (dates) fetches a high price in the market. However, date production has several drawbacks from the perspective of small-scale extensive farmers. For example, date palms do not produce

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[28] Drip irrigation developed as a result of farm ponds allowing on-farm pressurization, and as a technical response to the need to produce high-value products rather than to a lack of water per se. It was only one of the features of a larger technological package, including black mulch, fertigation, controled doses of inputs, labor-saving technologies, greenhouses, etc.

during a period of 5 years, post-harvest operations are difficult to master, and only high-quality products find their way to the most profitable market niches. As with the adoption of better irrigation technology, increased water charges may induce farmers to intensify production but does not reduce the constraints themselves. What is provided is a 'push' incentive (run higher risk or face a loss in income) rather than a 'pull' incentive (an opportunity that can be captured with little risk).

Moreover, many large citrus areas are owned by absentee-owners whose livelihoods do not depend on their agricultural activities. Their orchards are linked to social prestige and recreational use, and are not primarily driven by economic motives (GTZ 1995; Lavergne 1996). These owners may not shift to a more intensive and time-consuming activity for the sake of preserving their secondary agricultural revenue.

Another disincentive for farmers to shift from citrus and banana trees to vegetables is the resulting loss of their higher quota of water (with little or no hope of obtaining it again if they ever decide to revert to trees).

Land Rental

Since 2001, land market transactions have been allowed in the Jordan Valley, but renting plots had already become a widespread practice. As land pressure in the Jordan Valley is intense, farmers engaged in extensive agriculture may cede their land to other farmers who achieve higher profitability, either because they have other occupations or because net revenue falls below the land rent, which is estimated at $570/ha/yr (Salman 2001b). Since most farm managers are already tenants (according to Salman [2001a], 87% of farm managers in the Jordan Valley are tenants and they farm 51% of the total area), the most vulnerable of them may just give up agriculture. Nothing ensures that economic alternatives are available to them.

Others

Last, it is worth mentioning that pushing for much higher water charges or curtailing quotas further might lead farmers to respond by tampering with, or destroying, meters, bribery, or defaulting (Courcier and Guérin 2004; MREA and JVA 2006). Indeed a great number of meters have now been broken, in part as a response to the very costly fine sanctioning illegal use of water. Unrest and political interventions are also possible (and likely) reactions, as shown by the case of the bylaw on groundwater abstraction control (see above) and more recently in the south of the Jordan Valley, where the army had to intervene to quell violent conflicts that erupted after the government attempted to collect unpaid land and water fees (Al-Hanbat 2007; Al-Arab al Yawm 2007 and Al-Dustour 2007). Such outcomes are not attractive for the government, which has little incentive to antagonize supportive segments of the society if gains are not expected to be substantial (Richards, 1993).

Economic Impacts and Adjustments at the Farm Level

Based on the constraints and economic considerations discussed above we evaluated responses to increasing water prices in three different scenarios. In Scenario A, we consider an increase in water prices to a level where O&M costs of the JVA can be recovered, as this is the main objective of water pricing policies in Jordan (THKJ and MWI 1998c, 2002a; FORWARD 1998; Salman 2001a; THKJ et al. 2002; THKJ 2004). In Scenario B, we consider a water price increase that will allow the recovery of total costs of irrigation in the Jordan Valley (O&M plus capital costs). In these two scenarios, we consider that the actual block-tariff system is maintained (appendix 5). Scenario C is based on a recommendation by THKJ (2004) according to which prices in the Jordan Valley should be

raised to 80 percent of the present average cost of water borne by farmers in the Highlands.[29] In this scenario, water is charged at a flat rate ($0.116/m^3 [Al-Hadidi 2002]) regardless of the total water used in the farm.

We first analyze the financial impact of these scenarios on the different farming systems, assuming that farmers merely pay for the water fee (situation [f]), everything else being equal (including crop mix, irrigation efficiency and delivered water). The rate of bill recovery is assumed to be 100 percent. This potential impact is then compared with the relative costs and benefits, advantages and drawbacks, of other options ([a] to [e], as presented above) in order to evaluate farmers' likely strategies. The analysis of farmers' decisions cannot be based on crop budgets only. We must also consider both the a priori positive financial incentives to adopt improved technology or high-value crops, and the factors that impede these changes (various types of risk and alternative farmer-strategies). Although such an analysis is contingent by nature, it attempts to capture and incorporate the diversity of farming systems, constraints and farmer strategies. Table 11 specifies water costs for each crop and scenario (considering that farmers use their full quota), and table 12, the financial impact of the three scenarios on each farming system.

Water cost increases in scenarios A and B correspond to multiplying current costs by a factor of 1.4 and 4.15, respectively. In scenario C, due to the implementation of a flat charge, water costs are multiplied by 8.7 for vegetables, by 8.5 for citrus, and by 5 for bananas. Table 12 shows that extensive farming systems (citrus and mixed farms) would be most impacted because water costs represent a large portion of total costs (on citrus farms) and because their net revenue is very low.

Scenario A would have a limited impact on most farming systems in the Jordan Valley. Net revenues on vegetable and banana farms would decrease by less than 1 percent and 2 percent, respectively. Mixed farms would also be slightly affected by the increase (-2.6 %). Finally, citrus farming systems would be the most affected—net revenues would decrease by 4.2 percent to 13.2 percent in farms with micro-irrigation and gravity farms, respectively. In the latter case, impact is higher, but these absentee-owners are precisely those who have other sources of revenue and motivations and, therefore, are less sensitive to changes in farm revenue. In sum, these impacts are unlikely to significantly 'tip' farmers' perception of the constraints to intensification: the 'push' factor of declining revenues remains quite modest.

In scenario B, farm net revenues would decline more substantially. Productive systems

TABLE 11.
Crop-based water costs according to three different levels of price increases.

Water costs (US$/ha/yr)*	Vegetables	Citrus	Bananas
Current water costs	67	138	350
Scenario A. O&M costs recovery	94	192	485
Scenario B. Total costs recovery (O&M + capital costs)	278	573	1,454
Scenario C. 80% of water costs borne by farmers in the Highlands	586	1,172	1,740

Note: *Costs are calculated based on full quotas and average values for the on-demand period

[29] "The water production cost from private wells borne by the farmers (at present about 14 cents/m^3) should be taken as a guideline for adjusting the water tariffs charged by the JVA (at present 1.5 to 2 cent/m^3). The tariff for 'public' water of the JVA should not be lower than 80 percent of the average cost of the water produced from private wells" (THKJ 2004).

TABLE 12.
Impact of different levels of water price increases on farming systems in the Jordan Valley.

Farming systems		Open-field vegetable family farms	Entrepreneurial greenhouse farms	Citrus farms		Banana farms		Mixed farms
				Family farms***	Absentee-owner and family farms	Family farms	Entrepreneurial farms	Poor family farmers
Allocation type		Vegetables	Vegetables	Citrus	Citrus	Bananas	Bananas	Vegetables
Net revenue* (US$/ha/yr)		3,800	7,500	1,250	400	7,000	12,500	1,050
Production costs** (US$/ha/yr)		8,150	21,000	1,550	1,200	8,200	8,600	2,400
Actual water costs (% of net revenue)		1.8	<1	11	34.5	5	2.8	6.4
Actual water costs (% of total costs)		<1	<1	8.9	11.5	4.3	4.1	2.8
Decrease in net revenue (% of actual net revenue)	Scenario A	<1	<1	4.2	13.2	1.9	1.1	2.6
	Scenario B	5.5	2.8	34.8	negative revenue	15.8	8.8	20.1
	Scenario C	13.6	6.9	82.7	negative revenue	19.8	11.1	49.4

Note: *, **, *** As in table 2

(vegetables in open fields or under greenhouses) would again be slightly affected (net revenue would decrease by about 2.8% to 5.5%), with little change to be expected in current farming strategies (limited on-farm water savings, achieved by better management [response a], and in a bid to decrease overall water costs, might be observed). Mixed (poorer) farms would be substantially affected (-20.1%). Since net revenues come closer to the land rental value ($570/ha/yr), owners will increasingly rent out their land, while tenants will progressively shift to other jobs [response e], unless better market opportunities and subsidies for modernization are available to them. Shifting to micro-irrigation (investment of $1,760 per ha) would offset their loss and increase their actual revenue by more than 40 percent (+$670/ha/yr), but this remains hindered by the need of investments that are higher than the net annual revenue of these farmers (table 12).

The profitability of banana orchards would be moderately affected (net revenues decrease by 8.8% to 15.8%). Some farmers will be 'pushed' to shift to other very profitable orchards, such as date palm trees that are less water consuming, but incentives will remain limited unless import tariffs on bananas are lowered. Such shifts to palm trees would concern only the most capitalized and entrepreneurial farmers (i.e., no more than 50%). As 50 percent of bananas is still irrigated by gravity systems, adoption of micro-irrigation offers a means of limiting financial losses. Here the constraint is not so much in terms of capital (investments of 2,900/ha compare favorably with annual revenues of $7,000/ha) but the shift entails an additional burden due to the complexity of technology management (filtering, cleaning drippers etc.), and only yields a limited benefit (additional water costs of $1,100/ha would be partly offset by the $425/ha/yr generated by the higher yields obtained).

Finally, citrus farms would be greatly affected (scenario B). The profitability of family farms already using drip irrigation would decrease by

one-third. Family farms include many small owners who are likely to improve design, equipment and management along the lines defined earlier, with investments of $1,075/ha (close to the actual revenue) but with a yearly additional revenue of $430/ha/yr, which will almost cover additional water costs ($435/ha/yr).

Citrus farmers still using gravity irrigation (70% of whom have family farms, including shopkeepers, civil servants, retirees, old farmers, widows, etc.), will see their revenue become negative. They will thus have a strong incentive to capture the gains from a shift to microirrigation, with net revenues increasing from $400 to $815/ha instead of becoming negative (if response [f] is selected—table 12); yet this demands a high initial investment (equivalent to more than 3 years of annual revenue), which is a constraining factor for many of these farmers, especially if there is no proper financial scheme or support. Financial incentives will be the same for rich absentee-owners (with gravity irrigation), but they are more likely to accept losses, depending on their preference for criteria of leisure and prestige, and for non labor-intensive agriculture (GTZ 1995; Lavergne 1996; Venot et al. 2007).[30]

Farmers face the same a priori positive incentive to diversify into other fruit trees, since fruits like dates, mangoes, guava or grapes are more profitable than citrus. Again, the incentives to adopt improved technology or higher-value trees largely depend on the will/capacity of the farmers to intensify and on the availability of stable market opportunities. If their perception of risk and drudgery or their capital constraints remain too high, they will opt to rent out their land to investors. In both farms (irrigated by gravity or by drippers), increasing water prices would thus work to increase economic efficiency.

Finally, scenario C would have a dramatic impact on agriculture in the Jordan Valley. As in the two previous scenarios, citrus orchards

profitability would be dramatically entailed and most orchards would be replaced in one of the ways described above. In capitalized banana farms, a partial shift to date palm and other trees, and the use of more efficient drip irrigation systems might be observed. Nevertheless, the likelihood of losing the higher quota will certainly remain an impediment to this evolution. Mixed farm operators would see their profitability decrease by half and, as such, would rent out their land. Tenants, if they have the financial capacity, will run the risk to intensify or will be replaced by more entrepreneurial farmers. The profitability of greenhouses would decrease by 6.9 percent, but farmers would have to withstand the pressure due to the lack of cost-effective alternatives (MREA and JVA 2006). In the case of open field vegetable farms, farmers would lose 13.6 percent of their revenue, and would consider improving water application (response [a]) or adopting improved irrigation systems (response [b]). These responses would offset the losses due to higher water costs and increase revenues by 11 percent. Further intensifying agriculture by adopting greenhouses ($25,000/ha for the greenhouse only) is unlikely to be observed on a large scale, due to the critical capital and environmental constraints linked to the process. This third scenario is hardly imaginable since it would disrupt the economy of Jordan Valley and exacerbate the political protests that, in the past, have erupted for less serious policy changes (e.g., above).

Incentives provided by high water prices are, therefore, likely to influence technological change and crop mix, and to lead to a higher water productivity. We have earlier discarded the possibility of significant water savings under the present monthly quota system because the marginal value of water is too high in the critical period (April-November), while there is no alternative use when supply exceeds demand. This marginal value depends on the crop and on

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[30] Many of those farmers have, for example, refused heavily subsidised systems in MREA's pilot areas (Arrighi de Casanova 2007b): in a context of suspicion regarding future government regulations, farmers do not want outsiders to meddle in their farm activities (see also Van Aken 2004).

its physiological stage, but in this critical period, which generally includes flowering and/or fruit formation, it is higher than the average water productivity, which is itself an order of magnitude higher than the marginal cost of water.

This remains true for all crops in scenarios A and B, with one exception, i.e., gravity irrigation of citrus farms under scenario B. In this particular case, the average water productivity (0.04 cents/m^3) is slightly lower than average water costs (0.057 cents/m^3). In the critical period, the marginal cost of water is 0.071 cent/m^3 (for the second tier in the block tariff), but its marginal value is much higher than the average. Water stress at flowering and fruit formation stages has very severe impacts on yields (Arrighi de Casanova, 2007b) and the marginal value of water during this period is indicated by the level of bribes paid for illegal water at such times, which can be 10 times higher than the marginal cost of water. During the on-demand period, however, the marginal cost is $0.047 /$m^3$ (first tier), close to the average water productivity, pointing to possible cost-effective water savings over 2,400 hectares of citrus. These savings are minor.

Alternatives to Reduce Freshwater Diversion for Jordan Valley Agriculture

In conclusion, the scope for achieving gains in irrigation and economic efficiency through price incentives is limited. Gains are possible, but their magnitude and realization depend on the type of farm, and they cannot be obtained without support, including technical assistance, predictable water supply, secure markets, and subsidies to shift to drip-irrigation (where this has not yet happened) and, gradually, to precision irrigation. Several additional options have been proposed to limit freshwater diversion for agriculture in the Jordan Valley, including:

- Flexibility of water supply at the farm level is obtained not only through exceptional requests (e.g., land preparation for potatoes and solarization for vegetables), but also by digging farm ponds to buffer irregular supply

(more than half of the farmers have on-farm reservoirs [Shatanawi et al. 2005]), by using water from side-wadis and, wherever possible, by pumping groundwater that is partly replenished by 'losses' from the surface irrigation networks (21.7 Mm^3 are presently pumped for agricultural purposes, mostly in the south of the Jordan Valley [MWI-records for the year 2004]). Many farmers already have implemented these options.

- Effective freshwater savings in the Jordan Valley may come from greater use of treated wastewater blended with freshwater in the north of the Jordan Valley, as proposed by ARD and USAID (2001b)—(see also Al-Jayyousi 2001; McCornick et al. 2002, and KfW et al. 2006).

- Significant water savings could be achieved through a better in-season distribution of water in the King Abdullah Canal. With the completion of the Wehdah Dam on the Yarmouk River (which will provide upstream storage capacity), it will be possible to have a more flexible management of water allowances and a substantially increased economic output (Al-Jayyousi 2001; Salman et al. 2001; Shaner 2001; Courcier and Guérin 2004). Monthly quotas could be transformed to yearly quotas, with farmers keeping the latitude to distribute water along the year according to their needs (Petitguyot 2003). Eventually, with increased control on individual consumption, quotas could be made transferable, thus providing real financial incentives for technical and economic gains (Development Alternative 2004).

- With a more controlled water regime, an alternative would be to adopt bulk allocation and bulk charging procedures, whereby water user associations (WUA) would be in charge of managing a yearly amount of water and recovering charges (JRVIP 2001). This, however, is hindered by extant cultural and social structures and, as such, would require significant institutional transformations and changes in the agency (JVA)-farmer relationship (Van Aken 2004).

- The banana area could be reduced by substantially raising the price of the higher tiers of the quota, so that revenues of banana farmers would be reduced without affecting other crops. Banana farming could also be made less profitable by removing duties on imported bananas, in line with World Trade Organization rules (WTO 1999; Montigaud et al. 2006).[31] Such economic incentives could be quite effective in inducing a shift towards other trees and a full conversion to drippers, but the capital constraint and the potential loss of high banana allowances act as impediments to this evolution.

- The most efficient way to reduce diversions to the Jordan Valley (and to free more water for Amman) would be to gradually reduce the quotas to force adjustments—high-tech management, change in crops, etc. Yet, this has already been the case since 1998, with effective supply in the last 9 years varying between 50 and 80 percent of theoretical entitlements and crops facing water deficits during some periods of the year (MREA and JVA 2006). Additionally, a bonus might be granted to those who accept to shift from a high tree quota to the vegetable quota (provided proper market opportunities for vegetables are ensured). This, of course, would be hard to justify in the face of the recent contradictory measure of recognizing

more citrus allowances. For the sake of illustration, we can estimate what would happen if half the banana area was replaced by date palm trees (eligible to the citrus allocation) and a third of the present citrus area was replaced by vegetables. According to the quotas summarized in table 10, this shift would reduce agriculture freshwater diversion by about 14.3 Mm^3/yr, that is around 12 percent of the water released to the northern and middle directorates between 1999 and 2002.

- Last, both irrigation and economic efficiency can be enhanced by conventional positive incentives that affect the environment in which farmers take decisions to invest and intensify. Aside from the already mentioned technical and institutional interventions aimed at stabilizing pressure in collective networks and redesigning on-farm distribution, other positive incentives include: a) attractive output markets; b) crop insurance schemes for farmers tempted to diversify; c) subsidies to shift to well-designed drip-irrigation (where this has not yet happened); and d) gradually, move on to precision irrigation (see below). In practice, because pricing reforms often affect extensive family-based farming, concomitant state support to intensification or modernization is widely observed (Molle and Berkoff 2007).

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[31] Despite adhesion to the WTO, the government realized that there was little value in competing with other countries not abiding by the same rules (e.g., in Israel, agriculture is heavily subsidised; see Richards 1993). Jordan has to face "unfair market intrusions by countries with less stringent WTO membership conditions." For example, Jordan's decision makers realized that "the rapid decrease of tariff rates for olive oil, and the absence of the possibility to apply 'special safeguard measures', could lead to the abandonment of a great number of farms, increase desertification, create social unrest and considerable migration to towns" (WTO 2001).

Discussion and Prospects

This section recaps the conclusions of the above sections: results obtained in the Highlands and in the Jordan Valley bear both similarities and discrepancies. It also expands the discussion in relation to a wider socio-political and economic context, in which water policies in general, and pricing policies in particular, are embedded. Although frequently disregarded, these dimensions often determine much of what is eventually possible and desirable (Dinar and Saleth 2005; Molle and Berkoff 2007). The results obtained in both the Highlands and the Jordan Valley bear several similarities, and also bring lessons that have wider validity.

Limited Effectiveness for Pricing Mechanisms to Achieve Improvements in Irrigation Efficiency and Water Savings: Several studies based on modeling (Shatanawi and Salman 2002; Doppler et al. 2002; Salman et al. 2005 [for the Jordan Valley]; Salman et al. 2002; Salman and Al-Karablieh 2004 [for the Highlands]) have shown that demand is responsive to prices at levels which are, in general, not compatible with sustained farm incomes and equity. We have also stressed that suboptimal irrigation efficiency is primarily linked to unstable pressure in collective pressurized networks (in the Jordan Valley), which makes the functioning of poorly designed on-farm distribution networks precarious. These on-farm networks are subject to many technical problems (notably clogging of 'emitters', non-uniformity of water application, non-optimized blocks and rotations). In the Jordan Valley, another source of inefficiency (independent from farmers) is the lack of storage capacity at the system level for the excess water during the time of year when 'supply' exceeds 'demand' (although extra water is used for soil leaching, and there are indications that the soil acts as a buffer reservoir for citrus). With such water having no alternative use, and with irrigation controlled by strict quotas when demand exceeds supply, possible water savings are limited.

Consequently, the claim by the 2004 Masterplan (THKJ 2004) that the full cost recovery for irrigation O&M pursued by the Ministry of Water and Irrigation will, among four objectives, "increase the conveyance system and on-farm water use efficiency" is not valid. From the correct assumption that "low prices for irrigation water provide limited incentive to improve on-farm efficiencies," and it is too hastily inferred that raising prices will automatically improve on-farm efficiency and should, therefore, be "a prime target for implementing improvements" (USAID 2006). A World Bank (2003) report indeed acknowledges that "it was anticipated that increased water tariffs [of 1996] would reduce agricultural water use. This did not happen." Despite evidence to the contrary, these claims are still pervasive among donors, development banks, and some green NGOs, which support the "gradual removal of all subsidies on water supplied to agriculture, tourism and industry sectors" and the setting up of water prices "on the market price basis" (FOE 2002). Such removal may have other virtues but should not be expected to bring about improvements in irrigation efficiency (nor be justified by this).

Intensifying Agriculture: At What Cost? With limited scope for achieving water savings, farmers will potentially respond to increasing water costs by intensification. In intensive and profitable systems (vegetable and greenhouse farms) water costs are negligible compared to input and labor costs, and they will remain so at any politically acceptable water price level (Wolf et al. 1996). Farms with more extensive agricultural strategies will be more affected, including primarily: 1) mixed farms (often poor/indebted) and small orchards of citrus or banana in the Jordan Valley (Salman [2001a] and Van Aken [2004] underline that indebtedness and vulnerability are two major problems hindering the progress of agriculture in the Jordan Valley); 2) extensive open field vegetable farms in the Highlands and; 3) absentee-urban-owners and

rentiers with other sources of revenue (citrus and olive trees plantations). Price-induced pressure would have a beneficial impact, if these farmers were to adopt improved technology and higher-value crops. As noted earlier, these options were already available to these farmers and there are sound reasons why—despite their high return on paper—they did not adopt them earlier. Farmers engaged in extensive agriculture are often indebted (or weary to be so) or lack capital to embrace such ventures that incur considerable risk. In the case of rentiers, they lack the interest to burden themselves with intensive management and value their farm for other reasons. Intensification should be driven by market opportunities and not forced by circumstances. The latter would initially make farmers financially more vulnerable and then push them into risky ventures with a higher probability of going bankrupt (see Doppler et al. 2002 for the prevalence of risk in the Jordan Valley). It is doubtful whether the benefits of pushing the more vulnerable farmers out of business would outweigh the social costs incurred.[32]

Allocating water rights to all farmers and allowing them to be traded, as envisioned in the ASAL, could also lead to the same outcome, with the notable difference that poorer farmers (when the land or the well is owned by them) would get appropriate financial compensation. Whether such evolutions are desirable and pursued or not, depends on the context and on the overall policies of a given country. Most countries are confronted with this necessity of balancing family-farming and agro-business, social stability and economic efficiency. For example, recent simulation of the response of European agriculture to the European Water Directive Framework showed a need for a distinction between 'socially driven irrigation' and 'commercial systems', because of the expected dramatic impact of pricing policies on the former

(Berbel et al. 2005; see also the case of Spain in Arrojo 2001). As a rule, state policies include investments/subsidies in order to allow modernization of family farms, with the objective of enabling them to better compete with highly capitalized operators.

Increasing Economic Efficiency: High-Value Crops, for Which Market? The move towards a more intensive and higher-value agriculture is critically dependent on the availability of a market for it. With growing competition from other countries in the Middle East, identifying crops with a good return and limited risk is not easy. Hence, it has become a policy priority (Montigaud et al. 2006; Nachbaur 2004; Salman 2001b). With adequate support to intensification and marketing, water price increases thus have the potential to raise economic efficiency by inducing changes in citrus and banana cultivation. Likewise, economic benefits arise from small farmers renting out their plot to investors growing higher value crops, but these farmers must find alternative occupations or incomes.

The Politics of Water Management and Policy: Water pricing schemes largely reflect the political economy of a country, and political counterweights are often raised when prices depress revenues.

The negotiations around the bylaw and the amendment, carried out with a fair degree of participation of stakeholders (Chebaane et al. 2004), showed that agricultural interests retain significant political and bargaining power—the government is unwilling to alienate the support of Bedouin tribes or part of the Palestinian population, and to prompt claims from Islamist radicals that Islamic law is violated (Richards 1993). The teeth of the bylaw were removed through the implicit abolition of former abstraction limits (which were lower than the 150,000 m^3 threshold adopted) and through the recent

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[32] "Indeed, a senior government official stated that the net cost (US$3.5 million per year) of providing water to the Jordan Valley, which enabled sustainable livelihoods for the 300,000 people engaged in agriculture, was relatively small compared with the social costs that would be incurred if very high water charges caused farmers to abandon the land and migrate to Amman for employment" (Pitman 2004).

amendment, which abated the already low water fees. Some groups of influential farmers, with strong political linkages and opposed to a control of water abstraction, have tried to stop the process. They have succeeded in slowing it down through some support in the parliament. The bylaw has not been implemented yet (as shown by the fact that the bills for the first year have not been paid yet) and it remains a very sensitive and volatile issue.

The fact that illegal citrus orchards in the Jordan Valley have been regularized recently —quite in contradiction with policy objectives—also suggests that the populations concerned have enough political influence to counter the reduction of quotas. This does not mean that reforms are not desirable or should not be attempted, but it reminds us that reform costs, and not only benefits, must be carefully anticipated (Dinar and Saleth 2005). The high percentage of broken meters, for example, reminds us that fees which significantly affect the economic situation of farms and/or quotas that are too low tend to trigger defaulting, tampering or destruction of meters, social unrest and political stress, and corruption or collusion between officials and farmers (GTZ 2004; Courcier and Guérin 2004). Such outcomes are not attractive for the government, which has little incentive to antagonize supportive segments of the society if gains are not expected to be substantial (Richards 1993).

Recovering O&M Costs in the Valley is Possible: The above analysis indicates that the prime objective of financial autonomy of the JVA is attainable. Charges could be slightly raised to ensure revenue, while defaulting should be controlled by stricter enforcement. Raising prices to fully recover O&M costs would not dramatically affect farmers. From the point of view of the state, such recovery is very important in terms of fiscal discipline but less so in absolute terms—the 'fiscal drain' argument commonly raised to justify increased cost-recovery is hardly convincing since the present O&M subsidy to the JVA is worth less than 0.1 percent of state expenditures given at $3.7 billion (Jreisat 2005).

Yet, despite higher coverage of state-borne O&M costs, water charges do not instill any virtuous circle towards improved management and maintenance on both the manager and farmer sides (Small and Carruthers 1991; Easter and Liu 2005; Molle and Berkoff 2007). There is a lack of positive incentive stemming from the fact, that charges paid by farmers are not benefiting the scheme, managers do not depend on these payments (which are sent to the Ministry of Finance), farmers control neither part of the revenue nor water deliveries, supply is uncertain, and allocation not transparent enough. Under such conditions water pricing merely boils down to a taxation instrument. Bulk charging at the pumping station level and transferring responsibility for charging farmers individually to water user association, might be a way forward.

It is unlikely that raising fees much beyond the O&M cost recovery level can be tenable, because of the limited effect it will have on water use. In addition, raising charges above JVA's expenditures would be difficult to justify since it would look like a transfer of wealth to the state. These factors and the fact that instances of full cost recovery of public schemes in the world are scarce make scenario B unlikely, not to mention scenario C.

Improving Allocation of Water Resources: With price increases expected to have only minimal impact on water efficiency, the objective of reducing agricultural demand to sustainable levels in the Highland and to volumes lower than current diversions in the Jordan Valley through pricing mechanisms, is clearly unattainable and must be dismissed, in line with Berkoff (1994), who recognized "that it is inconceivable that (charges) would be high enough to balance supply and demand." Under such circumstances, the higher-level objective of regulating intersectoral allocation through prices, expressed in the ASAL despite considerable doubt from experts (Pitman 2004), is also unrealistic, a conclusion now widely recognized as generic (Bosworth et al. 2002; World Bank 2003b; Dinar and Saleth 2005).

That "the partial tariff increase (in the Jordan Valley) satisfied an immediate objective of

maximizing transfer of water to the Highlands" (World Bank, 2003a), is also unfounded since this transfer is a bureaucratic decision and completely independent of prices. Transfer has been continuously increasing and effective, and it is expected that in the future most of the Jordan Valley will be irrigated with treated wastewater only (McCornick et al. 2002). Rather, reallocation has been made possible by curtailing water use in the Jordan Valley through quotas.

State and Donors: Conflicting Viewpoints: Opposition to pricing by most quarters in the government is based on three considerations (Pitman 2004): a) social concerns and the view that farmers' access to groundwater is already too costly; b) the view that administrative allocation of surface water and technical/ institutional improvements in management are more efficient and equitable than pricing, in achieving sound management; and c) the understanding that alternative markets must be ensured before pushing farmers to abandon lower-value crops. With some caveats this study tends to confirm these misgivings.

Pitman (2004) notes that the "social-welfare dimension of water was the largest divergence of views between the Bank and the Government over the agricultural sector" and soured relationship between them. The possible impacts on poorer farmers have made the policymakers in Jordan more concerned with the potential social (and political) costs of reforms. Since arguments supporting reallocation of water to richer farmers are clearly not supported by decision makers (who dismiss them as "not valid, since it will result in the monopoly of big farmers in agriculture,"), it is not clear why funding partners are adamant to impose their view in that respect. A possible source of misunderstanding is that affected people include both poor farmers and rentiers, and that the former might be used to unduly shelter the latter from adverse policy measures.

Safety Nets: Policymakers' misgivings may be well-founded if one judges from experience in other domains where planned safety nets have been neglected, equity impaired, and social

objectives defeated. For example, the elimination of all direct subsidies to owners of small livestock herds over the period 1995–1997 proved to be very effective in reducing herd sizes by 25 to 50 percent, overgrazing and thereby rangeland degradation and desertification. However, an official evaluation found that "the poorest group —nomadic pastoralists—in the driest areas have fared worst as they do not have the income to buy even subsidized concentrates. All farmers monitored, with the exception of the medium-sized agro-pastoral farmers in the wettest areas in 1997/98, had negative profits since 1996" (Pitman 2004). Earlier consensus that 'attendant measures would be needed' seems to have been later forgotten (Richards 1993).

This suggests that too little attention is given to safety nets, and the assumption that people can be reabsorbed by the labor market without much hardship, is often not valid. Clearly, linkages to the macroeconomic framework must be strengthened if social objectives are to be fulfilled.

From Negative to Positive Incentives: Generally, negative incentives through pricing that deplete incomes or force costly/risky adjustments raise considerable opposition. This dissatisfaction may be expressed through political channels or in the streets. Such (stick) measures should be linked to positive incentives (carrot)—(Al-Weshah 2000). Positive incentives include a bonus for uprooting olive trees in the Highlands or accepting vegetable allowances in the Jordan Valley (or tree allowances for banana growers), attractive buy-out schemes of wells in the Highlands, aid or crop insurance schemes for farmers willing to diversify, etc. Likewise, the government's reluctance to raise prices before treated wastewater or market opportunities are available also indicates the fear of negative impacts in the absence of clear alternative opportunities and 'pull' factors.

Enforcement and Monitoring: It is clear in both situations that individual metering is extremely demanding and hard to administrate. The percentage of broken meters both in the Highlands and in the Jordan Valley is likely to

rise again after replacement campaigns. If fees significantly affect the economic situation of farms they will also probably trigger defaulting, tampering or destruction of meters, social unrest and political stress at unprecedented levels.

The implementation of the bylaw will also need a dramatic increase in both human and technical resources to control, protect and repair water meters (two expensive measures). These measures might come at a state's expense, eventually. Corruption and collusion between officials and farmers will also develop and be hard to control, especially in a context where the former are underpaid and some of the latter being socially influential (GTZ 2004). This does not mean that metering should not be implemented, but reminds us of the costs involved in the process and of the possibility of adopting other approaches (e.g., charges based on crop and area in the Highlands, or defined and recovered at the level of the pumping station in the Jordan Valley).

Quotas and Regulation: As shown from other situations where scarcity is high and volumetric control possible (Iran, Tunisia, Morocco, south of France, Italy, Spain, Australia, United States or the present case), quotas are invariably selected as the main regulation instrument, with prices controlling use beyond the quota when on-demand service is technically possible (Molle and Berkoff 2007). This is because quotas are, in general, transparent, equitable, easy to understand, and effective in reducing diversions without creating much of an impact on incomes—they have less impact on total revenue than price-based regulation (where some farmers have to be 'priced-out' until demand equates supply). Their application on wells, however, requires a major enforcement capacity. Their main drawback is the limited capacity to adjust to changes in demand. The present case provides such an example, where economic inefficiencies arise from the disincentive they generate for citrus and banana growers to adopt less water-intensive crops. In the absence of adequate conditions for quota transactions between users, careful downward adjustments of quotas, as implemented in the

Jordan Valley since 1999, are effective in forcing adjustments and saving water (however, the margin of flexibility for farmers is reduced, and the great diversity of efficiencies implies that some farms might be adversely affected by such a curtailment).

Highlands and Jordan Valley: Some Meaningful Discrepancies: Although the two situations show many commonalities, the comparison also manifested a few meaningful discrepancies, which are given below:

First, is the possibility offered to 'highlanders' to expand their plots of land. This allows them to capitalize on possible water savings and to increase the cultivated areas (and benefits) in proportion. Economic gains from improved irrigation efficiency are not derived from uncertain increases in yields only, as was the case in the Jordan Valley. It is more interesting for 'highlanders' to improve efficiency than for farmers in the Jordan Valley.

Second, quotas in the Highlands are merely thresholds, which can be exceeded at limited cost, while those in the Jordan Valley are rigid and cap diversions (although informal arrangements may offer some way out).

Third, water supply in the Highland is very reliable, because it depends on individual wells and compact networks. In contrast, allocation and distribution in the Jordan Valley are much more complex both technically (regulation of the KAC, rotation between farmers within pressurized networks, etc.,) and socially (practices are embedded in complex social and political contexts). This difference explains why water efficiencies are higher in the Highlands (with the additional benefit that return flows tend to return to the aquifer, while in the Jordan Valley, they mostly go to a sink— the Dead Sea). In sum, water management is technically simpler in the Highlands, but enforcement and control are problematic. In the case of the Jordan Valley, the opposite is true, where quotas are effective in controlling water use but management heterogeneous, which makes it difficult to achieve uniformity in water distribution and efficiencies.

Conclusion

We can conclude that some, but not all, of the benefits expected from water pricing policies could materialize in the Lower Jordan River Basin. On the positive side, in the Jordan Valley, we showed that full cost-recovery of O&M is achievable without major impacts on revenues, but the virtual link between payment and improved service should be activated by granting more financial autonomy to the JVA. More substantial increases in water prices and lowering of the current quotas (in both the Jordan Valley and the Highlands) can also be expected to raise overall economic efficiency by pushing farmers to intensify and invest in technology, or to rent out their land to investors (greenhouses or fruit-tree farmers). As for the farmers growing bananas, this incentive will be increased if import duties are removed.

However, it is clear that there is pervasive over-optimism among donors, development banks and some green NGOs about what can be achieved through pricing policies, and that policy objectives are often listed without due attention to the contradictions they entail, the trade-offs they imply and the constraints they face. Expectations of the ASAL, for example, were high but the goals of economic efficiency, equity and environmental sustainability (central to the definition of Integrated Water Resource Management) are not easily reconciled. In the Jordan Valley, the current system of quotas, the lack of storage, and the technical difficulties experienced in the pressurized networks indicate that little water can be saved. Irrigation efficiency is improved by technical interventions that ensure better uniformity and better timing of water applications, which in turn enhance ET (and yields), and not by merely reducing water use. Real savings will be possible, if monthly quotas can be turned into one annual quota (in such

conditions, possibility of trading water would also enhance both irrigation and economic efficiency, but control of supply is yet far from sufficient to allow such mechanisms to be put in place). In the Highlands, in line with worldwide experience, which shows that individual use of groundwater is extremely difficult to regulate, the objective of reducing abstraction to sustainable levels through the bylaw will not be met, partly because: a) high quotas will do little to regulate water use in under-irrigated rentier's farms (olive orchards); and b) water cost increases will remain modest compared to the high revenues of fruit tree entrepreneurs.

Finally, it is clear that negative price incentives would further depress the revenue of the most extensive farmers (citrus orchards, mixed farms in the Jordan Valley and open field vegetable farms in the Highlands) and force them to reconsider the benefits of crops/technology shifts and the risks and constraints that are associated with the choices. Yet, this reconsideration will be practically enforced on them in a situation of greater financial vulnerability (because of loss in revenue due to higher water costs), which in turn would increase the financial risk linked with such choices. A shift towards high-value crops would not only raise water productivity but also entail a transfer of wealth to the government and to wealthier entrepreneurs, an evolution that has thus far not been considered as desirable or politically palatable by Jordanian decision makers. Hence, price incentives should not be imposed on farmers, unless accompanied with positive incentives that reduce capital and risk constraints, offer attractive alternatives (market options, subsidies for modernization, technical advice, etc.), and exit options with appropriate compensation.

Appendices

Appendix 1
Details of Farming System Characterization

Farming Systems in the Highlands

Settled Bedouins

Nomadic Bedouins settled down in the eastern deserts during the 1970s, 1980s and even 1990s. Following governmental settlement policies, they partly gave up their livestock activity. Farmers can either be landowners or lessees, but in all cases the household partiipates in the farm work. Three main farming systems are identified below:

Vegetables in Open Fields: A Family Farming System: These farming systems are developed by Bedouins who settled down in the region in the 1980s and partially gave up livestock activity. They rent both the well they use to irrigate and the land they crop. Farmers always ensure they cultivate the maximum area (on average 20 to 25 ha) that can be irrigated as per the quantity of water they can pump from the well they rent. Most of the time, farming is a family-based activity—half of the work is usually done by the tenant's family (4 to 8 workers), the other half by permanent employees, supplemented by daily workers, when required.

In these regions, there is not much 'land pressure', and, as such, most farmers freely change the plots they crop every year to avoid land degradation (salinization, contamination by fungi or nematodes, etc.,). The crops grown are much varied— tomato and watermelon principally, followed by pepper, zucchini, cabbage and cauliflower. Of the two cropping seasons, one is in the spring (from March to July) and the other is in the summer (from August to October/November).

These systems have a low profitability. The net benefit per hectare averages $1,100 and the net income per family worker is lower than $2,500/capita/year: the household lives below the poverty line (evaluated at $660/ca/yr by the Jordanian Government, the DFIP and the UNDP).

Mixed Farms: A Family Farming System: Generally, there are two main plots, contiguous or otherwise: vegetables are cropped on 20 to 25 hectares and there is an olive orchard on 10 to 15 hectares (with, at times, other fruit trees such as peach and nectarine). If the plots planted with vegetables and olive trees are distant from each other, the farmer will often own two wells (otherwise, the orchard will be supplied with water from the well meant for watering vegetables). As the family continues part of its livestock activity it is not rare to see small herds (50 heads, goats and sheep) grazing in the vicinity of the farm. Cereals (wheat and barley) are often grown for the animals. The household, therefore, may have sources of revenue other than agriculture.

The cropping systems themselves are similar to those of the extensive open-field farms described above, but watermelon is less common (owing to its high consumption of fertilizer/chemical, risk of soil contamination). Farm profitability, however, is low, with a net income averaging $800/ha of vegetables. The olive orchard is managed by the family (harvest is a traditional family gathering, sometimes done with the help of daily workers) and its profitability reaches (for trees at maturity) $300/ha/year, significantly increasing the agricultural revenue of the family. With such increases, the total average revenue amounts to $621/ha/year.

Since agricultural activities usually do not provide revenues higher than the poverty line, farmers, more often that not, are compelled to rely on other sources of revenue that are derived from the wider economy.

Family Fruit-tree Farms: A Family Farming System: When profitability of vegetable farming decreased during the 1980s and the beginning of the 1990s, some Bedouins (owners) shifted to fruit-tree plantations, especially those who had the investment capacity to do so. They now manage an orchard of 10 to 20 hectares on average and have retained their olive plots (and

sometimes, though rarely, a small area planted with vegetables). This shift is still observed today resulting in vegetable cultivation giving way to fruit-tree farming. However, the household continues to retain a small herd. Farmers today, essentially have peach and nectarine trees. Although the initial investment for this system is high (nearly $29,000/ha), its net benefit reaches about $6,900/ha/yr.

Stone-fruit Tree Entrepreneurs

Stone-fruit production is still an expanding profitable activity in the Highlands, despite difficult regional and economic conditions. Large entrepreneurs continue to invest in orchards: they rent or purchase wells and land that is often abandoned by vegetable farmers during the last 10 years and engage in high/long-term investments to grow intensively managed and profitable orchards.

Generally, the owner's family is in charge of the management of the farm, the owner being referred to as a Muzakhein. In most cases, the family is of Palestinian descent and owns between 20 and 300 hectares. The owner of the farm is highly involved in commercialization and marketing of the product, while a caretaker (who often belongs to the owner's family) manages qualified permanent employees and takes care of day-to-day operations. Two main management types can be identified:

Very Intensively Managed Farming Systems with High-tech Irrigation Techniques: The owner is very closely involved in farm activities, the initial investments are very high ($600,000 to 700,000 for the area served by one well: 20 to 40 ha), a large part of the production is exported, often through a family-based network.

Investor's Farm Owned by Absentee-owners Not Involved in Farm Management: Investment is very high: $900,000 to 1 million for a farm of about 40 to 80 hectares with two wells. Half of the area is planted with low-benefit olive trees.[33]

As in family fruit-tree systems (adopted by the settled Bedouins), peaches and nectarines are the main trees planted in the entrepreneur's farm. However, entrepreneurs also grow plum, apricot and apple trees, which are more costly to produce and need closer management and more labor, but yield attractive returns. Yields and prices observed in these entrepreneurial farms are higher than in family farms: they have better-quality products and about 50 percent of these products are exported to the Gulf countries, Syria and Lebanon (against the 30% in family farms). These entrepreneurial farms are very profitable and per hectare net benefit averages $16,000 and $14,850 in intensively managed farms and absentee-investor's farms, respectively. The differences in profitability are related to differences in management.

Absentee-owners: 'Prestige' Olive Tree or Extensive Vegetables

Olive orchards are often developed in parallel to other activities (vegetables, stone-fruit orchard), mainly by settled Bedouins. However, a large share of the total irrigated olive-tree area in the highlands (7,000 to 7,500 ha) corresponds to what can be called 'prestige farms'. These farms have a high social and prestige and, sometimes, recreational value, but their conventional economic profitability is very low, sometimes even nil (Lavergne 1996; Fitch 2001; Venot 2004a). They may also include long-term strategies of land occupation and the planted area is maximized to correspond with the well capacity; hence the low depths of water application and frequent deficit irrigation (also observed by Hanson 2000). Most of these farms are found in the eastern desert zone.

Farms have an average area of 10 to 40 hectares. The owner rarely comes to the farm, and

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[33] Olive trees are grown, as farmers would not have enough water to irrigate their entire farm if it was fully planted with stone-fruit trees. Moreover, owners are sentimentally tied to this traditional crop and it is a way to appropriate land in these desert areas. Olive orchards have a low profitability: US$60/ha/yr when trees are young and US$550/ha/yr when they are mature (production is exported through the owners' own export channels).

when he does it is only to supervise the harvest period. All the work is done by permanent employees (either Egyptian or low-income Jordanian workers). The orchard is—with very few exceptions— irrigated by drippers. Trees begin to produce after 4 years; maturity is reached at 12 years and average yields of 4,500 kg/ha/yr can be maintained for 50 years. Profitability is negative for young trees (at $200/ha/yr) but reaches the (still low) level of $300/ha/yr when trees are mature (at current olive-oil and water prices).

A few absentee-owners/tenants living outside the region (notably in Amman) can also have extensive systems of open-field vegetables. They are not directly involved in farm management, hire a manager to take care of operations, and have other sources of revenue. The cropping patterns are similar to those in settled Bedouin vegetable farms but the profitability of this system is lower due to more extensive management: $600/ha.

Farming Systems in the Jordan Valley

Family Farming Systems: Vegetables in Open Fields

Land can be owned or rented. Landowners are mostly Jordanian with their origin in the Jordan Valley itself; and tenants can be Jordanian, Palestinian, or even Pakistani. Field work is entirely done by the family and, if necessary, with the help of daily workers (in rare cases some permanent workers can be found in the largest farms). Farms have an area of 3 to 6 hectares. Crops grown are very diverse and there are two main cropping seasons (first seedlings are done in October/November: Tashrini crops of squash, onion, pepper, cabbage, cauliflower and eggplant, etc.; the second crop is planted in January/ February: Khamsini crops as tomato, squash, potato, pepper, etc.,). On-farm investments remain limited; most farmers rent the land preparation equipment and some of them own trucks to transport their products. The average net income of farmers is $3,800/ha/yr. Revenue fluctuations are high, both temporally (from one year to another) and spatially (revenues are higher in systems developed in the north of the Jordan Valley that are more intensively managed than those in the south) and most of these open-field family farmers are in precarious situations.

A few small entrepreneurs who cannot invest in greenhouses also developed open-field vegetable production, which provides relatively high revenue. The benefit per hectare from these entrepreneurial systems is slightly lower than in the family systems, but it is not shared among several family workers and is earned by a single farmer.

Entrepreneurial Greenhouse Farms

Greenhouses allow the control of temperature and humidity and so the production of vegetables in winter (when prices are the highest). These systems are, therefore, very profitable and the net income averages $7,500/ha/yr. The main crops are: tomato, cucumber, melon, hot and sweet pepper, eggplant and bean. Greenhouse farms are mainly located in the middle of the Jordan Valley. Greenhouse production requires higher investments and closer management than open-field production. As such, farmers usually use greenhouses for only a part of their farms, depending on their investment capacity. Most of the greenhouses are developed by medium entrepreneurs in farms of 6 to 10 hectares. All the work is done by permanent employees, mostly Egyptian. The smaller entrepreneurs are closely involved in the management of their farms. Larger and richer entrepreneurs appoint a manager with knowledge in agricultural engineering. Greenhouses can be found in family systems too. Farms are smaller and slightly less profitable but still allow a net benefit per family worker well above the poverty line (average of about $15,000/yr).

Citrus Farms: Family and Prestige Farms

Citrus farms are located both in the north and in the middle of the Jordan Valley. In the north, colder and rainier climate, deeper and better soils, and better water quality are suitable for the

development of citrus orchards. Different species of citrus are widespread in the Jordan Valley (clementine, mandarin and various types of oranges, lemon, pomelos, etc.,). In order to minimize the risk linked to price fluctuation and to enjoy an extended harvest period, farmers diversify their cropping pattern. Most farmers are owners of their plots (Ducros and Vallin 2001). Farmers rent all the equipment needed for land preparation and transport. Two main kinds of farms, differing by their type of management, can be identified:

Family Farms with an Area of 3 to 6 Hectares: Management is relatively intensive (drip or open tube irrigation, use of fertilizers, etc.,). Most of the work is done by the family and there is often one permanent employee. The net income averages $1,250/ha/yr.

Prestige Farms Developed by Absentee-owners: Farms have an area of 1 to 20 hectares and can be divided into several noncontiguous plots. On-farm investments are minimal, all the work being done by a few permanent employees. There is often a villa in the farm. For these urbanites, the recreational, social and prestige value of the orchard is more important than its low economic value: the net income averages $400/ha/yr.

In general, the profitability of citrus orchards is now very low; the more extensive the management, the lower the expected revenue. Citrus farming systems have been highly affected by the changing conditions faced by Jordanian agriculture (notably price decrease and overproduction), but they had been far more profitable during the 1980s and early 1990s (GTZ 1995).

Banana Farms

Banana farms are located in the extreme north, the extreme south of the Jordan Valley, and along small side-wadis out of the JVA command area. Generally, banana-farming systems are less intensive (in terms of work input, fertilizer and water use) in the north than in the south. Family farms in the northern part have an area of 1 to 5 hectares, generally irrigated by drippers but sometimes by furrow, and are entirely covered with bananas. Half of the work is done by the family, the other half by daily-paid or permanent workers. Banana orchards require high initial investments but they ensure lofty returns: the net benefit averages $7,000/ha/yr in family systems of the northern Jordan Valley.

Entrepreneurial banana farms can also be found in the north and the south of the Jordan Valley. In these systems, the owners are mainly involved in farm management, while work is done by permanent employees. Entrepreneurial farms in the north often have an area of 1 to 5 hectares, which yield a net benefit of about $12,500/ha/yr.

Banana is the most profitable—and the more water-consuming—crop grown in Jordan. This profitability, however, is partly due to custom tariffs that make imported banana costlier: banana producers are thus subsidized by consumers.

Poor Farmers with Mixed Farms

This type of farming system is relatively rare in the Jordan Valley. Farmers are mainly former slaves of noble tribes, or Palestinian refugees of 1948 who live in the Jordan Valley. Most of the time, farmers are tenants or sharecroppers (generally on 1 to 3 ha at a maximum) but some may have benefited from the land reform of 1962 and have become owners. The household also diversifies its revenue with certain amount of livestock activity (goats, sheep, and cows). Farmers diversify their cropping pattern to mitigate risks linked to the market and choose low labor-intensive crops so as to face labor peaks, during which time the family workforce obtain work outside the farm to maximize the household's income. Initial and annual investments are very low. The net revenue reaches only about $1,050/ha/yr and does not allow a household with no secondary revenue to live above the poverty line.

Appendix 2
Net Crop Water Requirement (in m³/ha/year) in the Amman-Zarqa Basin (adapted from Fitch 2001)

Crop	Mafraq region (eastern desert area)	Zarqa River region	Weighed average
Tomato	7,500	6,130	7,010
Cauliflower and cabbage	5,000	3,840	4,580
Other vegetables	7,500	5,910	6,930
Watermelon	4,130	3,210	3,800
Sweet melon	5,810	4,580	5,360
Average on vegetables	5,990	4,730	5,540
Olive	6,880	6,880	6,880
Apple	10,620	9,750	10,310
Peach	10,040	9,230	9,750
Grape	10,430	8,220	9,630
Other stone-fruits	10,450	9,600	10,150
Other deciduous fruits	10,040	9,230	9,750
Average on orchards (olive excluded)	10,320	9,210	9,920

Notes: 1. The net requirement is the total crop requirement divided by an estimated 80 percent efficiency for drip irrigation in the Amman-Zarqa Basin
2. The weighed average is obtained on the basis of the crop share in the two regions

Appendix 3
Net Irrigated Areas (ha) in the Amman-Zarqa and the Yarmouk Basins (top) and in the Northern and Middle Directorates of the Jordan Valley (bottom)

Top

Evaluation based on landuse analysis from MWI/GTZ data (see figure 1)	Amman-Zarqa Basin		Yarmouk Basin	
	Total	Belonging to the eastern desert zone	Total	Belonging to the eastern desert zone
Vegetables	2,490	1,695	545	170
Olive trees	5,440	4,640	1,320	1,290
Other trees (mainly stone-fruits)	2,835	2,210	1,830	1,830
Total	10,765	8,545	3,695	3,290

Bottom

Crops	Autumn vegetables	Summer vegetables	Citrus and other trees	Bananas	Cereals (essentially rain-fed)	Total
Irrigated area (ha)*	5,210	3,130	8,060	285	2,660	19,345

Note: * Evaluation based on DoS records (average 2000/2004; available at www.dos.gov.jo)

Appendix 4
Crop Water Requirement (in mm/day) as presented in the Baker and Harza Study of 1955 and Originally Used to Calculate Irrigation Quotas in the Jordan Valley (left panel—south of the Jordan Valley; right panel—north of the Jordan Valley)—(Baker and Harza 1955)

Left panel

	Vegetables	Citrus	Bananas
January	1.1	0.9	1.9
February	1.4	1.1	2.3
March	1.9	1.5	3.0
April	2.1	1.7	3.4
May	2.6	2.1	4.2
June	3.0	2.4	4.9
July	3.0	2.5	4.9
August	2.9	2.3	4.7
September	2.4	2.0	4.0
October	2.1	1.7	3.4
November	1.7	1.4	2.8
December	1.4	1.2	2.3

Right panel

	Vegetables	Citrus	Bananas
January	0.3	0.3	0.6
February	0.6	0.5	0.9
March	1.2	1.0	2.0
April	2.1	1.7	3.4
May	2.5	2.1	4.1
June	2.9	2.3	4.7
July	2.9	2.4	4.8
August	2.9	2.3	4.6
September	2.5	2.0	4.0
October	2.1	1.7	3.4
November	1.2	1.0	2.0
December	0.5	0.4	0.9

Appendix 5
Current and Proposed Irrigation Water Tariff Structure in the Jordan Valley (FORWARD 2000)

| Water quality	Usage block (m³/month/3.5 ha maximum)	Irrigation tariff (per 1,000 m³)	
		Current	Proposed
Freshwater	0–2,500	$11.5 (JD 8)	$21.6 (JD 15)
	2,501–3,500	$17.3 (JD 12)	$43.2 (JD 30)
	3,501–4,500	$28.8 (JD 20)	$64.8 (JD 45)
	Over 4,500	$50.4 (JD 35)	$79.2 (JD 55)
Low-quality water (freshwater mixed with treated effluents or highly saline water)	0–2,500	$11.5 (JD 8)	It is proposed to maintain the current tariff structure
	2,501–3,500	$17.3 (JD 12)	
	3,501–4,500	$28.8 (JD 20)	
	Over 4,500	$50.4 (JD 35)	

Appendix 6
Crop-wise Water Prices and Water Costs in the Jordan Valley (Northern and Middle Directorates)

	Vegetable farms	Citrus farms	Banana farms	Weighed average*
Average water price per cubic meter	$0.013 (JD 0.009)	$0.014 (JD 0.010)	($0.023) JD 0.016	$0.018 (JD 0.013)
Total water costs per hectare and per year	$67 (JD 47)	$138 (JD 97)	$350 (JD 245)	$303 (JD 212)

Note: * Evaluation based on irrigated areas in the northern and middle directorates as given in appendix 3

Appendix 7
Example of Cropping Pattern and Water Requirement in a Vegetable Farm in the middle of the Jordan Valley (Petitguyot 2003)
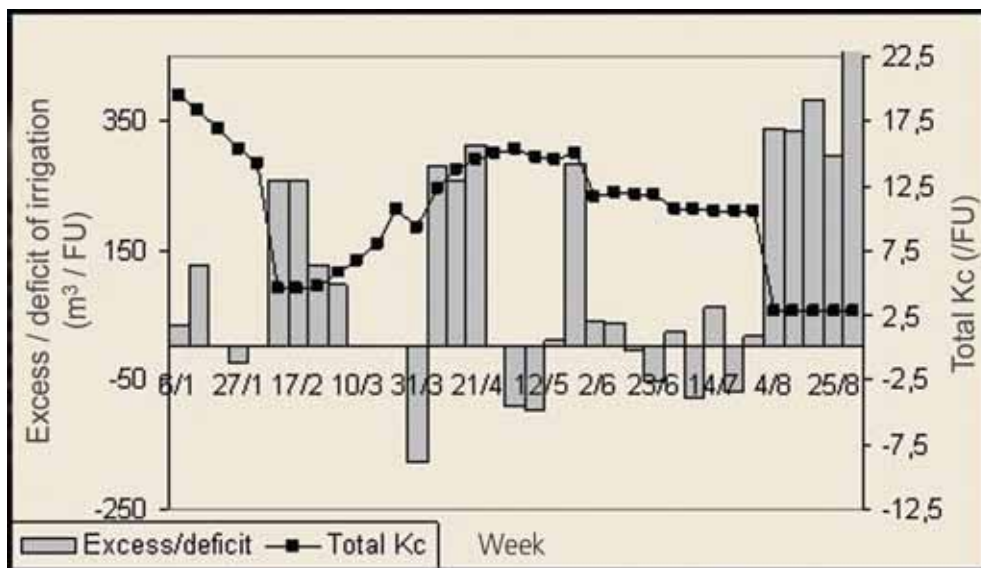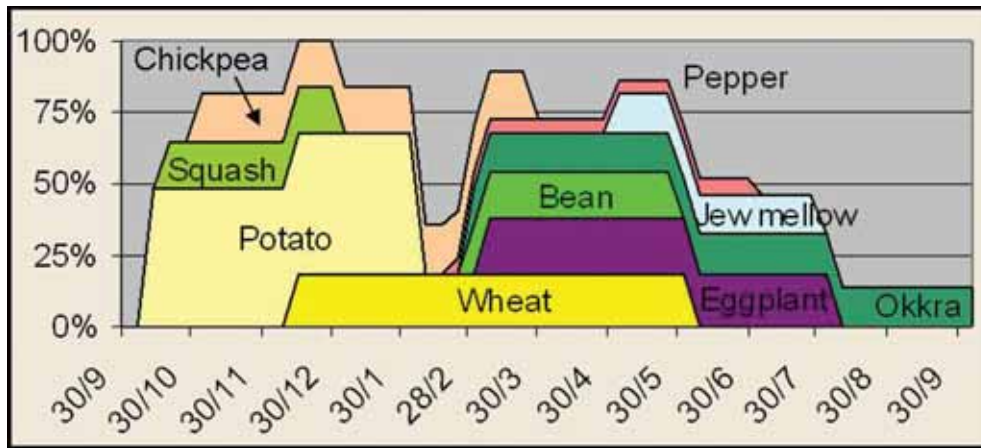
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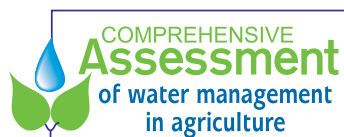Hussein, I.A.J. 2002. Water planning in Jordan: Future scenarios. Water International 17 (4): 468-475.

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