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Irrigation in the Jordan Valley: Are water pricing policies overly optimistic?

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ABSTRACT

Water is very scarce in the Hashemite Kingdom of Jordan. The development of both public irrigation in the Jordan Valley and private groundwater schemes in the highlands has diverted a large share of the country's water resources to agriculture. Many policy instruments have been used in the last 10 years to reallocate water to nonagricultural uses and encourage improvements in efficiency throughout the water sector. Demand management has been emphasized, with water pricing policies expected to instill conservation and motivate a shift toward higher-value crops. We examine the rationale for, and potential and current impact of, pricing policies in the Jordan Valley.

We describe the likelihood of success of such policies in terms of operation and maintenance cost recovery, water savings and improved economic efficiency, and we explore some of the alternatives available for meeting these objectives. We show that while operation and maintenance (O&M) costs can be recovered higher water prices have limited potential for achieving gains in irrigation efficiency. The current system of quotas, the lack of storage, and technical difficulties experienced in the pressurized networks indicate that little water can be saved. More substantial increases in water prices can be expected to raise overall economic efficiency by motivating farmers to intensify cultivation, adopt higher-value crops, improve technology, or rent out their land to investors. Yet such strategies are constrained by lack of capital and credit, and pervasive risk, notably regarding marketing. Pricing policies, thus, are best implemented together with positive incentives that reduce capital and risk constraints, and offer attractive cropping alternatives or exit options with compensation.

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1. Introduction

Water is very scarce in the Hashemite Kingdom of Jordan. Due to both physical water scarcity and rapid population growth over the second half of the 20th century the estimated per capita availability of renewable water is now only 163 m^3/year, while the average domestic consumption is 94 l per capita per day (34 m^3/year) nationwide (THKJ, 2004).

With the exception of some rain-fed agriculture in the mountains (mostly pasture, wheat and olive trees), the bulk of commercial agriculture is irrigated and can be found in two contrasting environments: the Jordan Valley, where a public irrigation scheme supplies approximately 23,000 ha, and the highlands where private tube-well-based irrigation has been developed on 14,000 ha during the last 30 years.

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The Jordan Valley irrigation scheme receives its water from the Yarmouk River, just upstream of the confluence with the Jordan River, at the northern end of the valley. Water is fed into a concrete canal that runs parallel to the river on the eastern bank. Additional inflows come from several *wadis* (lateral intermittent streams) that cut through the mountain ranges bordering the valley. The main water use areas and water flows in Jordan are shown schematically in Fig. 1.

Amman receives water from the Jordan Valley and aquifers, and from southern and eastern outer basins. Available options to meet the increasing domestic water demand include: (a) improving inflow from the Yarmouk River by construction of a new dam (Al-Jayyousi, 2001); (b) transferring more water from the valley to Amman, which will reduce the supply to agriculture even though treated wastewater will return to the 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); (d) relying on costly imports (THKJ, 2004).

In the early 1990s, aware of the incipient water crisis, the Jordanian government changed its policy focus from supply augmentation toward demand management (Al-Jayyousi, 2001). The World Bank and other development agencies 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, and reduce groundwater overdraft (Pitman, 2004). Pricing of irrigation water was chosen as an instrument to reduce demand for water (World Bank, 2003a).

In the highlands, pricing policies were expected to limit groundwater use with the ambitious target of reducing abstraction to "close to the annual recharge by the year 2005" and to promote higher-value agriculture (THKJ and MWI, 1997b, 1998a). 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 threshold quota and a block-rate tariff system above it (see Venot et al., 2007).

In the Jordan Valley, a block-rate tariff associated with crop-based quotas had been in place for some time and debate revolved around possible increases in water charges: more expensive water was expected to bring about improvements in irrigation efficiency and a switch to less water-intensive crops, thus releasing water for Amman (World Bank, 2003a). It 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 projects. The ultimate objective shall be full cost recovery subject to economic, social and political constraints" (THKJ and MWI, 1997a; see also THKJ and MWI, 1998b, 2004b; JRVIP, 2001).

Some of these reforms were embedded in the 1994 Agriculture Sector Structural Adjustment Loan (ASAL), funded jointly by the World Bank and the German KfW, and designed with the prime objective "to support a transition to an optimal use of water and land resources" and to address key problems of the sector: "the lack of a national water policy, competing sector institutions, and insufficient attention to demand management" (World Bank, 2003a; Berkoff, 1994). Implementing these policies proved difficult and generated discord, exemplified by the occupation of Parliament in opposition to higher water tariffs, requiring further intervention by His Majesty the King (Pitman, 2004).

We examine the rationale for, and potential and current impact of, water pricing policies in the Jordan Valley. We describe the likelihood of success of such policies in terms of recovering O&M costs, saving water and raising economic efficiency. Then we explore alternative options to meet these

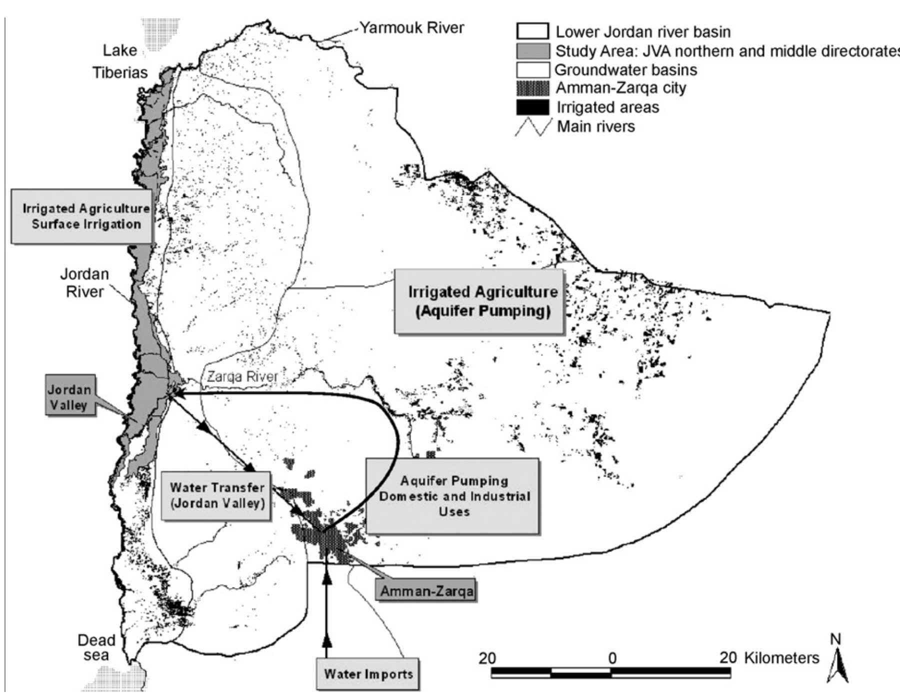

Fig. 1 – Main water uses and water flows in the Lower Jordan River Basin.

objectives. The possible impacts and responses to price increases are analyzed across five types of farming systems derived from a survey of 50 farms in the spring of 2003.

2. Irrigation management in the Jordan Valley

2.1. *Irrigation in the valley*

Irrigation has long been developed adjacent to wadis, on their alluvial fans in the Jordan Valley, and wherever springs are 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 the 69 km King Abdullah Canal. In 1962, a land reform program created thousands of small farms (3.5 ha on average) and settled numerous families, including Palestinian refugees (Khouri, 1981; Van Aken, 2004). Irrigated agriculture thrived in the late 1970s and 1980s.

In the Jordan Valley, the government improved and expanded irrigation facilities. Farmers adopted modern irrigation and cropping techniques, such as greenhouses, drip irrigation, plastic mulch, fertilizer and new varieties, and they utilized cheap labor from Egypt. During this period, agricultural revenues increased 10-fold for vegetables and more than doubled for fruits. Irrigated agriculture in Jordan enjoyed a boom in production and profitability, described by Elmusa (1994) as the ‘‘Super Green Revolution.’’

With increasing competition from neighboring countries (Turkey, Lebanon and Syria) and the loss of the Gulf export market in the 1990s, this profitability declined, strongly affecting farm revenues (GTZ, 1995; Fitch, 2001; Jabarin, 2001). The sector's contribution to Jordan's Gross Domestic Product declined from 8.1% in 1991 to 3.6% in 2003 (Nachbaur, 2004). At the same time, competition for water also increased as freshwater was progressively transferred to urban uses in the highlands. As a result, the agriculture sector has become more vulnerable to droughts, and agriculture in the southern part of the valley is increasingly supplied with treated wastewater (see McCornick et al., 2001, 2002; THKJ et al., 2002; THKJ and MWI, 2004a; JICA, 2004).

We focus on the northern and middle directorates of the Jordan Valley, where JVA's water allocation rules apply. The irrigated area is 19,345 ha, with 43% of the area producing vegetables (both in open fields and under greenhouses), 42% under citrus, and the remaining area planted to banana and cereals. A conversion from the earlier gravity network to pressurized systems was completed in the mid-1990s. Irrigation water is now provided to farmers from pumping stations that draw water directly from the King Abdullah Canal, supplying collective pressurized networks serving areas of approximately 400–500 ha.

Farming systems in the valley are heterogeneous. The survey identified five categories of farming systems (Table 1), including: (1) family farmers who either own or rent the land and grow vegetables in open fields; (2) entrepreneurial farmers who use capital, knowledge and labor-intensive techniques such as greenhouses and earn a high return on investment; (3) citrus orchards in the north of the Jordan Valley, operated either by owners or by managers hired by absentee investors; (4) highly profitable banana farms in the north of the valley; (5) mixed farms with more extensive vegetable cultivation combined with small orchards (the poorest category of farmers).

The main differences between these faming systems are the degree of capital use and intensity of production, the type of land tenure, the irrigation technology used, and whether management is by owners or tenants. Crop budgets and a review of the constraints specific to each farming system

Table 1 – Profile of main farming systems in the northern and middle directorates of the Jordan Valley[a]

Farming systems	Open-field vegetable family farms	Entrepreneurial greenhouse farms	Citrus farms		Banana farms		Mixed farms
			Family farms[b]	Absentee owner and family farms	Family farms	Entrepreneurial farms	Poor family farmers
Land tenure	Rent/ownership	Rent/ownership	Ownership	Ownership	Ownership	Ownership/rent	Rent/sharecropping
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 (m^3/(ha year))	5050	5050	10,100	10,100	15,000	15,000	5050
Main irrigation system	Micro-irrigation	Micro-irrigation	Micro-irrigation	Gravity irrigation	Gravity and micro-irrigation	Micro-irrigation	Gravity irrigation
Net revenue (US$/(ha year))[c]	3,800	7,500	1250	400	7,000	12,500	1050
Net revenue (US$/(farm year))	17,100	60,000	5625	4000	21,000	37,500	2100

[a] The data represent mean values obtained during a survey of 50 farmers in the Jordan Valley during 2003.
[b] Data for absentee owners using micro-irrigation systems are not shown here.
[c] The net revenue is the gross income net of all production costs. These costs include amortization of capital, financial costs, and hired labor valued on the basis of the daily wage observed in the valley.

were undertaken and consistency with other studies was checked (Salman, 2001b; ARD and USAID, 2001b). A detailed description of these farming systems can be found in Venot et al. (2007).

2.2. Water allocation

Since the 1960s, water has been allocated through a system of crop-based water quotas, coupled with volumetric pricing, beginning in 1961 at a cost of \$0.00141 fils/m^3 (Hussein, 2002). The official quota system has undergone several changes since the 1960s and has been used mainly as a guideline, with adaptations according to circumstances and national priorities (THKJ and JVA, 1988, 2001). According to quotas defined in 1988 (THKJ and JVA, 1988), each plot of vegetables grown between mid-April and mid-December received 2 mm of water/day. Citrus and bananas were supplied with 4 and 8 mm/day, respectively, from the beginning of May to the end of October. For all crops, water was supplied on demand during the rest of the year, when demand is lower.

Bananas and citrus are thirsty crops and have been cultivated traditionally in the northern part of the Jordan Valley (Khouri, 1981; Elmusa, 1994). In 1991, the orchard areas that could claim larger irrigation quotas were ‘‘frozen’’, institutionalizing inequity in access to water in the Jordan Valley. In 2004, in contradiction to its policy to reduce demand, the JVA also legalized citrus orchards planted between 1991 and 2001, granting them the citrus allocation instead of the vegetable quota they received earlier. All other areas continue to receive the vegetable allocation, provided that farmers declare to the JVA that they are cultivating their plots.

The 1997–1999 period was marked by a severe drought that forced reduced allocations. In 1999, vegetables and citrus farms received 75% of their allocation, while banana farms received 85% of their quota. Allocations were reduced by 25% in 2000 and 2003, and by 50% and 40% during the summers of 2001 and 2002, respectively (MREA and JVA, 2006). Some areas were left fallow and yields were significantly reduced, notably in citrus and banana plantations. Lower quotas have been maintained ever since, except in the south of the valley, where treated wastewater ensures a more reliable supply.

In 2004, the JVA reduced quotas to a level close to the reduced quotas of 1999 to better match supply and crop water requirements (THKJ and JVA, 2004; Table 2). At a regional scale, this generated total freshwater savings, in the northern and middle directorates, of about 20.2 Mm^3/year between April and October, roughly equivalent to 20% of the pre-1999 average amount of water delivered. The savings have been reallocated to domestic use in Amman.

2.3. Operation and maintenance cost recovery

JVA's revenues from irrigation water have gradually increased with time, as water charges established at \$0.0014 m^{-3} in 1961 later increased to \$0.0042 m^{-3}, then to \$0.0084 m^{-3} in 1989, and to an average of \$0.021 m^{-3} in 1996 (GTZ, 1993; FORWARD, 1998). A planned increase to \$0.035 m^{-3} has been delayed.

Revenues from water charges covered one-sixth of O&M costs from 1988 through 1992 (GTZ, 1993; Hussein, 2002), implying an average annual subsidy of \$3.4 million. In 1995, revenue accounted for less than 25% of O&M costs. Water charges were increased more than twofold in 1996. In 1997, with a rate of nonpayment of 20%, average revenues were equivalent to \$0.017 m^{-3} compared with \$0.025 m^{-3} of O&M costs, implying a recovery rate of 68% (FORWARD, 1998; World Bank, 2001).

Calculations for 1988 through 1992 show that fixed asset depreciation and financing costs were twice as much as O&M costs (GTZ, 1993). Similarly, the ratio of average capital costs to O&M costs was 2.07 from 1997 through 2002 (THKJ, 2004).

Based on the current block tariff system established in 1995 (Table 3) and the latest unit costs, we have estimated the yearly cost of water for each type of crop, considering that farmers use their full irrigation quotas (Venot et al., 2007). Total water costs are higher for banana plantations (\$350 ha^{-1} $year^{-1}$) than for citrus orchards (\$138 ha^{-1} $year^{-1}$). −1). They are lowest on vegetable farms, which require less water (\$67 ha^{-1} $year^{-1}$). The use of the new quotas led to lower water use and consequently to a lower recovery of O&M costs, because fixed costs such as salaries do not vary with actual supply. Water is now charged at an average price of \$0.018 m^{-3}, compared with \$0.021 m^{-3} in 1997. Current payments considering a 100% rate of recovery amount to 72% of O&M costs, while full costs are three times higher than O&M costs (THKJ, 2004).

Table 2 – Current quota system in the Jordan Valley (THKJ and JVA, 2004)

Period of the year	Quotas (m^3/(ha day))		
	Vegetables	Citrus	Bananas
16–31 March	15	On-demand but ≤20	
1–15 April	15	20	30
16–30 April	20	20	30
1 May–15 June	20	30	50
6 June–15 August	On-demand but ≤10	40	70
16 August–15 September	10	40	70
16 September–15 October	15	30	50
16–31 October	20	30	50
1 November–15 December	20	On-demand but ≤20	On-demand but ≤20
16 December–15 March	10	On-demand but ≤20	On-demand but ≤20

Table 3 – Current irrigation water tariff structure in the Jordan Valley

Usage block (m^3/ (month 3.5 ha maximum))	Current irrigation tariff (1000 m^{-3})
0–2500	$11.5 (JD8)
2501–3500	$17.3 (JD12)
3501–4500	$28.8 (JD20)
Over 4500	$50.4 (JD35)

Source: FORWARD (2000).

3. Analysis of responses and impacts

3.1. *Possible responses to increased water prices*

Farmers may respond to falling net 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 (illegal water use, bribery, and tampering of structures), or (f) doing nothing, and just paying the higher water charges. The response selected depends on the relative costs and benefits of these options. Beyond their economic impact on crop budgets, the first four options above are also constrained by the technical, financial and cultural factors reviewed below.

3.1.1. *On-farm management*

By improving on-farm practices farmers can reduce water losses and thus possibly decrease farm water requirements and their resulting costs. Yet, there are several constraints to increasing on-farm irrigation efficiency under current conditions:

- First, farmers experience many difficulties because of deficiencies in the collective pressurized networks that result in variable pressure and substantial variation in water distribution. Deficits are observed in higher locations, on sandy soils, and at the ends of water distribution lines. Secondary irrigation networks designed for 6 l/s flows were eventually equipped with 9 or 12 l/s flow limiters after farmers complained that the pressure was too low. This impeded the proper functioning of the networks. Rotations are difficult to establish and not respected, and water theft and tampering with equipment are pervasive (GTZ, 2004; MREA and JVA, 2006).
- The importance of stable pressure is illustrated in the case of farmers in the extreme north of the valley, most of whom initially shifted from gravity to micro-irrigation systems after pressurization of the network by the JVA in 1996. Most farmers reverted to gravity irrigation, as the delivery service did not match their expectations (Bourdin, 2000).
- Farmers also experience many technical problems due to: micro-irrigation systems that have been installed without technical guidance in 70% of cases; direct connection of old farm pipe networks to the JVA's pressurized system; poor design of blocks and rotations; and problems of filtration and clogging (Wolf et al., 1996; Courcier and Guérin, 2004; Shatanawi et al., 2005).
- Unless water can be traded, the economic incentive for a farmer to save water is small (Development Alternatives Inc., 2004) because: (1) he cannot use the water saved to expand cultivated land, and (2) the system of monthly quotas limits the abstraction of canal water at pumping stations. Water savings are not possible during critical periods in spring and autumn, because demand exceeds supply (Petitguyot, 2003) and the marginal value of water far exceeds its marginal cost. During the rest of the year, efficiency is lower because supply exceeds demand, but this occurs at times when there is no alternative use for water. If water storage facilities are not available, there is little rationale for saving water. In addition, the desirability of further water savings is not fully established, as it is feared that reduced salt leaching would increase salinity problems in the 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, citrus trees can 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 cases, farmers are billed according to their water quotas and not according to their effective use, either because the meter has been broken or because the actual use indicated is suspiciously low. When a meter reading indicates a volume less than 75% of a quota, the farmer is charged for the full quota.

3.1.2. *Adoption of technology*

Technological improvements can enhance irrigation efficiency. Better on-farm irrigation is possible if pressures in the main network are stable or if intermediate storage (farm ponds) and individual pumps are available. Internal rotations can then be redefined to better balance pressure in the network, but this requires technical assistance and capital. Existing users of micro-irrigation can improve irrigation uniformity if they redesign their network, in particular to use larger secondary pipes and better balance irrigation blocks, but they also need improved filtration, more frequent renewal of drippers, and more skilled operations.

MREA and JVA (2006) have shown that improving existing micro-irrigation systems would, on average, cost $1075, $1330, $970, $1435 ha^{-1} of citrus, bananas, and vegetables, either in open fields or under greenhouses, respectively, i.e., annualized investments of about $205, $224, $147 and $185 ha^{-1}, depending on the average lifetime of the material, corresponding to added net revenues of $430, $1460, $820, $650 ha^{-1} $year^{-1}$. These are average values that vary with the type of irrigation technology (gravity, open tubes, micro-sprinklers and drippers). These values were observed in pilot projects under relatively controlled conditions and should therefore be viewed as upper limits. Redesigning requires technical assistance and computer software to define blocks with a uniform pressure, stressing that improvements in irrigation are knowledge-intensive.

The estimated costs of converting to micro-irrigation are from $1400 to $2400 ha^{-1} for citrus and $2900 ha^{-1} for bananas. These costs represent annualized investments of $263–462 ha^{-1} year^{-1} for citrus and $615 ha^{-1} year^{-1} for bananas, depending on specifications. These investments might generate additional average net revenues of $850 ha^{-1} year^{-1} for citrus and $425 ha^{-1} year^{-1} for bananas, after accounting for depreciated investment costs (MREA and JVA, 2006). If pressure is too low to maintain a desirable supply rate, drippers will clog more easily and farmers will need to invest an additional $410 ha^{-1} in improved filtration or an intermediary farm pond and pump. Micro-sprinklers are more susceptible to low pressure, but drippers are more sensitive to variations in pressure.

Three important points can be made. First, the adoption and improvement of micro-irrigation technologies are, on paper, financially attractive, both before and after an increase in water costs (and more so before than after). Therefore, increasing water prices can motivate farmers to invest in technology, with the possibility of increasing income rather than incurring higher costs. However, adoption is often constrained by lack of capital or credit, as the costs of investing in technology in citrus farms are higher than the average annual net revenue (Table 5). Smaller, indebted farmers, or ones without collateral, cannot easily access credit and, therefore, retain older, simpler production methods, or rent out their land to commercial growers. Some urban absentee owners also have strategies that are inconsistent with intensification.

Second, micro-irrigation increases profitability by improving crop yields and quality, through better irrigation scheduling and uniformity. In addition, farmers can improve their control of nutrient status by applying fertilizer through a drip irrigation system (fertigation). Many farmers justified their investments in micro-irrigation from the 1970s through the 1990s by intensifying production and marketing higher-quality crops. Water savings were not substantial, as farmers used their full water quotas, regardless of their irrigation technology.

Third, field application efficiency is higher when using micro-irrigation, but this results from an increase in the fraction of water transpired productively by the crop, due to a more uniform water distribution, rather than from reduced water diversions to farms.

3.1.3. *Crop choice*

Higher water charges reduce farm-level net revenue and can motivate shifts to low-water-consuming crops and/or higher-value crops (Pitman, 2004; THKJ, 2004). The net revenue from citrus production is less than that from production of vegetables, mangoes, guava, grapes or dates that are becoming popular in some parts of the valley. Banana production is a profitable enterprise that can be replaced by crops with lower water requirements such as grapes or dates. Despite the apparent attractiveness of these newer crops, many farmers continue to produce citrus and other less-profitable crops.

Some farmers do not grow the most profitable crops due to environmental constraints (soil type, salinity, temperature), lack of skill or capital, indebtedness, alternative income sources, age, risk aversion and drudgery (Molle and Berkoff, 2007). It is difficult for many farmers to adopt riskier, more intensive and time-/input-consuming crops, unless relatively stable market opportunities are available.

Jordan's agriculture is notably constrained by difficulties in identifying and adapting to changes in market demand (Salman, 2001b; DOS and FAO, 2002; Al-Zabet, 2002; Nachbaur, 2004). For example, date production is attractive because palm trees are salt-resistant and dates attract high prices. However, date production has several drawbacks from the perspective of small-scale extensive farmers. In particular, date palms require 5 years to come into production, post-harvest operations are difficult to master, and only high-quality products reach the most profitable markets. Farmers facing higher water prices might wish to intensify production, but production and marketing constraints can limit farm-level responsiveness.

Many large citrus groves are owned by absentees whose livelihoods do not depend on agriculture. Their orchards have value in terms of social prestige and recreational use, and their production goals are not driven primarily by economic motivations (GTZ, 1995; Lavergne, 1996; Venot et al., 2007). These owners may not shift to a more intensive and time-consuming activity to preserve a secondary agricultural income. Some have even declined to accept highly subsidized equipment and design in pilot areas (Arrighi de Casanova, 2007b).

Another disincentive for farmers to shift from producing citrus and bananas to producing vegetables is the consequent loss of their higher water quota, with little hope of obtaining it again if they ever would like to revert to producing tree crops.

3.1.4. *Land rental*

Since 2001, land sales and renting have been allowed in the Jordan Valley, although renting plots had already become a widespread practice. As land pressure in the valley is very high, farmers who practice 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 land-rent value, estimated at $570 ha^{-1} year^{-1} (Salman, 2001b). Because 87% of farm managers are tenants (Salman, 2001a) and farm 51% of the total area, the most vulnerable farmers might retire from agriculture, although it is uncertain whether economic alternatives will be available to them.

3.1.5. *Others*

Last, it is worth mentioning that raising water charges much higher 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 large number of meters have been broken, in part as a response to the very costly fines imposed on illegal use of water. Unrest and political interventions are also possible and likely reactions, as when the army recently intervened to quell violent conflicts that erupted in the south of the valley after the government attempted to collect unpaid land and water fees (Al-Hanbat, 2007; Al-Dustour, 2007). Such outcomes are not attractive for the government, which has little incentive to antagonize supportive segments of society unless gains are expected to be substantial (Richards, 1993).

3.2. 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 that water prices increase to a level where the O&M costs of the JVA are recovered. This is the primary objective of water pricing policies in Jordan (THKJ and MWI, 1998c, 2002; FORWARD, 1998; Salman, 2001a; THKJ et al., 2002; THKJ, 2004). In scenario B, we consider a water price increase allowing the recovery of total costs of irrigation in the Jordan Valley (O&M plus capital costs). In both scenarios, we retain the block tariff system (Table 3). Scenario C is based on a recommendation by THKJ (2004) that prices in the valley should be raised to 80% of the present average cost of water borne by farmers in the highlands. In this scenario, water is charged at a flat rate of \$0.116 m^{-3} (Al-Hadidi, 2002) regardless of the volume of water used on 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]), *ceteris paribus*, including crop mix, irrigation efficiency and delivered water. The rate of fee recovery is assumed to be 100%. This provides a benchmark for the relative costs and benefits, and advantages and drawbacks of other options ([a] to [e]) 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, such as risk and alternative farmer strategies. Although such an analysis is contingent by nature, it attempts to capture the diversity of farming systems, constraints and farmer strategies. Table 4 describes the average water costs for each crop and scenario (assuming that farmers use their full quota), and Table 5 presents their financial impacts on each farming system.

Water-cost increases in scenarios A and B are 1.4 and 4.15 times, respectively, of present values. In scenario C, due to the implementation of a flat charge, water costs increase 8.7 times for vegetables, 8.5 times for citrus and 5 times for bananas. Extensive farming systems (citrus and mixed farms) would be most impacted because water charges represent a large portion of total costs (on citrus farms) and because net revenue is very low (Table 5).

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% and 2%, 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 4.2–13.2% on farms with micro-irrigation and gravity irrigation, respectively. In the latter case, the impact is higher but these absentee owners have other sources of revenue and are therefore less sensitive to changes in farm revenue. In sum, these impacts are unlikely to modify very much farmers' perceptions of the constraints to intensification. The motivation provided by declining revenues seems quite modest.

In scenario B, farm net revenues would decline more substantially. Productive systems (vegetables in open fields or under greenhouses) would again be slightly affected, with net revenue decreasing by about 2.8–5.5% and little change expected in current farming strategies. Mixed (poorer) farms would be substantially affected (−20.1%). Because net revenues are nearer to land rental value (\$570 ha^{-1}), owners will increasingly rent out their land, while tenants will increasingly seek other jobs, unless better market opportunities and subsidies for modernization are available (Table 5). Adoption of micro-irrigation (\$1760 ha^{-1}) would offset their losses and increase revenue by more than 40% (i.e., by \$670 ha^{-1} $year^{-1}$) but this remains hindered by risk and the need for credit.

Net revenues from banana production decrease by 8.8–15.8%, so that some farmers will be motivated to change to more profitable orchard crops that require less water, such as date palms. Incentives will remain limited unless import tariffs on bananas are lowered. Such diversification would involve only the best-capitalized and most entrepreneurial farmers, i.e., no more than 50% of all banana farmers. As 50% of bananas are still irrigated by gravity systems, adoption of micro-irrigation might limit financial losses. For such farmers, capital is less likely a constraint, as the investment cost is \$2900 ha^{-1} compared with annual revenues of \$7000 ha^{-1}. However, the additional maintenance and operation burden of filtering and cleaning drippers is substantial. Higher water costs of \$1100 ha^{-1} would be only partly offset by the \$425 ha^{-1} $year^{-1}$ generated by higher yields.

Finally, citrus farms would be greatly affected. 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 \$1075 ha^{-1}, but with additional revenue of \$430 ha^{-1} $year^{-1}$ that will almost cover additional water costs (\$435 ha^{-1} $year^{-1}$). Citrus farmers still using gravity irrigation will have a strong incentive to capture the gains from a shift to micro-irrigation, with net revenues increasing from \$400 ha^{-1} to \$815 ha^{-1} instead of becoming negative if response [f] is selected (Table 5). Yet this

Table 4 – Crop-based water costs according to three different scenarios

Water costs (US\$/(ha year))	Vegetables	Citrus	Bananas
Current water costs	67	138	350
Scenario A: O&M costs recovery-block tariff system	94	192	485
Scenario B: Total costs recovery (O&M + capital costs)	278	573	1454
Scenario C: 80% of water costs borne by farmers in the highlands	586	1172	1740

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

Table 5 – Impact of different levels of water price increase 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[a]	Absentee owner and family farms	Family farms	Entrepreneurial farms	Poor family farmers
Allocation type	Vegetables	Vegetables	Citrus	Citrus	Bananas	Bananas	Vegetables
Net revenue[b] (US$/(ha year))	3800	7500	1250	400	7000	12,500	1050
Production costs[c] (US$/(ha year))	8150	21,000	1550	1200	8200	8600	2400
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

[a] Data for absentee owners using micro-irrigation systems are not shown here.
[b] The data represent mean values obtained during a survey of 50 farmers in the Jordan Valley during 2003.
[c] The net revenue is the gross income net of all production costs. These costs include amortization of capital, financial costs, and hired labor valued on the basis of the daily wage observed in the valley.

demands a high initial investment, equivalent to more than 3 years of annual revenue, and poses problems for such growers, 70% of whom are family farmers, including shopkeepers, civil servants, retirees, old farmers, and widows. Financial incentives will be the same for richer absentee owners, but these owners are more likely to accept losses, depending on their preferences for leisure and prestige, and for nonlabor-intensive agriculture (GTZ, 1995; Lavergne, 1996; Venot et al., 2007).

All citrus farmers have the same incentive to diversify into other fruit trees, because fruits such as dates, mangoes, guava and grapes are more profitable than citrus. However, the adoption of improved technology or higher-value tree crops largely depends on the will and ability of farmers to intensify and on the availability of stable market opportunities. If their perceptions of risk, drudgery or capital constraints remain negative, the primary option that remains will be to rent their land to investors. On farms irrigated with gravity or drip systems, prices would motivate improvements in economic efficiency.

Finally, scenario C would have a dramatic impact on agriculture in the Jordan Valley. Citrus orchards would no longer be profitable and would be replaced completely in one of the ways described above. For well-capitalized banana farms, a partial shift to date palm and other trees, and the use of more efficient drip irrigation systems might be observed, but the likelihood of losing the higher water quota will dampen farmers' enthusiasm. Mixed farm operators would see their profitability decrease by one-half and would rent out their land. Tenants, if they have the financial capacity, will accept the risk of intensifying or will be replaced by more entrepreneurial farmers. The profitability of greenhouses would decrease by 6.9%, but they would be the only farms to withstand the pressure, for lack of cost-effective alternatives (MREA and JVA, 2006).

Open-field vegetable farms would lose 13.6% and would consider improving water application (response [a]) or adopting improved irrigation systems. Response [b] would offset the losses due to higher water costs and increase revenues by 11%. Further intensifying agriculture by building greenhouses ($25,000 ha^{-1} for a greenhouse only) is unlikely to be observed on a large scale due to critical capital and environmental constraints. This third scenario is very unlikely, as it would disrupt the valley economy and exacerbate the political protests that have erupted previously in the wake of less-serious policy changes, as in the case of groundwater use in the highlands (Pitman, 2004).

Changes stimulated by high water prices would, therefore, likely include technological change and (less so) changes in cropping patterns, and lead to higher water productivity. We have earlier discarded the possibility of significant water savings under the present monthly quota system because the marginal productivity of water is too high in the critical period of April through October, while there is no alternative use for water when supply exceeds demand. The incremental value of water depends on the crop and 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: gravity irrigation of citrus farms in scenario B, in which the average water productivity ($0.0004 m^{-3}) is slightly lower than average water costs ($0.00057 m^{-3}). In the critical period, the marginal cost of water is $0.00071 m^{-3} for the second tier in the block tariff, while the marginal productivity of water is much higher than the average.

Water stress at flowering and fruit formation stages can substantially reduce yields (Arrighi de Casanova, 2007b). The value of maintaining water deliveries during those stages is reflected in 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 $0.00047 m^{-3} (first tier), close to the average value, suggesting possible cost-effective water savings over 2400 hectares of citrus.

4. Discussion and prospects

The sociopolitical and economic contexts in which water policies in general, and pricing policies in particular, are embedded often determine much of what is eventually possible and desirable (Dinar and Saleth, 2005; Molle and Berkoff, 2007).

Several factors limit the scope for pricing mechanisms to improve irrigation and economic efficiency. We have stressed that suboptimal irrigation efficiency is due partly to unstable pressure in collective pressurized networks. These on-farm networks are subject to many technical problems, such as the clogging of emitters, nonuniformity of water application, and poorly designed block layouts and rotations. Another source of inefficiency, independent of farmers, is the lack of storage capacity at the system level. With inadequate storage, water supply can exceed demand at times. To some extent, excess water can be used for leaching salts or stored in the soil profile, but these activities are not perfect substitutes for surface storage facilities. Where excess water cannot be stored and where irrigation deliveries are controlled by strict quotas when demand exceeds supply, the potential for saving water is limited.

These conditions explain why complete recovery of O&M costs pursued by the Ministry of Water and Irrigation is unlikely to "increase conveyance system and on-farm water use efficiency," as anticipated in the 2004 Masterplan (THKJ, 2004). From the correct assumption that "low prices for irrigation water provide limited incentive to improve on-farm efficiencies" 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 (2003a) report acknowledges that "it was anticipated that increased water tariffs [of 1995] would reduce agricultural water use. This did not happen."

With limited scope for achieving water savings, farmers will potentially respond to increasing water costs by intensification. In intensive and profitable systems such as vegetable and greenhouse production, water costs are negligible compared to input and labor costs, and they will remain so at any politically acceptable level (Wolf et al., 1996). Farms with more extensive agricultural strategies will be more affected, including: (1) mixed farms and small orchards of citrus or banana that are prone to indebtedness and vulnerable (Salman, 2001a) and (2) absentee urban owners with other sources of revenue.

Price-induced pressure will have a beneficial impact if these farmers are 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 potentially high returns, farmers did not adopt them earlier. Farmers engaged in extensive agriculture are frequently indebted (Van Aken, 2004), wary of becoming so, or lack sufficient capital to embrace such risky ventures. Urban absentee owners have little interest in burdening themselves with intensive management and value their farms for other reasons.

Higher water prices can encourage competition, eliminate underachievers, and select more efficient farmers. For example, higher water prices might induce changes in citrus and banana cultivation or displace small farmers who might lease their plots to investors growing higher-value crops. Higher prices might increase farmers' financial vulnerability, motivating them to intensify production in ways that might increase the probability of bankruptcy or retirement from farming.

Pricing policies are more appropriate where farmers can easily find alternative occupations or sources of income. Where this is not the case, policymakers might inadvertently create volatile sociopolitical situations. Helpful remedies include providing farmers with technical information that enables them to reduce the market and financial risks that are pervasive in the Jordan River Valley (Doppler et al., 2002). With increasing competition from other countries in the Middle East, identifying crops with a good return and limited risk is not easy. This goal has become a policy priority (Montigaud et al., 2006; Nachbaur, 2004; Salman, 2001b).

Public officials in Jordan are concerned also with the potential social and political costs of reforms, particularly with regard to poor farmers. The experience, for example, of the elimination of all direct subsidies to owners of small livestock herds from 1995 through 1997 was effective in reducing herd sizes by 25–50%. This reduced overgrazing, rangeland degradation and desertification. However, the program reduced revenue and increased poverty (Pitman, 2004). Earlier consensus that attendant safety nets would be needed seemed to have been later forgotten (Richards, 1993). The government's reluctance to raise water prices before treated wastewater or market opportunities are available also indicates concern regarding potentially negative impacts in the absence of alternative opportunities.

Water pricing schemes largely reflect the political economy of a country, and political counterweights are often raised when prices depress revenues. The recent regularization of illegal citrus orchards in the valley suggests that some landowners have enough political influence to counter the reduction of quotas. The high percentage of broken meters suggests that quotas which are too low and constrain water use can trigger defaulting, tampering or destruction of meters, social unrest and political stress, and corruption or collusion involving officials and farmers (GTZ, 2004; Courcier and Guérin, 2004).

The above analysis indicates that the primary objective of financial autonomy of the Jordan Valley Authority is attainable. Raising prices to 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, because the current O&M subsidy to the JVA is worth less than 0.1% of state expenditures of $3.7 billion (Jreisat, 2005).

Yet, despite higher recovery of state-borne O&M costs, water charges do not generate a virtuous circle of improved management and maintenance by either managers or farmers (Small and Carruthers, 1991; Easter and Liu, 2005; Molle and Berkoff, 2007). Positive incentives are lacking if the charges paid by farmers are not reinvested in the irrigation scheme, managers do not depend on the payments (which are sent to the Ministry of Finance), farmers control neither part of the revenue nor water deliveries, supply is uncertain, and water allocations are not transparent. In such situations, water pricing generates revenue, but does not cause substantial changes in the quality of water delivery.

Last, reducing agricultural demand and current diversions in the valley through pricing alone is unattainable, as noted by 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 Agriculture Sector Structural Adjustment Loan 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 valley] satisfied an immediate objective of maximizing transfer of water to the highlands'' (World Bank, 2003a) is also unfounded because the transfer is a bureaucratic decision completely independent of prices. Water transfers have been continuously increasing and effective. In the future most of the valley might be irrigated with treated wastewater only (McCornick et al., 2002). Reallocation has been made possible by curtailing water use through quotas.

In water-scarce situations where volumetric control is possible, such as in Iran, Tunisia, Morocco, France, Italy, Spain, Jordan, and the United States, water quotas are often used (Molle and Berkoff, 2007). Quotas are generally easy to understand, equitable, effective in reducing diversions, and have less impact on net revenue than price-based regulations. The primary disadvantage of quotas is their limited capacity to adjust to changes in demand. This is true in the Jordan Valley, where quotas create a disincentive for citrus and banana growers to shift to less water-intensive crops. When water users are unable to trade their quotas, careful downward adjustments of quotas, as made in the valley since 1999, can motivate farm-level efforts to save water.

While the scope for improving irrigation and economic efficiency through price incentives is limited, several alternatives have been proposed, along the following lines:

- Flexibility of water supply at the farm level is obtained not only through exceptional requests but also through digging farm ponds to buffer irregular supply (Shatanawi et al., 2005), by using water from wadis and, wherever possible, by pumping groundwater. Many farmers have already implemented these options.
- Effective freshwater savings in the Jordan Valley might 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; KfW et al., 2006).
- Significant water savings could be achieved through better in-season distribution of water in the King Abdullah Canal. With the completion of the Wehdah dam on the Yarmouk River, it will be possible to provide flexible management of water allowances and increase economic output (Al-Jayyousi, 2001; Salman et al., 2001; Shaner, 2001; Courcier and Guérin, 2004). Monthly quotas could be transformed into yearly quotas, with farmers retaining the right to distribute water throughout the year according to their needs (Petitguyot, 2003). In the long run, quotas could be made transferable, thus creating opportunities for technical and economic gains (Development Alternatives Inc., 2004).
- The JVA might adopt bulk water allocation and charging procedures, whereby water user associations would manage a yearly amount of water and recover charges (JRVIP, 2001). This approach, however, is hindered by extant cultural and social structures, and would require significant 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 water quota so that revenue would be reduced without affecting other crops. Banana production could be made less profitable also by removing duties on imported bananas, in line with World Trade Organization rules (WTO, 1999; Montigaud et al., 2006). Such economic incentives could be quite efficient in inducing a shift toward other trees and a full conversion to drip irrigation, but the capital constraint and the potential loss of higher banana quotas are likely to hinder this shift if no positive incentives are available. A bonus might be granted to farmers who agree to shift from a high tree quota to the vegetable quota, providing that proper market opportunities for vegetables are ensured. This approach might be difficult to justify, however, given the recent contradictory measure granting new citrus quotas to land with vegetable quotas.
- Last, both irrigation and economic efficiency can be enhanced by conventional positive incentives that modify the environment in which farmers take decisions to invest and intensify. Positive incentives include: providing attractive output markets, crop insurance schemes for farmers tempted to diversify and further subsidies to adopt drip irrigation and, gradually, to implement precision irrigation. In practice, because pricing reforms often affect extensive family-based farming, concomitant state support to intensify or modernize is widely observed (Molle and Berkoff, 2007).

5. Conclusion

We conclude that some, but not all, benefits expected from water pricing policies can be expected to materialize in the Jordan Valley. On the positive side, a recovery of operation and maintenance (O&M) costs is achievable without major impact on revenues. The establishment of a block tariff system and the continued improvement in O&M cost recovery are notable achievements when compared with the situation worldwide (Bosworth et al., 2002; Molle and Berkoff, 2007). The relationship between water payment and improved water service should be enhanced by granting more financial autonomy to the Jordan Valley Authority. More substantial increases in water prices can also be expected to increase overall economic efficiency by motivating farmers to intensify and invest in technology, or to lease their land to investors. For banana farmers, this incentive will be increased if protective import duties are removed.

On the other hand, 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. Technical interventions improve irrigation efficiency not because water use is reduced, but because better uniformity and timing of water application enhance crop ET and yields. Real water savings may be possible if monthly quotas can be revised to form one annual quota. In such conditions the possibility of trading water would also enhance both irrigation and economic efficiency. Other enabling factors would need consideration, such as improving the control of the water supply.

Higher water prices would decrease the net revenue of citrus and banana farmers and motivate them to reconsider the benefits, risks and constraints of adopting new crops and technologies. Higher water prices also would increase financial vulnerability, thereby increasing the financial risk of such choices. Positive incentives that reduce capital and risk constraints, and offer attractive cropping alternatives and exit options with compensation should be implemented in conjunction with higher prices.

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