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Research Article

The Price to Pay for Treated Wastewater: an Evaluation of Water Pricing Scenarios in the Jordan Valley

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Abstract

Treated wastewater for irrigation could form a viable alternative to substitute fresh water resources in the Jordan Valley. Yet, investing in treatment infrastructure is costly and the subsidized water prices in the Jordan Valley results are low compared to the cost price for treated wastewater. Therefore, this study examines the effect of additional water volumes on net profits of four farm archetypes and the possibilities for cost coverage of treated wastewater under various pricing scenarios. The study accounts, in a stylized manner, for positive (festination) and negative (salinization) effects of the treated wastewater quality. The results show that additional volumes are highly profitable for vegetable farms yet; salinity levels negatively affect banana farms. The scenario with the highest pricing variant provides some compensation, yet, most of the costs have to be covered by other public funds.

Introduction

The pressure on water resources in the Hashemite Kingdom of Jordan is most visible in the severe competition over water resources between the agricultural sector and a fast growing, and increasingly affluent, population who demands their guaranteed supply of clean water. This situation is likely to exacerbate in the near future as a mounting population continues to grow (2.6 %) to a 10 million people in 2050 and climate, change is expected to affect the country negatively [1, 2]. The Jordan Valley (JV) is no exception; all water sources are fully committed in an advanced drip irrigation infrastructure that leaves little room for efficiency gains. Indeed a large part of the JV's agricultural potential remains idle and further intensification or expansion of the cultivated area remains fully dependent on the availability of additional water sources [3]. This study argues that treated wastewater (TWW) constitutes a viable alternative for irrigation in the JV as it allows further agricultural development and, simultaneously, substitutes the fresh water resources that are urgently needed for domestic use. Yet, more than 60 per cent of the wastewater is currently lost due to an inferior infrastructure and construction of sewage systems and treatment plants to collect and process the used water is costly. In an ideal situation, we could rely on water markets that efficiently reallocate available water sources of competing water suppliers between clients using prices that result from the supply and demand volumes of water. Under such conditions, water markets could generate the required capital for investments in water infrastructure to tap from unconventional water resources as TWW. Yet, in the JV water, markets are absent and water supply is under full control of the government [4-6], effectuated by the Jordan Valley Authority, who also determines a fixed and heavily subsidized price for water users. The first water tariff in the Jordan Valley was implemented in 1961. Farmers paid 0.001 JD/m3 independent of the amount of the water consumed. In 1966, this tariff was redefined to 0.001 JD /m3 for the first 1,800 m3 consumed, and 0.002 JD /m3 for additional volume. In 1995, agricultural water was again repriced by the Ministry of Water and Irrigation. Farmers pay now: 0.008 JD/M3 for the first 2 500 M3, 0.015 JD for additional volumes exceeding the 2 500 up to 3 500 M3, 0.02 JD for the next 1 000 M3 up to 4 500 and 0.35 JD for higher volumes. The subsidy effect of the water price for farmers becomes visible when we compare these to households that pay a 4.5 JD/M3 and higher prices when 20 M3 is exceeded. Farmers water prices are also far from covering the costs for production of TWW that vary, according to the Ministry of water and Irrigation, from 0.026 JD per cubic meter without operation and maintenance (O& M) cost to, 0.63 JD when O&M is included up to 1.3 JD/m3 [7], when capital costs are accounted. Even though the Jordan Water Strategy and Policies 2002, Article 43, declared that differential prices can be applied to irrigation water by quality, in practice the farmers in the Middle and South JV where most of the TWW is used, are paying the same price as farmers in the North JV where the use of freshwater prevails.

Hence, the question is to what extent farmers can contribute to cover these costs of additional infrastructural investments that can generate the TWW. Earlier studies (*Alfarra et al., 2009*) confirm that a large majority (96%) of the farmers is willing to accept TWW and willing to pay substantial higher prices. Yet, these studies did not include an assessment of the expected benefits for additional water volumes and the possibilities for cost coverage for water infrastructural works. Moreover, when evaluating the effect of TWW volumes famers will also consider the 'goods' and 'beds' of water quality as these differ remarkably from fresh water resources. At the positive side, TWW might contain rich sources of nutrients with advantageous effects on crop growth if these nutrient concentrations are delivered in the correct proportions. Negative, is the increased salinity level that is caused by the dissolved nutrients, which might affect sensitive crops and lower production potential. This paper is organized as follows. In section 2 we discuss the water quality aspects of the TWW and their impact on crop production. Accounting for these specificities of water quality, we evaluate the impact of additional TWW volumes on farm income and cost coverage for four farming systems archetypes under 5 water pricing scenarios.

Water quality of TWW

Calculating Nutrients in Irrigation Water

Table 1 shows the nutrients expressed in their weight equivalent of commercial fertilizers. The nutrients in KTR and

KAC-South are close to the ratio of commercial NPK fertilizers where we find 10 kg N, 20 Kg P2O5 and 30 K2O per 100 kg. The average commercial price for fertilizer in this composition in Jordan is 1500 JD per ton. Hence, as 1000 m3 water equals the amount of 100 kg of commercial fertilizers, it is equivalent to a value of JD 150, or 0.15 JD/M3. We conclude that when the price of water should consider the benefit for nutrition in the TWW, as this can help to reduce fertilizer costs. A GTZ project has proved from that farmers can save about 50% to 60%of farm fertilizer in each season.

Table 1: Amounts of nutrients in the irrigation water sources in the Jordan Valley.

Water source	N (kg/1000 m3)	P2O5 (kg/1000 m3)	K2O (kg/1000 m3)
KTR	18.6	8.9	31.4
KAC-south	18.4	7.05	31.3
KAC-north	1.4	0.52	12.7

Impact of salinity

A major degradation factor of re-used waters can be its high salinity levels that are caused by high ion concentrations that have a negative effect on water intake of plants as it competes with the plants' osmotic potential. Moreover, high ion concentrations might reach toxic levels that impede proper plant growth. Finally, high concentration of alkaline damages the structure of the soil, with a dramatic loss of water holding capacity as a result. Yet, the reaction of yield performance on higher salt concentrations is typically crop specific; crops might be highly sensitive or highly tolerant to salinity. Therefore, TWW with higher salt levels requires an appropriate selection of crops. Moreover, to prevent accumulation of salts in the root zone the water management should include a drainage system, regular leaching of the salts with fresh water, possibly with Calcium contents in case of high Alkaline concentrations . Concerning the effects of salinity on crop yield, there is a wide range in plant species response to salinity. Sugar beet, sugar cane, dates, cotton and barley are among the most salt tolerant; whereas beans, carrots, onions, strawberries and almonds are considered sensitive [8]. In general, salinity decreases both yield and quality in crops and previous research has led to the development of large databases on the salt tolerances of many crop species and varieties. Salt tolerance can be represented most simply based on two parameters: the threshold salinity (t) which is expected to cause an initial significant reduction in the maximum expected yield (Y); and the slope (s) of the yield decline. Slope is simply the rate that yield is expected to be reduced by for each unit of added salinity beyond the threshold value. The formula to calculate relative yields is [9].

$$YR = Y - s\,(ECe - t) \text{ where } ECe > t$$

Salts are added to the soil during each time of irrigation and accumulate in the root zone. In case that appropriate drainage systems are absent and insufficient freshwater is available for leaching soil salt levels might reach damaging concentrations. The crop removes much of the applied water from the soil to meet its evapotranspiration demand (ET) but leaves salts behind in the shrinking volume of soil water. The following table shows crop tolerance rating and their equivalent soil salinity. Figure 1 stylizes the yield reducing effects for crops with different sensitivity levels for salinity. We will use this relationship in the next section when we evaluate the introduction of additional TWW in the JV. The average salinity for treated wastewater at King Talal Reservoir (KTR) used in the Jordan Valley is 2.7 whereas the average salinity for freshwater resources from King Abdalah Canal (KAC) is 1.1. So, significant yield loss can be expected for sensitive crops that are cultivated on treated wastewater.

Pricing scenarios

In this section, we will evaluate various water-pricing scenarios and their impact on 1) farmers' income and 2) cost coverage for new TWW plants. We evaluate the situation for four prevailing farm archetypes, which are considered representative for the majority of farm households in the JV. Table 2 shows an agronomic-economic profile of the four archetypes. Water quota and net profits figures were derived from *Venot (2007)* [3]. Figures on fertilizer savings were obtained from [10]. Current water tariffs were provided by the JVA. Yield losses due to the sensitivity of crops and prevailing salt levels were estimated using the relationships explained in section 2. For the citrus and banana farms were assume that additional TWW volumes are still blended with fresh water and that the final ECe level is around 1.5 ds/m. Currently the average total water volume that is supplied to the JV is 250 MCM, 87 MCM of which is TWW. The average demand/supply ratio in the JV is 64 per cent, which means that 90 MCM of additional volume is required to let the JV occupy its total water requirements.

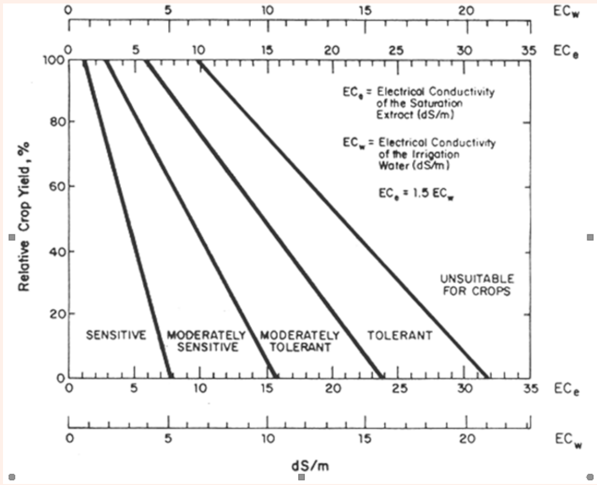

Figure 1: Weight gain of *Labeo rohita* (Rohu) and *Catla catla* (Catla) with increasing temperature. a, b: Markers showing common alphabets as superscript differs significantly (P<0.05)

Table 2: Four archetypes of farming systems in the JV: an agronomic-economic profile.

	Commercial vegetable farm	Citrus family farm	Commercial banana farm	Family farm, mixed
Before TWW				
water quota (m3/ha/yr)1	5050	10100	15000	5050
Fertilizer (JD/ha/year) 2	695	496	993	298
net profit (JD/ha/year) 1	5319	1550	8865	745
area ha1	8	4	4	7
Total water	40400	40400	60000	35350
Water costs (JD/farm)	323	323	480	283
Fertilizer costs (JD/farm)2	5560	2234	2979	596
Farm income JD/yr	42553	6200	35461	5213
After TWW				
Saving fertilizer (JD/farm)	2224	894	1191	238
Yield reduction: salinity	5	10	15	10
salinity losses (JD/farm)	2128	620	5319	521
Supply/demand ratio	64	62	87	64
Nett profit (JD/farm)	57969	8830	35943	6806
Nett increase	15416	2630	482	1594
%increase per farm	1,36	1,42	1,01	1,31

Using the above mentions cost estimates the total costs for: Running; Running and

O&M; Running and O&M and capital costs are, respectively, 15 million, 57 million and 117 million JD. The selection of water price scenarios is based on three criteria. First, we abstain from abrupt changes, as a sudden rise in prices would be met with disapproval and cause social unrest. Second, we capitalize on findings of that show farmers willingness to pay four to five times the current water price. Third, and finally, from Venot (2007) [3], we calculated the marginal contribution of water to the net farm profit and used this price as an upper bound for our assessment. We are now ready to run various water-pricing scenarios and evaluate their impact on farmers' income and on cost coverage of new TWW infrastructure. We evaluate the scenarios over a period of twenty years. For each year an additional amount of TWW (4.5 MCM) volume is generated resulting in the 90 MCM after twenty years. The amount of money that is used to cover the cost of the TWW infrastructure is the difference between the total amount generated with the new and the old water tariff. The effect of farmers' income accounts for the effect of rising salinity levels on crop yields, savings made on fertilizer and costs incurred by water tariffs. We designed a simple model that varies the water tariffs as fixed amounts or with gradual annual increases. Of all the various possibilities, we will run five water-pricing scenarios:

1. **Scenario I.** BUA, business as usual, the same water tariff that currently prevails.
2. **Scenario II.** FLAT. A flat-water tariff that covers the Running costs of the TWW plants.
3. **Scenario III.** GRADUAL/LOW. A gradual increase of the water tariff with 1 per cent per year
4. **Scenario III.** GRADUAL/MODERATE. A gradual increase of the water tariff with 5 per cent per year.
5. **Scenario III.** GRADUAL/HIGH. A gradual increase of the water tariff with 10 per cent per year.

Result

BUA

The results of the first scenario are depicted in Figure 2. Especially vegetable farms benefit from the additional water volume; vegetable crops are less sensitive to salt water and save substantially on fertilizer costs. Also Citrus and mixed farm increase their income with almost 70 per cent. Banana farms remain more or less the same, basically because they were already close to the maximum water level requirement (87 per cent) and the salt levels affect crop yields negatively. Yet, the coverage of cost for additional TWW infrastructure is extremely low. Under this scenario, the entire implementation of TWW plants will be dependent on subsidy from the government or foreign donors.

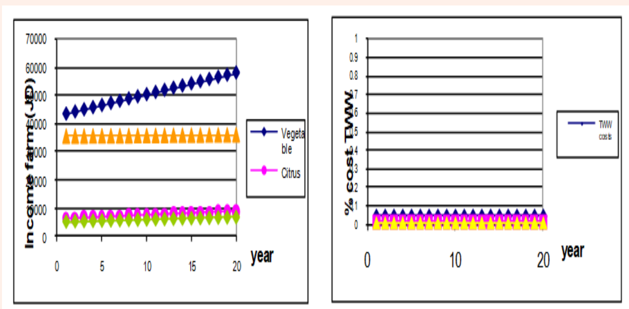

Figure 2: Effect on farm income (a) and cost coverage (b): scenario BUA.

Flat

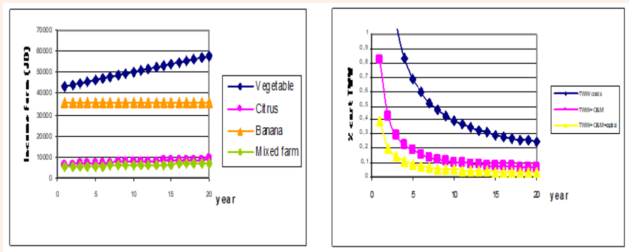

Figure 3: Effect on farm income (a) and cost coverage (b): scenario FLAT.

Figure 3 shows the results of the FLAT scenario. The income of the farmers is hardly affected as water only makes up a small amount of the total farm costs and benefits from the additional water volumes are substantial, except for the earlier discussed banana farms. Cost coverage is high initially but decreases rapidly to lower levels especially when O&M and capital costs are included. Hence, also in this scenario the subsidies will have to cover substantial amounts.

Gradual/Low

Figure 4 shows the results of the GRADUAL/LOW scenario. We can conclude that the trends on farmer income and cost coverage remain more or less the same as compared to the BUA alternative.

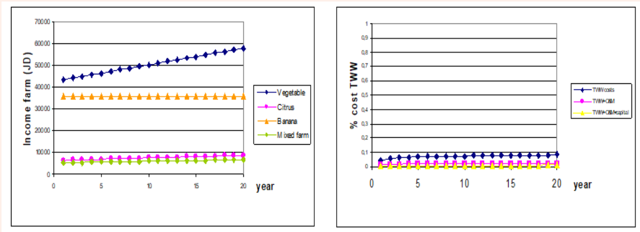

Figure 4: Effect on farm income (a) and cost coverage (b): scenario GRADUAL/LOW.

Graduate/Moderate

The results of the GRADUATE/MODERATE scenario are presented in Figure 5. The effects on farm income are noticeable. Banana farms are reducing their farm income while the increase in income for the citrus and the mixed farms is reduced. Cost coverage for the Running costs rise up to 30 per cent. We conclude that the annual increase of five per cent has on the long run some negative effects on income growth and only slightly compensate the TWW costs.

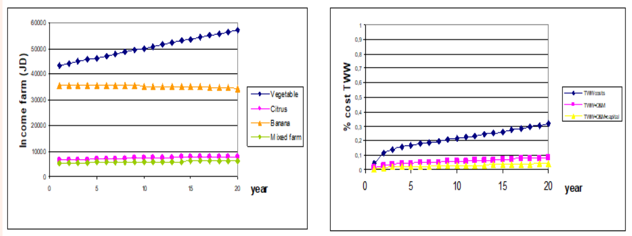

Figure 5: Effect on farm income (a) and cost coverage (b): scenario GRADUAL/ MODERATE.

Graduate/High

Finally, Figure 6 presents the outcomes of the GRADUATE/HIGH scenario. Here we see that farm income is affected negatively after some 10 years or so. Especially the Banana farms have a relatively substantial decrease, but also the lower income farms with citrus and mixed cultivation have negative net profits as compared to their starting year. Coverage of costs for running operations is almost a 100 per cent but coverage of the costs including O&M and capital is still small, despite the high increase in water tariff.

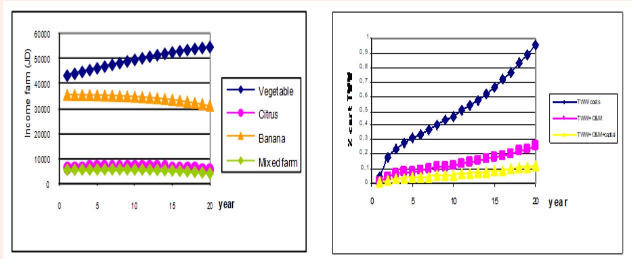

Figure 6: Effect on farm income (a) and cost coverage (b): scenario GRADUAL/HIGH.

Discussion

In this paper, we evaluated the effect of nutrients in TWW for its cost saving effects on fertilizers and quantified the crop specific effect of salinity levels on yields. This information was used to evaluate impact of additional TWW volumes on farmers' income under various water tariff scenarios. Moreover, we also considered the costs that had to be covered for additional water volumes. We found that a considerable amount of nutrients could be saved as the nutrient composition in the KAC has a remarkable coincidence with the NPK ratios of commercial fertilizer [11]. Also, found that up to 50 per cent of fertilizer costs can be saved at least when the TWW is used to frigate the crops. Yet, the negative side of the TWW water for irrigation is the sensitivity of the main crops banana and citrus for its moderate salinity levels. Future water distribution schemes that supply TWW to these farms should be supplied with sufficient fresh water to mitigate the effect of salinity. We found that farmers' income in general grows with additional TWW, except for banana, which is already supplied for almost 87 per cent and is affected by the TWW salinity level. Only when water tariff does increase at a high pace farmer incomes become lower as the total price for water starts to become a high share of the total costs. The coverage of cost for running costs, O&M and capital costs will be difficult to cover by farmer contributions alone. Yet, treatment of wastewater has also environmental and health benefits that are for the benefit of the society as a whole. Contributions to TWW infrastructure from other sectors in the society is, therefore, natural. We conclude that there are good prospects for agricultural expansion in the JV when the use of TWW in Jordan becomes more efficient through an increase in WRI. Farmer contributions through higher water seem justified as the benefits of an additional M3 TWW outweigh its costs by far. The objective of introducing a new pricing mechanism that includes different factors for not only cost recovery and benefit, but also to enforce farmers changes their attitudes. Such as changing their crops, which is sensitive to salinity and required high, amount of water, such as banana and citrus, to crops less water demand and more tolerance to salinity. Water scarcity in the region required a more responsible behaviour from users to value water that they can receive. In addition pricing can help farmers' to understand the true value of receiving treated wastewater in the region especially the coming era will bring more drought to the Jordan valley were fresh water will be more valuable for domestic uses. We recommend the introduction of a gradual tariff rise to let farmers get accustomed to a new water tariff situation. From field experience, we know that appropriate extension programs that explain the changes in water tariffs will be indispensable. Finally, we suggest that water tariffs are differentiated with lower tariffs for the poorer farmers and their families in the JV [14-18].

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