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Potentials and Limitations of Wastewater Reuse in Rural Areas in Jordan: The Reuse Options in the Jordan Valley

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Abstract: Recycled wastewater provides a viable alternative resource for water scarce regions. Treatment costs are an obstacle for purification up to drinking water quality, but water of lower quality may still be used for irrigation purposes. Study results from the Jordan Valley indicate that impacts of the use of treated wastewater on agriculture and rural development depend, at least in the short and mid-term run, on the socio-economic and institutional environment of farming systems rather than applied water qualities. Wastewater already amounts to around 5% of the total available water resources in Jordan and will increase to a share of more than 15% within the next 30 years. Potentials and limitations from this alternative water resource vary due to differences in the context of farming systems and agricultural development. Wastewater use in agriculture already takes place in Jordan but to a limited extent. Larger amounts are likely to replace currently used freshwater in irrigation. Administrative regulations and restrictions for wastewater reuse limit cultivation alternatives. Results are an increase in the minimum land size required for sustainable farming systems, a decrease in the number of farms in the Jordan Valley, lower labor requirements in agriculture and impacts on the market supply with specific products. Predictable benefits are extra income opportunities for farming systems that are based on agriculture, but also limitations for livestock holders, who currently rely on the extensive use of communal areas. The results from the study programs emphasize the need for a thorough examination of individual case in the run-up of approaches to introduce or enhance the use of treated wastewater in agriculture. Recycled water is a valuable resource of rising importance but appropriate plans for its use have to take into account measures with regard to potentially substantial secondary impacts.

Key words: Wastewater reuse, agriculture, socio-economic impacts, recycled water

INTRODUCTION

Water is the major constraint for agricultural development and sustainability in arid lands. The agriculture sector is the major consumer of water in Jordan, using up to 80 percent of available water. As water demand increases in the country and with everdecreasing supplies, water has to be utilized more efficiently and prudently. Agriculture will face increased economic pressure from municipal and industrial users.

Since the early 1980s the general approach has been to treat the wastewater and either discharge it to the environment where it mixes with freshwater flows and is indirectly reused downstream or to use the resulting effluent to irrigate restricted, relatively low-value crops. However, given the diminishing per capita freshwater supply, the increasing dominance of effluent in the water balance, the overloading of wastewater treatment plants, local riparian water rights and the need to protect domestic and export produce markets, effectively managing water reuse, including enforcement of existing regulations, has become increasingly challenging. Jordan is in the process of rehabilitating and expanding its wastewater treatment plants and exploring options for smaller communities. Reclaimed water, appropriately managed, is viewed as a major component of the water resources supply to meet the needs of a growing economy.

It has already been established that irrigated agriculture in the Jordan Valley using recycled water from the Amman-Zarqa basin is technically feasible, although less productive[1]. The overall conclusion is that irrigated agriculture can sustainably produce a wide variety of crops in the Jordan Valley using the quality of recycled water that is available from King Talal Reservoir (KTR). The restrictions on crops, primarily due to the salt and chloride levels, will require good management to be productive and prevent salinization of the soils. However,

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given poor management, any damage done can, in most cases, be reversed. This study was focused on identifying and characterizing options that would provide good returns from the resource, recycled water. In addition to improving the productivity of irrigated agriculture, the investigations closely considered potential options for exchange with fresh water, which could be used for domestic purposes. Bearing in consideration that according to the National Irrigation Policy[2]. No water shall be diverted without a replacement water source that is treated to a such a quality that it can be used unrestricted for agricultural.

The objectives of this particular study were to identify potential options for further use of recycled water in the Jordan Valley and to investigate each option to pre-feasibility level.

MATERIALS AND METHODS

Study area: The Jordan Rift Valley is divided into the Jordan Valley area and the Southern Ghor. This study is concerned with the Jordan Valley area, which lies o the North of the Dead Sea, as shown in Fig. 1. This area is divided into the North, Middle and Karameh (or southern) Directorates, which are in turn, subdivided into stage offices with each stage office supplying water to a number of development areas. The main source for irrigation water is the surface water in Jordan Valley and the groundwater in the highlands. Treated wastewater is a potential non-traditional water source, which can be used for irrigation. During the year 2003, Jordan had a total of 19 wastewater treatment plants serving 65-80% of the total population. Wastewater effluents from these treatment plants are estimated to be 60-80MCM[3]. Several factors and conditions restrict the use of treated wastewater in agriculture. The most important of these are: (1) Crop type; cultivated crops should not be fresh consumed by human such as lettuce and cucumber and (2) Irrigation systems should minimize environmental hazard and avoid direct contact between irrigation water and crops.

Table 1: Cropped, irrigable and irrigated areas in the Jordan Valley (in dunums)

JV	Irrigated areas	Irrigable areas	Cropped areas	Total area
North	68 713	100 259	100 808	127 119
Middle	42 846	71 305	75 001	97 427
South	34 101	103 708	21 635	115 071
Total	145 660	257 272	197 444	339 617

The Jordan Valley lands have been classified with regards to their irrigability. The irrigable areas in each of the three Directorates are presented in Table 1. Many of the irrigable lands of the Jordan Valley have been developed to allow intensive irrigation. In fact, stage office No. 9 has been developed but with the drought of the past few years has not been officially allocated water, although it does receive unofficial supplies. The allocation of official water rights to these areas will only occur when sufficient supplies have been secured (Personal Communication).

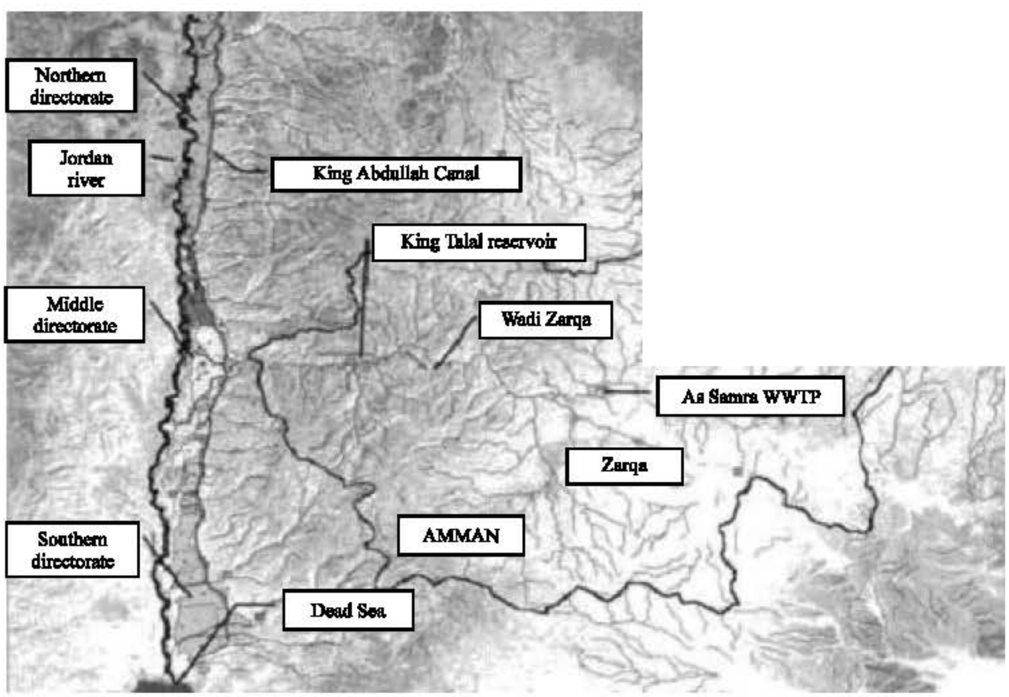

Fig. 1: Layout of the Jordan valley (JV)

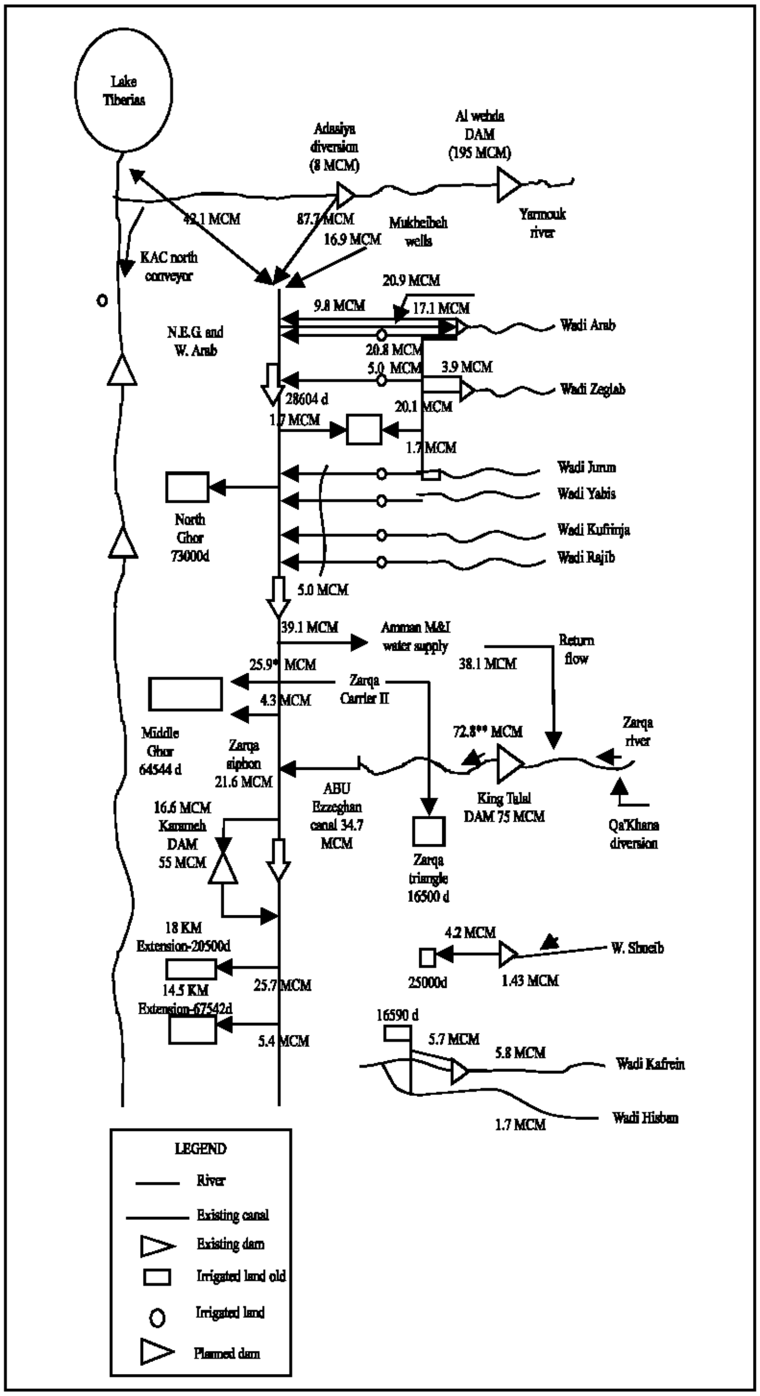

Fig. 2: Schematic of the Jordan valley water system (volumes are averages for 1995-2000)

Specific outputs required from this study are the expected water demands for the identified water reuse options for use in assessing the scenarios for managing the basin and the basic costs for developing these options for the overall economic analysis of the scenarios.

It is assumed that the restrictions of concern are with respect to human health and, therefore, the constituents of interest are the pathogens. Although the diversion of fresh water from the Northern Directorate for domestic water use in Amman is not a stated objective, if it was to occur it would have a very significant impact on the overall water balance in the Amman-Zarqa basin and Jordan Valley. It is important to realize that the allocation of projected recycled water resources to other uses will remove the opportunity of replacing any short-fall in fresh water resources in the Northern Directorate. With this in mind, the option to replace fresh water resources in the North Directorate is included.

Also, it is assumed that the effluent from the wastewater treatment plants will be treated to meet the Jordanian standards[4] for discharge to wadis. The process of investigating the potential options for using recycled water for irrigation in the Jordan Valley has been iterative. The latest versions of each of these options are presented herein. All of the options considered will place demands on the existing infrastructure, particularly storage. Without sufficient storage, such developments may not reach optimum agricultural production.

Water quantity in the Jordan valley: As shown in Fig. 2, water available to the Jordan Valley comes from the Yarmouk River, the Tiberias North Conveyor, Mukheiibeh wells, Wadi Al-Arab and other side wadis in the north; wadi Zarqa in the middle and wadis Shueib, Kafrein and Hisban in the south. Unlike the other water sources mentioned, the three side-wadis in the south are not connected to the King Abdulah Canal, the main carrier from north to south in the Jordan Valley. Wadis Arab, Ziglab, Zarqa, Shueib and Kafrein have in-stream dams[5].

The availability of new fresh water resources in the Jordan Valley is dependent on a number of major interventions, particularly the development of the Al Wheda dam on the Yarmook River. This dam will provide a further 50 Mm^3/annum for use in Amman and Zarqa and water to irrigate 35,500-dunnums (approximately 35 Mm^3/annum) in the Jordan Valley. Considering the Government's policy to not develop new areas of irrigation and the limitations on available land, it seems unlikely that this water would go to new lands[6].

Water quality in the Jordan valley: Water supplied from wadi Zarqa is a blend of surface runoff (floods), base flow from springs and effluent from Amman's wastewater treatment plants that is stored in King Talal Reservoir for use in the Middle and Karameh Directorates. In theory, the KTR water is blended before with fresh KAC water for use in these directorates, as shown in Fig. 3. However, most recently, the KTR water has been delivered at full strength. For 2002 and 2003, the portion of the water supplied to the Middle Directorate from KTR was 91 and 100%, respectively, based on records from the Middle Directorate. Ironically, those farmers in the Karameh

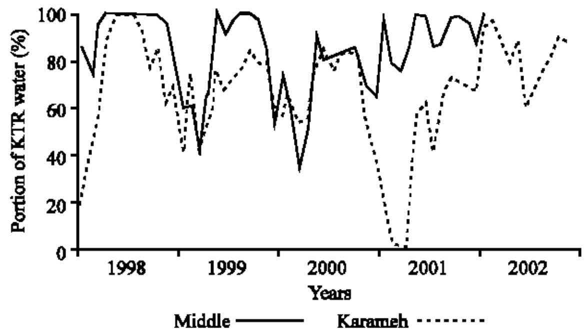

Fig. 3: Blending of KTR with KAC water to the Middle and Karameh Directorates

Directorate who presently use saline groundwater, view KTR water as being better quality, at least with respect to salt, than their present supply.

The effluent of As Samrah WWTP is discharged to Wadi-Dhuleil, which joins Zarqa River and reaches King Talal Dam (42 km downstream of the treatment plant). King Talal Dam is the largest in the Kingdom with a storage capacity of 72 Mm^3, supplies the rift valley crops with treated water from the As Samrah Treatment Plant, which is currently working over capacity[7]. King Talal Dam is released for irrigation and travels approximately 23 km to the valley floor, where it is mixed with high-quality water from Yarmouk River. The dam currently stores around 29% of its total capacity.

Options for wastewater reuse: The main option for increased water reuse in the Jordan Valley is agriculture. Because of differences in present water use characteristics and expected requirements and impacts of increasing the use of recycled water in each of the three directorates (Karameh, Middle and Northern), they are consider as three separate options. The option of groundwater recharge in the Jordan Valley will be considered under the investigations for groundwater recharge in the basin.

According to the existing data, 69, 60 and 33% of the irrigable area in the Northern, Middle and Karameh Directorates was used to produce at least one irrigated crop in 2003. In an intensively cropped area where water was not a constraint, it would be expected to see around 90% of the irrigable land irrigated, suggesting that all three Directorates have considerable room for intensification of irrigation within their existing boundaries. In the case of the Middle and Karameh Directorates this is due in part to shortage of water supply. It is conservatively assumed that given more KTR water, the expected maximum irrigated area for all

Table 2: Present, maximum and difference in irrigated areas (dunums)

Directorate	2003	Maximum	Difference
North	69000	69000	0
Middle	43000	49000	6000
South	34000	72000	38000
Total	146000	190000	44000

Directorates would be similar to that of the Northern Directorate, at 69%. The expected irrigated areas are summarized in Table 2.

Using the increases in areas from Table 2 and the existing cropping patterns, expected Gross Irrigation Requirements for the intensified Middle and Karameh Directorates were developed. For the Northern Directorate, where the quality of water would result in a dramatic change in cropping patterns, it was assumed that the cropping pattern would be similar to that in stage office 5 in the Middle Directorate, which, at 1.8, has the highest cropping intensity of the stage offices irrigated with KTR water.

RESULTS AND DISCUSSION

Karameh directorate intensification of irrigation option: The water reuse option in the Karameh Directorate is to use more recycled water for irrigated agriculture in stage offices 6, 9 and 10. In the case of stage office 9, this would be irrigating lands that are presently partly irrigated with groundwater and partly irrigated with tailwater from KAC. In the case of stage office 10 this would be supplementing existing water sources (Kufrein dam, Wadi Hisban and shallow groundwater) and in stage office 6 it would be to supply water as it is now, a blend of KTR and KAC water. Keeping in mind that the water from Kufrein dam is not considered as a source for domestic/municipal water[4] because there is a wastewater treatment plant upstream, therefore, there is no value in exchanging with KTR water.

The present cropping pattern in the Karameh directorate is dictated, in part, by the lack of water supply. Improved supply would result in further intensification. It is assumed that the resulting cropping pattern would be similar to that in stage office 5, presently the most intensively irrigated area using KTR water. With this and with 70% of the irrigable area in the directorate irrigated, the annual gross irrigation requirement would be around 63 M m^3. Including 20% for leaching, the potential total demand for water with the intensification of irrigated agriculture is estimated to be 76 M m^3. The total expected monthly demand for water (GIR) for each month are shown in Fig. 4.

It is assumed that areas that are not yet receiving reliable water supply, would not receive fresh water for blending, except in wet years. Using 2002 figures and assuming that existing areas in stage office 6 would

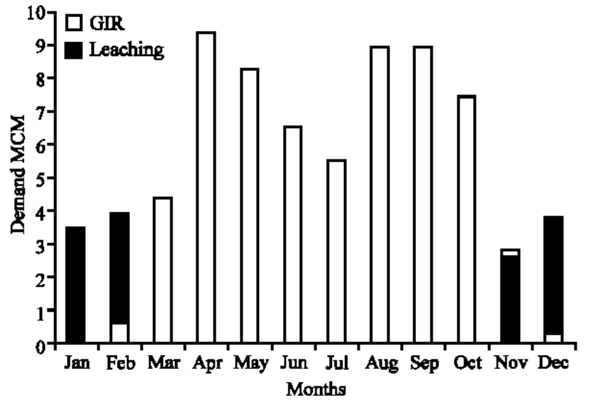

Fig. 4: Estimated water requirements for Karameh Directorate after intensification

receive 20% fresh water for blending, the fresh water supplied from KAC would be approximately 4.4 M m^3. The water to be supplied from KTR would therefore be 63.6 M m^3, which compares with approximately 24 M m^3, presently supplied to the directorate from KTR. This is an increase of 39.6 M m^3.

Estimated costs and facilities: The conveyance and delivery facilities for all three stage offices are in place, with the exception of the connection between KAC and stage office 10. The total design discharge was determined to be 180 LPs, the total length of the pipeline would be 5,500 m, its diameter needs to be 600 mm and the lift is 68 m, excluding friction losses. The total cost of this facility is estimated to be around JD 2,200,000 (US$3.15 M). Further investment would be required on-farm, primarily in stage office 9. These would include filter and application systems. These costs are not included here.

Benefits and impacts: The primary benefit from increased KTR supplies to the Karameh directorate is increased agricultural production extending to approximately 38,000 dunums, for a total area of 72,000 dunums. The total water requirement would be 76, 63.6 M m^3 of which would come from KTR or Karameh reservoir and the remainder would be fresh water from KAC and/or Kufrein. The main negative impact would be potential contamination of the groundwater underlying these irrigated areas.

Middle directorate intensification of irrigation option: The water reuse option in the Middle Directorate is to use more recycled water for irrigated agriculture in stage offices 4, 5 and 8 by intensification. Although there is some use of KAC water in these directorates, the opportunity for exchange with recycled water is very limited. As discussed above, present irrigated area in the

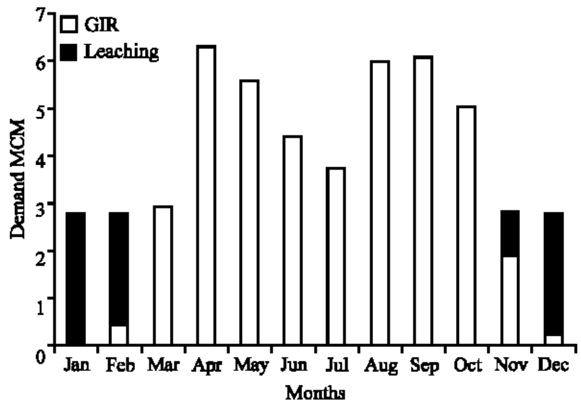

Fig. 5: Estimated water requirements for Middle Directorate after intensification

Middle directorate extends to a total of around 43,000 dunums. With further increases in supply of KTR water, the irrigated area in the directorate could be expanded to a total of 49,000 dunums, a 6,000 dunum increase. The total annual Gross Irrigation Requirement, assuming a cropping intensity similar to that in stage office No. 5, which is presently the highest, is estimated to be 43 M m^3. Including 20% for leaching, the total demand for water with the intensified cropping pattern is estimated to be 52 M m^3, of which 43 M m^3 would come from KTR. The expected monthly distribution of water requirements, including leaching (Fig. 5).

Estimated costs and facilities: The conveyance and delivery facilities for all three stage offices are in place. It is not anticipated that further major developments would be required for this intensification. Further on-farm facilities would be needed for the 6,000 dunums, including filter and application systems.

Benefits and impacts: The primary benefit from increased KTR supplies to the Middle directorate is increased agricultural production extending to approximately 6,000 dunums, which, along with general intensification, would consume a further 6 M m^3 of KTR water. The further negative impacts would be minimal.

Northern directorate intensification of irrigation option: The water reuse option in the Northern Directorate is to replace some or all of the existing fresh water, if were to be used for domestic purposes. This could apply to some or all of stage offices 1, 2, 3 and 7. Present irrigated area in the Northern Directorate extends to a total of around 69,000 dunums which presently consumes between 60 and 83 M m^3 including loses.

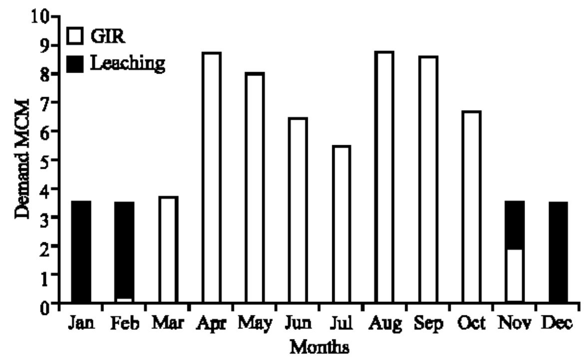

Fig. 6: Estimated water requirements for Northern Directorate after replacement of fresh water

In addition to KTR water, there is a source of recycled water from Irbid wastewater treatment plants (Irbid and Wadi Arab), which presently generate around 4 M m^3 of effluent each year and are projected to increase by a further 13 M m^3, by 2025. A conveyance pipe already exists from the Wadi Arab plant to the Jordan Valley, so losses will be minimal. The effluent is presently discharged into wadi Arab downstream of KAC, where some unplanned reuse is practiced.

The total annual Gross Irrigation Requirement is estimated to be approximately 59 M m^3 excluding reclaimed water from Irbid wastewater treatment plant. Including 20% for leaching, the total demand for water with the revised cropping pattern is estimated to be 72 M m^3. The expected monthly distribution of gross irrigation requirement and leaching, based on the revised cropping pattern (Fig. 6).

Estimated costs and facilities: The conveyance facility to the intake of the stage offices would have to be developed from Wadi Zarqa if this option were to be implemented. According to this design, pumping is not required to deliver to each of the stage offices in the Northern Directorate. If the pipeline were to reach all turnouts it would have to be nearly 67 km long and have a maximum diameter of 1600 mm. The total cost for such a pipeline is estimated to be in excess of JD 87 M. In addition, the use of KTR water would necessitate the use of filter equipment and the replacement of much of the existing application systems, which are presently developed to irrigate trees.

Benefits and impacts: The primary benefit from increased KTR supplies to the Northern Directorate would be to replace fresh water supplies diverted for domestic use. Assuming a blending ratio of 20% of freshwater, the quantity of KTR water required would be around 58 M m^3,

Table 3: Summary of the intensification of irrigation options

Option	Area[1] dunum	Volume of water KTR[2] MCM	Volume of water Total MCM	Fresh Replaced MCM	Capital cost Total MJD	Capital cost JD/Dn	Capital cost JD/CUM	Operating cost JD/CUM
Karameh	38000	39.6	39.6	0	2.2	58	0.056	0.074
Middle	6000	6.0	6.0	0	0.0	0	0.000	0.000
Northern	69000	72.0	72.0	58	87.0	1261	1.500	0.015

[1]Either increased area through intensification or replacement of area presently using fresh water
[2]Assumes 20% blending with freshwater

replacing a similar amount of fresh water. The negative impacts would be considerable, requiring a major adjustment to cropping patterns and potential contamination of the underlying groundwater. The expected reduction in yields and loss of certain crops has been detailed by Grattan[1]. Estimation of the cost will be undertaken as part of the economic analysis.

The intensification of irrigation reuse options: Table 3 presents a summary of the areas, water volumes and costs for the three basic options examined. In the case of the Karameh Directorate, where the option is intensification of irrigation on already developed lands, the total demand for water would be 76 M m^3. Of that 63.6 M m^3 would come from KTR and the remainder, as fresh water, from KAC and/or Kufrein. The total additional water requirements, compared to present, from KTR is 39.6 M m^3. The cost for implementing this, exclusive of on-farm costs, is JD 2,200,000 which is the conveyor from KAC to Kufrein (stage office 10).

With the middle directorate, the costs of intensification are nominal as the infrastructure is already in place. However, the volume of water involved (6 M m^3) is small. In practice, this intensification in the middle directorate is likely to happen with no intervention. The reason it is not presently functioning at this intensity is the constraint on water supply.

The cost of developing a conveyor to the Northern Directorate is high, even without considering the loss of yields caused by the lower quality water and the need for further on-farm developments, such as filters. This option is only a consideration if the fresh water in the north was needed elsewhere, however, the volume of water required to meet the needs of a water-short northern directorate is high (58 M m^3), which, if other options are developed elsewhere in the Jordan Valley or the Amman-Zarqa basin, will not be available to replace lost fresh water sources.

CONCLUSIONS

Irrigation water management in the Jordan Valley, despite considerable efforts in recent years, has much room for improvement. Using recycled water does increase the management challenges, but, in the absence of fresh water sources, the recycled water can be effectively used for sustainable irrigation in the valley. Improved irrigation water management with recycled water, as with fresh water will result in better agricultural returns.

Irrigated agriculture with recycled water from the Amman-Zarqa is sustainable although, the quality of water will have a major impact on cropping patterns presently using fresh water.

The major constituents that constrain irrigated agriculture, other than the microbiological contaminants, are salts in general and specifically chlorides. Any further elevation of these constituents will have a major negative impact in the Jordan Valley. Planned industrial developments in the Zarqa area pose a significant threat to the sustainability of irrigated agriculture in the Middle and Karameh Directorates. This needs to be carefully managed. Furthermore, further development of industries in this same area that could produce higher levels of heavy metals and trace elements will greatly increase the risk of such constituents becoming a threat to irrigated agriculture when presently, they are not.

Microbiological contamination of the KTR water reaching the Jordan Valley poses a significant health risk, primarily in the winter months. The prevalence of drip irrigation and the use of plastic mulches reduce the risk of the water coming in contact with the part of the crop that is likely to be eaten raw. However, the present levels of contamination are unacceptable.

The clogging agents in both the KTR and KAC water create a large maintenance problem for the farmers in the Jordan Valley. On-farm filter systems are used, but the frequency of failure is high. It is reported by the Irrigation Advisory Service that the appropriate media for filters is not available in Jordan. Centralized filter systems were installed at the Zagleb weir diversion, but these are no longer functioning, reportedly because back-flushing had to be done too frequently.

Further efforts in developing and introducing on-farm filter methodologies suitable for the Jordan Valley are needed and the overall concept of a more centralized filter system needs to be re-evaluated. The use of drip systems with larger emitters (bubblers) may be appropriate for some crops.

There is considerable confusion with regards to the quality of the KTR water, especially amongst the smaller farmers who do not have access to this type of information. For instance, many farmers still perceive Boron as a threat and yet others are unaware of the potential harm that chlorides will cause to their key crops or microbiological contamination will cause to them or the general public. Dissemination of the quality information which is already available will alleviate this situation.

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