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Water reuse for irrigation in Jordan: Perceptions of water quality among farmers

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ABSTRACT

The reuse of treated wastewater (reclaimed water) for irrigation is a valuable strategy to maximise available water resources, but the often marginal quality of the water can present agricultural challenges. Semi-structured interviews were held with Jordanian farmers to explore how they perceive the quality of reclaimed water. Of the 11 farmers interviewed who irrigate with reclaimed water directly near treatment plants, 10 described reclaimed water either positively or neutrally. In contrast, 27 of the 39 farmers who use reclaimed water indirectly, after it is blended with fresh water, viewed the resource negatively, although 23 of the indirect reuse farmers also recognised the nutrient benefits. Farmer perception of reclaimed water may be a function of its quality, but consideration should also be given to farmers' capacity to manage the agricultural challenges associated with reclaimed water (salinity, irrigation system damage, marketing of produce), their actual and perceived capacity to control where and when reclaimed water is used, and their capacity to influence the quality of the water delivered to the farm.

1. Introduction

Farmers are key stakeholders in the reuse of treated domestic wastewater (reclaimed water) for irrigation, but their position at the end of the water chain means that they are often marginalised in water resource decision-making processes (Huibers and van Lier, 2005). Farmers have the capacity to accept reclaimed water, visible through their decision to irrigate with the resource (Huibers and van Lier, 2005; Raschid-Sally et al., 2005), or reject reclaimed water, perhaps demonstrated through relocation or agricultural abandonment, or investment in the development of freshwater resources such as groundwater (Tsagarakis et al., 2007). The acknowledgement that there is a choice associated with the decision to reuse water makes it imperative to understand the factors and mechanisms at the farm level which make water reuse both acceptable and manageable.

Jordan has very limited water resources and has been reusing treated wastewater for irrigation for over 30 years as a means to overcome water scarcity (Haddadin et al., 2006). The country offers a valuable research case study to assess how water reuse has been conducted successfully and how likely it is to be continued into the future. An understanding of the essential factors and processes encouraging reuse in Jordan has considerable value to inform decision-making on reuse issues in other catchments of the region and elsewhere. The central aim of the research was, therefore, to explore how and why farmers continue to reuse water in Jordan. To examine this, an understanding of what farmers think about the water, what issues they experience, how they overcome these issues and what concerns they have for the future was sought.

Previous work on farmers' perceptions of reuse can be grouped according to either their investigation of the factors leading to farmers' acceptance of reclaimed water, or the perceptions of farmers towards the risks from reclaimed water. Menegaki et al. (2007) show that lack of water is a major driver for farmers' willingness to use reclaimed water in Greece. Tsagarakis et al. (2007) suggest that the use of empirically-derived symbols of water quality (rather than the conventional system of description of the treatment stage) led to greater willingness of farmers in Crete to use reclaimed water. In a similar manner, Menegaki et al. (2009) report that Greek farmers were more willing to use reclaimed water when it was called "recycled water" rather than "treated wastewater", which was attributed to the negative associations with the word "wastewater". Within the Middle East, the role of religion in inhibiting reuse has been investigated by several authors. Abu-Madi (2004) shows that 87% of farmers in Jordan do not consider religion to prevent water reuse for irrigation and suggests that religion can actually provide an incentive to use reclaimed water as water, which is acceptable from a religious view is also culturally acceptable. Many farmers in Palestine believe water reuse is permitted under Islam, and so religion is not seen as limiting factor (Al-Khateeb, 2001).

Keraita et al. (2010) compile research findings from studies around the world regarding farmers' perceptions of health risks.

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They conclude that awareness of health risks is not high among farmers. However, 89% of farmers interviewed in Nepal connect the reuse of untreated wastewater with negative health conditions, particularly skin irritations (Rutkowski et al., 2007).

There is a need to explore farmers' perceptions of treated wastewater. This is necessary not just in terms of their willingness to use the resource, or their awareness of health risks, which are recognised to be reduced when the water has been adequately treated and a number of post-treatment irrigation and harvesting strategies applied (WHO, 2006). Rather, it is just as salient to examine the underlying factors leading to either a positive or negative perception of reclaimed water. Our goal in this research is to identify those factors. We hypothesize that they are likely to be connected to the agricultural limitations which farmers associate with reclaimed water, their capacity to implement strategies to meet these challenges, and the benefits which they attach to the resource.

2. Research methods

2.1. Research area

Water reuse for irrigation takes place in many locations in Jordan. Direct reuse occurs near treatment plants where reclaimed water is directed onto land for the irrigation of fodder crops such as alfalfa, barley and maize. Khirbet As Samra is the largest wastewater treatment plant in Jordan and has recently been upgraded from stabilisation ponds to advanced tertiary treatment. It has an estimated discharge of 60 million m^3 (MCM) per year (Ammary, 2007; Grabow and McCornick, 2007), of which approximately 1 MCM is used directly on lands very near the wastewater treatment plant (personal communication with representative from Jordan Valley Authority, 2008), suggesting that 59 MCM flow down the Zarqa River to the King Talal Reservoir and then onto the Jordan Valley (Fig. 1). Blended freshwater and reclaimed water are used in the Jordan Valley for the irrigation of fruit and vegetable crops (Kfouri et al., 2009; McCornick et al., 2004; Molle et al., 2008). We consider this form of using reclaimed water to be indirect.

Within the Jordan Valley, several qualities of water are used for irrigation, as fresh surface water is mixed with reclaimed water in varying proportions. At the King Abdullah Canal North (KAC North) irrigated sites, fresh surface water from the Yarmouk River is used for irrigation. At the Zarqa Carrier (ZC) irrigated sites, water from the King Talal Reservoir is used for irrigation and at the King Abdullah Canal South (KAC South) irrigated sites, King Talal Reservoir water blended with water from the KAC North is used for irrigation.

2.2. Sampling

We interviewed 56 farmers who irrigate with reclaimed water, either directly or indirectly, or who use fresh water for irrigation. Our goal was to determine if different attitudes towards reclaimed water exist, depending on the quality of the water and the location of reuse. We devised a semi-structured interview schedule and then conducted preliminary interviews with 10 farmers in 2007 to test the schedule, to gauge attitudes regarding water reuse, and explore the willingness of the farmers to talk about reuse. These interviews were helpful in refining the interview schedule and identifying the locations of irrigated agriculture where further interviews could be conducted. We then formed a detailed sampling plan to ensure that a variety of farmers (using the size of the farm as an economic indicator) from several locations were interviewed during the main phase of fieldwork in late 2007 and early 2008. We interviewed six farmers near the Ramtha wastewater treatment plant and five farmers near the Khirbet As Samra plant (Fig. 1). These farmers are direct users of reclaimed water. Our sample of such farmers is fairly small due to the limited extent of agriculture directly around the treatment plants. We have a much larger sample in the Jordan Valley, where we interviewed 39 farmers who use reclaimed water indirectly (Table 1).

2.3. Specific methods

Careful consideration was given to the interview method. A questionnaire would have standardised the process of data collection and simplified analysis (Foddy, 1993) but would have restricted the depth of the data collected by imposing categories and potential answers on interviewees (Foddy, 1993; Rubin and Rubin, 2005). We needed also to learn about items such as leaching volumes, which must be reported in an organized, quantitative fashion. Hence, we adopted a semi-structured interview schedule that focused on factual information gathering, while giving farmers an opportunity to raise issues of their choosing and develop conversation about points which they thought particularly important. This method also offered practical advantages, as initial direct questioning about farm management gave the farmer, interviewer, and translator time to relax into the interview situation and develop a relationship of trust. This is particularly important due to the sensitive nature of discussions regarding the use of reclaimed water for irrigation in the region.

The sensitivity surrounding water reuse in the Jordan Valley is due partly to the ban on the import of some Jordanian fruits and vegetables imposed by Saudi Arabia during the early 1990s, based on concerns about the use of reclaimed water for irrigation (Haddadin and Shteiwi, 2006; Qadir et al., 2010b). Farmers in the region might still be cautious in discussing water reuse due to the economic repercussions this has had in the past and the fear of further effects in the future. Time was needed at the start of each interview to explain the independent position of the researcher and to emphasise that confidentiality would be maintained and care would be taken in reporting responses.

It is important to consider the accuracy of interview data, particularly concerning whether interviewees are telling the interviewer what they think is the 'right answer' instead of telling 'the truth'. It is essential to keep in mind that in most situations there is no one correct response, rather all answers are biased, and reflect the context in which they are given (Willis, 2006). Interview based research attempts to identify trends in responses and to explain them.

2.4. Data analysis

The interview notes were transcribed directly after the interviews. Then following the method given by Kitchin and Tate (2000), the transcripts were read several times before a coding framework was designed to organise the interview data into categories. All comments relating to each category were sorted into new documents and scrutinised for trends, areas of unity, diversity and controversy. The data were then further split into sub-categories or combined with other categories to aid analysis. We formed narratives based on the sorted categories and conducted a content analysis to tabulate the number of comments made for each topic, or on a specific theme.

3. Research findings

3.1. General perceptions of reclaimed water quality

Each interview started with an opening question, "what do you think about the water?" which revealed great diversity in responses that correlated strongly with the type of water being used. Of the farmers we interviewed, 27 of those who use reclaimed water

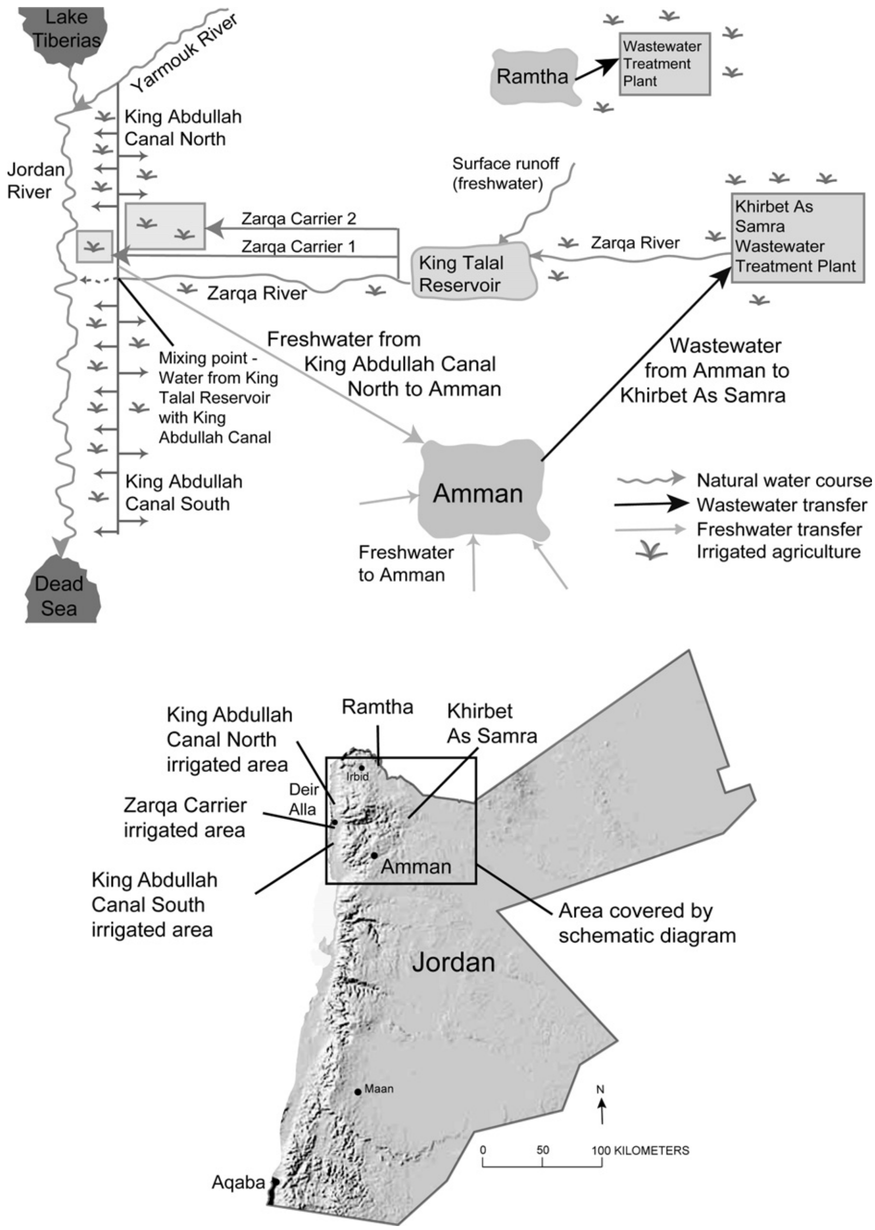

Fig. 1. Schematic diagram showing the transfer and use of reclaimed water in North-West Jordan (based on information from Bdour and Hadadin, 2005; Courcier et al., 2005) and map of Jordan (modified from USGS, 1998) with the locations of interviews conducted with farmers.

Table 1
Sample population according to location with average farm size, irrigation method and crops grown.

	Number of interviews	Primary irrigation method	Crops grown	Interview distribution according to farm size (ha)						
				<1.5	1.5–3	3–5	5–10	10–20	>20	Unknown
Ramtha	6	Flood	Fodder	–	–	1	2	1	1	1
Khirbet As Samra	5	Flood	Fodder	1	1	1	–	–	–	2
Direct reuse (total)	11			1	1	2	2	1	1	3
Zarqa Carrier	22	Drip	Fruits and vegetables	2	4	5	4	1	6	
King Abdullah Canal South	17	Drip	Fruits and vegetables	–	1	3	3	4	4	2
Indirect reuse (total)	39			2	5	8	7	5	10	2
King Abdullah Canal North	3	Drip	Fruits and vegetables	–	–	–	–	3	–	–
Desalination	1	Drip	Fruits and vegetables	–	–	–	–	–	1	–
Freshwater (total)	4									
Jordan Valley unknown location	2		Fruits and vegetables	–	–	–	–	–	1	1
Total interviews	56			3	6	10	9	9	13	6

Table 2
Nature of response by each farmers to the initial question, "what do you think about the water?" and results of content analysis showing total number of positive, negative and neutral comments recorded during the interviews regarding water quality.

	Ramtha	Khirbet As Samra	Direct reuse (total)	Zarqa Carrier	King Abdullah Canal South	Indirect reuse (total)	King Abdullah Canal North/desalination	Jordan Valley unknown location
n	6	5	11	22	17	39	4	2
Negative responses								
Number of farmers responding negatively to initial question	–	1	1	16	11	27	2	2
Total number of negative comments regarding water quality	1	2	3	48	24	72	2	–
Positive responses								
Number of farmers responding positively to initial question	4	2	6	1	3	4	1	–
Total number of positive comments regarding water quality	3	3	6	1	3	4	2	–
Neutral responses								
Number of farmers responding neutrally to initial question	2	2	4	1	3	4	1	–
Total number of neutral comments regarding water quality	2	1	3	4	4	8	1	–
Rainfall improves water quality								
Number of farmers connecting rainfall with water quality in response to initial question	–	–	–	4	–	4	–	–
Total number of comments connecting rainfall with water quality	–	–	–	8	4	12	–	–

indirectly, and one direct reuse farmer, spoke negatively about the water (Table 2). In contrast, six direct reuse farmers spoke positively about the water, compared to only four indirect reuse farmers. A chi-squared analysis to compare the differences in perception between the direct and indirect water users, based on initial responses, revealed that there is a statistically significant difference at the 0.01 significance level ($\chi^2 = 16.52$; df 5).

The difference in perception to water quality is further highlighted by the results of the content analysis which shows that a total of 72 negative comments towards water quality were made by the indirect users compared to just three negative comments made by direct users (Table 2). A greater number of negative comments were made by the farmers using water from the Zarqa Carrier (48 comments) than among those irrigating with water from KAC South (24 comments), which may indicate a difference in perception between these two irrigated areas.

Four indirect reuse farmers mentioned in their first response about the water that rainfall is important as it improves water quality. As the interviews progressed, the role of rainfall became more apparent as a total of 12 further comments were made that drew attention to the connection between water quality and rainfall (Table 2).

3.1.1. *Actual and perceived water quality*

Effluent from Khirbet As Samra was of the poorest quality in terms of organic load (biological oxygen demand and chemical oxygen demand), salts (electrical conductivity) and faecal coliforms (Table 3). Our data do not reflect recent water quality changes due to the upgrade of the plant which is reported to have reduced concentrations of BOD_5 and total nitrogen to below 30 mg L^{-1} (As Samra Wastewater Treatment Plant, 2010). The treatment processes at Ramtha include nitrogen removal (Al-Zboon and Al-Ananzeh, 2008), which substantially reduces the nitrogen content of the effluent. The data suggest that the water released from Ramtha, the King Talal Reservoir (Zarqa Carrier irrigated sites), and the KAC South is fairly similar in terms of BOD_5 and COD. The water quality data in Table 3 also reveal that there is a progressive reduction in solute concentration from Khirbet As Samra, to the King Talal Reservoir and the KAC South which would be due to the dilution of reclaimed water with surface runoff as the effluent travels from the wastewater treatment plant to the lower Jordan Valley.

We were interested to explore which specific features of water quality concerned the farmers. Analysis of the interviews revealed that responses should be grouped according to the effect of reclaimed water on soil salinity, the potential for introducing parasites such as nematodes, the potential damage to irrigation infrastructure such as pipe clogging, and societal concerns such as religious considerations or public acceptance of reuse for irrigation. Interestingly, health related issues were not mentioned by any farmer and were directly rejected as a concern by the 14 farmers (both direct and indirect users) who were asked specifically about this issue. Other researchers also found that farmers often do not see themselves or their produce at risk, or they may accept the risks due to the economic benefits of using reclaimed water (Keraita et al., 2010; Kilelu, 2004; Ouedraogo, 2002). Positive perceptions could be grouped according to acknowledgement of the value of the water as an irrigation resource and the nutrient benefits provided by reclaimed water.

3.2. *Negative perceptions of reclaimed water quality and management strategies*

3.2.1. *Soil salinity*

Reclaimed water is slightly saline (electrical conductivity can slightly exceed 2 dS m^{-1}) (Table 3) which can result in a reduction in crop productivity if not carefully managed when used for irrigation (Feign et al., 1991). Soil salinity was mentioned by 51% of the indirect reuse farmers (Carr, 2011) and we recorded leaching meth-

Table 3
Water quality at the locations where interviews were conducted.

Legal classification[a]	Treated waste water		Freshwater	
	Khirbet As Samra[b]	Ramtha[c]	King Talal Reservoir (Zarqa Carrier irrigated site)[d]	King Abdullah Canal South (KAC South irrigated site)[e]
pH	7.86	8.21	7.85	8.13
Electrical conductivity (EC) dS m^{-1}	2.04	1.71	1.91	1.02
Sodium adsorption ratio (SAR) mg L^{-1}	7.67	6.30	1.92	2.80
Biological oxygen demand (BOD_5) mg L^{-1}	152.36	18.50	11.26	12.80
Chemical oxygen demand (COD) mg L^{-1}	385.94	62.33	52.06	54.50
Sodium (Na) mg L^{-1}	261.14	232.46	125.67	112.88
Chloride (Cl) mg L^{-1}	364.61	398.76	276.66	171.47
Boron (B) mg L^{-1}	0.91	0.73	0.54	0.72
Ammonium (NH_4) mg L^{-1} N	129.63	1.00	51.88	7.10
Nitrate (NO_3) mg L^{-1} N	28.00	12.83	49.50	38.50
Phosphate (PO_4) mg L^{-1}	35.63	6.80	21.74	4.00
Potassium (K) mg L^{-1}	31.32	32.97	15.74	0.60
Faecal coliforms MPN 100 ml^{-1}	$<16 \times 10^6$	2400	<16,000	<16,000

Source: [a] JISM (2002) and McCornick et al. (2004); [b] Carr (2009) and JVA and GTZ (2005); [c] Carr (2009), Al-Zboon and Al-Ananzeh (2008), Bashabsheh (2007) and Malkawi and Mohammad (2003); [d] Carr (2009), JVA and GTZ (2005) and Shatanawi and Fayyad (1996); [e] JVA and GTZ (2003, 2005) and Shatanawi and Fayyad (1996).

ods, timings and quantities to explore how farmers attempted to overcome salinity challenges. Seven farmers told us that they use flood irrigation for leaching, while a further 10 farmers reported a preference for flood irrigation if sufficient water is available, but use drip irrigation when there is insufficient water. Five farmers told us that they only use drip irrigation for leaching, and three farmers said that they had insufficient water for any leaching. In total, 14 farmers told us their leaching schedules were limited by water shortage.

Twelve farmers told us that they leach at the start of the season (September). Two farmers are planning to change their schedule to leach at the end of the season (May), to make use of the residual moisture in the soil at this time. Six farmers told us that they leach by applying excessive quantities of water throughout the cropping season, when water is more readily available. We collected sufficient data from 16 farmers to determine that they use between 100 and 350 mm of water per year for leaching. This broad range in the quantities of leaching water applied also shows that there is large variation in the leaching strategy of each farmer.

For the direct reuse farmers, soil salinity was not directly identified as a concern but several farmers told us that the addition of chlorine based disinfectants to the effluent resulted in a high chloride concentration in the irrigation water which caused yellowing of their crops. Guidelines on chloride concentrations suggest that water with greater than 350 mg L^{-1} presents severe restrictions on use (Ayers and Westcott, 1985). The Cl concentration in the water at Ramtha reaches almost 400 mg L^{-1} (Table 3). The farmers explained how they had requested the wastewater treatment plant staff to reduce the chlorine additions to the effluent and the problem had been reduced.

3.2.2. Reduced plant productivity and plant pathogens

Eighteen of the indirect reuse farmers associated reclaimed water with reduced plant productivity. The reductions were difficult to quantify and tended not to consider differences in soil characteristics, climate or management. For example, three farmers with land in both the KAC North irrigated area and the Zarqa Carrier irrigated area explained how they were convinced that the productivity of their land irrigated by the KAC North (Yarmouk River) was higher than that irrigated by the Zarqa Carrier (King Talal Reservoir):

> "I can compare the productivity of land irrigated with the Yarmouk compared to an area irrigated with the King Talal Reservoir. The lifespan of the same crop in the Yarmouk area is longer than the King Talal Reservoir. Although all other factors are the same – planting, care etc. Productivity of the greenhouses in the Yarmouk area are better than the productivity of the greenhouses in the King Talal Reservoir area by 200 boxes. It depends a bit on the type of crop as these also show a different response. For example, cucumbers are more sensitive than tomatoes. I think that the water may bring pathogens to the soil. The Yarmouk water is definitely better."

Twelve farmers told us that pests carried in the irrigation water, such as nematodes, were transferred to their land, and several farmers claimed that additional pesticides were needed to counter additional plant pathogens. While the infection of crops with plant pathogens carried through domestic treated wastewater is unlikely, transfer through surface runoff and irrigation waters has been reported (Steadman et al., 1975). In principle, plant pathogens and pests can be transmitted through reclaimed water, but this depends on their prevalence in wastewater and their survival during treatment, transportation and/or storage. None of the farmers using reclaimed water directly described similar concerns regarding pathogens and pests, suggesting that crop infections and infestations are based on perception.

3.2.3. Damage to irrigation infrastructure

Indirect reuse farmers related aspects of water quality with damage to irrigation infrastructure resulting in higher costs and reduced profits. Nine farmers described how their drip irrigation emitters became clogged due to suspended solids, mineral precipitation or algal growth. Liu and Huang (2008) attribute clogging to mineral precipitation due to the high pH of reclaimed water, while Duran-Ros et al. (2009) identify the combined effects of algal growth and mineral precipitation. Indirect reuse farmers described pipe replacement, manual cleaning, the use of acid (to dissolve precipitates), or installation of water filtration units as methods to eliminate or reduce pipe clogging. The costs to overcome clogging were also discussed. One farmer explained how replacing his drip emitters was cheaper than paying his labourers to clean them by hand. Filtration was recognised to reduce the suspended solids and increase the life of drip emitters and pipes, but farmers told us how installation, operation and maintenance of filtration units raises the cost of the water.

The high pH of the water (Table 3) was recognised by farmers as preventing the effectiveness of pesticides, and some farmers spoke of "buying in" small quantities of freshwater from tankers specifically for mixing with pesticides. Freshwater from tankers is priced at approximately 1.5 US $/$m^3$ (Carr, 2009). This high price is feasible because only relatively small quantities of water are required for mixing pesticides. An alternative strategy described by some farmers was to add phosphoric acid to the irrigation water (to lower the pH) before using the water for mixing with pesticides.

3.2.4. Societal concerns

We asked farmers if they experienced problems selling their produce, to assess whether they experienced, or were concerned by, negative consumer attitudes towards the use of reclaimed water for irrigation. No farmer claimed to have had problems in recent years, although some farmers had experienced restrictions in the past.

Attempts were made to explore the extent to which religious views affect farmers' perception of water reuse. We asked seven farmers whether they had any aversion to reclaimed water for religious reasons. None of them considered religion to inhibit water reuse. However, follow-on comments, which were more common at the direct reuse sites, suggested that the history of the water and its spiritual impurities were considered. Several farmers explained that they tried to avoid touching the water, but if they did come into contact with it they must wash themselves and their clothes before praying.

3.3. Positive perceptions to reclaimed water

3.3.1. Availability of reclaimed water as an irrigation resource

Only one farmer spoke of the role of water reuse in reducing water shortage and scarcity in Jordan, suggesting that most farmers do not consider the importance of reclaimed water for maintaining agricultural productivity. This is perhaps because water shortage is experienced in the Jordan Valley despite the use of reclaimed water (39 farmers from the Jordan Valley spoke of water shortage during their interviews). Direct reuse farmers recognised that the continual supply of reclaimed water from the wastewater treatment plants allowed them to cultivate throughout the year. Some direct reuse farmers also described the direct economic benefits they had experienced due to the availability of water. At Khirbet As Samra, one farmer told us that he had always kept sheep, and when the treatment plant was built, he began growing his own forage with the available water, thus saving money normally used to buy fodder.

3.3.2. Nutrient benefits

Reclaimed water can contain substantial amounts of plant nutrients (Table 3), thus reducing the amount of chemical fertilisers needed to obtain profitable crop yields. Irrigation with reclaimed water at Khirbet As Samra led to sufficient additions of potassium and phosphate to meet the crop demand for these nutrients, although results vary with crop type and cropping intensity (Carr et al., 2011). Water from the King Talal Reservoir has sufficient nutrients to meet 75% of the fertiliser requirements of a typical farm in the Jordan Valley (MWI, 2004). However, excess nutrient availability can also reduce productivity, depending on the crop and its growth stage (Feign et al., 1991). Careful nutrient management to reduce fertiliser costs and prevent a reduction in crop yields due to excess nutrients is essential when reclaimed water is used.

To manage and benefit from the 'free' nutrients in the water, farmers must be aware that they are present and reduce chemical fertiliser inputs accordingly. Of the indirect reuse farmers we interviewed, 23 were aware of the nutrient content of the irrigation water (Carr et al., 2011). However, awareness of nutrients may not necessarily correspond to reduced fertiliser application as only 12 farmers who reported an awareness of nutrients also reduce the quantity of chemical fertiliser applied. Eight farmers told us that although they are aware of the nutrients, they continue to apply fertiliser in recommended or excessive quantities. The reasons given by farmers for the continual application of fertiliser, despite their awareness, include the perception that nutrients are a limiting factor for productivity, and larger yields result from greater additions of fertiliser, and concern that while nutrients are present in the water, their quantity is either insufficient to meet the demands of intense cropping or the crop is unable to take up nutrients from reclaimed water.

The interviews conducted with direct reuse farmers led to more limited data regarding fertiliser awareness and application. We only asked five farmers about their awareness to nutrients in the irrigation water and they all responded that they were aware. Three of these farmers told us that they reduce the quantity of chemical fertiliser applied, but they also apply chemical fertiliser because the nutrients applied with the water are insufficient to meet crop demand.

4. Discussion of perceptions to reclaimed water

In sum, direct and indirect reclaimed water users hold different perceptions regarding water quality. There is a possibility that perceptions are shaped by factors not raised during the interviews. For example, we could have received positive responses from the farmers due to a possible concern that the price of water will be raised, or that reclaimed water will not be provided, if a negative perception is documented. While it is important to consider that our data may be shaped by drivers not discussed by farmers, our analysis has focussed on the factors which we hypothesise to drive perception, based on our analysis of the responses recorded. The factors we have identified as important for perception include the quality of the water being delivered to the farm, the capacity of farmers to manage the agricultural hazards from irrigation with reclaimed water, societal concerns surrounding reuse for irrigation, and recognition of the benefits of reuse in terms of livelihood provision and economic gains.

4.1. Water quality

In the Jordan Valley, negative comments regarding water quality were made consistently by farmers, yet the water quality data suggest that the irrigation water supplied from the King Talal Reservoir and KAC South is of higher quality than that supplied at Khirbet As Samra, where positive comments regarding water quality have been recorded. This suggests that perception is independent of water quality. However, when water quality and perceptions data from the Jordan Valley are considered, a different picture emerges. A greater number of negative comments regarding water quality were made by farmers in the Zarqa Carrier irrigated area compared with farmers from KAC South irrigated areas. The water quality data suggest that KAC South water has, on average, a lower electrical conductivity, and lower concentrations of nitrogen, phosphate and potassium than water in the Zarqa Carrier. This suggests that farmers' negative perceptions might be associated with higher solute concentrations in irrigation water.

Perceptions towards reclaimed water could also be affected by the farmers' capacity to control where and when reclaimed water is used. Work from Nepal which showed that farmers who had no control over the use of treated wastewater, due to its provision via rivers, had a more negative perception of the water compared with farmers who actively chose to apply wastewater though redirecting sewage water onto their land (Rutkowski et al., 2007). Similarly, the interviews suggest that farmers who actively choose to apply wastewater effluent onto their fields (the direct users) view the water positively and are satisfied with the quality of the water they receive. The indirect reuse farmers, who passively use reclaimed water through its provision via the King Talal Reservoir and the Zarqa River (a natural water way), view the water negatively and tend to be unsatisfied with the quality they receive.

Freshwater dilution is recognised by farmers in the Jordan Valley as a mechanism by which the quality of reclaimed water is raised. Improvements to water quality associated with increased rainfall are likely to correspond to the effect of greater freshwater dilution on the water quality in the King Talal Reservoir, and higher flow rates in the Yarmouk River, which feeds water to the King Abdullah Canal. These two dilution points contribute to a higher ratio of freshwater to reclaimed water in the Jordan Valley during times of higher rainfall. The use of freshwater for diluting and improving poorly treated wastewater is a simple, low cost and effective strategy, particularly for lowering solute concentrations (Toze, 2006). The Jordan Valley Authority (JVA), responsible for water distribution in the Jordan Valley, uses freshwater–reclaimed water blending as a key strategy to raise the quality of marginal water to a standard better suited for agriculture and also to increase the volumes of water available for irrigation (MWI, 2009). Several farmers from the KAC North irrigated area mentioned dissatisfaction with the use of freshwater blending due to their view that it resulted in the contamination of good quality water with reclaimed water.

4.2. Management of reclaimed water

Farmers in the Jordan Valley report challenges in managing soil salinity due to a limited supply of water for leaching. The JVA has an important role to play in ensuring adequate water is provided to farmers for leaching management, but this is not easy, due to Jordan's delicate water availability situation (Qadir et al., 2010a). The difficulty that farmers have in overcoming this challenge and the subsequent effect that salinity can have on reducing land productivity may be leading to a negative perception of reclaimed water in the Jordan Valley.

The type of agriculture taking place, and the negative economic repercussions from irrigation with reclaimed water also are likely to influence perceptions. Agriculture in the Jordan Valley requires high investment in the form of irrigation infrastructure, seeds, fertilisers and pesticides. Several farmers associate reclaimed water with reduced life span of irrigation equipment and additional operation and maintenance costs due to the necessity of filtration units. These are likely to contribute to higher operating costs and lower net income. Reclaimed water is also associated with lower productivity due to salinity, and possibly water-derived pests, which could potentially reduce yields and lower income. In contrast, agriculture around the treatment plants involves flood irrigation though canals which have less potential for detrimental impacts than drip irrigation systems through clogging.

The capacity of the farmer to influence and control the quality of the water delivered to the farm may also influence perceptions. The direct reuse farmers spoke about their ability to discuss their water quality concerns regarding the chlorine content of the wastewater effluent with the wastewater treatment plant manager. This suggests that these farmers feel involved in managing water quality and this could be a factor contributing to the more positive perception of reclaimed water at the direct reuse sites. Further research into the effects of farmer involvement and participation in water quality management on perceptions towards reclaimed water would be of value.

4.3. Societal concerns surrounding reuse

There was little evidence that religious issues influence perceptions of reclaimed water in Jordan. However, the sensitivity surrounding water reuse for fruit and vegetable cultivation likely contributes to negative opinion in the Jordan Valley. The use of reclaimed water could be perceived to add an extra risk factor to agriculture in the Valley, due the possible imposition of government driven regulations or the effect of consumer prejudices which may limit access to markets or reduce prices.

4.4. Recognition of the benefits of reuse

The nutrient content of reclaimed water is recognised by most farmers, but many continue to apply chemical fertilisers in recommended or excessive quantities. These findings are similar to those of Ensink et al. (2002) who show that Pakistani farmers using reclaimed water continued to apply chemical fertilisers resulting in over-fertilisation and Mojid et al. (2010) who report similar results from Bangladesh. One of the key challenges of nutrient management when irrigating with reclaimed water is the availability of information on nutrient values and the provision of this information to farmers (Martijn and Redwood, 2005). Further work is needed to determine how farmers become aware of the nutrient content and the role of formal (institution driven) and informal (farmer to farmer) information exchange channels in providing this information. Determining optimal fertiliser requirements remains a challenging research area, even when the fluctuating inputs from reclaimed water are not considered as a variable (Haefele et al., 2003; Lobell, 2007; Rajsic and Weersink, 2008).

5. Conclusions

Water reuse is essential in Jordan. Treated wastewater makes a significant contribution to the limited irrigation water supply and ensures the continuation of agriculture in parts of the country. Water reuse for irrigation is conducted irrespective of the perception of the farmer towards the resource. However there are aspects of reuse that lead farmers to a more positive or negative view of reclaimed water, which may have implications for their acceptance of the resource. Farmer perceptions do not necessarily reflect the quality of water delivered to the farm. Additional factors influence farmer perceptions, such as the farmer's actual and perceived capacity to control water quality, and the farmer's ability to manage the negative aspects of the water that jeopardise productive agriculture.

Future research on water reuse should explore how farmers are involved in water quality decision-making in water reuse schemes, and how their involvement can be enhanced. In addition, further work is needed regarding both the positive and negative aspects of reclaimed water, and how those aspects can be managed successfully in various agricultural systems. These research areas require a multi-disciplinary approach to encompass both social and technical aspects.

Finding the means to ensure that reuse continues in a sustainable manner is vital. Policy makers have an essential role to play through facilitating the process and identifying mechanisms by which farmers can become integrated into management decisions surrounding reclaimed water quality and quantity provision.

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