Greywater Reuse in Urban Agriculture for Poverty Alleviation: A Case-Study in Jordan

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Abstract:
Although Jordan has a human development index higher than most developing countries, about seven per cent of its population earns less than the international poverty line of $1 US a day. Furthermore, because of its scarce water resources and rapidly growing population, the poor, who are increasingly moving to cities, face growing food and water insecurity. This paper describes a pilot project that allowed the poor in Tufileh, Jordan, to reuse untreated household greywater in home gardens. The women of the community used small revolving loans to implement simple greywater recovery systems and set-up gardens. The project allowed the community to offset food purchases and generate income by selling surplus production, saving or earning an average of 10 per cent of its income. Had the households used municipal sources for this supplemental irrigation, on average, they would have used 15% more water and had 27% higher water bills. Moreover, the project helped community members gain valuable gardening, irrigation, and food preservation skills. Women on the project report feeling more independent and proud because of the income they generated, the skills that they gained and their enhanced ability to feed their families. An environmental impact assessment demonstrated that the quality of the untreated greywater was adequate, and the negative impacts on soil and crops were negligible. Nevertheless, this could change if greater volumes of greywater are reused. A follow-up project will increase greywater recovery, pilot simple treatment devices, and improve gardening practices and production.

Keywords: *Water scarcity, Wastewater reuse, treatment, greywater reuse, urban agriculture, Jordan, gender impacts*

Introduction

Using a case study in Jordan, this paper discusses the benefits of greywater reuse within urban agriculture as a means for alleviating poverty.

Jordan has a medium human development index, higher than the average for developing countries. The nation's per capita income is $US 1,680 (World Bank, 2001) and has risen steadily over the last 25 years. Nevertheless, 15 per cent of the population lies below the national poverty line, based upon an annual household income of $US 3,204 (or $US 525 per capita), with an average of 6.1 people per household (Royal Scientific Society of Jordan, 1998). About seven per cent of the population earns less than the international poverty line of one dollar/day. Furthermore, Jordan's high population growth and unprecedented urbanization rate threaten its recent economic gains. Its population growth is 2.7 per cent, and the proportion of its population living in urban areas, already 73 per cent, is expected to reach 80 per cent by 2015 (United Nations Development Program, 2000). This trend has greatly threatened the food and water security of the poor, who increasingly find themselves in towns and cities.

Jordan has always had scarce water resources, but high population growth over the last 20 years has pushed its per capita water availability to below 198 m^3/c (World Bank, 2000), far below the benchmark level of 1000 m^3/c/y often used as an indicator of water scarcity. Below this, a country is likely to experience chronic water scarcity on a scale sufficient to impede development and harm human health (Falkenmark and Lindh, 1974).

To address this unprecedented water scarcity, Jordan's fresh water must be used where its social and economic value is highest. Although agriculture contributes only three per cent to Jordan's GDP, 75 per cent of renewable water is still used in irrigation, and the remainder for industry and domestic purposes (United Nations Development Program, 2000). When so little water is available, the hard reality is that the first priority must be for drinking and domestic purposes, not agriculture. Because, even with low urban tariffs, the value of water is at least 10 times higher in cities than it is in agriculture (Gibbons, 1986). The market, and in some cases the government, is forcing inter-sectoral transfers to occur. As early as 1991, the Jordanian government paid farmers $129 per ha not to plant vegetables and annual crops in order to preserve water for drinking (Shatanawi, Mohammad and Odeh Al-Jayyousi, 1995). The transfer of water from agriculture to cities means that Jordan will have to import more food, particularly cereals. In 1998, despite using 75 per cent of its fresh water in agriculture, Jordan was still forced to import 100,000 tonnes of cereal.

To mitigate the impact of transfers of water out of the agricultural sector, Jordan must treat and reuse virtually every drop of domestic wastewater. A small amount of fresh water should be reserved for salt-sensitive fruits and vegetables, or those eaten unpeeled or raw. All other crops will have to be grown increasingly, and eventually solely, with treated wastewater.

Although almost all of the wastewater generated in Amman is collected and treated for reuse in the Jordan Valley, the As-Samra wastewater treatment plant serving the city is overloaded. Furthermore, in the country as a whole, only 40 per cent of the wastewater is collected and treated. Plans are in place to increase collection and to improve the treatment, but this will take time and significant donor aid to implement. What can Jordanians, particularly the poor, do in the meantime? Those people with access to some land, typically living in peri-urban areas, can harvest the water within their own control, at the household level. This includes rainwater harvesting for drinking, and greywater recovery for reuse in home-gardens. While it empowers the poor to take responsibility for addressing their own food and water insecurity, on-site greywater reuse also decreases the amount of wastewater that municipalities must collect and treat.

In fact, the urban poor in other parts of the developing world are increasingly dependent on city gardens to generate income and to feed themselves. Such urban gardening cannot replace rural agriculture; rather, it complements it by focusing on specific, high-value crops such as tomatoes, mushrooms and olives, which are efficiently produced within the city. For instance, market gardens produce 60 per cent of the vegetables consumed in Dakar (de Zeeuw, 1999). In Dar Es

Salaam, urban gardening is the second largest employer; more than 90 per cent of leafy vegetables are grown in the city (Jacobi et. al., 1999). Furthermore, urban Jordanians are increasingly practising urban agriculture (UA). An IDRC-supported study estimated that 16 per cent of the households in Amman (Shakhatreh, Hussein and Khamis Raddad 2000) already practice UA, mainly for the production of fruits, vegetables and herbs. The annual value of UA in Amman is estimated at $ 4 million, meaning the value of UA in Amman alone is already nearly 2.5 per cent of the value of agriculture in Jordan as a whole. This percentage is likely to grow, as urban agriculture's contribution to GDP increases and the contribution of rural agriculture declines.

In addition to lack of land, lack of water is one of the main obstacles to home gardening in the Middle East. Yet treated greywater from a properly operating system can generally be safely used for irrigating almost any home garden produce, including raw vegetables. Because this wastewater from sinks, showers and laundry does not include toilet wastewater, its reuse tends to be easier, safer and less controversial than combined wastewater reuse. This paper outlines the impact of an untreated greywater reuse project on poverty in southern Jordan

Ain El Baida Case Study

Background

In 1997, CARE Australia implemented a Permaculture Pilot Project (PPP) at a kindergarten in Ain El Baida, a suburb of Tufileh, Jordan. CARE worked with a community-based NGO, the Ain El Baida Voluntary Society, to demonstrate confined space production techniques for both plants and livestock that conserve soil and water. Many types of fruit trees and vegetables are grown, such as olive, grape, cucumber and tomato. Small animal husbandry includes rabbits, goats, chicken and pigeons. Rooftop rainwater systems and the greywater reuse systems supplement municipal water supplies. At the kindergarten, the greywater is derived from the hand washing of more than 100 children, teachers and staff.

Following the success of the demonstration project, the Ain El Baida Voluntary Society used a revolving fund to loan money to 50 poor families in the area to set up PPP and greywater reuse systems in their own homes. Forty-nine of the 50 recipients are women. The loan repayment rate has been 100 per cent.

The International Development Research Centre (IDRC) funded an evaluation (Bino et. al., 2000) of the benefits and costs of the systems, and the impact of greywater reuse to see if they really have made a difference in the lives of the poor. The evaluation was conducted using a detailed survey of 15 families who received loans and implemented the systems in their homes, to determine reuse habits, and the environmental, social and economic impact of the project. In all cases, the impacts are attributable solely to the reuse of greywater for home gardens; the impacts of animal husbandry have been excluded. Where the following results indicate percentages related to residents, the results are actually referring to the sample. However, relative to the underlying population of loan recipient's (50), the sample size (15) is large, so the results will likely be representative of the beneficiaries.

Water Use and Greywater Reuse Habits

The average water consumption in the area, about 28 litres per capita per day (lpcd), is very low, and far less than the low Jordanian average of 135 lpcd (Ministry of Water and Irrigation, 1977). This low rate of consumption is typical of poor rural or peri-urban areas, which generally use water sparingly. Nevertheless, it is much less than the basic international water requirement of 50 lpcd suggested by Lundqvist and Gleick (Lundqvist and Gleick, 1997).

Most of the families in the study (87 per cent) used part of the loan to make some plumbing modifications in order to use greywater to irrigate vegetables, fruits and herbs. A small proportion used the loan for small animal husbandry; others irrigated using municipal water. The predominant greywater source is from the kitchen sink, but over half the households also manually collect and reuse ablution-washing water from the bathroom. About 74 per cent of the families use manual means for greywater separation, collection and distribution. Very simply, they disconnect the kitchen sink drain from the total wastewater drain, and place a bucket underneath the sink. Full buckets are carried to the irrigation site, or the water is conveyed to it using a hose. Most greywater is used immediately, but 13 per cent of the households store the greywater in an open barrel for a day or more, prior to irrigation.

A small portion of the households (13 per cent) use pipes for greywater separation and collection. Although, the greywater collection and distribution is labour intensive, it is easily done by hand since, in most cases, the gardens are small and the volume of water available is low.

Most sample respondents appreciate the benefits of the greywater reuse and want to upgrade their systems. Sixty per cent would like to reduce labour by installing pipes, and nearly 70 per cent want to expand greywater collection by separating from additional sources, including the laundry, washing basin and shower.

As explained further in the environmental impact section, greywater irrigation can be harmful to some soils and plants because of residual detergent and soap content. However, some of the households are already aware of this: 33 per cent indicated they do not reuse greywater containing dishwashing detergent, 20 per cent do not reuse greywater containing hand soap, and seven per cent wait until the second laundry rinse before reusing laundry water.

Economic Impact

This section outlines the economic benefits associated with the value of greywater irrigation and reuse by estimating the value of the crops produced for home consumption and sale, the value of the greywater used, and the costs of the greywater reuse systems.

The community of Ain El Baida is poor. The official poverty line in Jordan, based upon household income, is $3,204 (Royal Scientific Society of Jordan, 1998). As shown in Table 1, the average household income in the project area is about $3,239 — just slightly above the poverty line. Annual benefits arising from home gardening using greywater are substantial for families with such low incomes. Table 1 show that the gains represent from three per cent to 44 per cent of family income, with an average of 10 per cent.

All households were able to reduce their food expenses by consuming the fruits, vegetables and herbs they produced in their home gardens. In addition, about one-third of households generated income by selling the surplus. As shown in Table 1, the average annual value of the crops consumed or sold per household was $308, and it ranged from $11 to $850. While the average family saved 10 per cent of its household income, proportionately, the poorest families benefited the most. For instance, the value of food purchases avoided and income generated by Household Eight was 180 JD — 44 per cent of its 400 JD annual income.

Value of Greywater Collected and Used

In Tufileh, the municipal water tariff follows an increasing block structure. The first 20 m^3 per quarter costs a flat rate of 2.2 JD ($US 3.09), regardless of consumption. Consumption between 21-50 m^3 costs 0.120 JD ($US 0.17)/$m^3$. Consumption between 51-70 m^3 costs 0.346 JD ($US 0.49)/$m^3$. Table 2 shows the quantity and the value of municipal water used and greywater recovered per household. Because of the scarcity of water, before considering irrigating, all families will satisfy their drinking and domestic needs first. The market value of greywater is thus the marginal cost of the same volume of additional water purchased from the municipality.

As shown in Table 2, the average percentage of household water recovered as greywater is 15 per cent, varying from 0 per cent for households 2 and 14, which do not reuse greywater, to 27 per cent. The maximum amount of domestic water that can be recovered as greywater is about 80 per cent because flushed toilets will always consume some water. The percentage of domestic water recovered as greywater is low because the households are collecting greywater primarily from dishwashing and are neglecting other sources. Had the households irrigated with additional water from the municipality, instead of recovered greywater, on average, it would have cost 0.33/m^3 and increased water bills by 27%.

Net Annual Benefit of Greywater Reuse

The project allowed each family to save on food expenses and/or generate income; however, this becomes meaningless if the cost of greywater production exceeds the family's revenue. Table 3 shows the benefit/cost analysis for four typical families. It is divided into three components. First, the revenue, or total annual benefit of the crops consumed and sold by each household is reproduced from Table 1. As shown, the average annual benefit of greywater reuse is $489, and ranges from $267 to $844. The second section identifies the costs associated with greywater irrigation that must be subtracted from the annual benefit; these include the cost of seeds and plants as well as the annualized cost of installing a greywater system. Most households received seeds as gifts, or produced seeds themselves.

As shown, the average annual cost is $113; however, this ranges from $45 to $229. The costs vary depending on the complexity of the greywater reuse systems in place. Most households simply use a bucket under the sink to collect greywater, and carry it to the garden when full. Others use more sophisticated means of plumbing for separating greywater in the home and pipes or hoses to convey it to the garden.

Finally, the profit, or net annual benefit for each household is estimated by deducting the costs from the revenue. Each family earns a profit — the average net annual benefit is $376, and ranges from $170 to $615. The benefit-cost ratio of practising greywater reuse is very high, with an average ratio value of 5.3, and a range from 2.8 to 9.4.

Social Impact

The project has not only saved the families money or generated income, it has given them productive employment and useful skills. Psychological factors that sometimes characterize poverty such as feeling dependent, worthless and hopeless, are often greater inhibitors to development than the lack of money. The social impact of the reuse project included aspects relating to health, personal and women's development, as well as general community strengthening.

Health Impacts

Greywater reuse avoids almost all of the negative impacts associated with total wastewater reuse. While the IDRC does not recommend unrestricted irrigation (primarily vegetables eaten raw) using untreated greywater, the project team did not find any negative health impacts. Organic material in untreated greywater does begin to breakdown quickly and will go septic. However, the health impact associated with these non-fecal bacteria is low (Tullander and Tullander, 1967), unless diapers are washed in the laundry, in which case laundry greywater should not be reused without treatment. The likelihood of groundwater contamination is also low since greywater decomposes much faster than total wastewater in soils during infiltration (Lindstrom, 2000), and Ain El Baida residents do not use local wells for drinking water. Other concerns are mainly aesthetic. Most families did not consider odour a problem because the greywater was used while it was fresh. Few families complained about flies or mosquitoes.

Positive health impacts can only be measured over the long term, but IDRC studies in Nairobi, Kampala and Harare demonstrated that UA improves the nutrition of the poor, as measured by caloric and protein intake and children's weight (Egziabher et. al., 1994). Half of the households in Ain el Baida depend upon their gardens for basic food needs in terms of fruits, vegetables and herbs. These food groups are essential to good health, and the project allowed 40 per cent of the families to consume products that they would have otherwise been unable to afford, so it is likely that long-term nutrition in the area will improve.

Personal Development and Environmental Awareness

Over half of the households reported that as a result of the project they had gained specific skills including agricultural knowledge, food preservation and marketing. More generally, 20 per cent of participants indicated they improved their management skills, and seven per cent improved their ability in home economics. It is evident that at the individual level, overall environmental awareness relating to water conservation and environmental risks associated with using bleach, detergents and even soaps has risen. These skills can help improve the quality of life of individual members of the community, as well as the community as a whole.

Gender Dimension

Women played a key role in the project. In Ain El Baida, typical of most local communities in Jordan, women manage the household budget, and take primary responsibility for the health and nutrition of the family. While women secured the loan and were responsible for repayment, the project involved the entire family, as men made some of the plumbing modifications and mothers delegated the maintenance of the systems and irrigation to their children. In fact, more boys (53 per cent) participated in the project than girls (13 per cent). This implies the evolution of social and cultural traditions; perhaps these young males will be more likely to accept future changes to the conventional role of the adult male in household duties.

Women benefited the most from the skills and education gained within the community as outlined above. One-quarter of the respondents reported feeling self-satisfaction, independence and pride as a result of participating in the greywater reuse project. Forty per cent reported that their husbands were supportive of the project at its inception, while another 20 per cent of the husbands became supportive after witnessing the project's benefits.

Community Strengthening

The project has strengthened the community, with the Ain El Baida Voluntary society playing a key role. Community support, as well as peer pressure, likely contributed to the high rate of loan repayment. Benefits were also dispersed within the community; those who did not qualify for PPP loans were able to buy food from their neighbours. Furthermore, 86 per cent of neighbours encouraged the beneficiaries, and after having observed the greywater reuse techniques and the associated benefits, indicated their willingness to participate in permaculture practices.

Environmental Impact

While the economic impacts seem positive, in the long run these will be meaningless if the practices harm the health of the beneficiaries. Furthermore, if the harmful impacts of untreated greywater reuse accumulate in the soil and reduce the productive capacity of the communities, economic gains may only be temporary. This section examines the project's environmental impacts in terms of the quality of the water, soil and crops.

Water Quality

Six representative samples of greywater and one baseline tap water sample were collected and analyzed for organic content, detergent concentration, salinity, alkalinity and microbial quality.

The organic content of the greywater samples, measured by Biological Oxygen Demand (BOD_5), ranged from 275 mg/l to 2,287 mg/l. This is a little higher than typical BOD_5 values for greywater, but not surprising given the low water consumption in Ain El Baida. The BOD_5 will be high in samples comprised mainly of kitchen greywater, because it contains significant organic food remains such as rice, tomatoes and cooking fat. Placing a screen in the sink drain, which will trap coarse food particles, can substantially reduce the organic content of kitchen greywater.

The detergent concentration measured by the Methylene Blue Active Substances (MBAS), ranges from 45 mg/l to 170 mg/l, consistent with the use of sulfonate-based dishwashing detergent.

The pH of the baseline tap water was 8.35. Three of the greywater samples had a pH higher than 8.35, likely due to the presence of dishwashing detergent or hand soap containing caustic soda, which is a strong base. The other three samples had a pH lower than 6.7, which may have resulted from the presence of foods high in acid, such as tomatoes and cooking oil. The lower pH levels have a positive effect, because the higher the pH, the higher the alkalinity.

Irrigation water should not contain a high salt content. Salinity, expressed by Electrical Conductivity (EC), measures the concentration of soluble salts, which can be toxic and reduce the amount of water in the soil available to plants. Alkalinity, expressed by the Sodium Adsorption Ratio (SAR) is a measure of the exchangeable sodium content in the soil. High alkalinity reduces soil permeability, infiltration and aeration (Withers and Vipond, 1974).

The average EC of the greywater samples was 818 deciSemens/cm (ds/cm), and varied from 457 ds/m to 1,135 ds/cm. The salinity of the tap water is 594 ds/cm. The salinity of the samples was a little higher than the medium salinity in the baseline tap water because of the addition of salts contained in food particles. Where the greywater salinity was lower than that of the tapwater, those households diluted the greywater with rainwater.

The average sample SAR was about 3, and ranged from 1.0 to 6.8. The tap water SAR was only 0.83. Higher detergent content corresponds with higher SAR values, indicating the detergent and soap contains sodium that is increasing the alkalinity of the water.

Waster is classified using salinity and alkalinity because both jointly influence irrigation water quality, especially in terms of infiltration. Despite the addition of detergents, the greywater alkalinity was low, reflecting a class 1, or low hazard. The salinity constituted a medium to high (class 2 to 3) salinity hazard (USDA, 1974). The combination of the two factors means that for five of the six samples, including the baseline tap water, there is a slight to moderate restriction on use for irrigation. The sixth sample would not have restrictions (UN Food and Agriculture Organization, no date).

The microbial quality of the greywater, using the World Health Organization (WHO) recommended fecal indicators (World Health Organization, 1989), was not measured. Because toilet water is not reused, at the time the study was formulated, it was thought that fecal contamination as high as the standard of 1,000 fecal coliform/100 ml and 1 nematode egg per litre was unlikely. During the study, it became clear that some of the households do bathe babies in the sink and wash diapers in the laundry—practicies that could contribute to fecal contamination. While the team found no signs of ill health resulting from untreated greywater irrigation, microbial contamination is being measured in the next stage of the project and simple treatment devices installed (see conclusion).

Impact on Soil

The impact of greywater irrigation on soil was assessed by testing six soil samples irrigated by greywater and two baseline samples that were not irrigated with greywater.

The average EC of soil irrigated with greywater was 2.76 ds/cm, varying from 1.01 ds/cm to 6.78 ds/cm. The average salinity of the baseline soil was 2.57 ds/cm, with a range from 0.93 ds/cm to 4.21 ds/cm. Soil with an EC less than four is not considered saline (Withers and Vipond, 1974), meaning that neither the soil subject to greywater irrigation, nor the baseline soil is saline. Although the salinity of the irrigated soil is slightly higher than the salinity of the baseline soil, in this case, soil salinization arising from greywater irrigation is unlikely due to the small amounts of greywater applied.

The average SAR of the samples was 3.7, and varied between 1.71 and 5.59. The average SAR of the baseline soil was 2.84, and ranged from 1.54 to 4.14. The SAR of alkaline soils generally exceeds six, meaning the soil irrigated with greywater is good for cultivation of most crops. Measuring the soil pH corroborated the SAR results. The pH of alkaline soil is generally greater than 8.5 (Withers and Vipond, 1974) supporting the conclusion that soil alkalinity is not a problem. However, all soil samples irrigated with greywater had a higher SAR than the baseline soils. Over the long-term, it is possible that untreated greywater irrigation could increase soil alkalinity to the point that it affects yields and damages the soil.

Impact on Crops

Representative samples of olive tree leaves, tomato plant leaves and loquat plants were collected. The content of the nitrogen, phosphorus, potassium, magnesium, sodium, chloride, iron and zinc was assessed.

Results from the tests have shown that greywater irrigation appeared to have little or no impact on crops. Although the magnesium level was higher and the zinc level lower than optimal for tomato and olive crops, they were still within acceptable ranges. In fact, the variation is attributed to soil conditions and other site-specific reasons, rather than to irrigation water quality.

A few families complained about the yellowing of leaves, likely due to residual values of bleach from laundry greywater.

On the whole, the impact of greywater irrigation was probably beneficial for most crops, due to the presence of nutrients such as phosphorus, potassium and nitrogen. The exceptions are salt-sensitive crops that are being grown in Ain El Baida including onions, plum, loquat, apple and pear trees, as well as tomatoes, cucumber and grapes, which are all moderately sensitive to salt (Khouri et. al., 1994).

Recommendations

While the pilot project has obviously been successful, it can be improved. IDRC is supporting a follow-up plan to optimize the existing project, in anticipation of wider implementation in Jordan and perhaps elsewhere in the region. All aspects of the project are being improved, from greywater collection, through to treatment and reuse. Efforts are being made to increase the greywater recovery rate, so those crops requiring more water can be irrigated. Pipes and storage tanks are being installed for residents willing to pay for them. Environmental education is being expanded and incentives put in place for the use of potassium-based, rather than sodium-based soaps and detergents. The environmental impact arising from the use of untreated greywater was negligible; however, if water quantities are increased, or if soils high in salinity or alkalinity are used, it could become significant. The use of simple treatment devices, including screens in sinks, grease traps and trickling filters are being investigated. Residents are being encouraged to occasionally alternate greywater irrigation by harvesting rainwater, and use drip irrigation and mulches to improve water efficiency. Finally, the community will be encouraged to plant more salt-tolerant crops such as olives and pistachios.

Conclusion

Accompanying the rapid urbanization of the developing world is a trend that will soon see more of the worlds poor living in urban rather than rural areas. These urban poor are encountering increasing food and water insecurity. Reusing household greywater is one option the poor have to increase access to good nutritious food, preserve valuable fresh water for drinking, and generate income. With a little support, this strategy is something the poor can do to help themselves. This case study in Tufileh, Jordan demonstrates that where the poor have some access to land, as in many peri-urban areas, such an approach can measurably reduce poverty in terms of both its economic and social dimensions.

First, by adopting greywater reuse, each family in the project area was able to reduce its food expenditures by consuming its garden produce. Some families generated additional income by selling surpluses. These savings are substantial for such poor families — the average family saved or earned 10 per cent of its income, while the poorest saved or earned 44 per cent. Had the households used municipal sources for this supplemental irrigation, on average, they would have used 15% more water and had 27% higher water bills. These savings will be enhanced as more higher quality greywater is recovered allowing unrestricted irrigation of higher value, faster growing crops, such as vegetables normally eaten raw.

Second, there was little evidence of negative health impacts due to grey water irrigation, while positive impacts in terms of improved nutrition are likely. The project has helped improve the home gardening and irrigation skills of the recipients. Furthermore, it has increased the environmental awareness of the community in terms of water conservation and the negative impact of bleach and detergents on soil and food quality. In particular, Ain El Baida women have benefited. They report feeling more independent because of the skills they gained and the income they generated. The women also take great pride in the increased ability to feed their families.

Finally, to date, untreated greywater irrigation has had minimal negative impact on soil quality, and on the quality of the food grown. This is partly attributable to the small amounts of greywater applied to the vegetation, and partly to the low baseline salinity and alkalinity of the soils in the area. Moreover, some of the households are already practicing simple measures that reduce environmental and health risks, such as avoiding the use of greywater containing detergents, bleach or soap. Nevertheless, the use of untreated greywater for unrestricted irrigation is not recommended. A follow-up project is focusing on increasing the volume of greywater recovered, the use of simple treatment devices, and improved gardening practices.

Acknowledgements

The authors gratefully acknowledge the Inter-Islamic Network on Water Resources Development and Management (INWRDAM), Amman, Jordan and its subconsultants for carrying out the evaluation study, and CARE Jordan for reviewing the results.

Table 1. Ain Al Baida Permaculture and Greywater Reuse Project: Income (JD) generated per year

Family No	Sale of crops	Family use of crops	Family use and sale of crops	Total income	Percentage generated/cost saved of total family income
1	260	40	300	5520	5%
2	200	400	600	6000	10%
3	120	70	190	3960	5%
4	50	0	50	1800	3%
5	8	0	8	2400	0.003%
6	0	150	150	2400	6%
7	0	100	100	1680	6%
8	0	180	180	408	44%
9	0	360	360	1200	30%
10	0	180	180	900	20%
11	100	200	300	1800	17%
12	0	180	180	1200	15%
13	0	240	240	1800	13%
14	100	240	340	2880	12%
15	0	100	100	600	17%
Averages JD/Year ($US/Year)	**56 ($79)**	**163 ($229)**	**219 ($308)**	**2303 ($3239)**	**10%**

According to the beneficiaries, the selling price reflects retail price in the area.

Percentage generated/cost saved calculated by dividing the estimated value of the “Family use and sale of crops” by the family’s “total income prior to project implementation

Table 2. Comparison of the cost of municipal water and the value of greywater collected

	Municipal water		Greywater			
Household No	Quarterly municipal water use (m^3)	Cost of quarterly billed water (JD)	Quarterly volume collected greywater (m^3)	Quarterly Value of greywater (JD)	Greywater / municipal water use (%)	Greywater value / municipal water cost (%)
1	48	5.56	9	2.66	19%	48%
2	33	3.76	9	1.08	27%	29%
3	66	11.34	15	5.19	23%	46%
4	57	8.22	8	2.77	14%	34%
5	60	9.26	5	1.73	25%	19%
6	N/A	N/A	0	0	0%	0%
7	36	4.12	9	1.08	25%	26%
8	N/A	N/A	4	N/A	N/A	N/A
9	30	3.32	5	0.6	17%	18%
10	21	2.32	5	0.6	24%	26%
11	N/A	N/A	8	N/A	N/A	N/A
12	55	7.53	4	1.35	7%	18%
13	23	2.56	6	0.72	26%	28%
14	50	5.8	0	0	0%	0%
15	48	5.56	5	1.28	10%	23%
Averages	**43.19**	**5.78**	**6.67**	**1.58**	**15%**	**27%**

The average results do not include Households 6, 8 and 11, for which complete information is not available (N/A).

Table 3. Annual Benefits of Greywater Irrigation (JD)

Household	***1***	***2***	***3***	***11***	***Average***
Benefit (Revenue)					
Crops sold	260	200	120	100	170
Crops used by household	40	400	70	200	177.5
Total Annual Benefit (JD)	300	600	190	300	347.5
Total Annual Benefit ($US)	$422	$844	$267	$422	$489
Costs					
Seeds	0	10	0	0	2.5
Plants	21	0	10	10	10.25
Greywater system	36.5	152.5	59	22	67.5
Total Annual Costs (JD)	57.5	162.5	69	32	80.25
Total Annual Costs ($US)	$81	$229	$97	$45	$113
Net Annual Benefit (Profit)					
Net Annual Benefit (JD)	242.5	437.5	121	268	267.25
Net Annual Benefit ($US)	$341	$615	$170	$377	$376
Benefit/Cost Ratio	**5.2**	**3.7**	**2.8**	**9.4**	**5.26**

The estimated costs of the greywater reuse system are conservative, because they include one-time plumbing modifications that are unlikely to re-occur on an annual basis.

The analysis does not include the value of household labour contributed (operation and maintenance of the greywater systems) or saved (time spent going to the market to buy food or operation and maintenance associated with combined wastewater systems, such as regular pumping out of septic tanks).

Not all of the benefit can be attributed directly to the greywater applied, because once the greywater and gardening systems are in place the crops benefit from rain during the winter and, in the case of some households, other supplemental irrigation. However, in most cases, without installing the greywater reuse systems, very little gardening would take place.

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