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Technology tracking: Understanding decisions to adopt, not to adopt, and dis-adopt household greywater filtration systems

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Jordan is one of the world's water-poorest countries. The demand for potable and productive water is ever increasing due to population growth, climate change, increasing numbers of refugees hosted by the country, as well as heightened demand from a growing economy and its different sectors. Household greywater filtration systems (HGWFS) are ideal for repurposing greywater, from wastewater into productive use for small-scale agricultural production. Given that 50 to 80% of residential wastewater is in the form of greywater, there is significant potential for saving fresh potable water and improving household livelihood systems through effective utilization of treated greywater for productive purposes. However, broad uptake of the technology is not forthcoming. This comparative study examines two technology dissemination pathways and their role in influencing household decisions to adopt, not to adopt, and dis-adopt the HGWFSs. Quasi-experimental (cross-sectional) design was utilized with a one-shot survey of 252 households (adopters and non-adopters) selected through a combination of purposive and stratified sampling approaches. Qualitative data was also collected through key informant interviews and focus group discussions separately held with male and female members of the community. It was found that lack of technology tracking was a determinant factor in fostering negative perceptions on the technology up-take and its eventual dis-adoption in two of the governorates considered.

Key words: Technology tracking, greywater filtration systems, dissemination pathways, water saving, gender.

INTRODUCTION

The Hashemite Kingdom of Jordan ranks as the world's second water-poorest country, with annual precipitation of less than 200 mm (Government of Jordan (GoJ), 2009; FAO AQUASTAT, 2014; WHO, 2014). Jordan has a negative water balance estimated at 20% meaning that the country's total water use far exceeds its renewable

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water supply; with the difference covered through pumping from nonrenewable and fossil aquifers, as well as the reuse of treated wastewater (Iskandarani, 2002; Humpal et al., 2012). The demand for fresh water, however, is ever increasing due to population growth, climate change, increasing number of refugees hosted by the country, as well as heightened demand from different sectors within a growing economy. Recent climate change models predict that the region will continue to experience hotter and drier summers which will further diminish their already limited water resources (Intergovernmental Panel on Climate Change [IPCC], 2014; Haddad et al., 2017). Agriculture uses more than 50% of the country's water resources, a disproportionate figure that is not representative of the sector's 3% contribution to the Gross Domestic Product (WANA, 2017). Demand for alternative safe water sources is thus very high and growing.

Greywater is household generated wastewater from the kitchen sink, laundry, hand-wash basins, showers or baths that can be used for toilet flushing or irrigation after treatment (Bino and Al-Beiruti, 2007; Gross et al., 2015). For instance, rural households in Northeastern Jordan generate 12 to 19 L of greywater per capita per day of which 50% comes from kitchens and the remaining from ablution and hand-washing points (Suleiman et al., 2010). On average, a Jordanian household can recover 57% of household greywater for reuse, which can provide daily supplemental irrigation for approximately 20 olive trees grown in a home garden (Al-Beiruti, 2003). The financial benefits of using greywater on rural income are also well documented in the literature. Studies show an increase in income of 10 to 40% resulting from growth in profit due to increased agricultural production and savings from reduced water bills and periodic cesspit cleanings (Al-Beiruti, 2003; Imhof and Muhlemann, 2005; Morel and Diener, 2006). Other benefits recorded in the literature include environmental returns through conservation of freshwater for future use, as well as reduced pollution to underground recharge if treated greywater is used (Jeppesen, 1996; Friedler, 2008; Mourad et al., 2011). In a water-scarce arid environment like Jordan, on-site greywater treatment can help households reduce their demand on freshwater supply, promote water conservation, and provide a critical input for home gardening (Boufaroua et al., 2013; Gross et al., 2015). Several variations of HGWFS are widely disseminated throughout Jordan as part of the country's strategy to reduce demand on fresh water.

Literature on technology up-take indicates that adoption or the decision to start using a technology is not an end by itself and that there is a lot to learn from technology "tracking" after its adoption (Rogers, 2003; German et al., 2006). Technology tracking is a way of following up on the fate technologies after their adoption. Technology tracking acknowledges the challenges in blanket recommendations of technologies and innovative packages and seeks to highlight the effects of variations at the household level, including differences in capabilities and endowments, household labor, gender roles, etc., and their effect on the continued adoption and diffusion of technologies (Chambers et al., 1987; Scoones and Thompson, 1994). Through technology tracking, we get better insight into major constraints hindering their further dissemination; biophysical, social or economic implications of adoption; and opportunities to adapt the technology to respond to unforeseen challenges (Reij and Waters-Bayer, 2001; de Grassi and Rosset, 2003). This is especially important in the case of the household greywater filtration systems (HGWFS), as long-term application of untreated or inadequately treated greywater could have significant environmental, social, health, and economic implications.

Two HGWFSs were considered in this study, the first developed and promoted by the National Center for Agricultural Research and Extension (NCARE) and the second promoted by an international non-governmental organization, Mercy Corps (MC). The two units costed the same, were about the same size, served the same purpose, and were disseminated in four governorates of Jordan. The main difference between the two HGWFSs lied in the type of filtering medium used to treat the greywater. One used volcanic tufts while the other used sand. Each HGWFS installed in targeted households were equipped with a drip irrigation system to minimize physical contact with the treated greywater, to reduce the magnitude of the odor, and increase the water use efficiency. For the purposes of this study, the two HGWFSs were considered as one and the same. Moreover, in this study *adoption* is defined as a household's decision to start using a new technology; *non-adoption* as a household's decision not to use a new technology for various reasons, including lack of full knowledge about the technology, lack of financial resources, lack of access to essential inputs, etc., and dis-adoption is conceptualized as abandonment of the technology after trying the technology for some time. Dissemination pathways are also key factors in this study and are conceptualized as the mechanism through which information on the technology is communicated with different stakeholders. Different dissemination pathways with different information packages and modalities of communication will thus have different effect on technology adoption (Mauceri et al., 2005). The viability of the dissemination pathway or the method by which knowledge is transferred, as well as technology tracking after adoption, that is, the advisory and monitoring services provided during the adoption and post-adoption phases, thus make a difference in influencing households decision to sustainably adopt a technology (Rogers, 2003; German et al., 2006; Nyasimi et al., 2017). This paper assessed the effect of the different dissemination pathways and technology tracking systems on households' decision to adopt, not-adopt, or dis-adopt

HGWFS. Specifically, the study considered the effectiveness of dissemination pathways in (i) identifying potential adopters, (ii) transferring information, and (iii) facilitating access to the technology; and examined the technology tracking mechanisms in place to ensure continued adoption. The resulting benefits of the technology were analyzed using a gendered lens to shed light on the differential gains or losses for men and women under the different scenarios.

MATERIALS AND METHODS

Description of water supply conditions in the study area

The study covers four villages in Mafraq, Madaba, Karak, and Ma'an governorates which in a sequential progression represent the north, central and southern parts of Jordan. The villages are characterized as rural and peri-urban settlements connected to municipal fresh water supply systems, but using on-site sanitation systems (cesspits or cesspools). Municipal water in the sample governorates is supplied for few hours with low pressure once a week, which is stored by households in water tanks on their roofs or underground. Most households live under the condition of continuous water shortage and often purchase additional water from private vendors to meet their household and agriculture needs. They also adjust their water use practices (using less water or doing laundry and cleaning once a week) in an effort to reduce water stress conditions, and ensure water is available for household uses until the next water supply day.

Research design

Data collection

Quantitative and qualitative data were collected from the four villages using a combination of methods including household surveys, focus group discussions (FGD), and key informant interviews (KII). All data collection efforts were gendered so as to effectively capture the differential gains or costs to men and women in the community associated with access to and management and use of the technology. Quantitative data was collected using a cross-section quasi-experimental design which involved a one-shot survey of 252 households selected using a multi-stage sampling approach. First, the governorates and villages were purposively selected to ensure the inclusion of the villages in Ma'an, Mafraq, Madaba and Karak where MC and NCARE introduced the grey water filtering technology. At the village-level, households were stratified into adopters and non-adopters and random samples drawn from each stratum. Using Power Analysis, the minimum sample size needed to ensure XX% confidence and YY% standard deviation (SD) precision was determined to be 252 households. The sample households were then distributed across villages proportional to the population sizes and proportional to the number of adopters and non-adopters within each village. Accordingly, a total of 115 adopters and 137 non-adopters were included into the study and were distributed as presented in Table 1. Given that the population of adopters was small, the research team made a decision to include into the sample all adopters of the technologies in the four villages and randomly selected non-adopters to serve as the control group. 15% of the respondents in Ma'an and Mafraq were women, while women represented a higher percentage (51%) in Madaba and Karak. This was because more women were targeted by NCARE in Madaba and Karak.

Additional information on men and women's perceptions and experiences with regard to the grey water treatment technology was solicited through 16 FGDs, including 4 with men and 4 with women groups from among adopters of the HGWFS: one set (male and female) for each governorate and 4 with men and 4 with women groups from among non-adopters. The FGDs focused on perceptions of adopters and non-adopters around water shortage, roles and responsibilities of family members in household water management (fresh and greywater), any differential access to information and training, willingness to pay for the HGWFS installation, and considerations taken in household decision-making processes. In addition, a total of 12 interviews were held with key informants, including relevant individuals at the International Center for Agricultural Research in the Dry Areas (ICARDA), NCARE, International Fund for Agricultural Development (IFAD), Mercy Corps, and heads of community-based organizations (CBOs) in charge of disseminating the technology.

Empirical model

Following Swagata et al. (2008), the binary logistic regression model was used to analyze households' adoption decisions of HGWFS. The dependent variable *Decision to Adopt* the HGWFS is a binary variable with a value of 0 and 1 representing the decision to reject or adopt the technology, respectively. The explanatory variables covered a set of socio-economic conditions selected based on the key informant interviews held with relevant individuals. These include income, garden size, number of fruiting trees owned, average age of olive trees, connection to municipal sewage systems, the household size, and location of the governorate. The binary logistic regression used to analyze the relationship between the dichotomous choice variable (*Y*) and both categorical and metric explanatory variables can be formulated as follows:

$$Y = \begin{Bmatrix} 0 & \text{if a household is not willing to adopt} \\ 1 & \text{if a household is willing to adopt} \end{Bmatrix}$$

I was hypothesized that a household will be more likely to adopt the HGWFS if the logit (*Z*), derived from the willing respondents, is greater than the one derived from those unwilling to do so. *Zi* of the i^{th} household is a linear function of *n* explanatory variables *X*=(*X1,…,Xn*):

$$Z_i = ln\left(\frac{P_i}{1-P_i}\right) = \beta_0 + \sum_{k=1}^{n} \beta_k x_{ik}$$

where xi is the observed value of the explanatory variables for observation *i* and

Pi = Probability (Yi=1lXi=xi)

where *β0* is the intercept term and *βk* are the coefficients associated with each explanatory variables *Xk*. These were estimated using Maximum Likelihood Estimation (MLE) method. The Statistical Package for the Social Sciences (SPSS) (IBM Corp., 2011) was used for all analysis in this paper.

RESULTS AND DISCUSSION

Research shows that decisions to adopt a technology are influenced by several factors, such as its compatibility, the relative advantage it offers, complexity of the

Table 1. Household survey.

Governorate	Madaba	Karak	Ma'an	Mafraq	Total
	NCARE		MC		
Adopters	8	5	74	28	115
Non-adopters	8	9	41	79	137
Total	16	14	115	107	252

Table 2. Description of the variables used in the analysis (Own Elaboration from Survey, 2017).

Variable	Description of the variable and their specific codes
ADOP	Adoption of the HGWFS
Socio-economic characteristics	
Principleincome	1=government, 2=military, 3=pension, 4= self-employment, and 5=labor income
Gardensize	Size of the household garden (in dunum)
Olivefruiting	Number of fruiting olive trees
Oliveavgage	Average age of olive trees
Municipalsewer	Household connection to municipal sewage system (0 = not connected; 1=connected)
Hhsize	Size of the household
Governorate	Name of governorate (0=Mafraq, 1=Ma'an)

technology, its triability or ability to be tried out in part, its observability or the degree to which results of the innovation are visible to others, overall policy environment, as well as the socio-economic characteristics of the adopter (Rogers, 1995; Chianu and Tsujii, 2004; Lee, 2005; Sidibe, 2005). The study looked at the role of the different technology dissemination pathways and tracking systems followed by NCARE and MC in influencing decisions to adopt, not to adopt, and dis-adopt the HGWFS. More specifically, it considered the implications in terms of: *selection criteria* used to identify potential adopters, facilitating equitable *access to information*; *tracking technology adoption* through periodic monitoring; and the overall effect on *perception* about the technology. The benefits of adopting the technology from the perspective of the two technology dissemination pathways and tracking systems in terms of their implications on household labor demand, economic benefits, and community empowerment through skill building were also assessed and are presented subsequently.

Selection criteria

Technology dissemination begins with identification of the right target group. At face value, both institutions used the same criteria to identify potential adopters of the technology, including (i) household size which was used as an indicator of the amount of greywater that can be generated, (ii) size of the home garden to ensure demand for treated greywater as it cannot be stored, (iii) connection to the municipal sewage line, and (iv) willingness of the household to adopt the technology. NCARE used these criteria to carefully and rigorously select 13 households in Madaba and Karak, while MC identified about 102 households through CBOs in Ma'an and Mafraq governorates. At the individual level, NCARE primarily focused on women members of selected households in recognition of the fact that they are in charge of water management at the household level. MC, on the other hand, relied on established CBOs, namely Petra Pottery Cooperative Society and Anakid Al-Khair Cooperative, to identify potential adopters from among their constituencies.

The validity of the general selection criteria is more or less confirmed by the results of our regression analysis on selected variables (Table 2). The results indicate that households who are not connected to the municipal sewer line and have large gardens with older and fruiting trees were more likely to adopt the technology at 1% significance level (Table 3).

Access to information

Lack of access to information is among the primary reasons for low rates of adoption of agricultural technologies. The two institutions used different pathways to transfer information to potential adopters of

Table 3. Binary regression results.

Variable		Score	df	Sig.
Step 0	Principle income	33.016	1	0.000
	Garden size	7.237	1	0.007
	Olive fruiting	17.155	1	0.000
	Olive avg. age	20.742	1	0.000
	Municipal sewer	31.530	1	0.000
	Household size	0.040	1	0.842
	Governorate	32.532	1	0.000
Overall statistics		99.204	7	0.000

the HGWFS. In the case of MC, KIIs and documentations provided by MC indicate that, information was mainly transferred through the selected CBOs in Ma'an and Mafraq. MC initially trained the heads of the CBOs on the benefits of the technology, installation and maintenance of the unit, as well as the potential costs of adoption. The knowledge was then transferred to potential adopters through trained heads of CBOs. The decision to adopt or not to adopt the technology thus mainly rested with the men, the official members of the CBOs. This was later confirmed by women from the community who attested to the fact during FGDs. Women were thus not afforded the same opportunity to learn about the benefits and responsibilities associated with the technology and receive the associated training. Further analysis of the survey data revealed that only 58% of the adopters reached by CBOs received installation-related training (Table 4), while 59% received management related trainings (Table 5), and about 40% of the adopters did not receive training on both.

On the other hand, analysis of information collected from NCARE, indicates that a series of trainings were provided for the women, beginning with the initial sensitization and installation procedures but lasting through the adoption and post-adoption phases. The training went beyond general benefits of the technology and offered training on effective management of water at the household level, including methods to improve the quality of the water before it leaves the house, monitoring the quality of the water in the treatment unit, as well as its management during irrigation.

Access to technology

Affordability is one of the major factors that affect adoption of agricultural technologies (Rogers, 1995). Prior to installing the treatment unit, households are also required to separate their plumbing system to allow the greywater to go into the treatment unit, and the black water into the cesspit; and to set up a drip irrigation system, which is also expensive. According to analysis of survey data, the main sources of income for households in Ma'an and Mafraq include military and government related jobs, pension, and self-employment. Military jobs accounted for about 46% of the household income, followed by government jobs (42%). Pension and self-employment offer minimal income opportunities for the community. In the case of Madaba and Karak income is mainly secured from pension with over 60% reported to be retirees. Other income sources include government jobs (24%), and to a lesser extent private businesses. NCARE was able to circumvent the challenge associated with the initial cost of adoption by bearing the full cost of required equipment, installing the HGWFS and drip irrigation, and covering associated maintenance costs. Adoption of the technology thus came at zero cost to the beneficiaries and adopters only had the responsibility of periodically cleaning the system. In the case of MC, the cost was covered through revolving credit facilitated by the CBOs. While both approaches managed to make the technology accessible and affordable to the users, they also present some serious challenges.

In the case of NCARE, provision of the technology at no cost created a sense of dependency wherein the beneficiaries of the technology as well as potential adopters expected NCARE to continue providing them with free but continuous support in monitoring and maintaining the system. This was evident in the FGDs held with both adopters and non-adopters of the technology in Madaba and Karak. While this may be feasible to do for a few households at the outset of technology dissemination, it is not a sustainable approach both in terms of its financial and associated labor implications to promote large-scale adoption of the technology. However, the approach also has its merits in that by seeing it through all the different stages of adoption, it clearly demonstrated the benefits of using the treatment unit thereby creating interest and positive perceptions among nearby communities.

In the case of MC, availability of credit created opportunities to afford adoption of the technology. Analysis of survey data indicated that, on average, a household borrowed about 600 Jordanian Dinars (JOD, about 840 USD based on exchange rate of November2015, JOD1=US$1.4) to be repaid within a

Table 4. Installation related training received by members of CBOs.

Variable		Frequency	Percent	Valid percent	Cumulative percent
	No	43	42.2	42.2	42.2
Valid	Yes	59	57.8	57.8	100.0
	Total	102	100.0	100.0	-

Table 5. Management related training received by members of CBOs.

Variable		Frequency	Percent	Valid percent	Cumulative percent
	No	42	41.2	41.2	41.2
Valid	Yes	60	58.8	58.8	100.0
	Total	102	100.0	100.0	-

period of 24 to 30 months. Subsequent evaluations by MC indicated a 100% loan repayment by CBO members who adopted the technology (Alulayyan, 2014). While this is a good success indicator for the revolving loan scheme, we found that it nonetheless masks the many challenges in the use and management of the treatment units, which are detailed subsequently

Technology 'tracking'

Technology 'tracking' includes among other things, advisory services that are provided to adopters of a technology to address unforeseen setbacks and to adapt the technology to fit existing socio-economic and biophysical conditions. In the case of MC, it was found that the HGWFSs were used for a maximum of two years before they were removed or dis-adopted by 86% of the respondents, even though households continued to pay their loans. Further analysis of surveyed data indicated that 66% of the respondents have completely uninstalled the unit, while 21% claimed that the infrastructure is still there though not in use. The high repayment rates, according to information solicited through FGDs, were thus not directly associated with the continued use of the technology, but more of a testament of members' commitment to their CBOs and the power of peer pressure. Further analysis of survey data indicated that the main reasons for dis-adoption were bad odor (76%), followed by clogging of the system and other technical difficulties (56%). KII with technical experts from NCARE revealed that these challenges could have certainly been avoided had there been an effective monitoring and technology tracking system in place to solve problems as they arise, use the challenges as teachable moments to build the capacity of the communities, and to provide essential feedback to researchers to fine tune the technology.

According to KII held with heads of CBOs, technology 'tracking' on the part of MC took the form of site visits and collection of water samples from selected units during the few months after adoption. But the adopters were not informed of the reasons for the test nor the results. In the case of adopters targeted by NCARE, FGDs with adopters revealed that frequent visits from NCARE and their participatory approach to involve adopters in the monitoring process had the opposite effect of building positive perception about the technology, the quality of the water generated, and to build local capacity. It was found that the women were quite knowledgeable about the technology (especially maintenance requirements in kitchens, such as separating grease and food particles in the water, and at the unit), and the challenges and benefits associated with its use.

Perception

Warranted and, at times, unwarranted perceptions of the technology also influenced decisions to adopt, not to adopt, and dis-adopt the technology. In this case, perceptions of the HGFWS technology were not always positive. It was found that causes for the negative perception mainly revolved around the odor of the treated water and often times related to cultural and religious views. While many variations of the technology tried to address this problem, it is important to also note that it is partially caused by lack of proper and regular cleaning on the part of the users. FGDs revealed that at times users of the technology merely used the system as a greywater disposal unit to reduce the inflow into cesspit tanks and hence the hefty costs associated with emptying the tank. For others the challenge related with ability to maintain the unit and fix malfunctions within the system. This was especially true in the case of adopters through local CBOs who did not receive adequate technical support.

It was also found through FGDs that assessment of the perception of users and non-users of the technology vary across gender and communities. In the case of communities targeted by MC, male members of the community had relatively positive perception than women members of the community. The men highly appreciated the cost saving from pumping cesspit tanks. While this perception was also shared by the women, it was over-shadowed by the challenges associated with the smell which created problems for them with their neighbors and made the outside space of their home unusable. The smell also influenced their perception of the quality of the water and its fitness to irrigate olive trees. But despite these challenges the technology offered several benefits to the adopters.

Benefits of adopting the technology

Implications on labor demand

In addition to saving fresh water, we found that the HGWFSs offered several benefits for the household, including economic and labor benefits. However, we observed that the benefits were not 'gender neutral'. In terms of labor demand, the technology requires intensive labor during the installation phase of both the filtration and the drip irrigation system, and less so for periodic cleaning and maintenance of the unit. The major labor implication in terms of increasing/decreasing men or women's drudgery therefore depends on their roles, frequency, and cumbersomeness of the tasks involved in the use and management of the technology.

Analysis of the data collected indicated that men were predominantly responsible for installation, cleaning and maintenance of the unit, while women were primarily responsible for irrigating the olive gardens. In the case of NCARE's targeted adopters, women were responsible for both the post-installation cleaning the unit and irrigating the olive trees, while men took on the bulk of the responsibility during the installation and maintenance phases of the HGWFS. Moreover, in both cases of MC and NCARE women were responsible for the management of the quality of the water leaving the house, including the selection of less soapy dish-washing or laundry detergents, types of items they clean in the sink, and separating greasy dishes from non-greasy.

Adoption of the technology thus put additional labor demand for the men during the installation phase, particularly for those who cannot afford to hire outside labor, periodic but less-intensive demand for cleaning (in the case of MC targeted adopters), and for maintenance as needed. Women, on the other hand, took on the additional responsibility of cleaning the system (in the case of NCARE targeted adopters). However, in both cases women enjoyed reduced labor demand for irrigation as the greywater treatment unit is attached to an automated drip irrigation system. Prior to the installation of the unit, women had to manually irrigate the garden using buckets, often at night, when the municipal water is released. This was also confirmed by 90% of the non-adopters interviewed who reported that they irrigate their fields manually. While irrigating the field is predominantly a woman's task, in some cases it is a family shared responsibility. In this case, the labor saving combined with the quality of life improvement was appreciated by all members of the family. As stated by one interviewee:

"*In the past [before HGWFS installation], my husband and I got tired while we watered the plants. We had to share this duty as we have 25 olive trees. Now we are happy because we don't have to water the trees one by one. The children are more comfortable when water is supplied and they don't need to water trees. The GWT unit makes all household [members] more comfortable because we don't have to water plants [manually*]."

In general, it was found that women were quite appreciative of the technology, which not only reduced their drudgery associated with irrigating the olive trees, but gave them extra time to complete other household tasks or for leisure. Women targeted by NCARE confirmed during FGDs, that they did not consider cleaning the HGWFS tasking, but on the contrary consider its trade-off with the many benefits it offers quite substantial.

Economic implications

The economic benefits afforded by adopting the technology were manifold, including cost savings from emptying cesspit tanks; increased yield from their olives which had constant supply of water and hence increased production of and the likelihood to harvest olives and its byproducts, including olive oil; and for the women entrepreneurs' additional income from making and selling olive soaps. However, adopters of the technology in Ma'an and Mafraq governorates mostly used the treated greywater to irrigate ornamental plants and less so for their olive trees. This, as was found through FGDs, was due to lack of confidence in the quality of the water.

The cost of emptying the cesspit tank was quite hefty as the tank needed to be emptied quite frequently depending on the size of the tank and the amount of waste generated. According to the data analysis, the cost of emptying cesspit tanks ranged between 35 and 40 JOD (49 and 56 USD) per truck/month and could thus cost a household between 420 and 480 JOD/year or 588 and 672 USD/year. This is assuming that it is only done once a month, which is not always the case. Another cost saving was achieved through reduced demand for freshwater which households used to irrigate olive trees or garden trees. The trees were watered during days when water was released from the municipality, usually once a week during the summer season. The increase in olive production, due to continuous irrigation of the trees, also had positive implications. Home processed olive oil and other related products saved the household money, and in the case of the women entrepreneurs generated additional income from making and selling olive-oil soaps.

Community empowerment

In addition to the awareness raising events held at the community level, specialized technical support was offered by both institutions to selected adopters of the technology. NCARE and MC both were active in raising awareness on water scarcity and in promoting the use of greywater to irrigate olive and other trees in home gardens. This was also evident in our discussions with, and survey of, non-adopters who served as a control group. We found that neighboring communities were fairly aware of the technology and the benefits it offers, though less so of its adverse effects. For instance, analysis of the data indicates that 7% of the adopters in Ma’an and Mafraq currently use untreated greywater to irrigate their trees. However, the figure is not very high as compared to the 65% of the non-adopters who are doing the same in the two governorates. In this regard, we see that the awareness raising efforts have succeeded in sensitizing adopters of the cons of directly using untreated greywater in their home gardens.

Technology tracking in the form of continuous follow-up on the part of NCARE, though unpractical for large-scale dissemination efforts, was quite useful in providing practical skills and on-the-job training. NCARE periodically monitored the quality of the water coming in and out of the system and frequently met with the adopters allowing them to address concerns together and more promptly. A good example of this participatory work, as reveled through FGDs, was the simple solution that was devised to address the odor problem. The women together with NCARE used plastic cups to cover the holes of the drip irrigation and buried the tube under the soil thereby minimizing exposure, odor, and physical contact with the treated greywater.

Potential for large-scale uptake of the technology

Technology diffusion involves several stages, including initiation, adoption, implementation, evaluation and integration (Rogers, 1983). Adoption on the other hand initially refers to the decision to adopt the technology among few individuals who had access to relatively more information and are willing to take the risk, followed by later adopters who are willing to adopt the technology based on evidence from the early adopters (Griliches, 1957; Mansfield, 1961). Both technology adoption and diffusion are thus processes with several steps, including awareness raising and initiation of interest, evaluation to ensure fit-for-purpose, and trying it at a smaller scale before confirming adoption (Beal et al., 1957).

The two dissemination pathways followed by MC and NCARE have resulted in achieving first level adoption among a selected few who had access to the information, and the financial and technical support (to varying degree) to do so. However, we found that the lack of technology ‘tracking’ on the part of MC and the dependency syndrome developed by NCARE’s approach have not generated sufficient interest for late adopters. Moreover, the technical challenges associated with the upkeep were in fact the main reasons for dis-adoption of the technology for the majority of the adopters in Ma’an and Mafraq. However, another explanation for dis-adoption could be MC’s approach to target CBO heads who in turn targeted male members of the household at the onset of technology adoption instead of targeting women in the household who deal with day-to-day water management before water leaves the house and maintenance of the system. This supports the case that dissemination pathways should conduct gender analysis to determine who does what in the household before promoting technologies for household adoption.

The body of literature on adoption-diffusion corroborates the challenges of re-gaining lost trust, and re-igniting interest in the same technology (Pannell et al., 2006). However, we find that despite the challenges associated with adopting the HGWFS, 92% of the adopters are still interested in adopting an improved version of the HGWFS that is adapted to addresses their concerns. The continued interest thus attests to the need for the technology and the benefits it renders. Moreover, of the total respondents 65% of adopters and over 90% of non-adopters were willing to pay an average of 5 JOD (7 USD) per month for periodic maintenance and advisory services. This could be an excellent opportunity to engage local youth through small businesses that provide technical and advisory services, including maintenance and cleaning of the treatment unit.

Therefore, based on the findings of this study, we propose that the most effective dissemination pathway should include gender sensitive selection criteria that offer equitable opportunities for both men and women to access information, credit, as well as advisory services during and after the initial adoption phase. The evidence from NCARE clearly demonstrated women’s role in the maintenance and use of the technology, and thus the importance of targeting women with technical support. The dissemination pathway pursued by MC also had its merits in making the technology financially accessible, though not for all members of the community, but lacked the necessary support to adapt the technology to meet arising needs. The right dissemination pathway should thus have a well thought out feedback loop that connects users with technology providers and accounts for gendered differences and roles within households.

On a broader scale, large-scale adoption of the technology also requires a conducive policy environment. For instance, the low cost of water in the country poses a serious challenge. In addition to being cheap, the lack of a stringent system to collect monthly fees also serves as a disincentive to conserve water and opt for water saving technologies. For instance, we found that over 50% of the surveyed households in Ma’an and Mafraq have, on average, unpaid water bills ranging between 200and 300 JOD (between 280 and 420 USD). This is an exorbitant amount considering the fact that average water bill for a family ranges (depending on family size and availability of a garden) between 40 and 80 JOD/year. The arrears thus represent years of unpaid bills. We also found that payment of water bills did not improve substantially due to the cost savings from using the HGWFS. In this regard, only 14 and 35% of the survey respondents ‘strongly agreed’ and ‘agreed’ that the cost saving afforded them opportunities to catch up with their payments respectively. The main incentive for adopting the HGWFS was thus the cost saving from emptying cesspit tanks and not necessarily savings from water bills. This is generally true for households living in areas where a municipal sewer system is not present. Therefore, more needs to be done to raise awareness on water scarcity, the need to conserve water, and the potential of marginal waters, including greywater to meet certain demands. Policies that encourage the use of marginal water for agriculture through various incentives, and continually strive to build confidence in the quality and safety of treated marginal water will also be useful.

Conclusion

The comparative study identified several merits as well as challenges with the technology dissemination pathways and tracking systems used by the two institutions. It was found that the dissemination pathway used by MC offered greater opportunities for technology adoption, though it lacked the tracking system to discourage dis-adoption of the HGWFS in Ma’an and Mafraq. NCARE’s choice of dissemination pathway provided limited opportunities for technology adoption but the tracking allowed adopters of the technology to continually and fully benefit from the HGWFS. Based on the findings of the study, the importance of technology ‘tracking’ and maintenance of adequate contact between users and researchers to build confidence and encourage late adopters to take on the technology was emphasized. It was also highlight that dissemination pathways are not gender neutral and thus call for conscious efforts to ensure that men, women, and youth can have equitable access to the technology and evenhandedly share in the benefits.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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