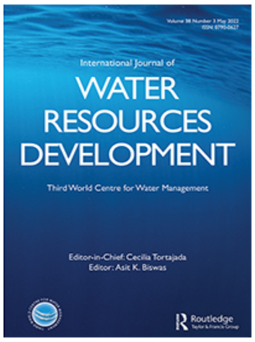

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Willingness of farmers to use treated wastewater for irrigation in the West Bank, Palestine

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ABSTRACT
Limited water resources are among the main obstacles to development in Palestine. This research investigates farmers' perceptions and willingness to use treated wastewater (TWW) for irrigation. Despite the availability of large quantities of TWW, just 11% of the interviewed farmers use it in irrigation. Just 24% of them confirmed that they had participated in awareness workshops related to TWW, but 75% stated they would be willing to use TWW for irrigation. We find that the main obstacles to the use of TWW in irrigation are availability of freshwater, non-availability of TWW and psychological aversion.

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Treated wastewater; reuse; irrigation; farmers' perceptions; willingness to use; West Bank

Introduction

Due to fast-growing populations, increasing water demand, climate change, imbalances in rainfall distribution and economic development, many countries and regions around the world increasingly face severe water shortages as well as wastewater issues related to contamination (Bodin et al., 2019; Chen et al., 2018; Larsen et al., 2016; Saladini et al., 2018). One-fifth of the world's population (1.2 billion people) live in water-scarce areas, while one-third live in moderate- to high-stress areas (International Organization for Standardization (ISO), 2019). Cape Town, South Africa, is a good example of an area threatened by water scarcity. In 2018, the city nearly ran out of water, in a so-called Day Zero crisis (Booysen et al., 2019). One study predicts that in China water availability will be reduced by 1800 m^3/day per capita by 2030, widening the annual gap between water supply and demand by 201 billion m^3 (Chen et al., 2017).

In developing and emerging countries, studies of the water sector find that limits on water availability can constrain socioeconomic development (Hoffman, 2019; United Nations Department of Economic and Social Affairs (UNDESA), 2015).

Water shortage and scarcity are serious challenges in the Middle East. In the 1970s, the region suffered a severe water shortage so that it became difficult for its countries to meet the rapidly increasing demand for basic water supply (Allan, 1997).

Water crises are mostly caused by the way water is used. Agriculture is the main water-consuming sector globally, and in the Middle East and North Africa (MENA) 87% of the withdrawn water is allocated to agriculture and only 13% to municipal and industrial uses,

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compared with 69% and 31%, respectively, worldwide (Abu-Madi, 2004). Since the 1970s, food imports to Middle Eastern countries have steadily increased. In the last two decades, more than 60% of the wheat consumed in the Middle East has been imported to meet more than half of its calorie demand; no other region is as dependent on food imports (Food and Agriculture Organization (FAO), 2019; World Bank, 2008).

In Jordan, increasing pressure on water resources has led to a serious and rapidly growing water deficit. Only 66% of the country's water demand, estimated at some 1300 million m^3/year in 2004, is supplied, with a per capita share of 162 m^3/year. The deficit is being covered through exploitation of groundwater resources at 130% of their safe yields (Abu-Awwad, 2011). The water security challenges arising from rapid growth in global demand require serious consideration of sustainable development (UNDESA, 2015). Available resources should be well managed to meet current demand and also preserved for future generations, so nations should give high priority to the search for alternative sources.

Proper integrated water recourses management (IWRM) is one of the main alternatives to manage existing water resources effectively. On the other hand, it is urgent to find new resources to increase the quantity and availability of water for future generations. In addition to IWRM, non-conventional water resources (rainwater harvesting, seawater desalination and wastewater treatment) are important alternatives to provide more water that can be used for many purposes.

Treated wastewater (TWW) is one of the main additional sources of water for irrigation. Use of TWW reduces the amount of freshwater (FW) used for irrigation and the amount of wastewater discharged into the environment, which is a significant threat to public health, the environment and the economy, especially in the MENA (Al-Najar et al., 2015; Shomar & Dare, 2015).

TWW is an important resource and has potential for use by farmers (Mizyed, 2013). Integrated and cross-sectoral efforts are required in the water, agriculture, health, social and environmental sectors to create a framework for using TWW for irrigation. This will require overcoming many challenges to implement improved policies, institutional dialogue, financial mechanisms and interdisciplinary research (Qadir et al., 2010; Shomar & Dare, 2015).

Palestine, like most countries in the MENA, is a semi-arid area with limited FW resources. Besides being a water-scarce country, it also has a complicated political situation under which most of its natural water resources are controlled by the Israeli occupation (Mizyed, 2013). Palestine comprises the West Bank and the Gaza Strip, both of which face several challenges in the water sector. Although in some parts of Gaza wastewater reuse represents a significant potential source of additional water, this paper focuses only on the West Bank.

The West Bank depends mainly on groundwater from wells and springs, and an allotment from the Israeli Water Company (Mekorot), for its various sectoral water needs. The total quantity of water available in the West Bank in 2011 was about 139.6 million m^3, of which 88.3 million m^3 went to all domestic uses and most of the rest to agriculture (Palestinian Water Authority (PWA), 2012).

The World Health Organization (WHO) recommends a minimum of 150 litres/day per person for domestic water consumption (Yassin, 2020). In the West Bank only 82 litres/day per person are available (PWA, 2013). In 2011, there was a deficit of 128.2 million m^3 (PWA, 2012). About 5% of the population of the West Bank is not connected to a municipal water network, and about 60% is not connected to a wastewater collection network (Palestinian

Figure 1. Treated wastewater (TWW) flow in Ein Qinia village, north of the West Bank.

Central Bureau of Statistics (PCBS), 2011). The complicated political situation in the West Bank contributes to an unstable economy, hinders the installation of infrastructure, blocks access to advanced technologies, and limits control over water and wastewater resources (Selby, 2003; Zahra, 2001).

The Palestinian Water Authority (PWA) and non-governmental organizations (NGOs) are the main bodies that support the water and sanitation sector in the West Bank, while projects are funded largely by foreign aid. There are seven centralized urban wastewater treatment plants (WWTPs) in the West Bank: Al-Bireh, Ramallah, Jenin, Tulkarm, East and West Nablus, and Jericho. But the plants in East Nablus, Al-Bireh, Jenin and Jericho are the only ones operating properly; the others operate at moderate or poor efficiency due to overloading and poor management (Palestinian Hydrology Group (PHG), 2008).

Although a large quantity (≈ 9 million m^3/year) of TWW is generated (Yassin, 2020), irrigation has gained little traction in the West Bank, and more water flows to the wadis without any kind of use (Figure 1) as a result of mixed levels of public and farmer acceptance and political constraints on water use (Faruqui et al., 2001; PWA, 2013). The amount of TWW that is clearly available for use is related to many local factors, apart from the political ones. Despite the logic of connecting treated municipal wastewater with the agricultural sector, the use of TWW for irrigation has several known limitations. Health aspects, socioeconomic conditions, religion, and public and farmer perceptions should be studied.

Although wastewater reuse has significant potential to reduce the scarcity of water in the West Bank, the uncertainty among farmers is still evident in their contrasting attitudes to the use of TWW for irrigation. Since the farmers would be the ones using the TWW, and they might not be interested or willing to use it, this paper studies, analyses and measures farmers' perception and willingness to use TWW for irrigation in the West Bank.

Methodology

Study area

The West Bank (Palestine) is a typical arid to semi-arid region in the Middle East, with a total area of about 5860 km^2 (Central Intelligence Agency (CIA), 2018) and a population of nearly 2.9 million (PCBS, 2018). A Mediterranean climate prevails, with wide seasonal variations. Rainfall varies in time and space, with annual rainfall from 153 mm near the Jordan River to 698 mm in the central mountains (PCBS, 2017). In general, rainfall decreases from west to east, and 80% of the total annual rainfall usually occurs in winter (Geomolg, 2020).

Land use includes rough grazing and subsistence farming (62%), arable land (14%), irrigated farming (3%), permanent crops (14%), built-up areas (5%), woodland/forest (1%) and Israeli settlements (1%) (Geomolg, 2020). Groundwater is the main source of water for domestic and agricultural uses (PWA, 2013).

Agricultural development in the West Bank is challenged by several factors, including water shortage and poor water management, low soil fertility, poor financial resources and low investments in the agricultural sector, unstable crop prices, and high risk due to droughts and land fragmentation (Shadeed, 2013). But water shortage is probably the hardest of these challenges. Hence, rainfed agriculture prevails in most of the West Bank areas. In 2015, the agricultural water supply–demand gap for all crops in the West Bank was estimated at 47 million m^3 based on the irrigated areas, including open fields and greenhouses (Ministry of Agriculture (MoA), 2016).

The West Bank is composed of 11 governorates (Figure 2). Of these, Jenin, Nablus and Jericho (circled in Figure 2) are of crucial importance for agricultural production and water use, so they were selected for this study. They have been three of the main sources of agricultural production in Palestine, with a diversity of crops. Jericho is above the largest aquifer in the West Bank (East Aquifer), and Jenin and Nablus are above the North-East

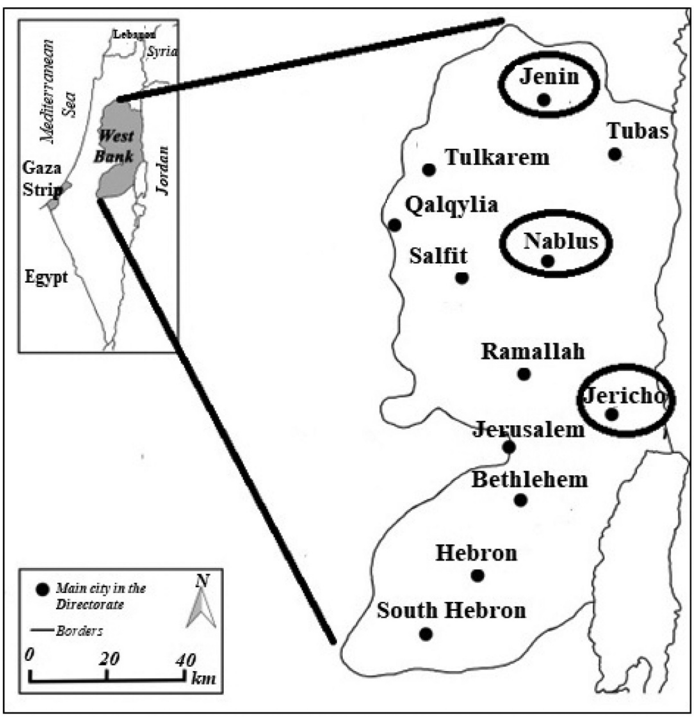

Figure 2. West Bank governorates. Source: Hamarsheh & Amro (2020).

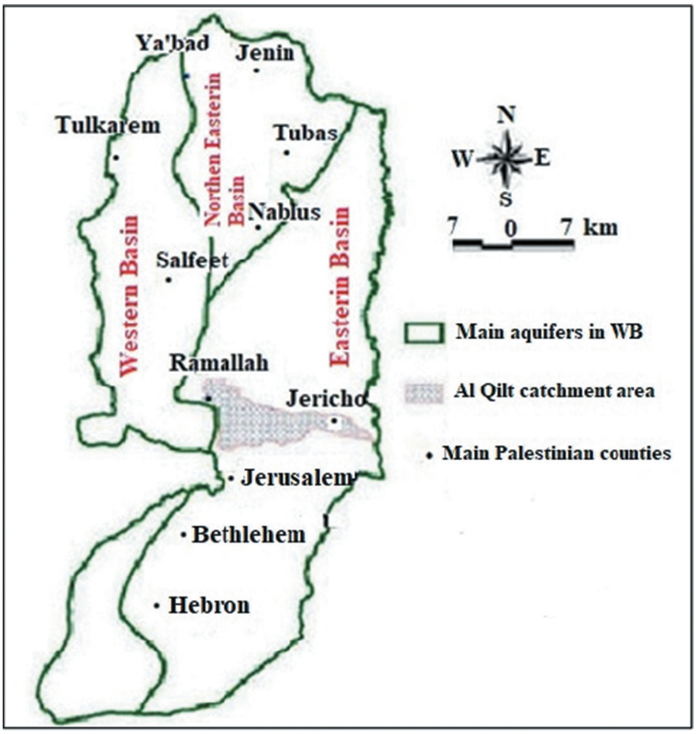

Figure 3. Governorates and aquifers in the West Bank. Source: Daghrah (2010).

Aquifer (Figure 3). For irrigation, partial use of TWW is a common factor between these three governorates. Even if the TWW is used only partially it can be of significant value to the agriculture sector.

Sample and data collection and analysis methods

Following the advice of experts in relevant institutions, namely the Ministry of Agriculture (MoA), the Palestinian Central Bureau of Statistics (PCBS) and the PWA, we interviewed farmers who had an agricultural area > 50 *dunum*s (5 hectares) and who were using irrigation. They are the most influential actors in water resources management. They are also potential users of TWW for irrigation (Al Karmi, 2020; Yassin, 2020). According to the PCBS (2012), there were 291 such farms in our study area: 166 in Jericho, 81 in Nablus and 44 in Jenin. There are no recent official statistics on the number of farms in each governorate. The number of farms has decreased due to land fragmentation, water shortage and decreasing interest in working in the agricultural sector among the young (Al Karmi, 2020).

Despite the lack of recent official statistics, closure and mobility restrictions imposed by the Palestinian government as a result of the coronavirus disease (COVID-19) pandemic, the complicated political situation, the absence of farmers who could provide clear and accurate information, and the hesitation of some farmers to participate in the study, we succeeded in interviewing 115 farmers (64 in Jericho, 33 in Nablus and 18 in Jenin), where they represented 40% of the total study population, which would provide enough information to achieve the objectives of the study. Of the farmers we interviewed, 13 used TWW as the main source for irrigation and 102 used groundwater (wells and springs) and tap water as the main sources.

Cross-sectional data were collected from mid-February to mid-May 2020 using a face-to-face survey. The questionnaire had two parts. The first part solicited farmers' demographic characteristics (age, gender, education and average monthly income) and farm characteristics (arable area, area used for agriculture and main water source for irrigation, including TWW). The second part enquired about current issues that influence the use of TWW in irrigation, and the factors that may influence farmers' decisions in the future. The questionnaire was pilot tested in the three governorates, where 15 farmers were interviewed (five in each governorate), and it was then revised, making it clearer and more comprehensive. The variables and their description are listed in Table 1.

The data were analysed using SPSS (v. 22). Descriptive statistics were used to describe the characteristics of the respondents (e.g. age, education and income). A Kolmogorov–Smirnov test was used to check for the normal distribution of continuous variables such as income and the area used for agriculture (Verma & Abdel-Salam, 2019). Since these variables are not normally distributed, a Mann–Whitney *U*-test (Verma & Abdel-Salam, 2019) was used to investigate whether the variables were similar for users and non-users of TWW. To assess the relationship and significances between categorical variables (e.g. TWW use and farmer characteristics), a chi-squared test was used, and a Fisher's exact test was applied when the percentage of the expected count of cells was < 5% (Verma & Abdel-Salam, 2019).

Understanding the willingness of farmers to use TWW for irrigation is one of the most important tools still missing in the West Bank. For this purpose, we developed the following logistic regression model:

$$\ln\left(\frac{P_i}{1-P_i}\right) = B_0 + B_1X_1 + B_2X_2 + \ldots + B_mX_m \qquad (1)$$

where P_i is the probability that a farmer is willing to use TWW; $1 - P_i$ is the probability that a farmer is not willing to use TWW; B_i is the slope coefficient of the ith factor; X_i is the ith influencing factor; m is the index of independent variables; and i is the index of farmers ($i = 1, 2, \ldots, n$).

Results and discussion

Descriptive results

The first set of results considers farmers' characteristics by location (Table 2). About 45% of the interviewed farmers were between 35 and 49 years old, 40% between 50 and 64 years, 10% between 20 and 34 years, and 4.3% > 64 years. More than half had a secondary level of education (57%), followed by undergraduate (21%) and elementary (20%); only 1.7% were illiterate. There were no significant differences between the three governorates in age or education.

Table 1. Description of all variables.

Variables	Description
Dependent variables	
Using TWW	Dichotomous: yes (1), no (0)
Willing to use TWW	Dichotomous: yes (1), no (0)
Independent variables	
Age	Categorical: < 30 (1) to > 64 years (4)
Education	Categorical: illiterate (1) to undergraduate (4)
Main source of irrigation water	Categorical: tap water (1), well (2), spring (3), TWW (4)
Location	Categorical: Nablus (1), Jenin (2), Jericho (3)
Knowledge of the availability of TWW and its importance in irrigation	Dichotomous: yes (1), no (0)
Area used for agriculture	Continuous: *dunum*
Monthly income	Continuous: US dollars
Reasons why farmers do not use TWW at present	
Availability of FW	Dichotomous: yes (1), no (0)
Non-availability of TWW	Dichotomous: yes (1), no (0)
Customers' opposition	Dichotomous: yes (1), no (0)
Health risks	Dichotomous: yes (1), no (0)
Religious reasons	Dichotomous: yes (1), no (0)
Concerns because they may be criticized by people	Dichotomous: yes (1), no (0)
Farmer's own aversion	Dichotomous: yes (1), no (0)
Factors that may influence farmers' willingness to use TWW in irrigation in future	
Availability of FW	Dichotomous: yes (1), no (0)
Laws and regulations (national laws, regulations, guidelines and enforcement regarding the reuse of TWW)	Dichotomous: yes (1), no (0)
Quality of TWW	Dichotomous: yes (1), no (0)
Exposure to reports and studies on the use of TWW for irrigation	Dichotomous: yes (1), no (0)
Direct communications of professional experts	Dichotomous: yes (1), no (0)
Price of TWW relative to FW	Dichotomous: yes (1), no (0)
Customers' opposition	Dichotomous: yes (1), no (0)
Fertilizer savings	Dichotomous: yes (1), no (0)
Information in the media (television, radio, newspapers)	Dichotomous: yes (1), no (0)
Concerns about health risks	Dichotomous: yes (1), no (0)
Farmers' involvement in decision-making pertaining to the use of TWW for irrigation	Dichotomous: yes (1), no (0)
Personal psychological aversion	Dichotomous: yes (1), no (0)
Religion	Dichotomous: yes (1), no (0)

Note: FW, freshwater; TWW, treated wastewater.

With regards water sources for irrigation, about 90% of the farmers used mainly groundwater (51% wells, 36% springs), and almost 3% used tap water, while 11% used TWW (5%, 4% and 2% in Jenin, Jericho and of Nablus, respectively). About 78.6% of the FW farmers agreed that there was a water shortage in their area. This means that there is a great need for additional water. TWW is recognized as a good solution to this problem.

The average monthly income of farmers was approximately US$1087. It was highest in Jenin governorate (US$1219), followed by Jericho (US$1138) and then Nablus (US$914). The average arable area was 63.4, 61.6 and 30 *dunum*s, and the irrigated area was 58.6, 57.6 and 29.1 *dunum*s for Jenin, Jericho and Nablus, respectively (Figure 4).

About 23.5% of the farmers had participated in awareness workshops related to TWW reuse and related topics. And about 59.1% said that they knew the meaning and importance of TWW. These results demonstrate the need for awareness campaigns and educational activities that target different segments of society, especially farmers.

Table 2. Farmers' characteristics, by location.

Characteristics	Nablus (33)		Jenin (18)		Jericho (64)		Total (115)	
	N	%	*N*	%	*N*	%	*N*	%
Age (years)								
20–34	9	27.3	0	0	3	4.7	12	10.4
35–49	13	39.4	7	38.9	32	50	52	45.2
50–64	8	24.2	11	61.1	27	42.2	46	40.0
Over 64	3	9.1	0	0	2	3.1	5	4.3
Education								
Alphabet	2	6.1	0	0	0	0	2	1.7
Elementary	8	24.2	6	33.3	9	14.1	23	20.0
Secondary	13	39.4	9	50	44	68.8	66	57.4
Undergraduate	10	30.3	3	16.7	11	17.2	24	20.9
Main irrigation source								
Tap water	0	0	1	5.6	2	3.1	3	2.6
Well	27	81.8	11	61.1	21	32.8	59	51.3
Spring	3	9.1	0	0	38	59.4	41	35.7
Treated wastewater (TWW)	3	9.1	6	33.3	3	4.7	12	10.4
Using TWW								
Yes	3	9.1	6	33.3	4	6.2	13	11.3
No	30	90.9	12	66.7	60	93.8	102	88.7
Water shortage (for non-users of TWW)								
Yes	29	96.7	7	58.3	44	73.3	80	78.4
No	1	3.3	5	41.7	16	26.7	22	21.6
Water shortage (for non-users of TWW as a main source)								
Yes	29	96.7	7	58.3	45	73.8	81	78.6
No	1	3.3	5	41.7	16	26.2	22	21.4
Participation in awareness workshops related to TWW								
Yes	12	36.4	4	22.2	11	17.2	27	23.5
No	21	63.6	14	77.8	53	82.8	88	76.5
Know about the availability of TWW and its importance in irrigation								
Yes	22	66.7	9	50	37	57.8	68	59.1
No	11	33.3	9	50	27	42.2	47	40.9
Monthly income, US$ (mean ± SD)	913.6 ± 318.5		1219.4 ± 320.5		1138.3 ± 962.2		1086.5 ± 753.9	

Note: TWW, treated wastewater.

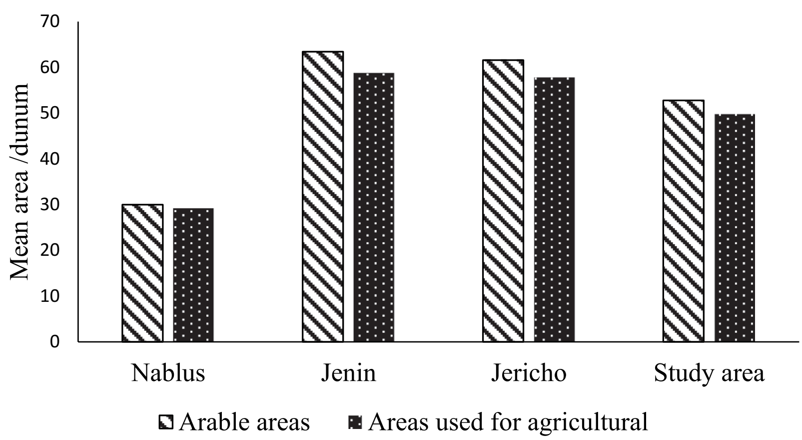

Figure 4. Arable area and mean irrigated area per governorate.

Farmers' characteristics depending on the use of TWW

We see no significant difference in the distribution of education (p = 0.243) or age category (p = 0.074) between farmers who use TWW for irrigation and those who do not (Table 3). However, there is a significant difference in the distribution of the main source of water (p = 0.000). There is also a significant relation between the location of the farms and the rate of use of TWW (p = 0.009): it is 46.2%, 30.8% and 23.1% in Jenin, Jericho and Nablus, respectively.

Jenin is one of the oldest agricultural areas in the West Bank. It also has the most irrigated land (45,957 *dunums*), followed by Jericho (40,567 *dunums*) and then Nablus (17,359 *dunums*) (Al Karmi, 2020). The Jenin WWTP was constructed in the 1970s and then rehabilitated in 2011–12, and has been working continuously since (Yassin, 2020). Its capacity is 9250 m^3 of TWW/day; actual inflow is 4000 m^3/day, and the main treatment process is aerated lagoons. The capacity of the Nablus WWTP is 14,000 m^3/day of TWW; actual inflow is 11,000 m^3/day, and the main treatment process is activated sludge. The capacity of the Jericho WWTP is 9600 m^3/day of TWW; actual inflow is 1200 m^3/day, and the main treatment process is activated sludge (Yassin, 2020).

There is a significant relation between mean monthly income and TWW use (p = 0.075): the mean income of farmers using TWW (US$1600) is much higher than that of farmers who do not (US$1021). This shows the high economic value of wastewater reuse at the farm level. The average price per m^3 of TWW used in irrigation (US$0.25) is less than FW (US$0.45). In addition, the users of TWW confirmed that they save about 70% in the use of fertilizers.

We see a significant difference in the mean area used for agriculture between farmers using or not using TWW (p = 0.001): the mean area irrigated by TWW (85.7 *dunums*) is greater than that irrigated by FW (45 *dunums*) (Table 3). Hence, the availability of TWW could encourage farmers to increase their area of irrigation because of its low price and embedded fertilizer value.

Reasons for not using TWW

About 11% of the farmers are using TWW for irrigation (Table 2). This proportion is very low despite the presence of large volumes (> 9 million m^3/year) of TWW at the source in the West Bank. In the last 10 years (2009–19) more than 21 WWTPs have been constructed in the West Bank, with a total capacity of > 22,310 m^3/day (Yassin, 2020). However, to make the TWW accessible to farmers would require huge investments, especially in constructing water transport pipes and storage reservoirs. This explains the difference between the volume of TWW available at the source and at the farmlands. In our survey, farmers identified three main reasons for not using TWW for irrigation (Figure 5).

Availability of freshwater (FW)

About 43% of the farmers do not use TWW for irrigation because they have access to FW (Figure 5). Despite the water shortage in the West Bank, most of the surveyed farmers said that they have access to wells and springs at a very low average price (US$0.43/$m^3$), so it is

Table 3. Distribution of characteristics among farmers using treated wastewater (TWW).

	Using (13)		Not using (102)			
	N	%	*N*	%	Test statistic	Significance (*p*)
Age (years)						
20–34	0	0	12	11.8	6.246[a]	0.074
35–49	3	23.1	49	48		
50–64	9	69.2	37	36.3		
Over 64	1	7.7	4	3.9		
Education						
Alphabet	1	7.7	1	1	4.146[a]	0.243
Elementary	3	23.1	20	19.6		
Secondary	8	61.5	58	56.9		
Undergraduate	1	7.7	23	22.5		
Irrigation source						
Tap water	0	0	3	2.9	63.457[a]	0.000
Well	1	7.7	58	56.9		
Spring	0	0	41	40.2		
TWW	12	92.3	0	0		
Location						
Nablus	3	23.1	30	29.4	8.388[a]	0.009
Jenin	6	46.2	12	11.8		
Jericho	4	30.8	60	58.8		
Monthly income (US$) (mean ± SD)	1600.0 ± 1794.4		1021.1 ± 469.8		464.5[b]	0.078
Area used for agriculture (mean ± SD)	85.7 ± 58.4		45.0 ± 47.8		293.5[b]	0.001

Notes: [a]Fisher's test.
[b]Mann–Whitney *U*-test. Values shown in bold = $p \leq 0.05$.

difficult for TWW to compete. About 66% of the farmers who do not need to use TWW because FW is available agreed that there is a shortage of FW in their area. Two situations can be identified:

- Where FW is available and meets all the farmer's irrigation needs, it will be difficult to change their attitude towards TWW use. About 9% of the farmers are in this category, and using TWW is not an option for them.
- Where the available FW does not meet a farmer's irrigation needs, reducing the agricultural area is a preferred option. About 91% of the farmers we interviewed said that due to the water shortage they were not irrigating all their arable land. Providing TWW for those farmers could enable them to cultivate more land.

Non-availability of TWW

Non-availability of TWW was the second reason farmers gave for not using it. These farmers are concentrated in the Nablus and Jericho governorates. Some 33% said that that TWW is not available in their area; 29.4% said that they did not know about the availability of TWW in their area; and 70.6% said their farm was too far from TWW sources. The main reason for this latter condition is the absence of development projects that aim to transport TWW from WWTPs to agricultural lands with a high demand for water. Some of the farmers had limited knowledge regarding the value or availability of TWW in their area.

Psychological aversion

Psychological aversion is the third reason given by farmers for not using TWW for irrigation. About 15.7% of the surveyed farmers who did not use TWW gave aversion as

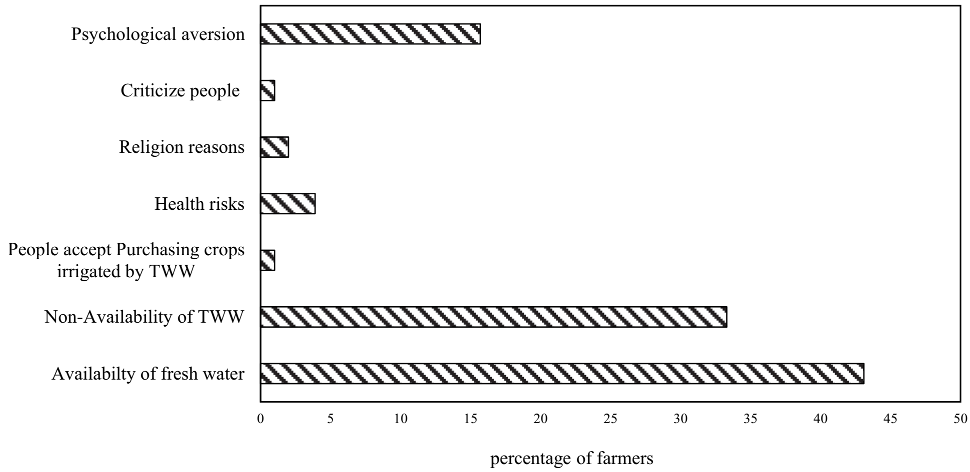

Figure 5. Current reasons for not using treated wastewater in irrigation.

a reason (Figure 5). This factor is related to the specific characteristics of the farmer, including education, awareness and culture.

Factors that may influence the attitudes of farmers towards using TWW for irrigation in general

We find that the perceptions and attitudes of farmers towards using TWW for irrigation could be affected by a number of factors (Figure 6). The most prominent are the availability of FW (75%), laws and regulations regarding use of TWW (70.4%), quality of TWW (66%), direct communication of professional experts (65%), and reports and studies (65%). Among non-users only, these factors rank as 72%, 77%, 64% and 63%, respectively (Figure 6).

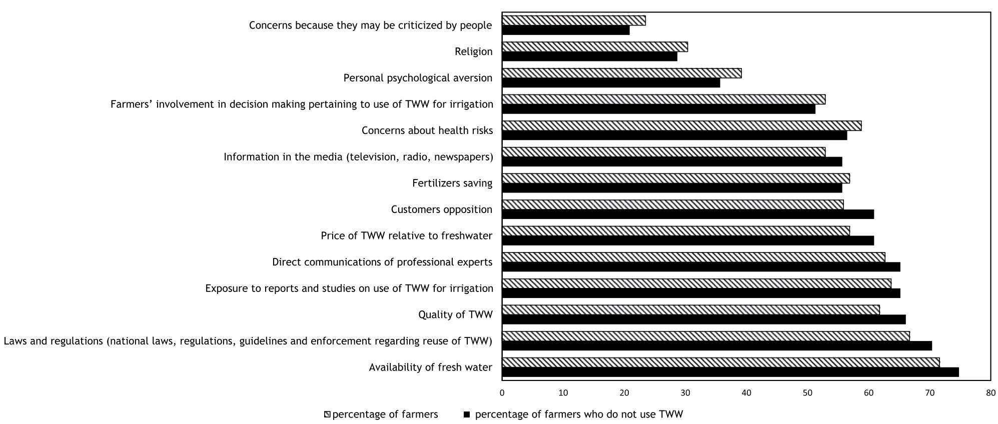

Figure 6. Factors influencing farmers' willingness to use treated wastewater for irrigation.

Of the farmers we interviewed, 75% were willing to use TWW for irrigation. The factors in this willingness were grouped into five categories: economic, awareness, health concerns, psychological aversion and legal frameworks (Table 4).

Both fertilizer savings ($p = 0.015$) and the price of TWW relative to FW have a significant relation ($p = 0.000$) with willingness. Among those who were not using TWW and gave price as a reason, 86% said they were *willing* to use it, and 14% said they were not. For fertilizer savings as a reason ($p = 0.015$), 81% of the non-users said they would be willing to use TWW, and 19% that they would not.

Regarding awareness, all the specific factors we asked about (reports and studies, direct communication of professional experts, and different media) had a significant relation ($p < 0.05$) with willingness to use TWW: farmers who were interested and affected by awareness raising were more willing.

Regarding health, water quality had a strong effect on willingness to use TWW. A total of 84% of the farmers who use FW in irrigation are more willing to use TWW if they have enough knowledge about this water and its quality.

Psychologically, farmers feel comfortable and responsible if they are involved in the decision-making process related to the use of TWW for irrigation ($p = 0.001$). Hence, the farmers will be more willing to use TWW in this case.

In legal frameworks related to the use of TWW, institutional laws and regulations play the main role in willingness to use TWW ($p = 0.003$). Some 89.5% of the non-users who are interested in the laws and regulations on the process of using TWW for irrigation are more willing to use it.

Factors that can be used to predict the willingness of farmers to use TWW in irrigation

The process of predicting a farmer's willingness to use the TWW is a new idea in the West Bank, as this idea depends on studying some factors that can be developed in a reliable and accurate statistical model. Five components were developed covering economic aspects, awareness, health, laws and legislation, and psychological aspects. Table 5 presents the results of the logistic regression model, with their coefficient values, McFadden's R^2, log-likelihood ratio (LLR), and the significance of the log-likelihood statistics.

Average monthly income has a significant negative impact on the willingness to use TWW: farmers with greater monthly income are less willing to use TWW for irrigation. The LLR of the economic component (30.39) is statistically significant: income has a significant negative impact on willingness to use, as does the price of TWW ($p < 0.05$). Where the price of TWW is lower than the price of FW, farmers are more willing to use TWW for irrigation (Figure 7). This finding is supported by the literature, which reports similar trends among farmers in different countries. Economically, the price of TWW is a critical factor that can used to predict the attitude of farmers towards using it for irrigation. McNeill et al. (2009) mentioned that in Palestine one of the key steps for the sustainable implementation of wastewater treatment and reuse projects is an economic analysis to ensure proper prices for wastewater collection and irrigation water.

Table 4. Factors affecting farmers' willingness to use treated wastewater (TWW).

	Willing to use (73)	Not willing to use (29)	Total (102)	Chi-squared	Significance (*p*)
Economic					
Price of TWW relative to FW					
Yes	86.2 (50)	13.8 (8)	100 (58)	14.159	0.000
No	52.3 (23)	47.7 (21)	100 (44)		
Customer acceptance of crops irrigated by TWW					
Yes	75.4 (43)	24.6 (14)	100 (57)	0.951	0.329
No	66.7 (30)	33.3 (15)	100 (45)		
Fertilizer savings					
Yes	81.0 (47)	19.0 (11)	100 (58)	5.921	0.015
No	59.1 (26)	40.9 (18)	100 (44)		
Awareness					
Reports and studies related to the use of TWW					
Yes	83.1 (54)	16.9 (11)	100 (65)	11.663	0.001
No	51.4 (19)	48.6 (18)	100 (37)		
Direct communication of professional experts					
Yes	82.8 (53)	17.2 (11)	100 (64)	10.674	0.001
No	52.6 (20)	47.4 (18)	100 (38)		
Information provided by the media (television, radio and newspapers)					
Yes	81.5 (44)	18.5 (10)	100 (54)	5.542	0.019
No	60.4 (29)	39.6 (19)	100 (48)		
Health					
Quality of TWW					
Yes	84.1 (53)	15.9 (10)	100 (63)	12.771	0.000
No	51.3 (20)	48.7 (19)	100 (39)		
Health risks					
Yes	71.7 (43)	28.3 (17)	100 (60)	0.001	0.979
No	71.4 (30)	28.6 (12)	100 (42)		
Psychological					
Farmers' involvement in the decision-making process					
Yes	85.2 (46)	14.8 (8)	100 (54)	10.456	0.001
No	56.2 (27)	43.8 (21)	100 (48)		
Farmers criticized by people					
Yes	70.8 (17)	29.2 (7)	100 (24)	0.008	0.927
No	71.8 (56)	28.2 (22)	100 (78)		
Personal psychological aversion					
Yes	65.0 (26)	35.0 (14)	100 (40)	1.395	0.237
No	75.8 (47)	24.2 (15)	100 (62)		
Availability of FW					
Yes	76.6 (56)	23.3 (17)	100 (73)	3.339	0.068
No	58.6 (17)	41.4 (12)	100 (29)		
Legal and religious					
Laws, regulations and standards concerning TWW reuse					
Yes	80.9 (55)	19.1 (13)	100 (68)	8.697	0.003
No	52.9 (18)	47.1 (16)	100 (34)		
Religious reasons					
Yes	64.5 (20)	35.5 (11)	100 (31)	1.089	0.297
No	74.6 (53)	25.4 (18)	100 (71)		

Notes: Values shown in bold = $p \leq 0.05$.
FW, freshwater; TWW, treated wastewater.

Fortunately, the prices of TWW in the West Bank are lower than the prices of FW, as the study showed that the average price of FW in the three governorates is US$0.45, while the average price of TWW in the three governorates is US$0.25. This may constitute an incentive to use treated water, especially when irrigation water is consumed more.

Table 5. Logistic regression analysis predicting the willingness to use treated wastewater (TWW) for irrigation.

	Economic	Awareness	Health	Psychological	Laws and legislation
Income	−0.002 (0.006**)	−0.002 (0.004**)	−0.002 (0.003**)	−0.002 (0.002**)	−0.002 (0.004**)
Knowledge (availability and importance of TWW)	1.205 (0.064)	1.206 (0.052)	1.318 (0.044*)	1.359 (0.034*)	1.285 (0.037*)
Price of TWW relative to FW	2.309 (0.008**)				
Customers' opposition	−1.220 (0.146)				
Fertilizer savings	0.619 (0.403)				
Awareness by media and through direct communication with experts		1.543 (0.003**)			
Health risk			−1.121 (0.108)		
Quality of TWW			2.712 (0.000**)		
Personal psychological aversion				−0.330 (0.577)	
Concerns because they may be criticized by people				−0.029 (0.967)	
Farmers' involvement in the decision-making process				1.653 (0.008**)	
Availability of FW				−0.223 (0.753)	
Laws, regulations and standards					1.608 (0.003**)
Religion					−0.561 (0.297)
McFadden's R^2	0.254	0.205	0.280	0.214	0.293
LLR statistic	30.93	24.99	34.09	26.12	34.09
Probability (LLR statistic)	0.00	0.00	0.00	0.00	0.00

Notes: FW, freshwater; TWW, treated wastewater.
Significant at $*p < 0.01$; and $**p < 0.05$.

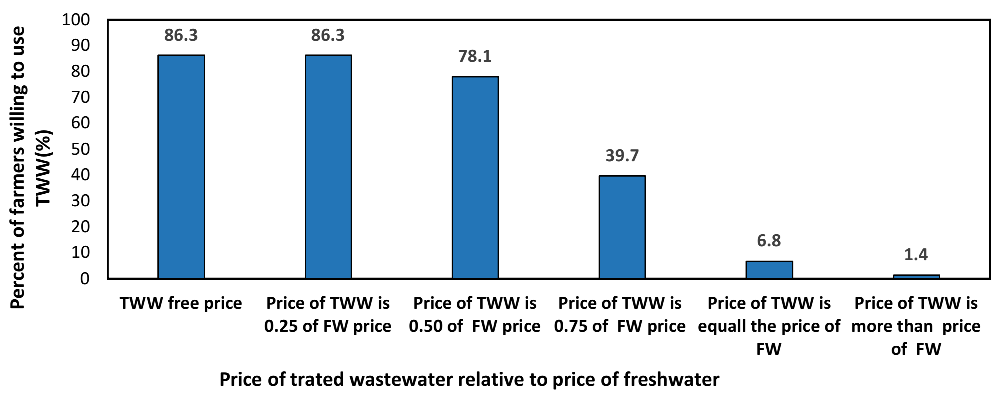

Figure 7. Willingness to reuse treated wastewater (TWW) based on its price relative to the price of freshwater (FW).

In a 2004 study in Jordan and Tunisia, a regression model showed that water prices and agricultural profitability have a significant influence on the willingness of farmers to pay for and use TWW: 97% of the farmers showed an interest in using TWW if it was given to them free of charge and if the supply were reliable and allowed unrestricted irrigation. This willingness fell to 84% and 47% with proposed prices of US\$0.05/m^3 and US\$0.10/m^3, respectively (Abu-Madi, 2004).

In a 2010 survey in South Africa, 71% of respondents indicated a willingness to use TWW for irrigation if it cost less than FW; but if not, only 15% were willing to use it (Adewumi et al., 2010).

A September 2017 study in the Baba-Abbas region of Lorestan province, western Iran, tested the appropriateness of TWW for crop irrigation based on its quality (physico-chemical properties) and farmers' willingness to use and willingness to pay; 120 farmers were interviewed. (Wheat and corn are the dominant crops in the region.) Sewage water is treated and conveyed to the flow of the Kashkan River, and provided directly to farmers during the dry summer. All the farmers of the region have water rights to the source (the Kashkan River), but the supply is not reliable in seasons with high demand for irrigation, that is, from mid-spring to mid-fall. Periods of severe water shortage often occur, especially in summer. Farmers pay for the use of river water. TWW is pumped into the river at regular times, but sometimes it is not enough for all the farmers in the county. In periods of water shortage it is conveyed to the farms of the study area through a canal, with different levels of quality and different prices. Almost all the farmer participants (92%) were willing to use a good-quality level (complete treatment) of TWW, while more than half (56%) were willing to pay for the same quality of TWW at a price equal to FW. It appears that the price of TWW is one of the main factors in farmers' use of TWW, partly because they believe that this kind of water is of lower quality and thus it should be cheaper than FW (Deh-Haghi et al., 2020).

Kurian et al. (2019) highlighted a serious shortcoming of previous analyses and pointed to confusion between the implementation of nexus research and the application of nexus principles in development practice. They stated that there is an economic value for the reuse of TWW, and the establishment of a reliable price is necessary to guarantee efficient allocation. Molinos-Senate et al. (2013) confirmed that to encourage the use of TWW, its price should be significantly lower than that of drinking water.

Farmers who have knowledge and understand TWW's health implications and the legal frameworks that regulate it are more likely to accept using it. Equally, those who are more familiar with the TWW concept, its availability and its importance for irrigation are more willing to use it. This is consistent with many research results. In Palestine, in 2019, the Applied Research Institute of Jerusalem offered agricultural demonstrations on farmland to teach farmers how to deal with and use TWW for irrigation. Through these demonstrations, farmers learned more about the importance and benefit of using TWW in agriculture. This strengthened the farmers' capacity to irrigate suitable crops with TWW and taught them how to harvest the products and how to handle them after harvest, including processing and marketing. Through this project more farmers will be willing to use TWW for irrigation.

This finding is also in line with results reported by Haddad (2005) from a study in Palestine to evaluate public attitudes towards socio-cultural aspects of water supply and sanitation services. He found that farmers more familiar with the consequences of using TWW had a more positive attitude towards its use.

In South Africa, the more knowledgeable potential users were, the better empowered they were in deciding to (or not to) embrace reuse (Adewumi et al., 2010). And in a study in western Iran, knowledge about TWW positively affected the willingness to use it for irrigation (Deh-Haghi et al., 2020).

Awareness is one of the main factors that affect this willingness. Knowing the level of awareness of the farmers allows us to predict their willingness to use TWW. Professional reports and studies, along with media such as radio, television and newspapers, are crucial in disseminating environmental information and promoting awareness of TWW. Direct communication by professional experts (seminars, lectures and workshops) and indirect communications (reports, studies, posters and brochures) will encourage conservation of drinking water and use of alternative water resources, such as TWW, for irrigation.

In Palestine, Zimmo et al. (2005) concluded that farmers still hesitate to use TWW, mostly due to the lack of a proper demonstration site. This shows the urgent need for public education, including farmer awareness and training programmes, and sites demonstrating wastewater reuse.

A study in Palestine in 2012 concluded that lack of awareness is one of the major reasons for the limited spread of TWW use in agriculture, so training and awareness programmes should be conducted to ensure the sustainability of WWTP, and waste-water-related topics should be added to the school curriculum in all grades (Arafat, 2013).

One of the main results in a study conducted in the agricultural region north-east of Cape Town, in Western Cape province, South Africa, by applying the institutional analysis and development framework for using TWW was that the awareness regarding water scarcity should exist. This helps the government, the municipalities and the users to see TWW reuse as a real option for water security (Saldías et al., 2016).

McNeill et al. (2009), in a study about reusing TWW for irrigation in the West Bank, concluded that one of the key steps for sustainable implementation of wastewater treatment and reuse projects is the development of a public awareness campaign and education plan to encourage the acceptance of TWW reuse in agriculture.

Kurian et al. (2019), in a study about the lessons emerging from a collaboration with UN-Habitat to stimulate discussion about the Sustainable Development Goals (SDGs), found that improving public and farmers' awareness of the advantages of reused water and promoting community involvement in water management issues may reduce the reluctance to use TWW and increase the willingness to use it. Similarly, a study by Saliba et al. (2018) of stakeholders' attitude towards the reuse of TWW for irrigation in the Mediterranean region found that greater awareness of the water consumed by house-holds and farmers enhances the willingness to use TWW to curb excessive water use, which is one of the major causes of water scarcity.

Water quality is an important factor related to health, as well as environmental and technical aspects, and it has a significant effect on the willingness to use TWW. Several studies have considered the importance of the quality of TWW for use in irrigation. Such use carries some health risk due to the possible presence of a wide spectrum of pathogens, including *Escherichia coli*, *Salmonella* spp. and *Shigella* spp., as well as intestinal nematode eggs. This should be treated as a major concern (Al-Nakshabandi et al., 1997).

The level of TWW quality is one of the main factors why wastewater is reused. This requires that the wastewater be treated so that it meets the quality requirements for the intended use.

A perception survey by Po et al. (2003) found that trust in the Water Corporation of Western Australia to provide safe and reliable TWW was critical for whether farmers and residents were willing to use it.

In South Africa, a study conducted in Western Cape province with the objective of providing an overview of water resources and wastewater generation and discussing the need to reuse wastewater indicates that only 48% of respondents trusted the service provider to supply the appropriate quality of TWW. This poor response is likely influenced by the historically poor quality of TWW supplied to these respondents which has forced users to provide their own on-site treatment (Adewumi et al., 2010).

Abu-Madi et al. (2008) reported that psychological aversion to wastewater-irrigated crops is one of the obstacles to the use of TWW in agriculture, and that it stems from a concern regarding the quality of the irrigation water. Thus, improving the quality of TWW might lower this barrier.

A 2014 study of the possibility of TWW reuse for irrigation in the Northern Jordan Valley concluded that the expectation of very high-quality effluent from the WWTP has made it possible to explore new water reuse methods in Jordan (Myszograj et al., 2014). In contrast, in the a study by Deh-Haghi et al. (2020) in western Iran, participants noted in field interviews that they were unwilling to use TWW because of its poor quality relative to FW.

Technically, the quality of TWW can influence the type of irrigation system in which it is used. A study at the As-Samra experimental site (40 km north-east of Amman, Jordan), where turbo-emitter-type trickle irrigation was installed, found that the major drawback of the system was the susceptibility of its emitters and tubes to clogging (Al-Nakshabandi et al., 1997). Such clogging problems are often related to poor water quality (Ayers & Westcot, 1985). Another study concerned the Khirbet As-Samra WWTP, from which TWW was being used for irrigation in the Central Jordan Valley. The TWW was collected in the King Talal Dam and then mixed with water from the King Abduilah Canal (KTC) which receive the water from the Yarmouk River for further use in agriculture. The treated water has reduced the water quality the canal. Comparison of the results of water quality tests with guidelines for water to be used for irrigation, salt tolerance of agricultural crops and the potential clogging of drip irrigation systems reveals that treated effluent from the WWTP can be used for irrigation, with some restrictions. Moreover, concentrations of all trace elements were low and within guidelines for irrigation water. But clogging of drip emitters is expected due to high calcium and magnesium content, along with high bacterial counts and nutrients that promote algal growth (Shatanawi & Fayyad, 1996).

The use of TWW (reclaimed water) for irrigation is a valuable strategy to maximize the 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 TWW. Farmers' perception of TWW 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 (Carr et al., 2011).

Greater involvement of farmers in the decision-making process will also make them more willing to use TWW, according to several studies. A study by Abu-Madi et al. (2008) of the perceptions of Jordanian and Tunisian farmers and public found that psychological aversion is a reason for about 16% and 50% of farmers being unwilling or uncertain about using TWW for irrigation in Jordan and Tunisia, respectively. Involving these farmers through education and awareness might mitigate this disincentive (Abu-Madi et al., 2008). On the other hand, one of the key steps for sustainable implementation of waste-water treatment and reuse is to involve consumers, farmers and other stakeholders in the decision-making process (McNeill et al., 2009).

A study in the south-east of Italy concluded that one of the best ways to enhance the reuse of TWW in agriculture is to involve stakeholders before any specific proposal is developed – not just to inform them of the final results but to allow their full involvement from the earliest stages of the decision-making process (Saliba et al., 2018).

In the present study, farmers who were more aware of the laws, regulations and standards that relate to the use of TWW were more willing to use TWW. This is consistent with other studies that find that knowledge of legal aspects increases the willingness to use TWW for irrigation (Saliba et al., 2018). Legal frameworks and their understanding are important for ensuring a more sustainable management and protection of water resources, as well as to set monitoring mechanisms for more efficient water and waste-water services (PWA, 2016).

None of the five components of the predictive model is statistically rejected – all are significant in predicting the willingness to use TWW – but knowledge of laws and legislation is the best predictor (McFadden's R^2 = 0.293, LLR statistic = 34.09).

Conclusions and recommendations

This paper studied the main factors that currently hinder farmers' willingness to use TWW for irrigation and those that can influence their decisions in the future. Our results indicate that the current availability of FW, the non-availability of TWW at the farm and physiological aversion are the main factors that stop farmers from using TWW. But this attitude can be affected by many other factors, which are important for decision-makers to consider when starting any TWW reuse project in the agricultural sector. The quality of TWW is related to the health of farmers and consumers, the environment, and the type of irrigation system, and also significantly influences the willingness of farmers to use this kind of water. The price of TWW relative to FW also plays an important role, because it affects the profit farmers can make when selling the crops. Awareness is one of the most important factors in the attitude of farmers towards using TWW for irrigation. Awareness, either from the media or from interactions with professional experts, is important to understand the importance of TWW, its benefits and how to use it in irrigation. Knowledge of the relevant regulations, laws and standards is also an important factor.

Decision-makers and institutions in the water sector and agriculture should develop a comprehensive and detailed plan addressing farmers' concerns before starting any project aimed at the use of TWW in irrigation. These concerns include farmers' economic situation, the price of FW and its availability in or close to their farms, the level of understanding of technology, etc. Farmers should be encouraged to be key players in the preparation of the plans. The consideration of these factors is likely to increase the acceptance of TWW in irrigated agriculture.

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