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Private micro-irrigation costs using reclaimed water

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Abstract

The cost of reusing water in micro-irrigation at the field level has not been studied in depth although the use of effluents in agriculture is a viable alternative in areas where water is scarce or there is intense competition for its use. The aim of the present study is to analyse the private costs of water reuse in micro-irrigation in an experimental plot. This analysis is intended to provide information about the decision a farmer would make when the choice to use conventional or reclaimed water is guided by cost criteria. The components of the total costs of different combinations of four types of filters and five emitters that can be installed in micro-irrigation systems using reclaimed water have been studied with the data obtained from an experimental plot in conditions similar to those of fruit orchards. Different scenarios that compared the costs of using conventional or reclaimed water in terms of water price and nutrient content were also studied. The results show that a proper combination of filters and emitters can save up to 33% in irrigation costs. Capital costs and maintenance costs were the most variable among the different combinations. Scenario analysis showed that the greater price of reclaimed water could be compensated by high nutrient contents, which would reduce fertilizer costs.

Additional key words: clogging; drip emitters; types of filter; water economics; water reuse.

Resumen

Costes privados del riego por goteo utilizando aguas regeneradas

El coste de la reutilización de agua en sistemas de riego por goteo a nivel de parcela no se ha estudiado en profundidad aunque la utilización de aguas residuales en agricultura es una alternativa viable en áreas con escasos recursos hídricos o con fuerte competencia por su uso. El objetivo del presente trabajo ha sido analizar los costes privados del uso del agua regenerada del riego por goteo en una parcela experimental. Se pretende que este análisis aporte información sobre cual sería la elección del regante según un criterio de costes si pudiera optar entre utilizar agua convencional o regenerada. Para ello, se analizaron los distintos componentes de los costes totales de diferentes combinaciones de cuatro tipos de filtros y cinco emisores comerciales, partiendo de los datos obtenidos en una parcela experimental en condiciones similares a las de una plantación de frutales. Se estudiaron también distintos escenarios en los que se comparaban los costes del uso de agua convencional o regenerada en función del precio de la misma y del contenido en nutrientes. Los resultados obtenidos indican que una correcta combinación de filtro y emisor puede ahorrar hasta un 33% de los costes de riego. Los costes de inversión y los de mantenimiento fueron los que más variaron entre las distintas combinaciones. El análisis de escenarios evidenció que el mayor precio del agua regenerada podría compensarse con una aportación elevada de nutrientes por parte de la misma, lo que permitiría reducir los costes de fertilización.

Palabras clave adicionales: economía del agua; goteros; obturación; reutilización del agua; tipos de filtros.

Introduction

The use of effluents in agriculture is a viable alternative in areas where water is scarce or there is intense competition for its use. In Spain, reusing treated water for agricultural irrigation, among other uses, is regulated by Royal Decree 1620/2007, of 7 December (BOE, 2007).

In addition to increasing the water supply, water reuse can reduce fertilizer consumption which can offset the cost of implementing a system to irrigate with reclaimed water (Trooien and Hills, 2007).

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Abbreviations used: EAC (equivalent annual costs); WWTP (wastewater treatment plant)

The best way to apply effluents from the environmental and public health points of view is by means of micro-irrigation (Bucks *et al*., 1979). However, emitter clogging is a serious problem when using effluents in micro-irrigation systems (Ravina *et al*., 1997) because the reduction in emitted flow affects water distribution and, consequently, crop yields (Tajrishy *et al*., 1994). Moreover, emitter and filter clogging makes it more difficult to manage irrigation systems when using effluents. Therefore, several researchers have studied micro-irrigation system behaviour using different effluents, filters and emitters (Tajrishy *et al*., 1994; Ravina *et al*., 1997; Puig-Bargués *et al*., 2005; Cararo *et al*., 2006; Capra and Scicolone, 2007; Duran-Ros *et al*., 2009; Liu and Huang, 2009).

Other authors have studied some economic issues related to reclaimed water reuse along the Spanish Mediterranean. Molinos-Senante *et al*. (2010) made a cost-benefit analysis of wastewater treatment; Seguí and Alfranca (2004) assessed two reclaiming and reusing effluent systems from both technical and economical points of view; and Seguí *et al.* (2009) evaluated reclaimed water reuse for wetland restoration in a natural park using the travel cost technique. Nevertheless, in none of these studies has the cost of reusing water in micro-irrigation at the field level been studied in depth. Therefore, the aim of the present study is to analyse the private costs of water reuse in micro-irrigation using four filtration systems and five types of emitters in an experimental plot under similar conditions to a typical crop in the region, such as a fruit orchard. This analysis is intended to provide information about the decision a farmer would make when the choice to use conventional or reclaimed water is guided by cost criteria.

Material and methods

Experimental setup

The experiments were conducted in an experimental plot located at the wastewater treatment plant (WWTP) (42º 2' N, 2º 52' E, 44.4 m asl) of Celrà (Girona, Spain), which treats urban and industrial wastewater from that municipality. The tertiary effluent from the WWTP, which was obtained by filtration of secondary effluent through a disc filter with a 130 µm filtration level and subsequent treatment by ultraviolet radiation, was used in the experiments.

The behaviour of four different filtration systems was studied. The first filtration system consisted of two sand filters in parallel, both filled with 175 kg of silica sand with an effective sand size of 0.27 mm. The second system was formed by two disc filters with a filtration level of 130 µm. The third filtration system had one screen filter with a filtration level of 120 µm followed by two disc filters in parallel, with the same characteristics as the filters used in the second filtration system. Lastly, the fourth filtration system consisted in one screen filter with a filtration level of 120 µm.

Each filtration system supplied water to 20 laterals of 87 m long. Five types of laterals were used, each with a different emitter type (UN, TI, RM, TO and P2) and four replications. Four of the emitters (UN, TI, RM, TO) were integrated into dripline wall and the other one (P2) was inserted into thick-walled dripline. Three of them were pressure compensating (UN, RM, P2) while the other three were not. The nominal discharge of the tested emitters at 100 kPa ranged from 1.8 to 2.3 L h^{-1} and their price varied between € 0.15 and 0.81 m^{-1}. The field experiments lasted 1,000 hours and were carried out without plants, because the initial aim was to study hydraulic performance in the irrigation system when reusing reclaimed water. The complete experimental setup is detailed in Duran-Ros *et al.* (2009).

Calculation of costs

The concepts shown in Table 1 were considered to compute the costs associated with irrigation using the following equation:

$$C = C_{cap}(i,j) + C_w(i,x,q,p) + C_e(j,x) + \\ + C_m(i,j,x,q) + C_{fin}(i,j,x,q,p) + C_{fert}(x,q) \quad [1]$$

the independent variables being i = filter type; j = emitter type; x = irrigation dose (m^3 ha^{-1} yr^{-1}); q = water quality (in terms of clogging hazard and nutrient content); and p = water price (€ m^{-3}), variable depending on the water used (conventional or reclaimed water).

In order to allow an appropriate comparison of the different cases analysed the costs are expressed as equivalent annual costs (EAC). For simplicity, we will refer to them as costs through the paper.

The irrigation costs were computed for each combination of filter and emitter type. At this step, the ferti-

Table 1. Components of the analysed cost

Component	Description	Information source and assumptions
Capital cost (**C_{cap}**)	Irrigation system acquisition (depending on the price of materials: tank, pump, filter, pipes, valves, fittings and laterals), installation and financial cost. Their equivalent annual cost was used in the analysis.	The price of materials was obtained from supplier rates. Price of labour for installation: € 23 h^{-1} first official. Pump and tank life: 15 years. Remaining life of components: 10 years, except for TO laterals, which have an expected useful lifespan of 2 years. Residual value of the installation: 0. Interest rate: 4%.
Water (**C_w**)	It includes water consumption for both irrigation and filter backwashing.	Reclaimed water price: € 0.08 m^{-3} (Sala, 2010). Conventional water price: € 0.02 m^{-3}. In the area, irrigators pay for irrigated surface, not for water volume consumed. These payments vary for each user association (irrigation communities).
Energy (**C_e**)	It includes the electricity cost of pumping for irrigation and filter backwashings.	Electricity price without time discrimination (3.01 tariff, July 2010): € 0.133245 $(kW\ h)^{-1}$
Maintenance (**C_m**)	It includes the cost of emitter control and clogged emitter replacement at the end of each irrigation season, as well as sand replacement in sand media filter.	In the sand filter it is necessary to replace the sand media after every 1,000 hours of irrigation. The data concerning the number of clogged emitters and their replacement times have been obtained experimentally. Empirical data for emitter clogging were adjusted at 0, 125, 300, 475, 600, 800 and 1,000 irrigation hours using a quadratic regression to extrapolate the data for the different applied irrigation water tested. For the TO emitter, as clogging was so abundant, it was cheaper to replace the whole lateral than replace every clogged emitter. So, lateral replacement costs have been considered.
Financial operation cost (**C_{fin}**)	Variable cost for working capital.	Interest rate: 4%. Rest period for working capital: 4 months (assuming that the costs are concentrated in the middle of the irrigation season in July, and harvest time in November).
Fertilizer (**C_{fert}**)	In fact, this is a cost decrease caused by the nutrient supplied by reclaimed water for irrigation. This component is taken into account when the use of reclaimed water is compared to the use of conventional water, and considering the total cost of fertilizer as a cost associated with irrigation.	It was assumed that an apple tree needs to be fertilized with 117 units of N, 30 of P and 95 of K, according to the recommendations of several area experts, for an expected production of 40 t/ha (average yield of apple orchards in the province of Girona in 2009 (DAR, 2010a)). The nutrient content of reclaimed water was obtained by analysis. The conventional fertilization considered was typical of fruit producers in the area and has the following composition (N, P and K): 26-0-0, 9-0-11 (water soluble), 12-12-17 and 0-0-30. A 23% of N was applied by fertirrigation. For the fertilizers supplied in solid form, the cost of renting machinery was considered according to utility rates in the area (€ 80 ha^{-1}).

lization costs were not taken into account. The calculations were made for an orchard of 1 ha, planted with apple (*Malus* × *domestica*) trees 1.0 m apart in rows 3.5 m apart. Each tree would be irrigated by two emitters. The considered applied irrigation water, estimated from average measured data, was 4,100 m^3 ha^{-1} yr^{-1}, delivered during the five month-long irrigation season. The irrigation data using reclaimed and conventional water were compared. Regarding the use of conventional water, it was estimated that the filters were backwashed every five days and the emitters clogged 10% as much as with reclaimed water. Then, the fertilizer cost was included to study the savings in fertilizer resulting from the use of reclaimed water.

The effect of the applied irrigation water was also analysed considering reclaimed water doses ranging from 0 up to 8,000 m^3 ha^{-1}. In this analysis the maintenance costs were computed from the empirically obtained degree of clogging.

Scenario analysis definition

Since the field study was conducted under very specific conditions, it was thought appropriate to examine what the economic performance would be under different possible circumstances. To achieve this goal, various scenarios taking into account different water prices and nutrient contents and their combinations were considered. Again, the irrigation water needs were established on the basis of an apple orchard.

Three different prices for conventional water were established: one with a purchase price similar to the average price in the area (€ 0.02 m^{-3}), and the other two higher [€ 0.07 and 0.12 m^{-3}, the latter one being the water price for the new Segarra-Garrigues (Lleida, Spain) irrigation area (DAR, 2010b)]. Likewise, three different prices for the reclaimed water were established: € 0.08, 0.14 and 0.20 m^{-3}. The minimum price was established from average values in the same region (Sala, 2010). The water treatment costs in the Blanes (Costa Brava, Girona, Spain) WWTP can be used as a reference: € 0.06 m^{-3} in 2006, without considering fixed costs (Borràs *et al.*, 2007). With regard to the water nutrient content, three different levels were considered. The lowest level, with 5 mg L^{-1} of nitrogen and 4 mg L^{-1} of phosphorus, was obtained from the analysis of the effluent used in the experiments. These levels are typical of effluents from a WWTP with denitrification and phosphorus reduction. The high level, with 45 and 6 mg L^{-1} of nitrogen and phosphorus, respectively, corresponded to the maximum values of effluent treatment plants managed by the Costa Brava Consortium (CCB, 2010). Finally, an intermediate concentration level of 25 mg L^{-1} of nitrogen and 5 mg L^{-1} of phosphorus was considered. The presence of potassium in the reclaimed water was not considered due to a lack of experimental data. Taking into account all the combinations, 27 different scenarios were studied.

On the other hand, in the scenarios with a different nutrient content it was assumed that the clogging level produced by the reclaimed water was the same. This was because the water underwent received tertiary treatment and therefore the micro-organisms that could induce clogging were very low.

Results

Costs of the different filter and emitter alternatives using reclaimed water

Prior to performing the cost analysis, clogging equations were determined for the applied irrigation water for each combination of filter and emitter. Figure 1 shows two examples that are representative of the two different groups of cases observed. The first one is when clogging appeared at very low levels of applied water [Combined filter-TO emitter]. In this situation, a regression curve was computed to estimate the per-

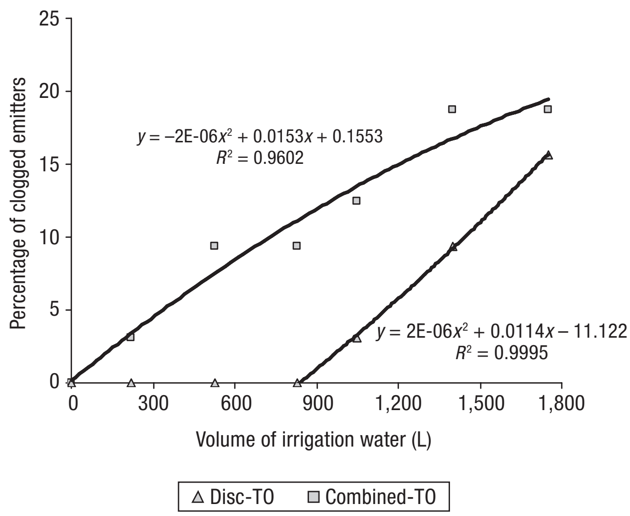

Figure 1. Examples of the empirical results of emitter clogging versus applied reclaimed water volume.

centage of clogged emitters for any volume of applied irrigation water in the range of the experiment. The second group of cases [Disc-TO] shows a greater resistance to clogging. It has to be pointed out that with the other tested emitters less clogging was found with combined filter than with disc filter. Despite of the variability on results, which is attributable to the inherent variability on effluent characteristics, two different clogging patterns were considered. The first one was in the range where no clogging was observed (0 to 830 L in the [Disc-TO] combination). In the second, when clogging began to appear, the percentage of clogged emitters were fitted with a quadratic function. This analysis was performed for each combination of irrigation equipment because it was necessary to determine maintenance costs.

The cost analysis of the different combinations of irrigation equipment is shown in Table 2. Capital and maintenance cost were the two components that had more effect on total costs, because the other components had more constant values. When analysing the total costs together, the minimum value was obtained with the [Screen-TI] combination because it had the minimum capital costs and also maintenance costs since this combination had very few clogging problems during the experiments. Therefore, under the experimental conditions, this combination would be the best choice.

However, as the characteristics of the reclaimed water were variable, and there were few differences in the observed costs of other options, other combinations that had a cost difference of less than 10% of the minimum ([Screen-RM], [Screen-TO], [Sand-TI], [Disc-RM] and [Disc-TO]) were also examined in detail. These combinations had a small maintenance cost and a reasonable capital cost, or low capital cost that mitigated the high maintenance cost (*e.g.* [Sand-TI]).

Although most of these combinations used screen filters, other configurations with disc and sand filters were also included. The best emitters changed depending on the filter. Thus, TO and RM emitters were selected with screen and disc filters, and TI with screen and sand filters.

When analysing the cost components individually, capital costs were lower with the emitter TI for each filter type. Capital costs were cheaper with screen filters, followed by disc, sand and the combined, respectively.

If only water used for irrigation was considered, the cost of water would be the same in all cases. However, the water consumption for filter backwashing varied

Table 2. Equivalent annual costs (EAC) for an irrigation season using reclaimed water for different combinations of filters and emitters. The cells in bold show those combinations with a cost smaller than 110% of the minimum cost

Filter and emitter	Capital cost (€ ha^{-1})	Water (€ ha^{-1})	Energy (€ ha^{-1})	Maintenance (€ ha^{-1})	Financial operation cost (€ ha^{-1})	Total EAC (€ ha^{-1})	% of the minimum EAC
Sand-UN	1,783.49	345.23	134.88	88.98	7.59	2,360.17	118.26
Sand-TI	**1,582.88**	**345.23**	**134.72**	**95.27**	**7.67**	**2,165.76**	**108.52**
Sand-RM	1,727.32	345.23	134.88	88.98	7.59	2,304.00	115.45
Sand-TO	1,728.56	345.23	149.58	341.71	11.15	2,576.24	129.09
Sand-P2	1,914.80	345.23	140.48	98.88	7.79	2,507.18	125.63
Combined-UN	2,268.36	328.92	134.88	157.84	8.29	2,898.28	145.23
Combined-TI	2,067.75	328.92	134.72	305.38	10.25	2,847.02	142.66
Combined-RM	2,212.19	328.92	134.88	23.00	6.49	2,705.48	135.56
Combined-TO	2,213.43	328.92	149.58	257.40	9.81	2,959.15	148.28
Combined-P2	2,399.67	328.92	140.48	23.00	6.57	2,898.63	145.24
Disc-UN	1,729.95	329.22	134.88	23.00	6.49	2,223.54	111.42
Disc-TI	1,529.34	329.22	134.72	447.37	12.15	2,452.80	122.90
Disc-RM	**1,673.78**	**329.22**	**134.88**	**23.00**	**6.49**	**2,167.37**	**108.60**
Disc-TO	**1,675.03**	**329.22**	**149.58**	**23.00**	**6.69**	**2,183.52**	**109.41**
Disc-P2	1,861.26	329.22	140.48	165.61	8.47	2,505.04	125.52
Screen-UN	1,703.60	328.53	134.88	23.00	6.49	2,196.49	110.06
Screen-TI	**1,502.99**	**328.53**	**134.72**	**23.00**	**6.48**	**1,995.72**	**100.00**
Screen-RM	**1,647.43**	**328.53**	**134.88**	**23.00**	**6.49**	**2,140.32**	**107.25**
Screen-TO	**1,648.67**	**328.53**	**149.58**	**23.00**	**6.68**	**2,156.46**	**108.05**
Screen-P2	1,834.91	328.53	140.48	23.00	6.56	2,333.47	116.92

for each type of filter, with the sand filter consuming the most water during backwashing, and the screen filter, the least.

The differences for energy consumption costs among the different combinations of filters and emitters were very small.

The maintenance costs of the [Sand-TI] combination were considerably greater than the other selected cases. This result is explained, first, by the cost of replacing the sand media, which is exclusive of this type of filter and, second, by the cost of replacing the clogged emitters, which is similar to other selected cases.

Comparison between the use of reclaimed and conventional water

Figure 2 shows the cost, including the cost of fertilizer, of an irrigation season using reclaimed and conventional water. The results show that the best combinations of filter and emitters when using reclaimed water are consistent with those obtained with conventional water. Although this result was influenced by the assumed hypothesis of emitter clogging caused by conventional water, it is remarkable that the costs of using reclaimed water were higher than those of using conventional water. The low price of conventional water for irrigation purposes in the study area, as well as the quality of reclaimed water used —with very low nutrient content— were determinant for achieving these results.

Effect of different applied irrigation water

Figure 3 shows the evolution of annual costs of an irrigation season, which included fertilization cost, depending on the applied irrigation water. The most relevant result is that in all cases the [Screen-TI] combination had the lowest cost. But this performance was not repeated in all combinations of irrigation equipment. For instance, the [Disc-TI] combination had one of the smallest costs for reduced amounts of irrigation water but it was the sixth most expensive combination when higher quality irrigation water was applied. Also noteworthy is the [Combined-UN] case, because from medium to high amount of applied irrigation water, the costs increased considerably faster than for any other combination of filter and emitter.

Thus, the costs for each particular combination of irrigation materials did not always vary directly with the volume of water, mainly because of the effect of maintenance costs, which are affected principally by emitter clogging.

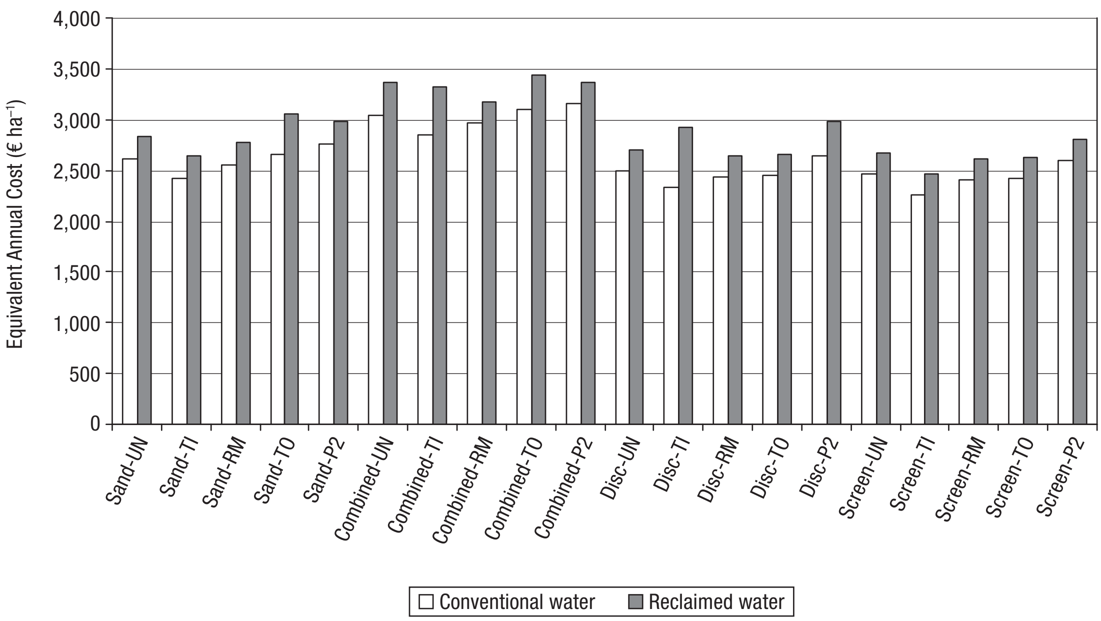

Figure 2. Comparison between the equivalent annual costs of an irrigation season (including fertilizers) using conventional or reclaimed water for the different combinations of filters and emitters.

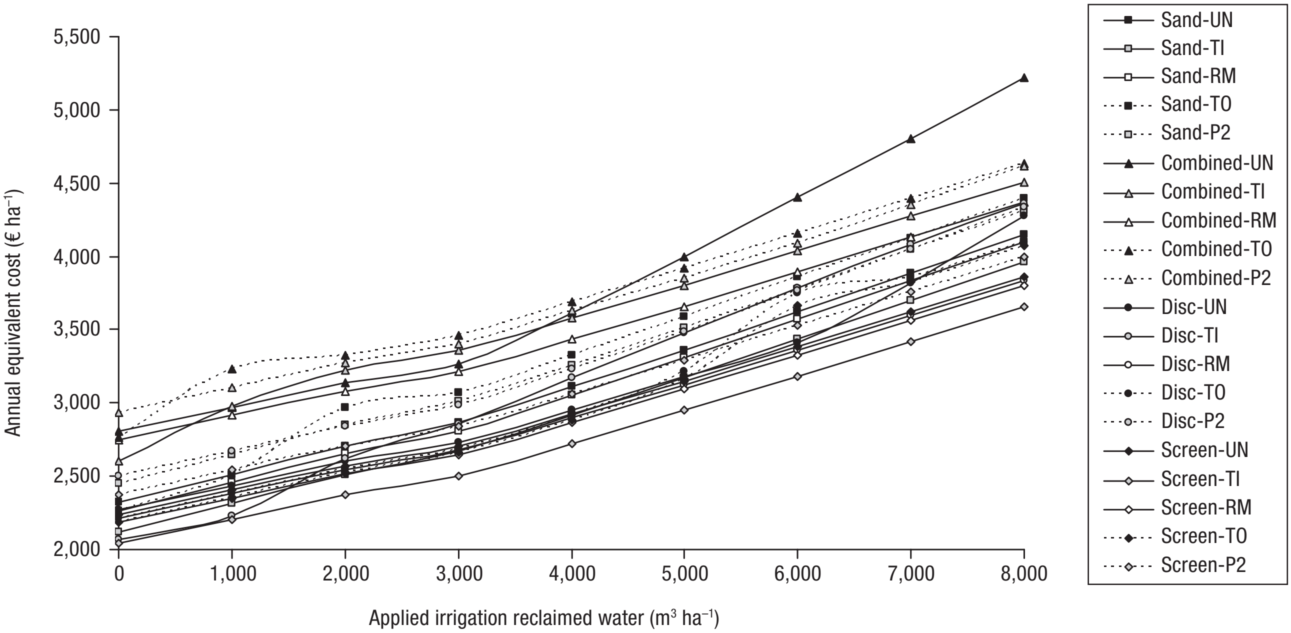

Figure 3. Annual equivalent costs of an irrigation season (including fertilizers) using different amount of applied irrigation reclaimed water for the different combinations of filter and emitters.

Comparison of different scenarios

The costs for the 27 scenarios were examined. In Table 3 the cost differences between the use of conventional and reclaimed water for 18 of them, the most relevant, are detailed. As the initial scenarios with a price of reclaimed water of € 0.20 m^{-3} always yielded higher costs, they were not further analyzed.

If these costs are compared, the minimum cost always corresponds to the [Screen-TI] combination, for both conventional and reclaimed water. When the results of each scenario were analyzed for a set emitter type (UN, TI, RM, TO, or P2) and the optimal filter was selected for both the conventional and reclaimed water, the minimum cost was always achieved using the screen filter. If each type of filter was considered independently and the optimal emitter was searched, the minimum cost using conventional water for each scenario would be obtained with the emitter TI. However, the minimum cost using reclaimed water was for emitter TI if sand and screen filters were used and for emitter RM when both the combined filtration system and disc filter were installed.

In only 8 scenarios (scenarios 3, 8, 9, 13, 14, 15, 17 and 18) was the use of reclaimed water economically preferable to the use of conventional water. As scenarios 13, 14 and 15 had a price of reclaimed water smaller than the conventional price, the result was predictable. Scenarios 7, 8 and 9 resulted in a price difference of only € 0.01 m^{-3} for conventional water, but only a medium nutrient content (scenario 8) and a high one (scenario 9) offset the water price difference, not a small nutrient content (scenario 7). The same thing happened with scenarios 17 and 18, which had a price difference of € 0.02 m^{-3}. Lastly, the price differential between conventional and reclaimed water in scenario 3 was € 0.06 m^{-3}, but the high nutrient content of reclaimed water compensated for the water cost difference. It should be pointed out that when the water price differentials were higher, the nutrient content did not balance the price gap. This was the case of scenarios 10, 11, 12, which had a price differential of € 0.07 m^{-3} and the smaller cost of conventional water made it preferable to reclaimed water.

Discussion

According to the experimental conditions under which the irrigation experiments were carried out, the alternative with the smallest cost (€ 1,995.72 ha^{-1} yr^{-1}) had a screen filter and emitter TI. The maximum difference between the best and worst alternatives reached € 963.43 ha^{-1}, which represented a saving of 33% of the irrigation costs. These results indicate the impor-

Table 3. Equivalent annual cost differences between the use of conventional and reclaimed water for each scenario. Different prices of conventional (€ 0.02, 0.07 and 0.12 ha^{-1} yr^{-1}) and reclaimed water (€ 0.08 and 0.14 ha^{-1} yr^{-1}), and nutrient level of the reclaimed water (low, medium and high) are considered in the scenarios. Positive values (figures in bold) show that using reclaimed water has a lower cost than conventional water

	Scenarios																	
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
	0.02						**0.07**						**0.12**					
	0.08			**0.14**			**0.08**			**0.14**			**0.08**			**0.14**		
	Low	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**	**Low**	**Medium**	**High**
Sand-UN	–225	–101	–5	–487	–363	–267	–16	**108**	**204**	–278	–155	–58	**193**	**316**	**413**	–70	**54**	**150**
Sand-TI	–225	–101	–5	–487	–363	–267	–16	**108**	**204**	–278	–155	–58	**193**	**316**	**413**	–70	**54**	**150**
Sand-RM	–225	–101	–5	–487	–363	–267	–16	**108**	**204**	–278	–155	–58	**193**	**316**	**413**	–70	**54**	**150**
Sand-TO	–388	–264	–167	–650	–526	–430	–179	–55	**41**	–441	–317	–221	**30**	**154**	**250**	–232	–109	–12
Sand-P2	–225	–101	–5	–487	–363	–267	–16	**108**	**204**	–278	–155	–58	**193**	**316**	**413**	–70	**54**	**150**
Combined-UN	–332	–208	–111	–582	–458	–361	–124	**0**	**97**	–374	–250	–153	**85**	**208**	**305**	–165	–42	**55**
Combined-TI	–466	–342	–246	–716	–592	–496	–258	–134	–38	–508	–384	–288	–50	**74**	**170**	–300	–176	–80
Combined-RM	–209	–85	**12**	–459	–335	–238	–1	**123**	**220**	–251	–127	–30	**208**	**331**	**428**	–42	**81**	**178**
Combined-TO	–334	–211	–114	–584	–461	–364	–126	–3	**94**	–376	–253	–156	**82**	**206**	**302**	–168	–44	**52**
Combined-P2	–209	–85	**12**	–459	–335	–238	–1	**123**	**220**	–251	–127	–30	**208**	**331**	**428**	–42	**81**	**178**
Disc-UN	–209	–85	**11**	–459	–335	–239	–1	**123**	**219**	–251	–127	–31	**207**	**331**	**427**	–43	**81**	**177**
Disc-TI	–596	–472	–376	–846	–722	–626	–388	–264	–168	–638	–514	–418	–180	–56	**40**	–430	–306	–210
Disc-RM	–209	–85	**11**	–459	–335	–239	–1	**123**	**219**	–251	–127	–31	**207**	**331**	**427**	–43	**81**	**177**
Disc-TO	–209	–85	**11**	–459	–335	–239	–1	**123**	**219**	–251	–127	–31	**207**	**331**	**427**	–43	**81**	**177**
Disc-P2	–339	–215	–119	–589	–465	–369	–131	–7	**89**	–381	–257	–161	**77**	**201**	**297**	–173	–49	**47**
Screen-UN	–208	–85	**12**	–458	–334	–238	–1	**123**	**220**	–250	–126	–30	**207**	**331**	**428**	–42	**81**	**178**
Screen-TI	–208	–85	**12**	–458	–334	–238	–1	**123**	**220**	–250	–126	–30	**207**	**331**	**428**	–42	**81**	**178**
Screen-RM	–208	–85	**12**	–458	–334	–238	–1	**123**	**220**	–250	–126	–30	**207**	**331**	**428**	–42	**81**	**178**
Screen-TO	–208	–85	**12**	–458	–334	–238	–1	**123**	**220**	–250	–126	–30	**207**	**331**	**428**	–42	**81**	**178**
Screen-P2	–208	–85	**12**	–458	–334	–238	–1	**123**	**220**	–250	–126	–30	**207**	**331**	**428**	–42	**81**	**178**

tance of the combinations of filter type and each specific emitter, as several experiments have shown (Ravina *et al*., 1997; Capra and Scicolone, 2007; Duran-Ros *et al*., 2009).

According to Capra and Scicolone (2007), disc and screen filters are cheaper and easier to use. However, sand filters are indicated when the irrigation water has high levels of suspended solids, but these filters are more expensive and are only appropriate for farms with high technical and professional standards. Our results confirm this fact.

Quantitatively, the highest cost was due to capital cost, followed by water, energy, maintenance and financial operation costs. However, the maintenance cost, which is greatly influenced by the characteristics of the irrigation water, led in some cases to an important increase in the total cost. For this reason, maintenance should not be underestimated in the design stage of a drip irrigation system with reclaimed water. In addition, transport and distribution costs might be high, and they must be calculated case by case depending on the distance from each orchard to the water supply. Seguí *et al*. (2009) pointed out that transport and distribution costs are one of the main costs of irrigation projects with reclaimed water. In our experiment, the transport and distribution costs were minimal because the experimental plot was located beside the WWTP. As there are several WWTPs in the main irrigated areas of the province of Girona (*i.e.,* the Muga and the Lower Ter river basins), the costs of reusing reclaimed water in most of the irrigated farms would be minimized (Elbana *et al*., 2010).

The influence of applied irrigation water on costs, which varied depending on the irrigation equipment, was also observed. For some combinations of materials, the cost was fairly proportional to the applied irrigation water, but not for others. This means that a combination of irrigation equipment could present an acceptable cost in some range of applied irrigation water, but not a very acceptable one in others, where a more intense equipment operation regime represented higher costs, as with the [Combined-UN] alternative. In either case, the [Screen-TI] combination was again optimal for any of the applied water amounts tested.

The analysis of different scenarios shows that with the optimal combination of filter and emitter, the use of reclaimed water with high nutrient contents (45 and 6 mg L^{-1} of nitrogen and phosphorus, respectively) cost less than using conventional water, even though it had a price up to € 0.06 m^{-3} lower than that of reclaimed water.

To promote the use of reclaimed water for irrigation in the studied area, thereby releasing conventional water for other uses, some tariff reductions could be implemented (Sala, 2010). Thus, it might be economically attractive for farmers to choose reclaimed water for irrigation. Other implemented actions could include penalizing the price of conventional water, redistributing user rights by replacing some conventional water rights with reclaimed water rights, or providing a high level of nutrients in the reclaimed water for irrigation. The last option would also help to reduce the cost of wastewater treatment, but would require important and currently difficult-to-implement operational changes in water treatment plants. Besides, increasing nutrient levels in WWTP effluents could make the environmental, urban and industrial reuse of reclaimed water difficult.

Other elements could affect the farmer's decision about what type of water (reclaimed or conventional) to use, if it is possible to choose between the sources. A key issue in this decision is the water supply guarantee for regenerated water, which could be a more determinant factor than the water cost in those areas that experience occasional supply restrictions. This is the case of the study area, which was affected by exceptional supply situations in 1999, 2000, 2002, 2005 and 2007-2009.

Moreover, and assuming that farmers cannot choose a water source, and that they are forced to use reclaimed water, the current price would have different implications depending on the type of production. The demand curves determined by Pujol (2002) and Pujol *et al.* (2006), for the irrigation of the Lower Ter River basin (where the experimental plot is located) show that the fruit orchards and ornamental plant nurseries in the area could pay the current price of reclaimed water but profits would be reduced, while farms producing fodder to feed their livestock would be in an extreme situation, and producers of corn and other cereals could not afford that price.

Finally, it is should not be forgotten that the social acceptance of using reclaimed water is still limited (Molinos-Senante *et al*., 2010), and some farmers may have non-economic objections to using it. In the study area today there are some farmers who use reclaimed water. Elbana *et al*. (2010) surveyed these farmers, who were satisfied using this water resource. They pointed out that water supply safety is the principal advantage and the main reason for using reclaimed water for irrigation, especially in drought periods. They also confirm that health problems have never been an issue, and that the WWTPs conduct regular analyses to ensure that the water quality is adequate for agricultural use. Saving fertilizer is considered another very important advantage of using this type of water for irrigation.

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