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Farmers' profiles and behaviours toward desalinated seawater for irrigation: Insights from South-east Spain

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ABSTRACT

In South-east Spain the implementation of desalinated seawater for irrigation was planned as an alternative water supply for farmers. However, most high-volume desalination plants are underused as farmers' current demands are lower than was previously expected. In order to develop programmes promoting an effective behavioural shift of farmers toward desalinated water, it is necessary to first explore their preferences and attitudes. This paper shows the results of a survey examining the attitudes and behaviour of farmers toward the use of desalinated seawater for irrigation in the South-east of Spain. The results show the existence of different farmer typologies regarding desalinated seawater use, as well as their preferences and attitudes. The main finding of this study has been to identify further factors, besides price, that condition the acceptance of the use of desalinated seawater. Finally, a series of measures are proposed to encourage the use of desalinated seawater for irrigation based on the identified profiles. The insights gained from this study could be useful for other regions where the construction of desalination plants has been planned as a measure to increase the availability of irrigation water.

1. Introduction

Providing food to a growing population is one of the main challenges humanity has to face given estimations over 9 billion people by the middle of the 21st century (Ai et al., 2020). In order to meet the food demand in 2050, global production has to be increased by at least 70% (Gilbert, 2012). Approximately 45% of food is currently produced under agricultural irrigation schemes. This is the main consumer of global water resources, translating to approximately 80% of available water. In developing countries, the water consumption for irrigation reaches 90%. This is also the case in arid or semi-arid regions (Velasco-Muñoz et al., 2018a). The main constraint on food production in global agricultural systems is water availability owing to different reasons. On the one hand, there is strong competition for water for irrigation, urban supply, or for tourism purposes (Aznar-Sánchez et al., 2018). On the other hand, global climate change means that rain cycles vary, long-term droughts occur, and water supply imbalances are a reality. Further consequences of climate change are a higher frequency and stronger intensity of extreme climates and changes in soil humidity, evapotranspiration flows, and surface runoffs (Zhang et al., 2018). Lastly, changes in land use and the intensification of water consumption have brought about degradation of the main water ecosystems such as aquifers. Such worsening conditions cause biodiversity losses, water salinization, flood water, scarcity in complementary water services, as well as higher vulnerability and inequalities for users (IWMI, 2007). In this sense, an additional reduction in human welfare and an increase in water deficits are evident (Velasco-Muñoz et al., 2018b). According to the United Nations World Water Development Report, a global scarcity of drinking water resources amounting to approximately 40% is

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expected by 2030 (WWAP, 2015). In this context, the most efficient and sustainable use of water resources for agriculture has become an urgent priority, especially in those regions which are particularly vulnerable to climate change, as the Mediterranean basin is.

During recent years, desalinated water has become a competitive option in quality water supply for irrigation in arid or semi-arid regions. Some studies conclude that desalinated seawater is a technically and economically viable alternative that contributes to the sustainability of agriculture and water resources. The use of desalinated seawater shows some advantages compared with other irrigation options. This water source provides a good chemical quality, high supply reliability, and immediate accessibility. Furthermore, it reduces vulnerability to drought even in the driest periods without precipitation (Ghaffour et al., 2013). A more stable income flow can be assured in the farmers' agricultural holdings, as well as higher stability in agricultural employment and improved economic performance (Tenne et al., 2013). Moreover, seawater desalination plants can help reduce the effect of sea intrusion in aquifers (Jorreto et al., 2017).

In South-east Spain, we find a paradigmatic situation. The intensive use of groundwater has allowed the development of an intensive agricultural model which is able to supply fresh produce to European markets throughout the year (Aznar-Sánchez et al., 2011). However, in order to maintain this activity, water ecosystems have been placed under immense pressure. Water management has become one of the main environmental problems in this region (Galdeano-Gómez et al., 2017). Therefore, the Spanish Water Authorities began to implement policies devoted to mitigating water scarcity as early as 1990 (Garrido et al., 2006). Since then a set of measures has been implemented in order to monitor demand entailing water fees, payment systems to reduce consumption, and buying rights and concessions for water use (Carmona et al., 2011; Garrido et al., 2013). In general terms, these types of proposals have not been successful because of the lack of political engagement, adequate control mechanisms, and cooperation among farmers (Rupérez-Moreno et al., 2017). The Spanish Government has opted for seawater desalination as a significant alternate water supply (Palomar and Losada, 2010). With the implementation of the AGUA Programme in 2004, the Spanish Government designed the construction of 21 high-volume desalination plants with a total capacity of 1063 hm^3/year. Of the total potential output, 46% is planned to be devoted to agriculture (Downward and Taylor, 2007; Zarzo et al., 2013). From this initial proposal, 17 desalination plants have already been built and most of them are located in South-east Spain (Table 1). However, the low level of desalinated seawater demand from farmers in this region has resulted in some of these desalination plants operating at a reduced capacity during recent years (Martínez-Álvarez et al., 2016, 2017). In previous analyses of the low use of desalinated seawater by farmers in South-east Spain, its high price has been quoted as the sole reason for such behaviour (Grindlay et al., 2011; García-Rubio and Guardiola, 2012; Swyngedouw, 2013; March et al., 2014).

Previous studies about the adoption of alternative water sources have demonstrated that one of the major barriers was often the lack of community acceptance (Hurlimann et al., 2009). Understanding the reasons behind the acceptance and implementation of alternative water sources is crucial to achieve successful implementation (Mankad, 2012). In order to develop effective programmes to change farmers' behaviour toward desalinated water, it is necessary to explore their preferences and attitudes. Furthermore, the exploration of economic and social factors conditioning their behaviours is essential in order to design socially fair measures and legitimate interventions. There are some empirical studies aimed at understanding farmer's perceptions and acceptance of different water sources for irrigation, such as waste water (Owusu et al., 2012; Antwi-Agyei et al., 2016; Dare and Mohtar, 2018), recycled water (Menegaki et al., 2007; Bakopoulou et al., 2010; Carr et al., 2011) and desalinated water (Aznar-Sánchez et al., 2017; Ghermandi and Minich, 2017). However, a clear limitation of these studies is that they do not examine the motivating factors and real behaviours of users. They study the reliance on hypothetical scenarios and measure intentions, rather than explore the users' current acceptance level and their related behaviour (Mankad and Tapsuwan, 2011). However, it is well known that attitude does not necessarily equate to actual behaviour (Randolph and Troy, 2008; Dolnicar et al., 2011). Consequently, some studies analyse farmers' attitudes and behaviours toward irrigation water based on real experiences of use (Barnes et al., 2009). To our knowledge, there are no studies that have examined attitudes and behaviours regarding desalinated seawater for irrigation. A further observed weakness is that most water literature does not distinguish between different types of farmers. Detecting the diversity and heterogeneity within farmers is very important since policy makers need to define groups who are both active and less enthusiastic regarding alternative water sources (Gilg and Barr, 2006) in order to address proper measures according to their needs. Studies have suggested that interventions are more likely to succeed when they are designed to incorporate the target groups' attitudes and

Table 1
Large seawater desalination plants in the South-east of Spain under the AGUA programme* (capacity over 20,000 m^3/day).

			Use of desalinated water (hm^3/day)		
Province	Desalination plants	Capacity (m^3/day)	Urban	Agriculture	% Agriculture
Almería	Carboneras	120,000	3	37	92.5
	Campo de Dalías	86,000	15	15	50.0
	Níjar-Rambla Morales	58,000	0	20	100.0
	Bajo Almanzora	58,000	5	15	75.0
Murcia	Valdentisco-Mazarrón	200,000	20	50	71.4
	Águilas	172,000	10	50	83.3
	San Pedro del Pinatar I	68,000	24	0	0.0
	San Pedro del Pinatar II	68,000	24	0	0.0
Alicante	Torrevieja	230,000	40	40	50.0
	Alicante II	68,000	24	0	0.0
	Mutxamel	52,000	18	0	0.0
	Javea	29,000	10	0	0.0
	Denia	26,000	9	0	0.0
Southeast		1,235,000	202	227	52.9
Spain		1,670,000	353	227	39.1
% Southeast/Spain		74.0	57.2	100.0	

Source: Authors' own elaboration from García-Rubio and Guardiola (2012). * AGUA Programme (Actions for the Management and Use of Water)

Fig. 1. Location of Campo de Níjar in the Southeast of Spain.

behaviours (Antwi-Agyei et al., 2016).

This study aims to bridge the above-mentioned gaps by investigating the attitudes and behaviours of different farmers towards of the use of desalinated seawater for irrigation in South-east Spain. The following key questions have been specifically analysed in this study: 1) Farmer typology regarding their use of desalinated seawater, 2) farmers' preferences and attitudes towards desalinated seawater and 3) farmers' assessment of proposed incentives to increase their usage. The main novelty of this study is that it is the first one that examines attitudes and behaviours regarding desalinated seawater for irrigation and distinguishes between different types of farmers. The results of our study show relevant empirical implications, which provide orientation to policy makers regarding interventions that are likely to increase farmers' use of desalinated seawater. Furthermore, the insights gained from this study could be useful in other regions where the construction of desalination plants is under consideration for the purpose of increasing the availability of irrigation water.

2. Materials and methods

2.1. Study area

The study was conducted in the Campo de Níjar region, located in the South-east of Spain in the administrative province of Almería (Fig. 1). This area belongs to a semi-arid climate, with an average annual rainfall lower than 200 mm, a mean annual temperature of 18 °C, and a high solar radiation (more than 3000 sunlight hours per year) (Toro-Sánchez, 2007). Nowadays, this region counts with the second largest concentration of greenhouses in the province of Almería, embracing over 5300 ha. It has also been the region where the greenhouse-surface has grown the most. The horticultural crops in this region are those with the highest salinity tolerance level, such as tomato and watermelon. Agriculture is the main economic sector, and it employs over 60% of the population. It is dominated by smallholder farmers with an average farm size of two - 3 ha (García-García et al., 2016).

This region suffers the most severe water scarcity problems in South-east Spain. The Campo de Níjar basin counts surface water supplies of 0.4 $\times$ 10^6 m^3, a groundwater availability of 11.2 $\times$ 10^6 m^3, and an irrigation consumption of 34.3 $\times$ 10^6 m^3 per year. In this intensive agricultural system, the main source of water is groundwater (96.6% out of the total consumed water for irrigation) and it is subject to overexploitation. Its Horticultural Water Exploitation Index amounts to 2.9 (García-Caparros et al., 2017), the highest in the province of Almeria. The irrigation system used by farmers in this region has been intensively modernised during recent years owing to the introduction of automated fertigation, localised irrigation, and the use of tensiometers which improve water use efficiency (Valera et al., 2016). However, the savings of water produced as a consequence of these efficiency improvements could not cope with the increased water demands because of the increased number of greenhouse establishments, which amounts to a 3% annual increase during the last decade (García-García et al., 2016). This increase exerted pressure on aquifers and caused serious availability and quality problems. It also resulted in an increased electrical conductivity of water. Different assessment studies on irrigation performance conducted in this region have pointed out that crop yield and water productivity have started to be severely affected by water salinity, which also constrained crop diversification (Fernández et al., 2007; Sánchez et al., 2015a, 2015b). The groundwater the farmers have access to through wells in this region therefore shows poor quality.

In this context, it was expected that desalinated water would play an important role as an alternative water source for irrigation. Therefore, the seawater-desalination plant in Carboneras was opened in 2005 with a net producing capacity of 42 hm^3/year which could be doubled to 84 hm^3/year. This plant was the first to be built under the AGUA Programme in Spain and is the largest in Europe. At its inception, two water management and delivery systems were considered: The first implied a desalinated water supply at each irrigation community where a joint water mixture took place. The second model proposed a direct supply to end users who individually mix water sources in their own irrigation pool. Finally, the second option was implemented since it allowed each farmer to produce their own water mixture according to their crops' needs. This desalinated water supply system was called 'water a la carte' (on demand) (Baeza-Cano and Escribano-Fornieles, 2008). This all means that the Campo de Níjar region is the most suitable location for our research as it has a long tradition in the use of desalinated seawater and we find farmers with comprehensive experience of irrigating with it. Moreover, the exploitation level of this desalination plant by farmers is much lower than previously expected during the construction project. Only an annual average of 9 hm^3/year has been devoted to agriculture out of a desalinated seawater output of 27 hm^3/year. There is a large group of farmers who have decided not to irrigate with desalinated seawater even though the offer is available.

2.2. Questionnaire development

The research was conducted in two phases. The first involved a qualitative study with a focus group and interviews with experts. A focus group discussion was held with ten farmers of the studied region: five who do not use desalinated seawater for irrigation and five who do. Afterwards, five experts on intensive agriculture in Almeria were also interviewed. From the overall information obtained, it was possible to formulate the forced-choice questions for the target farmers. The first version of the questionnaire was tested in the study region as a pilot survey with five farmers highly experienced in the intensive cultivation of vegetables but who do not use desalinated seawater for irrigation and five other experienced farmers who do. The questionnaire included 17 questions and was divided into three sections according to the pursued objectives:

1. *Characterisation of farmers.* Four groups of questions were formulated in the questionnaire regarding the following topics: a) farmer's attributes (age, experience as farmer, and level of education); b) agricultural holding characteristics (type of soil, greenhouse type, dimension, construction year, climate monitor system, employed labour and percentage of farmer family-bounded labour); c) crop characteristics (level of monoculture, yield differences, and trading channel); and d) water use (technological irrigation level, share of desalinated water, electrical conductivity level of irrigation water, and percentage of average water consumption per hectare).
2. *Preferences and attitudes regarding desalinated seawater.* Within this section, three questions were asked. In the first question, farmers were asked to rank according to their preferences the following water-source supplies for irrigation under the same price conditions: groundwater, surface water, desalinated seawater and recycled water. They had to indicate in which order they would employ the sources of water listed above. In the second question, they had to assess the factors they perceived to be relevant for the use of desalinated seawater: availability, price, crop yield, crop quality, crop diversity, soil quality, water consumption, and additional fertilisation. They were asked to rate each factor with a 6-point Likert scale from −3 to 3, where the range from −3 to −1 is considered disadvantageous, the range from 1 to 3, advantageous, and 0 represents a neutral position. In the third question, farmers who irrigate with desalinated seawater were asked for the reason for it. They had to choose among the following options: bad quality well water, the possibility for crop diversification, yield increases, the option to produce organic vegetables, the option to cultivate on hydroponic soil and others.
3. *Incentives to increase the use of desalinated seawater.* In the last section of the questionnaire, farmers were asked about five incentives that would encourage them to use desalinated seawater for irrigation: price reduction for all users, subsidies for start-up investments, tax relief, information campaigns, and volume discounts. The incentives were rated on a 3-point Likert scale (3 representing very important, 2 important, and 1 not important).

2.3. Sample size and selection

The second phase of the research involved the quantitative data collection. To determine the study sample size, a maximal error level of 5% and a trust level of 95% were established. The representative sample was obtained from the cultivated surface devoted to each type of crop in 2016, with report-based data (Consejería de Agricultura, Pesca y Desarrollo Rural, 2017). We interviewed 150 farmers in a greenhouse region of 5331 ha where desalinated seawater can be used. Their cultivated surface accounted for 493.5 ha of the total cultivated area. This constituted a sample of intensive agriculture in the Campo de Níjar region; the sample error represented approximately 4.21%.

For the sample selection, we considered crop type and its usual seasonal cycle. In the region, tomato is the most common crop type since it is the least demanding crop regarding water quality, measured by its level of conductivity. Tomato crops in all their cycles made up 75% of the total studied cultivated region. The crop distribution of the selected farmers responds to the crop distribution of the region (Table 2). Furthermore, within each type of crop, a user's selection of desalinated seawater has been chosen: non user, user of less than 50% desalinated seawater, and user of more than 50% desalinated seawater of the total consumed water for irrigation. Furthermore, we intended to have a good territorial representation of the interviewed farmers to collect different cases appearing in the studied region regarding the agronomic and hydric perspectives. The selection of each respondent was undertaken in collaboration with the Irrigation Communities that manage groundwater supplies and the Community of Desalinated Seawater Users (*Comunidad de Usuarios de la Comarca de Níjar*) that manages the desalinated seawater supply from the plant in Carboneras. We conducted interviews from February to April 2018. Interviews took approximately 460 min to complete.

2.4. Data analysis

The treatment of information collected from the interviews began with the analysis of the main agricultural holding features through statistical classification techniques and cluster analysis. This allowed us to implement the characterisation of agricultural holdings in the Campo de Níjar region, as well as determine the three types of agricultural holdings according to the use of desalinated seawater for irrigation. Later on, this particular analysis of the agricultural holding types has provided better insights to the farmers' attitudes and behaviours towards the use of desalinated seawater for their crop irrigation.

Table 2
Sample distribution per crop type and desalinated seawater use.

Crop type and cycle	Cultivated surface (ha)	Desalinated water use	Survey surface (ha)	Conducted surveys
Tomato (long cycle)	2612	Non-user	246.1	18
		User (≤50%)		27
		User (>50%)		30
Tomato (autumn) and watermelon (spring)	1599	Non-user	147.3	11
		User (≤50%)		16
		User (>50%)		18
Tomato (autumn) and courgette (spring)	586	Non-user	53.1	4
		User (≤50%)		6
		User (>50%)		6
Pepper (long cycle)	160	Non-user	12.9	1
		User (≤50%)		1
		User (>50%)		2
Other crops (cucumber, courgette, aubergine, other varieties of tomatoes)	374	Non-user	34.1	2
		User (≤50%)		4
		User (>50%)		4
Total	5331		493.5	150

The cluster analysis was conducted through the application of the K-Means algorithm and the SPSS software tool (version 23). First, we applied the DBSCAN −Density-based spatial clustering of applications with noise− algorithm proposed by Ester et al. (1996). Both algorithms have been used in many studies, some devoted to agriculture (Mucherino et al., 2009), as a way to determine the optimal number of groups that can be set up within a sample. This grouping technique delivers a significant advantage over the cluster analysis based on the K-Means algorithm since DBSCAN does not require previous specification of the desired number of clusters. The DBSCAN algorithm identified the most relevant clusters in the sample of interviewed farmers. Therefore, a Principal Component Analysis based on the k-means algorithm has been excluded, since no transformation of high dimensional data to lower dimensional data was necessary (Ding and He, 2004; Jolliffe, 2011). The size of our sample (150 farms), with 17 variables and well-defined ranges, does not require this application. And the DBSCAN algorithm is especially indicated to find non-linear groups, especially when the dimension is not a problem (Schubert et al., 2017). Based on this methodology, the characteristics of each group could be defined, as well as their quantitative and qualitative relevance. Average behaviour values within each agricultural holding cluster can be given. Afterwards, a particular analysis of the agricultural holding types has allowed a better approach to farmers' preferences regarding water sources for irrigation, their attitudes and behaviours towards the use of desalinated seawater, and their priorities regarding incentives for promoting it.

3. Results and discussion

The results obtained from the analysis have been structured in four main sections: farmer and agricultural holding characterisation; type of farmers; preferences and attitudes toward desalinated seawater; and incentives to foster the use of desalinated seawater for irrigation.

3.1. Characterisation of farmers

The descriptive statistics of the studied variables in the research are shown in Table 3. They have been grouped in four areas:

A. *Farmer's attributes*: the mean farmer age in the region is 47 years old, where the oldest farmer is 58 and the youngest is 31 years old. The mean active age is very advanced, since 86% of the sample are over 40 years old. If age and cumulative experience in the intensive agriculture sector are compared, we find a close relationship between these two variables. The mean period devoted to agriculture is 20 years, where the minimum is 10 and the maximum 31. It should be noted that 67% percent of the farmers have only completed compulsory education. Only 6% of the sample farmers have a university degree, and they are younger.

B. *Agricultural holding characteristics*: The most used soil type is sanded soil; the most usual greenhouse type is the sloping roof; the mean holding dimension is 3,3 ha of greenhouse-cultivated surface, the smallest being 0,9 ha and the largest 17 ha; the oldest greenhouse was built in 1994 and the most modern in 2013. Only 20% of the agricultural holdings are equipped with a climate monitoring system. The employed labour varies significantly according to the agricultural holding dimension and the seasonal task (sowing, harvesting, holding cleaning, etc.). Thus, in the smaller agricultural holdings up to 80% labour is farmer family-bounded. In sharp contrast, almost all labour in the bigger agricultural holdings comes from external sources. This can be easily observed in the high variation coefficient of this variable which amounts to 131,3%.

C. *Crop characteristics*: tomato cultivation stands out in its long cycle (from autumn to spring), as well as the alternation of tomato with watermelon and courgette. In the Campo de Níjar region, further types of crops are marginal, even when they are very usual in the Almeria intensive agriculture like peppers, cucumbers, melons, aubergines, and green beans. There is a high rate of tomato monoculture; over 65% of the agricultural holdings produce tomatoes in any given season, especially during autumn. Fifteen percent of the agricultural holdings only sow tomatoes each year as long-cycle cultivation. The average yield per square meter during the last three cultivation seasons shows a yield structure coherent with the intensive agriculture yields in the Spanish South-east. The trading channels used by the farmers vary significantly and the variation coefficient is high.

D. *Water use*: The technological level of the watering systems is quite advanced. As a result, 90% of the agricultural holdings are equipped with an automated irrigation and fertilisation system. They also use tensiometers. 85% of the interviewed farmers state having access to their own or community-managed wells, whereas 46.7% also have access to a desalinated water supply. They usually mix desalinated water with underground water and it is also used as a unique water supply. This diversity can be observed in the percentages of desalinated water use which range from 0 percent—not used at all—to a maximum percentage of 95— complete dependence on desalinated seawater. This correlates with a high variation coefficient (71.3%). The

Table 3
Variables and descriptive statistic data.

Area	Variable	Description	Min.	Max.	Average	Standard deviation	Variation coefficient
Personal farmer data	V_1	Farmer's age (years old)	31.00	58.00	47.42	8.04	16.9%
	V_2	Years of farming experience	10.00	31.00	20.24	4.99	24.7%
	V_3	Level of education. 1 no schooling, 2 compulsory education, 3 upper secondary school, 4 university degree, 5 vocational training and 6 others.	1.00	4.00	[a]	[a]	[a]
Agricultural holding data	V_4	Type of soil. 1 local ground, 2 sanded soil, 3 hydroponic soil, and 4 others.	2.00	5.00	[a]	[a]	[a]
	V_5	Type of greenhouse. 1 flat arch, 2 sloping roof, 3 asymmetric, 4 cylindrical multi-tunnel, 5 raise dome multi-tunnel, 6 venlo, 7 mesh, and 8 Others.	2.00	5.00	[a]	[a]	[a]
	V_6	Agricultural holding size: Naperian logarithm of the holding size in square meters.	9.10	12.04	10.00	0.75	7.5%
	V_7	Construction year. Four-digit year.	1994	2013	2004	5.28	0.3%
	V_8	Climate monitoring system. 1 yes, or 2 no.	1	2	1.18	0.38	32.6%
	V_9	Number of labours per year.	1.42	43.8	7.37	9.68	131.3%
	V_{10}	Percentage of farmer family-bounded labour.	0	0.8	0.4	0.24	59.8%
Crop data	V_{11}	Monoculture level. 1 non-repeat cultivation, 2 repeated cultivation owing to holding constraints, 3 repeated cultivation owing to market conditions or 4 repeated cultivation for other reasons.	1.00	4.00	[a]	[a]	[a]
	V_{12}	Yield differences in kilograms regarding the average yield of the province per cultivation type and cycle.	0.5	1.5	0.93	0.22	23.5%
	V_{13}	Trading channel. 1 agricultural cooperative, 2 local market, 3 direct sale, 4 wholesalers and 5 others.	1.00	5.00	[a]	[a]	[a]
Irrigation system	V_{14}	Technological level. The higher the number, the higher the irrigation level.	16	31	19.93	3.88	19.5%
	V_{15}	Percentage of desalinated seawater use.	0	0.95	0.44	0.31	71.3%
	V_{16}	Level of electrical conductivity in irrigation water (dS/m).	1.27	5.11	2.47	0.95	38.6%
	V_{17}	Percentage of average water consumption per ha, crop type, and cycle compared with the average in the province (100%).	0.8	1.15	1.00	0.12	12.3%

[a] In qualitative variables no data are provided.

mean conductivity of irrigation water in agricultural holdings which use water coming from aquifers is 5.11 dS/m. This indicates that these agricultural holdings have to mix community-managed or own well water with desalinated seawater or only cultivate tomatoes as this is the only crop type that can tolerate the high conductivity level.

3.2. Typology of farmers

The cluster analysis deepens the knowledge of farmers attributes devoted to the cultivation of vegetables in the Campo de Níjar region. For the cluster analysis a data panel has been constituted obtained from the 150 interviewed farmers and with the values of the 17 variables shown in Table 3. The DBSCAN algorithm has identified three main clusters in the sample of interviewed farmers, to which a subsequent K-Means analysis was applied through SPSS. Thus, the 150 farmers have been classified into three homogeneous groups which have been labelled as follows: 'intensive user' (cluster 1), 'user' (cluster 2) and 'non-user' (cluster 3). Of the 17 studied variables, 14 have played a crucial role in this three-fold classification. This is shown in Table 4.

Based on this methodology, the characteristics of each cluster could be defined as well as their quantitative and qualitative relevance. Similarly, the average farmer's behaviour within each cluster can be distinguished. In this sense, each cluster has been characterised according to the significant variables identified when classifying the three main groups of farmers (Table 5).

The main characteristics of each cluster are explained below. They are expressed according to the average registers of the 14 representative variables.

A. *Cluster 1: Intensive users* (N = 25, 16.7% of sample). They have a higher level of education (upper secondary school) but fewer years of farming experience compared with the other two clusters. They own the agricultural holdings with the biggest average dimension, their greenhouses are modern with a high technological level (multi-tunnel), and they cultivate on hydroponic soils. Furthermore, they employ the highest number of labour per year. Only a small share is farmer family-bounded labour. This cluster is characterised by repeated crops, season after season. This is a free decision since they have opted for a specialisation strategy and it is not a consequence of internal or external constraints. In this group we can find the highest number of farmers who sell their produce directly without commercial mediation by a cooperative or a local market. This cluster of farmers shows a high technological level regarding the irrigation water control and analysis. The analysing elements of soil humidity, salinity, and volume of consumed water are systemised. The use of desalinated water is very present in these agricultural holdings; it represents 77% of the irrigation water consumption. For this reason, the salinity level of their irrigation water is quite reduced. The number of cubic meters of irrigation water per hectare and year is under the average of the Almeria province. This is a consequence of the high technological level of their irrigation systems, the cultivation on hydroponic soils, and the good quality of the consumed water.
B. *Cluster 2: Users* (N = 65, 43.1% of sample). They have the longest experience in the sector and their education level corresponds to compulsory schooling. They own traditional greenhouses with sanded soils that were built over ten years ago. The average holding dimension is less than 2 ha. The employed labour amounts to seven employees per season, and 21% of them are farmer family-bounded labour. The tomato monoculture is widely extended. They usually trade their produce through a cooperative or a local market. They mostly use underground water for irrigation and they have their own wells or are members of a community-managed well. However, the mixture of groundwater and desalinated seawater is usual. The aim of this practice is to reduce the salinity level of irrigation water and improve the crop output. High quality irrigation water is obtained using this mixing technique. The water consumed per hectare is also lower than the average in Almeria province.
C. *Cluster 3: Non-users* (N = 60, 40.2% of sample). They show long experience in the intensive agriculture sector and their educational level is basic. There are some similarities with the

Table 4
ANOVA analysis.

Variable	Description	Conglomerate Root mean square	gl	Error Root mean square	gl	F	p-value ([a])
V_1	Farmer's age (years old)	245.150	2	64.846	147	3.780	.025
V_2	Years of farming experience	256.845	2	19.321	147	13.294	.000
V_3	Level of education.	11.570	2	.301	147	38.461	.000
V_4	Type of soil.	6.200	2	.885	147	7.002	.001
V_5	Type of greenhouse.	11.047	2	.792	147	13.945	.000
V_6	Agricultural holding size	5.934	2	.405	147	14.666	.000
V_7	Construction year.	524.421	2	20.894	147	25.099	.000
V_8	Climate monitoring system.	.027	2	.159	147	.170	.844
V_9	Labour	1201.916	2	48.000	147	25.040	.000
V_{10}	Percentage of farmer family-bounded labour.	16565.761	2	315.304	147	52.539	.000
V_{11}	Monoculture level.	16.653	2	1.115	147	14.938	.000
V_{12}	Yield difference in kilograms compared to the mean yield of the Almería province.	.136	2	.047	147	2.880	.059
V_{13}	Trading channel.	15.959	2	1.082	147	14.753	.000
V_{14}	Technological level.	105.056	2	16.360	147	6.422	.002
V_{15}	Percentage of desalinated seawater use.	58342.648	2	181.620	147	321.234	.000
V_{16}	Level of electrical conductivity of irrigation water (d/m).	7.901	2	.752	147	10.513	.000
V_{17}	Percentage of average water consumption per ha, crop type, and cycle compared to the average in the province.	.821	2	.005	147	177.885	.000

[a] With a 95%-reliability, all variables are significant except for V_1, V_8, and V_{12}.

Table 5
Farmer group clusters.

Variable	Description	Cluster 1 Intensive users	Cluster 2 Users	Cluster 3 Non-users
V_2	Years of farming experience	18.35	24.71	20.53
V_3	Level of education	Upper secondary education	Compulsory education	Compulsory education
V_4	Type of soil	Hydroponic/Sanded	Sanded	Sanded
V_5	Type of greenhouse	Multi-tunnel	Sloping roof	Sloping roof
V_6	Agricultural holding dimension (ha)	3.3	1.8	0.9
V_7	Construction year	2007	2004	2000
V_9	Labour	19.5	6.4	3.3
V_{10}	Percentage of farmer family-bounded labour	11	21	56
V_{11}	Monoculture level	Repeated crop due to prices	Repeated crop out of necessity	Repeated crop out of necessity
V_{13}	Trading channel	Cooperative/direct sale	Cooperative/local market	Cooperative/local market
V_{14}	Technological level	23.1	19.6	18.3
V_{15}	Percentage of desalinated seawater use	77	43	0
V_{16}	Level of electrical conductivity of irrigation water (d/m)	2.05	2.88	3.15
V_{17}	Percentage of average water consumption per ha, crop type and cycle compared to the average in the province (100%)	85	92	111
	Agricultural holdings total:	25	65	60

previous cluster but their agricultural holdings are smaller and older. Due to the reduced dimension, the number of employed labour is also small. Most employed labour is farmer family-bounded. They usually sell their produce through traditional trading channels and they cultivate almost exclusively tomato. They choose this crop type because of the high salinity level in the irrigation water they have access to. They consume the highest irrigation water volume per year, which is higher than the average consumption of water for irrigation in the province of Almería. This high level of water consumption is because of the need to wash soils to reduce high salt concentrations. They also consume more water than the other two groups as a consequence of the low technological level of their irrigation systems.

3.3. Preferences and attitudes regarding desalinated seawater

In the questionnaire three questions were asked regarding this subject. In the first step, farmers were asked to indicate their preferences regarding the different sources of irrigation water under the same price conditions. The two preferred options in the three clusters were groundwater and surface water (Fig. 2). Clusters 2 and 3 preferred recycled water as a third option and at the last instance, desalinated water. Only cluster 1 has preferred desalinated seawater as a third option and recycled water in the fourth position. In this case, their experience as irrigation farmers with desalinated seawater seems to have positively influenced their preferences. This is the most differentiating factor compared to the other two groups. The set of factors that condition these preferences will be analysed later. Similarly, in their study on the use of waste water for irrigation of vegetables in Ghana, Owusu et al. (2012) have shown how previous experience increases positive attitudes. In their study on the use of recycled water in India, Rekha and Ambujan (2010) also found that the experience of farmers with effluent irrigation is one of the key variables which affects their positive perceptions because it helped them critically evaluate the adverse and beneficial effects of this source of water.

In the second step, farmers were asked to assess the different factors linked to the use of desalinated seawater for irrigation:

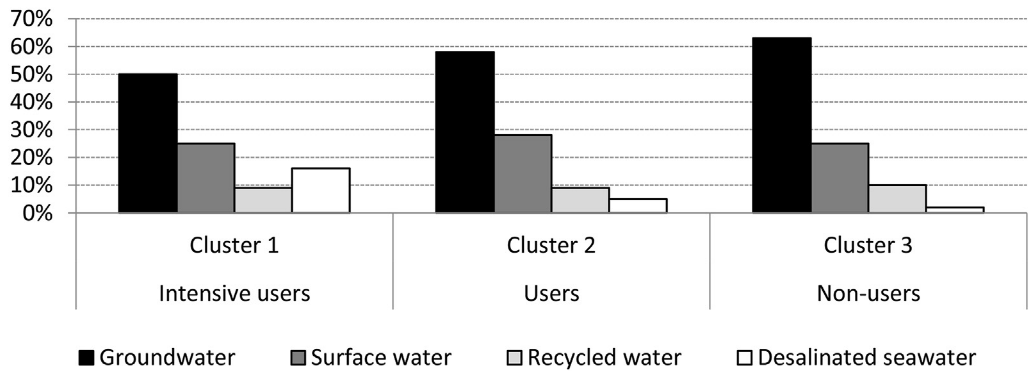

Fig. 2. Preferences regarding water supply sources under the same price conditions per cluster type.

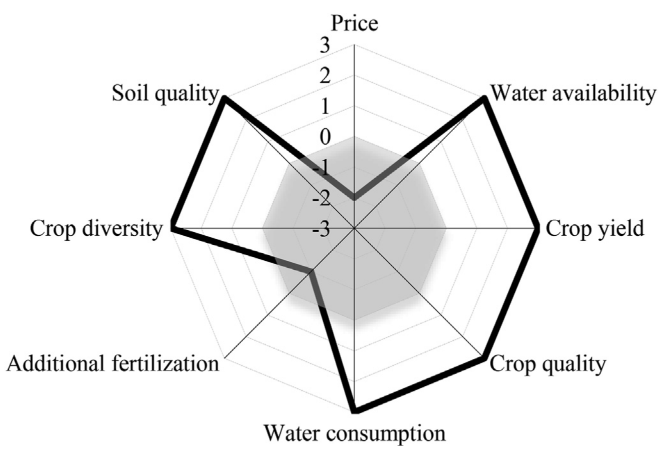

Fig. 3. Assessment of factors related to the use of desalinated seawater for irrigation (cluster 1).

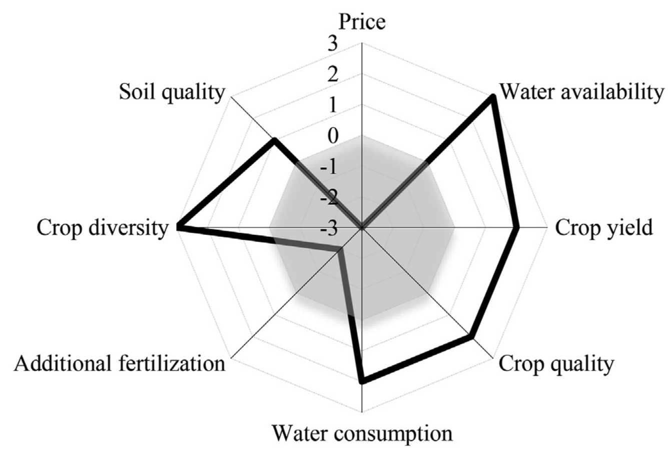

Fig. 4. Assessment of factors related to the use of desalinated seawater for irrigation (cluster 2).

price, availability, crop output, production quality, consumed water, necessity of additional fertilisation, crop variety, and maintenance of soil quality. In cluster 1 (Fig. 3), farmers consider that the use of desalinated water has more advantages than disadvantages. Thus, they give the highest value to the agronomic advantages like output increases and crop quality. They also consider that this source of water helps maintain soil quality as it has a lower salt concentration level. Furthermore, they also value positively that the total amount of the consumed irrigation water is reduced since they do not have to wash the soil due to salt surplus. Desalinated seawater also offers the option to introduce a higher cultivation variety since they are not constrained to salt-tolerant crop types. They consider that the two main disadvantages of desalinated seawater are the high price and the need to add fertilisers.

In the case of cluster 2 (Fig. 4), advantages and disadvantages are the same as in cluster 1 but with slight assessment differences. Thus, advantages regarding crop outputs and quality are not clearly perceived, and they are not taken into account when assessing water consumption and the maintenance of soil quality. However, disadvantages are more pronounced.

In cluster 3 (Fig. 5) assessments are quite different. The only two mentioned advantages are the constant availability of desalinated water and the option to introduce new crop types. Besides its high price and the need to add fertilisers, they also consider negatively that outputs are reduced because of its low level of essential salts for the crops. Furthermore, they do not seem to be convinced that water consumption is reduced and that desalinated water contributes to maintaining soil quality. These results show that farmers are concerned not only with water price, but also with its singular chemical composition. These findings disagree with other analyses indicating that price is the only explanatory factor for the low use of desalinated seawater for irrigation in Spain (Grindlay et al., 2011; García-Rubio and Guardiola, 2012; Swyngedouw, 2013; March et al., 2014).

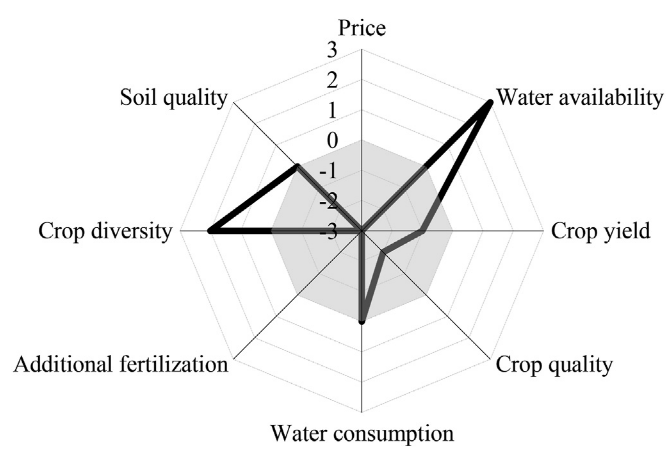

Fig. 5. Assessment of factors related to the use of desalinated seawater for irrigation (cluster 3).

The great discrepancy regarding the assessment made by users and non-users has also been pointed out by a study about the use of waste water for irrigation in Nepal (Rutkowski et al., 2007). Water availability is considered the most important factor in all the three clusters. This result was expected. The greater the scarcity of water in a territory, the more its availability is valued. And the study area suffers the most severe water scarcity problems in South-east Spain. In all analysed cases, the main disadvantage for desalinated water use is its high price, which is approximately double the price compared with groundwater. This disadvantage does not appear in the case of recycled water. Its low price is one of the main fostering factors for its use (Mojid et al., 2010; Petousi et al., 2015). Moreover, the need to add fertilisers seems to be a relevant weakness in the use of desalinated seawater for irrigation due to its high level of purity. This could also increase productions costs. In contrast, the nutrient richness and the subsequent reduction of fertilising inputs are considered an important advantage for the use of waste water (Dare and Mohtar, 2018). In the same sense, farmers perceive in further studies that the use of waste water increases vegetable yields due to nutrient effects (Mojid et al., 2010; Carr et al., 2011). In our research, only the users of desalinated seawater for irrigation share this perception. In this sense, the wide gap between farmers' perceptions in cluster 3 (non-users) and scientific evidence regarding the effect on crop yield and quality stands out. In the study region, Valera et al. (2017) analyse tomato, watermelon, and pepper crops and conclude that a higher crop output and quality are achieved when irrigating with desalinated seawater compared with groundwater-irrigated crops. Abreu et al. (2018) have found that courgette plants irrigated with desalinated seawater increased courgette production outputs. They show a higher presence of glucose, fructose, and vitamin B3, as well as an improved antioxidant activity. Reca et al. (2018) study the watermelon and demonstrate that the use of a higher share of desalinated seawater (higher than 70%) is economically profitable due to the output increases which further compensate for the higher cost. The advantage on which the three clusters agree is the high level of availability as it can be used at any time throughout the year. The continuous flow and the availability of water throughout the year have also been mentioned by farmers as an important advantage of the use of recycled water for irrigation (Carr et al., 2011).

Thirdly, farmers were asked for the reasons they started using desalinated seawater as an irrigation source for their crops: low quality of underground water, crop diversification, output increases, organic crops, cultivation on hydroponic soils or other reasons. Over 60% of the farmers were forced to use desalinated seawater for irrigation because of the poor quality of underground water (brackish water) that they had access to (Fig. 6). The second most mentioned reason was the possibility for crop diversification. The use of desalinated seawater for irrigation allows the cultivation of plants which are less tolerant to salt. These two main reasons are the most relevant driving forces for the use of desalinated seawater for irrigation in our study region, representing over 80% of the answers. They also agree with the main factors behind the willingness to switch to desalinated water in Israel's Arava Valley (Ghermandi and Minich, 2017). The other reasons are related to the search for production improvement and are less significant. Thus, the third most chosen reason is the wish to improve outputs through the use of an irrigation water of a higher quality than underground water. The fourth reason stated in our study is that desalinated seawater allows organic cultivation since its use contributes to soil quality improvements owing to its low salt concentrations. The fifth ranked reason is that it allows cultivation on hydroponic soil. This cultivation practice requires nutrient solutions which are not possible with a high-conductivity water supply.

These findings have important implications for policy makers. Farmers are not only concerned with water price but also with agronomic effects on the crop quality. Under this situation, a strategy based on reducing the price of desalinated seawater in order to foster its use would not be a sufficiently effective method. Further measures should be introduced in order to overcome other barriers for its implementation. The huge gap between the non-users' perceptions and the scientific evidence is one of the most important barriers identified. The introduction of information campaigns is essential to close this gap. Information campaigns should be specifically addressed to non-users as they show the most negative perceptions toward the use of desalinated seawater. Farmers may be misinformed, as most of them do not have access to the full information on the benefits of irrigating with desalinated seawater. If they have to make decisions on desalinated seawater use, they need to have a better understanding of the scientific results regarding its quality and benefits.

The information is more likely to be transmitted and retained if it is relevant (Dean et al., 2016). Therefore, messages to non-user farmers should focus on their negative valued aspects which disagree with scientific evidence (crop output and quality). Moreover, the provision of comprehensive and open information is a key factor for establishing partnerships between the stakeholders involved in the desalinated water supply based on trust. It is very important to ensure that information initiatives are accessible to the target end-users. Therefore, it is necessary to develop effective communication channels and to build up trust between farmers and other stakeholders, such as policy makers and scientists. The studies also reveal that farmers generally reject the adoption of practices that interfere with their production (Gachango et al.,

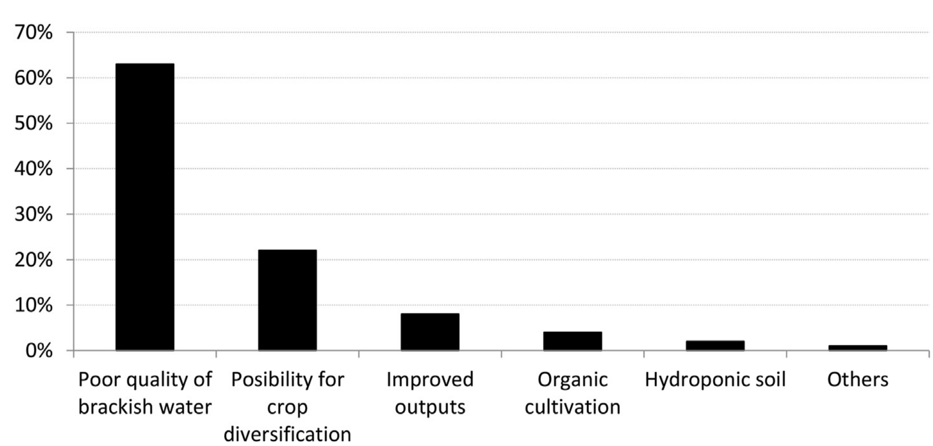

Fig. 6. Reasons why farmers have started to use desalinated seawater for irrigation.

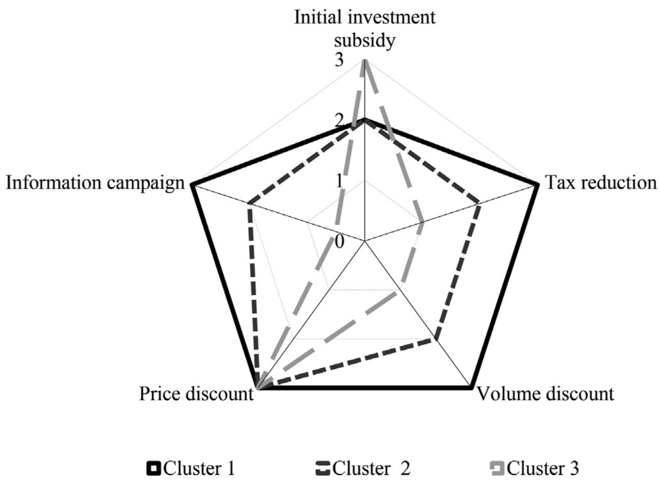

Fig. 7. Main measures promoting the use of desalinated seawater.

2015). It would be very interesting to launch programmes on technical advising and training regarding the use of desalinated seawater for irrigation.

3.4. Incentives for increasing the use of desalinated seawater

In the last section of the questionnaire, farmers were asked to assess incentives that could be implemented to foster the use of desalinated seawater for irrigation. The interviewed farmers again showed different opinions according to the cluster that they belong to (Fig. 7). The three clusters agree on the fact that price relief of desalinated seawater would be the most effective measure. This result was expected. Any producer will agree to a discount on the price of their inputs. In fact, previous literature considers price as the only factor determining farmers' preferences. Therefore, this result is consistent with this body of literature. Farmers from cluster 1 also point out that further tax measures and volume discounts on the consumed desalinated seawater would foster its use. They also value the relevance of information and dissemination campaigns on the effects of irrigating with desalinated seawater. This is a peculiarity of cluster 1. Cluster 2 values most the measure regarding price relief for all users. Cluster 3 farmers also value this measure most, but they also value to the same extent subsidies for the initial investments that are needed to start up using desalinated seawater for their crops (piping network, access points and registration fee to become part of the users' irrigation community). In this sense, the costs of system establishment have also been well evidenced as a possible barrier to implement decentralised water systems (Mankad and Tapsuwan, 2011). In our study, farmers who do not use desalinated seawater are small-scale farmers. Therefore, the connection to the main supply system represents a significant investment for them. All this suggests that supporting initial investments would be critical in promoting the general use of desalinated seawater. In this sense, when farmers from Israel were asked for their preferred type of assistance in the shift to desalinated water, the financial incentives covering up to 50% of building cost were considered the best (Ghermandi and Minich, 2017).

4. Conclusions

A survey of 150 farmers was conducted in South-east Spain, in the province of Almería, to provide current data on: 1) Farmer typology regarding their use of desalinated seawater; 2) farmers' preferences and attitudes towards desalinated seawater; and 3) farmers' assessment of proposed incentives to increase the use of desalinated seawater for irrigation. The cluster analysis has classified farmers into three homogeneous groups denominated as follows: 'intensive user' (cluster 1), 'user' (cluster 2) and 'non-user' (cluster 3). We list below the significant variables that allow us to identify the three farmers' groups: years of experience, education level, soil type, greenhouse type, agricultural holding dimension, year of initial greenhouse construction, employed farmer family-bounded labour, monoculture level, trading channel, technological level of the irrigation system, use percentage of desalinated seawater, level of electric conductivity, and consumed water on average.

Preferences and attitudes regarding desalinated seawater showed wide differences among the three farmer clusters. Groundwater and surface water are the preferred irrigation supplies by all farmers. Only in cluster 1 was desalinated seawater preferred in the third position before recycled water. Results showed that farmers are not only concerned about the water price but also about its singular chemical composition. The wide gap in cluster 3 (non-users) between farmers' perceptions and scientific evidence regarding the effect on crop yield and quality stands out. The use of desalinated seawater for irrigation by current farmers can be mainly explained by these two reasons: the poor quality of the underground water they have access to and the possibility of diversifying their crops.

Our findings indicate that there is still a great potential for increasing the farmers' level of desalinated seawater use. To achieve this goal a wide range of solutions should be introduced. On the one hand, economic incentives should be considered, like price discounts and investment subsidies. The latter should be addressed to non-user farmers and could be highly effective. Moreover, according to our findings, further measures should also be launched such as information and communication campaigns. They should be specially addressed to non-user farmers and focused on the key factors they are concerned about. The most appropriate communication channels should be involved. In the same way, the introduction of training and advisory programmes is considered an adequate and necessary promotion tool. Policy and management recommendations are made considering our research region but they can also be generalised for its application elsewhere.

It should be taken into account that the study was conducted in South-east Spain and that there could be differences in attitudes and behaviour of farmers in other geographic locations under a different water context. Nevertheless, the survey developed in this study could potentially be used in other regions where desalinated seawater projects are to be developed. Furthermore, the insights learned from this study could be useful for other areas where the construction of desalination plants has been proposed in order to increase the availability of irrigation water. It would also be of great interest for future studies to include other factors like environmental values, institutional conditions, and water shortage awareness, which all help understand in greater detail the possible reasons for attitudinal and behavioural changes. This study provides good foundations for future policies and strategies encouraging farmers to increase the use of desalinated seawater for irrigation.

CRediT authorship contribution statement

José A. Aznar-Sánchez: Conceptualization, Methodology, Investigation, Validation, Writing – original draft, Writing – review & editing, Supervision. **Luis J. Belmonte-Ureña:** Conceptualization, Methodology, Formal analysis, Investigation, Writing – review & editing. **Juan F. Velasco-Muñoz:** Methodology, Investigation, Writing – review & editing. **Diego L. Valera:** Methodology, Investigation, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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