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Why (Not) Desalination? Exploring Driving Factors from Irrigation Communities' Perception in South-East Spain

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Abstract: Desalination for sustaining agricultural production is conceived as an alternative water source in some Mediterranean countries faced with climatological and hydrological constraints. Although high costs are often cited as limiting factors, how farmers discern desalinated water has not been discussed in-depth in the literature. This paper aims to deepen how desalination is perceived by irrigators, what driving factors are affecting irrigation communities' decision-making processes, and what learnings can be drawn from their experiences regarding desalination acceptance or rejection. Eleven irrigation communities have been selected from Alicante and Murcia regions (South-East Spain), which account for more than 60,000 irrigators and 120,000 ha. Questionnaires were conducted between March and December 2019. Results highlighted the main advantages (water availability and supply security) and disadvantages (high price affecting profitable crop options, high-energy consumption, water quality standards, the production capacity of desalination plants, no seasonal variation in water production, and shortages due to technical problems) of using desalinated water. Additionally, through the analysis of regional and national press news, it can be concluded that socio-political aspects, such as corruption, cost overruns, and political disputes are also considered.

Keywords: water scarcity; desalination; irrigation communities; perception; driving factors; adaptation; water–energy–food nexus; Alicante; Murcia; South-East Spain

1. Introduction

The widely heard warning that 'the next war will be a water war' reveals that the issue of water conflict is expected to be one of the major threats to human life [1]. Water stress, which refers to the pressure on the quantity and quality of renewable water resources, is recognized as one of the most urgent environmental challenges facing humanity. As of 2018, average water stress worldwide is 13%, as reported by the Food and Agriculture Organization of the United Nations. According to predictions, by 2070, 20% of existing water will be diminished and the surface area under conditions of water stress will increase from 19% to 35% due to climate change [2]. About 60% of the global population currently lives in conditions of severe water scarcity for at least one month per year [3], and over one-third of the world's population lives in water-stressed countries, while by 2025, this figure is predicted to rise to nearly two-thirds [4,5]. Agriculture is the sector most affected by water scarcity, as it accounts for 70% of global freshwater withdrawals [6]. In fact, agriculture is both cause and consequence of water scarcity, as the excessive use and degradation of water resources are threatening the sustainability of livelihoods dependent on water-agriculture nexus. Irrigation systems are under pressure to produce more food with lower supplies of water [7]. Irrigated agriculture covers only 20% of total arable land; however, it consumes more than two-thirds of the total available freshwater, and the demand for good quality, non-saline water is increasing [8,9].

Water-scarce countries and communities need a radical re-think of water resource planning and management that includes the creative exploitation of a growing set of viable but unconventional water resources for sector water uses, livelihoods, ecosystems, climate change adaptation, and sustainable development [10]. The mismatch between water availability and demand in different temporal and geographical scales calls for new approaches [11]. The world's oceans contain over 97.5% of the planet's water resources and it has two unique features as a water source—it is drought-proof and is practically limitless. However, the high salinity of seawater and the significant costs associated with seawater desalination means most of the world's water supply has traditionally come from freshwater sources: groundwater aquifers, rivers, and lakes. Moreover, changing climate patterns combined with population growth pressures, and limited availability of new and inexpensive freshwater supplies, are shifting the water industry's attention: the world is looking to the ocean for 'freshwater' because conventional water sources are no longer sufficient to meet human demands in some water-scarce regions. Accordingly, desalination has been considered as an essential way to solve the global water crisis, able to deal with the problem of water resource shortage and to providing a reliable source of water even during extended drought conditions [12]. That is, desalination can extend a steady supply beyond what is available from the hydrological cycle, providing an 'unlimited', climate-independent and high-quality water supply [13].

The first large-scale desalination plants were built in the 1960s, and as reported by the International Desalination Association, there are now some 20,000 facilities globally that turn seawater into freshwater, and more than 300 million people currently getting their water from desalination plants. The Mediterranean region is one of the most vulnerable areas to climate change and droughts and water shortages are expected to continue [14,15]. Water supply from surface and groundwater sources has become increasingly unreliable in many coastal areas due to increased demand, saltwater intrusion into aquifers, and changing weather patterns. Spain built Europe's first desalination plant nearly 60 years ago (first plant installed on the island of Lanzarote in the Canary Islands in 1964) and is the largest user of desalination technology in the Western world (most often consisting of the majority of Europe, Australasia, and most of the Americas). Given the increasing controversy over surface water transfers, the government launched a program in 2004 (Programa AGUA) that aimed to increase water supply via desalination, wastewater reuse and irrigation efficiency, as the new panacea for Spain endemic and recurrent water crisis that until then had been addressed through water transfers between regions. The program outlined plans for the construction of 21 desalination plants along the Spanish Mediterranean coast, with a combined production capacity of 1063 million cubic meters (MCM)/year (approximately, the amount of water expected to be transferred from the Ebro river). From a hydraulic solution to another also hydraulic measure. The country has around 900 desalination plants, including the plant with the largest production capacity in Europe (Torrevieja with 80 MCM/year), and 8 out of 20 top world companies related to the construction of desalination plants [16]. The result: the widespread use of desalination in Spain is 5.7% of the global production and accounts for over half of the total desalination in Western Europe (9.2%), composed by the members of the Treaty of Brussels [17]. The amount of desalinated seawater has been increasing in Spain, especially in the eastern coastal regions, where the temporal irregularity in river flows and the excessive exploitation and pollution of underground waters (by agricultural activities and seawater intrusion) calls for alternative water sources to meet the water demands of the tourist populations and the irrigated agriculture [18]. In the regions of Murcia and Valencia, 17 large desalination plants have been built with a capacity of

442 MCM/year. In these regions, characterized by intermittent water scarcity seasons and frequent drought periods, agricultural production often cause the depletion of the existing water resources [19].

Different key barriers limit the promotion of desalination: (1) its management is more complex than the management of conventional resources; (2) its cost is more expensive than the cost of conventional resources; (3) it is perceived as being riskier than beneficial; and (4) its use is conditioned by regulation [20]. Research has particularly considered the technological aspects of desalination, with the vast number of publications addressing novel ('emerging') techniques that can produce desalinated water at lower economic costs and with less negative environmental implications [21]. In some cases, reductions in the economic cost of desalination associated with technological advances, coupled with rising costs and the diminishing supply and security of 'conventional' water resources, have made desalination a cost-competitive and attractive water resources management option around the globe [22]. However, the perception of the irrigators, due to their ergonomic characteristics and their quality/price profitability, is of vital importance and can be an obstacle to further developing desalinated seawater projects according to risk evaluation [23,24]. This fits well with an ongoing global debate around desalination as a water technology that affects nature–society relations, with emphasis on assessing technology, costs and design issues in parallel with farmers' opposition and public rejection as issues with the potential to affect desalination projects before, during, or after their execution [25]. Accordingly, successful implementation of a desalination project depends not only on its economic and environmental feasibility, but also mainly on the support of farmers and the general public, who, ultimately, pays for, and might be affected by, the associated risks [26]. In the last two decades, a significant body of knowledge has been accumulated identifying driving factors able to influence the acceptance or rejection of desalinated water [27]. For policymakers and managers attempting to pursue new desalination schemes, attention has been put on consumers' perception but there is little literature available on farmers' reactions to guide their policy, regulation, and investment decisions [28]. That is, although high (energy) costs, lack of essential ions for crop growth, and brine disposal are often cited as limiting factors to promote desalination, farmers' perspective regarding how to overcome such limitations is poorly studied on the literature [29]. Issues such as perceived health risks, environmental concerns, advances in science and technology, previous experience in using alternative water sources, water scarcity scenarios, perceived benefits, institutional trust, and corruption should be addressed [30].

The degree of adaptation and adjustment to the water variability will undoubtedly depend on farmers' adaptation capacity, which is based on the economic and technological development, and individuals' perception, attitudes, and yuck factor. In other words, how farmers perceive the risks and the process of dealing with water scarcity and how they perceive desalination as the potential solution to address this gap will determine and influence the success or failure of any decision and initiative taken by managers and politicians. The aim of this paper is to expand the understanding on how irrigation communities from South-East Spain perceive the pros and cons of using desalinated seawater. The results have two main practical implications: (1) by learning on which scenarios and under what terms desalination is conceived as a strategic mechanism to reduce water scarcity, and (2) by offering guidance about interventions that are likely to increase irrigators' acceptance.

2. Materials and Methods

2.1. Questionnaire Design

A questionnaire of 35 questions (combining multiple choices, open-ended and closed-ended questions) has been designed to deepen on irrigation communities' perception of desalinated seawater (Appendix A). The structure of the questionnaire was divided up into four different blocks according to the following topics. The first block contained ten questions about the profile of the irrigation community: year of registration, the number of irrigators, irrigated and irrigable surface and location, main crops, and irrigation method. The second block asked about water concession and desalinated seawater use in eight questions: water sources and volumes, water scarcity strategies, connection to the desalination plant, water concession and cost, and reasons for using desalinated water. The third block, based on eight questions, was about impacts and benefits when using desalinated seawater: electrical conductivity standards and assessments, identification of problems (boron) and measures of control, the priority of use according to different water sources, and main benefits and risks of using desalinated water. The last block contained nine questions about future scenarios motivating the use of desalinated seawater: reasons to increase the use of desalinated water, the maximum cost of desalinated water, environmental impacts clearly detected, measures to increase irrigators' acceptance of desalination, and climate change adaptation. The first version of the questionnaire was reviewed by a group of experts in seawater desalination from both irrigation communities and the Central Union of Tagus-Segura transfer Irrigators (hereinafter, SCRATS) in order to state the relevance and completeness of all questions. Experts provided suggestions and corrections, and, once considered, the questionnaire was tested in the study area.

2.2. Survey Methodology and Data Analysis

Questionnaires were conducted between March and December 2019. The questionnaires, in Spanish, were sent to each irrigation community secretary before the meeting took place, so that they could prepare some requested data. A face-to-face meeting was fixed with each irrigation community in its office. The president, secretary or technician of each irrigation community completed the questionnaire. Many of them commented that it was the first time that a direct interview on desalination was done from the academic field. Each meeting in person lasted between 60 and 90 min. During the meeting, the questionnaire was completed, and complementary data and information were obtained to further explore some specific open-ended questions. The interviews were audio-recorded. Two weeks after each meeting, the questionnaire was forwarded to each irrigation community secretary in order to be reviewed. Descriptive statistics and discursive analysis from the content of the questionnaires and qualitative information obtained during the interviews were used in data analysis.

2.3. Newspaper Literature Review

In order to check the answers obtained from the questionnaires and provide insights into local desalination for irrigation discourse, a regional and national literature review process focused on newspaper articles have been conducted. According to Lawhon and Makina [31], newspapers represent an important and under-examined proxy, which can contribute to our analysis of what issues are locally deemed important, how they are talked about, and how local framings relate to global environmental discourses as well as the topics and frames typically used and examined in scholarly research. Furthermore, newspapers create hybrid geographies reflecting both real space and non-spatial characteristics based on unique place interpretations that can influence the way that local people enact and perceive desalination and support or reject initiatives to reduce risks associated with water (scarcity, drought, contamination, allocation, etc.) [32]. Therefore, five newspapers have been consulted: La Verdad (Murcia, Spain), La Opinion (Murcia, Spain), and Diario Información (Alicante, Spain) from the regional press, and El País and El Mundo from the national press. The information from these newspaper archives is available digitally through, in part, restricted access. Fortunately, due to the emergency because of Covid-19, some newspapers have opened access to their publications and when this has not been the case (La Verdad) we have taken advantage of academic licenses and free months subscription. The combination of regional and national background is informed by our desire to compare specific and place-based knowledge with global and discursive representations of desalination challenges. Special issues of these newspapers were taken into consideration, especially those dedicated to the World Water Day. A five-year time period is used (1 January 2015–30 June 2020), which corresponds with a period of considerable discussion about the future of the Tagus-Segura transfer (hereinafter, TST) in the region, and associated attention on water by the politicians, managers, and citizens. Two keywords have been used simultaneously: "irrigation" and "desalination". Among the three newspapers from the regional press, more than 2000 results have been collected, which have had to be refined to avoid duplication of similar news and eliminate those that, containing the keywords used, referred to technical issues not relevant to this investigation. The results obtained from the national press do not reach 500 news. Opinion pieces and letters to the editor have been excluded from the analysis.

3. Study Area

The irrigation communities surveyed in this study are located in South-East Spain, mainly located in the Region of Murcia, as well as the Alicante and Almería provinces, and included within the Segura River Basin District. This area is characterized by a semiarid Mediterranean climate and water scarcity, as a result of the high water demand exerted by agricultural activities. During the second half of the 20th century, in order to meet the strong increase in the demand for water resources for agricultural and urban-tourist uses, a policy framework based on surface and groundwater exploitation has been promoted, including water transfers such as the TST, which began to operate in 1979 to transfer resources from the head of the Tagus River to that of the Mundo River, in the Segura basin, through a 286 km channel and 33 m^3/s. Selected irrigation communities are integrated in the SCRATS, since most of them were formed after the opening of the TST. This infrastructure is of enormous importance, since in total it represents more than 30% of the water resources available in the Segura river basin. The volumes to be transferred in a first phase were set at a maximum of 600 MCM/year, and in a second phase at 1000 MCM/year. However, not all the water from the TST reaches the Segura River Basin District. The distribution is made proportionally according to the maximum transferable volume: 335 out of 400 MCM/year for irrigation are destined for the Segura hydrographic basin [33]. However, since it came into operation, the average flow rate has not exceeded 320 MCM to be distributed among different water uses. In addition, in 2014 the operating rules of the TST were modified, raising the threshold of minimum reserves stored in head reservoirs from 240 to 400 MCM/year to be able to transfer, which has further reduced water shipments, with long periods of closure of the transfer. In order to address this situation, the AGUA Program (2004) was enacted to promote desalination. The Hydrological Plan of the Segura River Basin District fixed a maximum potential desalination capacity of 332 MCM/year in 2015, while 2033 scenario fix a maximum potential capacity of 339 MCM/year. However, actual production capacity is not expected to reach this horizon, since the high rate of the desalinated resource exceeds the payment capacity of a large part of the agricultural users (around 60% of the production of desalinated water goes to agricultural uses).

The sum of all the water resources available at Segura River Basin District reports that 1280 MCM/year are available for consumptive and non-consumptive use. However, the total estimated demands in 2015 was 1878 MCM/year, highlighting a water deficit of almost 600 MCM/year. Furthermore, by subtracting the average figures transferred by the TST, the deficit could exceed 900 MCM/year.

3.1. Desalination for Irrigation Uses

In our study area, the reverse osmosis is the seawater desalination process in all the plants analyzed. However, there are four types of desalination plants according to their owners, which have supplied desalinated water to the irrigated communities surveyed, permanently or temporarily. Firstly, there are up to four desalination plants operating owned by the Sociedad Estatal de las Cuencas Mediterráneas (hereinafter, ACUAMED), a Spanish public company dependent on the Spanish Ministry for the Ecological Transition and the Demographic Challenge. These plants are Carboneras, which opened in 2005 with a maximum production capacity of 44 MCM/year and 120 thousand cubic meters (TCM)/day; Valdelentisco, which started operating in 2008, with a current production capacity of 48 MCM/year and 128 TCM/day; Águilas-Guadalentín, whose construction was complete in 2011, and have a desalination production capacity of 70 MCM/year and 200 TCM/day; and Torrevieja—that was the last one to go into operation, with a desalination capacity of 80 hm^3/year and 240 TCM/day, and is connected with the reservoir of La Pedrera, with a storage capacity of 246 MCM, which in turn is part of the Tagus-Segura post-transfer hydraulic infrastructure.

Secondly, there is the desalination plant of Alicante I, owned by the Mancomunidad de Canales del Taibilla (MCT), the entity in charge of the urban raw water supply of 80 municipalities mainly in the Region of Murcia and the province of Alicante, operating since 2003 with a production capacity of 24 MCM/year and 65 TCM/day. Thirdly, there are two desalination plants owned by the irrigation communities of Mazarrón (Virgen del Milagro), with a production capacity of 12 MCM/year, and Águilas (Miguel García), with 8 MCM/year. After a period characterized by water scarcity in the mid-1990s, many farmers and irrigation communities opted to install little desalination plants, mainly in Alicante, Murcia, and Almeria provinces [34]. The National Government (40%), Regional Government (20%), and the irrigation community (40%) financed these desalination plants. Lastly, the Murcia regional government installed the Escombreras desalination plant in 2009, which has a production capacity of 22.8 MCM/year.

3.2. Recent Development of Desalinated Water Production

The modification of the TST regulation in 2014 and 2015 (by the Royal Decree 773/2014 and the fifth additional provision of Law 21/2015) have intensified the restrictions in water transfers, which have even closed the delivery of water during several months a cause of the drought experienced between 2015 and 2018 in the headwaters of the Tagus and Segura river basins. This situation has motivated the approval of emergency measures by the Segura River Basin Authority in May 2015 (Royal Decree 356/2015, extended to September 2019) in the so-called Drought-Decree. This Decree has enabled temporal authorizations for the use of desalinated water in the Segura River Basin to the SCRATS of 39 MCM/year until the end of 2018, and 79 MCM/year in 2019 from the Torrevieja and Valdelentisco plants, whose price was subsidized after the approval of the Order AAA/2965/2015 in November 2015 by the Spanish National Government. This subsidy established a fixed price of 0.30 €/m^3 for the desalinated water coming from the Torrevieja desalination plant, as well as a 0.10 €/m^3 reduction for the desalinated water produced in the Valdelentisco plant. Likewise, the Drought Decree has allowed extending the desalination distribution network, especially for the Águilas-Guadalentín and Valdelentisco plants. The guiding principle of these actions was to apply a shock plan to optimize the development of the desalination in the Segura River Basin (expressed in Spanish as ”Por un Mediterráneo sin sed”).

In order to solve the lack of infrastructure and regulation capacity, as well as the limitations of the distribution network, the SCRATS manages a system of water concession swap between irrigation communities that have allowed the exchange of conventional water concessions for desalinated water ones among coastal and inland irrigators. In this way, the irrigation communities of Alhama de Murcia, Librilla, Lorca, El Saltador, and Pulpí receive additional conventional water sources conceded to another one, such as Campo de Cartagena or even the MCT, which transfer their water rights in exchange of desalinated water produced in the Torrevieja desalination plant. However, the irrigation communities that receive conventional water sources through this swap system have to pay this water as if it were desalinated, in order to transferors do not suffer additional expenses. All these measures, activated following the enactment of the Drought Decree, has enabled the expansion of the production of desalinated water for irrigation uses, especially in the desalination plants owned by ACUAMED (Figure 1).

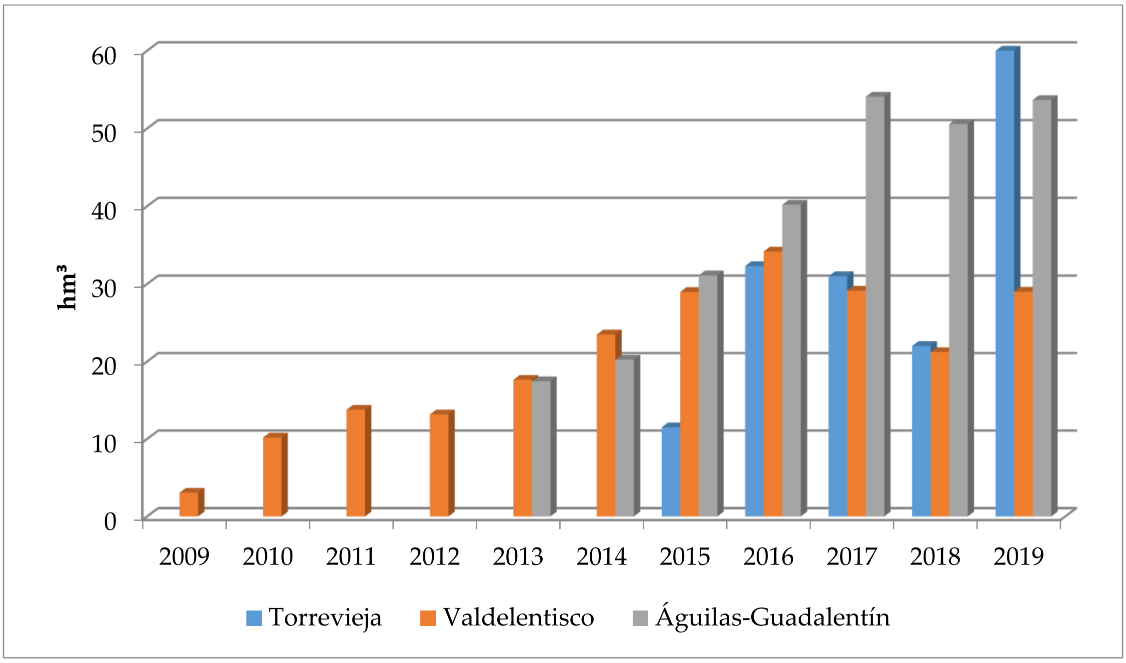

Figure 1. Desalination production for irrigation uses in Sociedad Estatal de las Cuencas Mediterráneas (ACUAMED) plants (2009–2019).

4. Results

4.1. Irrigation Communities Characterization

The 11 irrigation communities surveyed account for almost 60,000 irrigators and more than 120,000 hectares (ha), which represents more than 80% of the TST irrigated land (Table 1). Regarding its irrigated surface they can be grouped in small irrigation communities (El Saltador, Mazarrón, Librilla, and Puerto Lumbreras), with less than 5000 ha; medium irrigation communities between 5000 and 7000 ha (Águilas, Alhama de Murcia, Pulpí, and Totana); and large irrigation communities with more than 20,000 ha (Campo de Cartagena, Lorca, and Riegos de Levante). Taking into account the average farm size, or the ratio between irrigated area and number of irrigators, it could be stated that the irrigation communities where the largest farms and large agro-export companies are located are Águilas, Campo de Cartagena, Mazarrón, Puerto Lumbreras and Pulpí, which presents a higher presence of drip irrigation. In relation to the main crops, although there are differences in the diversity and importance of each crop, there is a general specialization in horticultural products (lettuce, tomato, broccoli, artichoke, or celery), as well as citrus, table grapes, melons, and watermelons.

Table 1. Irrigation community's description.

Irrigation Community	Irrigated Surface (ha)	Irrigators	Average Farm Size (ha)	Drip Irrigation Surface (%)	Concessions and Temporal Authorizations of D.W.	Connections with Desalination Plants
Águilas	≈5000	1620	3	100	21.5 MCM (16.5 from A.G. and 5 MCM from M.G.)	Águilas-Guadalentín and Miguel García
Alhama de Murcia	5096	2318	2.2	80	1.1 MCM from A.G. [1] and 2.2 MCM of temporal authorization from V. and T. by swap	Valdelentisco
Campo de Cartagena	38,319	9678	3.9	96	28 MCM of temporal authorization from T. and E.	Torrevieja and Escombreras
El Saltador	≈2300	1000	2.3	98	2 MCM of temporal authorization from T. by swap and a not specified volume from C.	Carboneras and Bajo Almanzora

Table 1. *Cont.*

Irrigation Community	Irrigated Surface (ha)	Irrigators	Average Farm Size (ha)	Drip Irrigation Surface (%)	Concessions and Temporal Authorizations of D.W.	Connections with Desalination Plants
Librilla	2025	1916	1	40	2 MCM of temporal authorization from T. by swap.	None
Lorca	23,905	12,500	1.9	80	23 MCM from A.G. and a not specified volume from T. by swap.	Águilas-Guadalentín
Mazarrón	3595	1150	3.1	100	14 MCM from V.M.	Virgen del Milagro and Valdelentisco
Puerto Lumbreras	≈3000	880	3.4	90	6 MCM from A.G.	Águilas-Guadalentín
Pulpí	≈7000	1239	5.6	70	6.5 MCM from A.G.	Águilas-Guadalentín and Bajo Almanzora.
Riegos de Levante	≈24,000	22,000	1	45	Punctual and temporal authorizations from Alicante I and temporal authorizations from T. transferred to SCRATS	Torrevieja and Alicante I
Totana	6979	4216	1.6	80	2.78 MCM from A.G.	Águilas-Guadalentín

Note: A.G.: Águilas-Guadalentín; B.A.: Bajo Almanzora; C.: Carboneras; M.G.: Miguel García; T.: Torrevieja; V.: Valdelentisco; V.M.: Virgen del Milagro; MCM: million cubic meters. [1] Cannot be received due to lack of distribution network.

4.1.1. Administrative Situation, Management System, and Technical Limitations

It should be borne in mind the administrative situation regarding water concessions and desalination water rights, as well as the different management models that irrigation communities have according to desalinated water use. In this regard, they have been grouped according to these characteristics (Figure 2). In relation to water allocation, four out of eleven irrigation communities have only temporal authorizations for the use of desalinated water (Alhama de Murcia, Campo de Cartagena, Librilla and Riegos de Levante). These are mainly the irrigation communities that have no connection with the Águilas-Guadalentín desalination plant or the small desalination plants owned by the irrigation communities, which have already allocated all their production through water concessions.

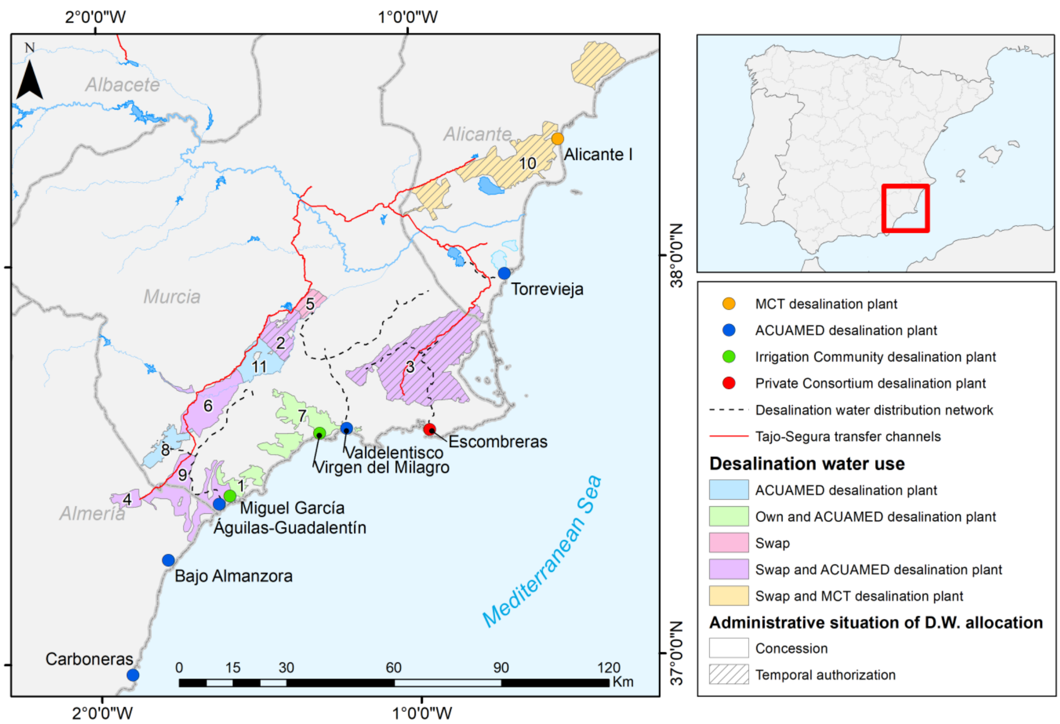

Figure 2. Study area location and group of irrigation communities according to their use of desalinated water. Irrigation communities: 1. Águilas; 2. Alhama de Murcia; 3. Campo de Cartagena; 4. El Saltador; 5. Librilla; 6. Lorca; 7. Mazarrón; 8. Puerto Lumbreras; 9. Pulpí; 10. Riegos de Levante; 11. Totana.

Furthermore, it also needs to differentiate which irrigation communities use desalinated water directly from that which have established agreements, managed through the SCRATS, for a swap system that enables the exchange of water allocations with littoral irrigation communities, and the regional urban water supplier, the MCT, which transfer their conventional water sources rights for desalinated water produced in the Torrevieja desalination plant. Among irrigators who are involved in this swap system it can be distinguished three different realities: (1) those who do not use desalinated water at all due to lack of connections with no desalination plant (Librilla) or because swap all their temporal authorization for desalinated water use in exchange of conventional sources (Riegos de Levante); (2) those who receive water from conventional sources through the swap system and also use desalinated water through temporal authorization (Alhama de Murcia) or desalinated water concessions (Lorca, Pulpí and El Saltador), and (3) those who swap their conventional water concession in exchange of desalinated water produced in the Torrevieja plant (Campo de Cartagena). Likewise, among the irrigation communities which have approved desalinated water concessions, we can differentiate between those who owned a little desalination plant and also use desalinated water from an ACUAMED plant (Águilas and Mazarrón) and those who only use water from the ACUAMED desalination plants (Puerto Lumbreras and Totana).

In addition to this, it is necessary to take into account the time that the irrigation communities have been using desalinated water, which can influence the perception of this supply source. In this regard, three groups can be distinguished. First, the irrigation communities with their own desalination plant (Mazarrón and Águilas), which have been using desalinated water since the mid-1990s and early 2000s, respectively. Secondly, those irrigation communities that begin to use the desalinated water from the Águilas-Guadalentín plant before 2015 (Lorca and Pulpí). Thirdly, the other irrigation communities began to use desalinated water between 2015 and 2016 after the approval of the Drought Decree.

It must be also considered that some irrigation communities cannot receive their entire desalination water concession due to technical limitations, such as the case of Alhama de Murcia, El Saltador, and Pulpí. In the first case, in spite of having a concession of 1.1 MCM could not receive it at the end of 2019 because it was not yet connected to the distribution network of the Águilas-Guadalentín plant. The remaining two irrigation communities have been affected by the suspension of the production in the Bajo Almanzora plant, which stopped working since 2012 after being affected by a flood episode that disabled the infrastructure and paralyzed the concession procedures.

4.1.2. Percentage of Desalinated Water with Respect to the Total Available Resources

At the end of 2019, the situation of the proportion of desalinated water in relation to the water available at the delivery points of each irrigation community was remarkable in some irrigation communities (Figure 3). On the one hand, in the irrigation communities with its own desalination plant, those of Águilas and Mazarrón, desalinated water represents more than 90% of total available water. Those that receive water from the Águilas-Guadalentín desalination plant (owned by ACUAMED) through approved concessions (which are Águilas, Totana, Lorca, Puerto Lumbreras, and Pulpí) present also high proportions of desalinated water. On the other hand, there is a group of irrigation communities whose administrative situation regarding the use of desalinated water is temporarily authorized. Reasons are several: the concession process is pending (Campo de Cartagena, Alhama de Murcia, Librilla, El Saltador); technical problems in the desalination plants, as occurred in Bajo Almanzora that affected El Saltador; or lack of distribution network in the case of Alhama de Murcia regarding Águilas desalination plant. In this case, the proportion of desalinated water is lower than in the other irrigation communities, between 20% and 30%. It has to be noted that the irrigation community of Librilla accounts for water from conventional sources that receive by the swap system as desalinated water. Respecting Riegos de Levante irrigation community, they give their desalination water concession up to be used by the Campo de Cartagena irrigation community, so they do not use desalinated water except in specific situations in which they resort to the desalination plant Alicante I, belonging to the MCT, in charge of urban water supply. These issues may help to explain why the proportion of desalinated water is lower in this group of irrigation communities. Notwithstanding, during drought situations, the proportion of desalinated water available at the irrigators' delivery points exceeds 50% in seven irrigation communities and 33% in other three.

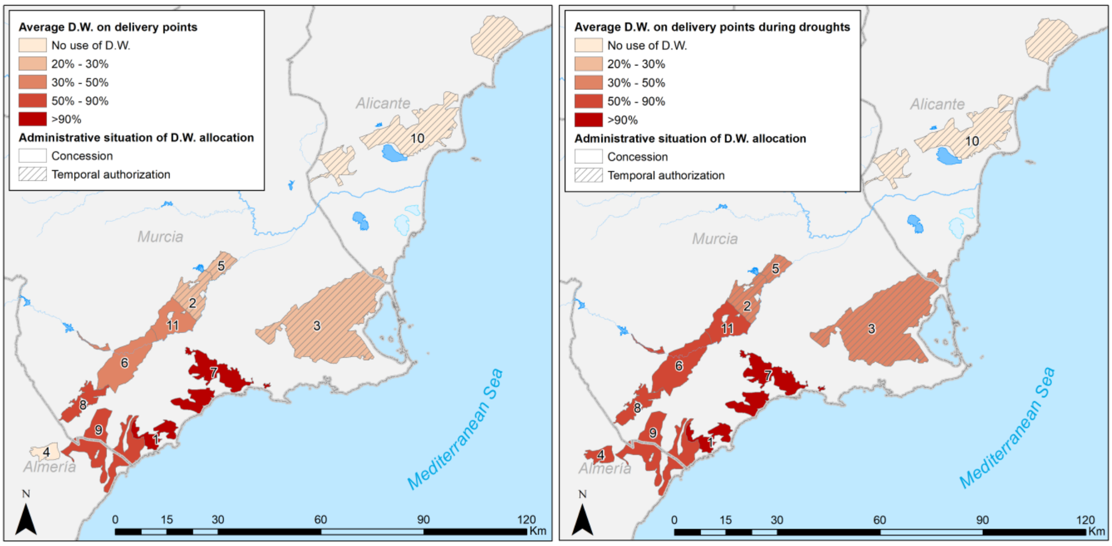

Figure 3. Average desalinated water (D.W.) use on delivery points in normal hydrologic conditions and drought situations. Note: irrigation communities: 1. Águilas; 2. Alhama de Murcia; 3. Campo de Cartagena; 4. El Saltador; 5. Librilla; 6. Lorca; 7. Mazarrón; 8. Puerto Lumbreras; 9. Pulpí; 10. Riegos de Levante; 11. Totana.

Despite the fact that desalinated water represents a large percentage of the total water resources used, it must be borne in mind that in most cases all supply sources are mixed in irrigation ponds. Only the irrigation community in Mazarrón declares that they irrigate only with desalinated water. Moreover, in Lorca, they affirm that sporadically when there is no other option, they have watered only with desalinated water, and in Totana they point out that some plots are also irrigated only with desalinated water. The factors that motivate the mixture are, mainly, to minimize the use of desalinated water to save costs by taking advantage of the conventional resources available and to increase the quality of the water resulting from the mixture.

4.2. How Desalination Is Perceived by Irrigators?

With the aim of evaluating how irrigators perceive desalinated water, three questions have been raised:

(1) What causes have motivated the use of desalinated water and which factors explain the seasonal variation in its consumption?
(2) How is desalinated water quality evaluated, including its evolution and future prospects?
(3) To what extent is this water source accepted among the irrigators, with respect to other water sources?

4.2.1. Motivation and Causes that Explain the Use of Desalinated Water

Regarding the reasons indicated for desalinated water use, the main causes pointed out by all the irrigation communities, except for the Águilas one, are to overcome structural and temporary under-provision of water. Only 3 out of 11 irrigation communities surveyed have a water concession equal to or greater than their water demand. Total water demand for all surveyed irrigation communities is 472 MCM/year, while the average water volume available is only 230 MCM/year and 142 MCM/year during drought situations. According to irrigators, this under-provision occurs in a greater number of cases with respect to water from the TST (8 out of 11), followed by other surface water sources (5 out 11), desalinated water (4 out of 11), purified water (2 out of 11), and underground water (1 out of 11). Water from TST represents more than half of the volume of the concessions of the surveyed irrigation communities (265 MCM/year); however, the available volume from this source is reduced to half in normal hydrologic situations and to 14% during droughts. Other causes that motivate the use of desalinated water is the need for higher water quality through its mixing with other poorer quality water resources, pointed out in 4 out of the 11 irrigation communities. In a testimonial way, the irrigation community of Campo de Cartagena indicates that they use desalinated water because there is no alternative and the Lorca one states that they also use desalinated water to favor the regularization of the irrigated surface. In summary, the main reason to use desalinated water is to ensure water supply. For practically all the irrigation communities, with the exception of those that have their own desalination plant, the average volume of water available at their delivery points is lower than their water concession. This situation is experienced most intensely in the irrigation communities of Pulpí, which only has available 23% of their water concession; El Saltador, with 33.1%; Alhama de Murcia, with 41.7%; Totana, with 48.3%; or Librilla, with 50.9%. Furthermore, these figures are much lower during drought situations in which the water available at the delivery points may be shorter than 20%. Likewise, it should be noted that in some irrigation communities the concession volume is even lesser than the water demand, which indicates that, except for the irrigation community of Águilas, all the others indicate that are affected by under-provision of water.

This situation has led to the progressive desalination development, especially from 2015 with the tightening of the conditions for the TST, the advent of a drought situation and the approval of the Drought Decree. Furthermore, to alleviate this situation, irrigators have implemented a series of measures. The ones most frequently indicated are the general restriction of water, with the exception of the Águilas and Mazarrón irrigation communities, which have their own desalination plant, and the establishment of water rights transfers, a measure that is centrally managed by SCRATS (both pointed out by 8 out of 10 irrigation communities). In the second place, the irrigators note that they depend on the use of emergency wells (managed by SCRATS during droughts situations), the making of recommendations on the water use to the irrigators and requesting temporal authorizations for the use of desalinated water (pointed out by 7 out of 10 irrigation communities). To a lesser extent, some irrigation communities declare to deal with under-provision through controlled deficit watering (pointed out by 4 out of 10 irrigation communities) or controlled overexploitation of aquifers (pointed out by 2 out of 10 irrigation communities). However, it is worth noting that in those irrigation communities involved in the swap system there is a greater heterogeneity of measures aimed to solve under-provision of water (Figure 4).

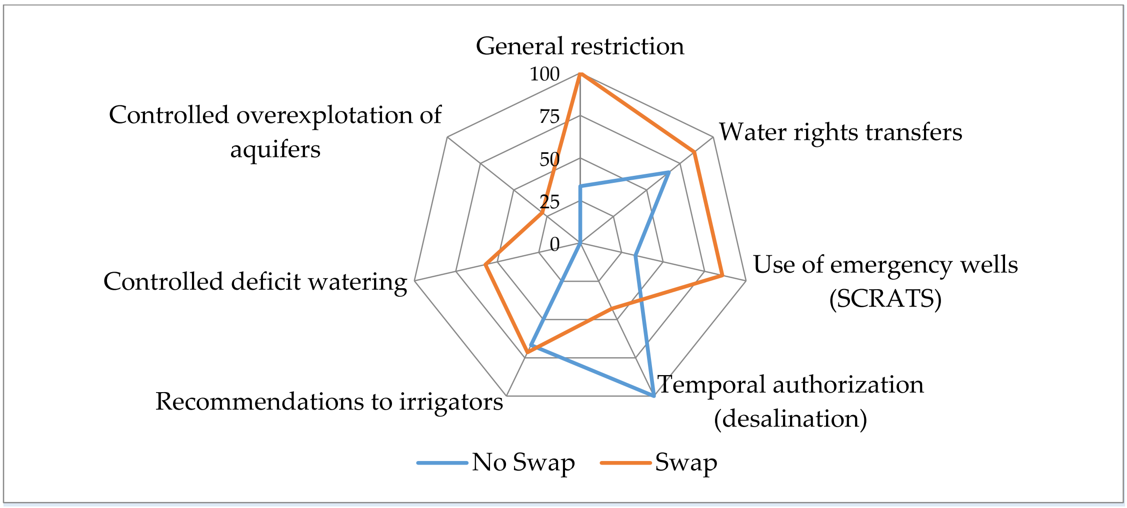

Figure 4. Measures applied to solve under-provision of water according to irrigation communities' involvement in the swap system (in percentage).

4.2.2. Perception of Desalinated Water Quality and Seasonal Water Use Variation

Regarding desalinated water quality perception, it should be noted that the best evaluations are made by irrigation communities with a considerable proportion of desalinated water in the total water they use, such as Águilas, Pulpí, and Lorca, which are also three of the four irrigation communities that have been using desalinated water for the longest time (Table 2). Likewise, it is worth noting that the worst desalinated water valuations are made by the irrigation community of Campo de Cartagena, which, in relative terms, is one of the communities that use less desalinated water (28.3% of the total water resources in normal conditions and 37.8% during droughts), and Librilla, which does not use desalinated water since it receives water from other conventional sources of supply through the swap system. This last case is striking since Librilla is the unique irrigation community that evaluates the quality of desalinated water as "bad" and the evolution of its quality as "fair". This case is explained by the influence that the problems experienced in the neighboring irrigation community of Campo de Cartagena with desalinated water quality and the high boron content have had on the perception of the irrigators of Librilla.

Table 2. Perception of desalinated water quality by irrigation communities.

Irrigation Community	First Year Using D.W.	Current D.W. Quality	D.W. Quality Evolution	Future Prospects on D.W. Quality
Águilas	2002	Very good	Very good	Very good
Alhama de Murcia	2015	Good	Good	Good
Campo de Cartagena	2015	Fair	-	-
El Saltador	2015	Good	Good	Good
Librilla	-	Bad	Fair	-
Lorca	2013	Very good	Very good	Very good
Mazarrón	1995	Good	Good	Good
Puerto Lumbreras	2015	Good	Good	Good
Pulpí	2013	Very good	Very good	Very good
Riegos de Levante	2016	Good	-	-
Totana	2016	Good	Good	Good

Note: A 5-Point Likert scale has been used (very bad, bad, fair, good, very good). D.W.: Desalinated Water.

Regarding seasonal variations in desalinated water use, irrigators claim heterogeneous responses. On the one hand, Alhama de Murcia, Campo de Cartagena, Puerto Lumbreras, and Totana affirm that there is not a maximum and minimum desalinated water use throughout the year since they receive a uniform monthly volume, although irrigation needs do with higher demand during summer. On the other hand, El Saltador and Lorca claim that desalinated water use rises during drought situations due to the reduction of the TST contribution. Likewise, some of the irrigation communities specialized in greenhouse and hydroponic crops, such as Águilas, Pulpí, or Mazarrón, pointed out that the maximum water use is produced between September and April. Beyond the seasonal variations in desalinated water use, the main factors that explain the greater use of this water source are that it is the only source available; it allows alleviating the structural under-provision of water; and it is a solution to drought situations. To a lesser extent, irrigators point out that the greater use of desalinated water is explained by its subsidized cost, because it allows avoiding the overexploitation of the aquifers during drought situations and that it increases the quality of the water used for irrigation (Figure 5).

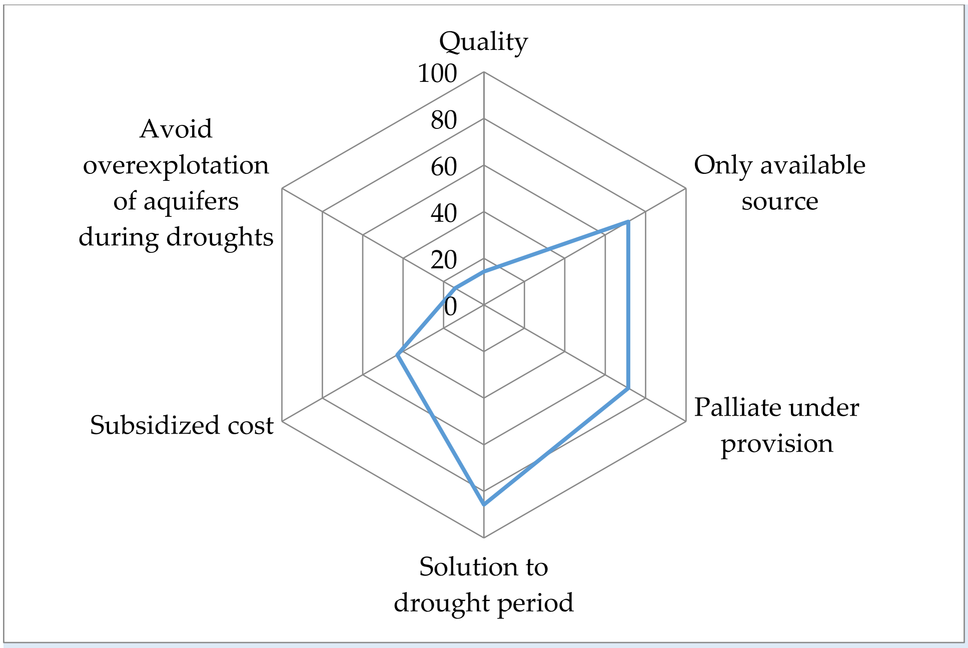

Figure 5. Explaining factors for a higher desalination water use.

4.2.3. Acceptance of Desalinated Seawater among Farmers

In a scenario based on a hypothetical situation where water prices where the same for all the supply sources, desalinated water appears as the third option after surface water (both from the Segura basin and from the TST) (Figure 6). These results confirm that in recent years it has been an evolution in the acceptance of desalinated water among farmers since in the Níjar municipality, located a few kilometers further south our study area, in 2016 desalinated water was the worst valued option [35]. However, in that case, the obtained results came from farmers who did not use desalinated water, although they were considering the possibility of using it.

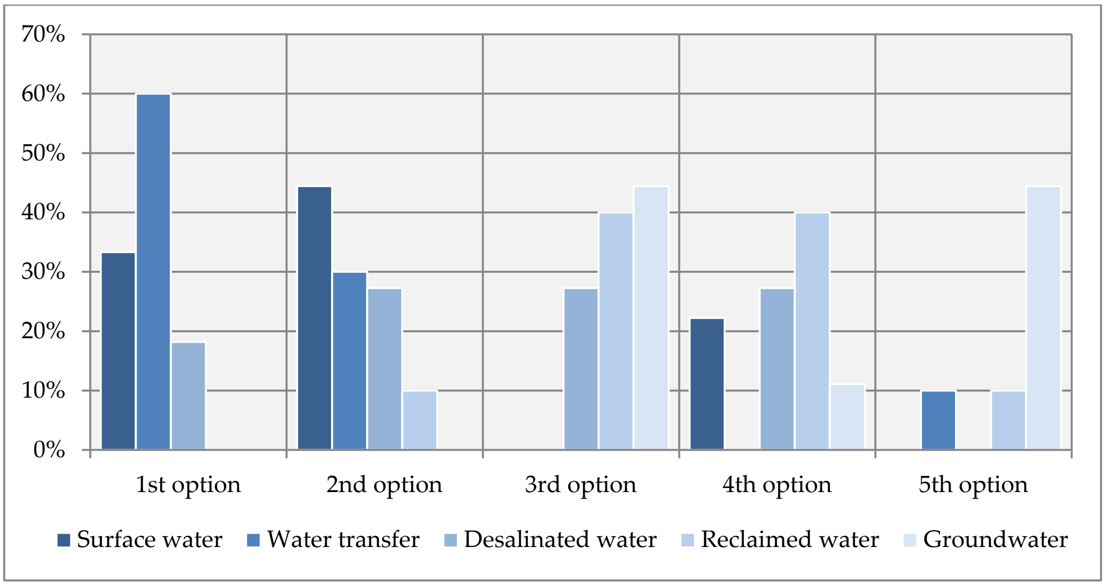

Figure 6. Priority of water use for irrigation according to supply sources regardless price.

For most irrigation communities, factors that will influence the future acceptance of desalinated water are mainly its price and the availability of water from conventional sources. Other reasons mentioned, although to a lesser extent, are the quality of desalinated water and its environmental impact. In order to increase desalinated water acceptance all irrigation communities agree pointing out the necessity to reduce its price. Other economic measures indicated are the promotion of subsidies for technical innovation and improve water quality (pointed out by 6 out of 11 irrigation communities), and receive financial bonuses according to the volume of water consumed (pointed out by 4 out of 11 irrigation communities). Likewise, the irrigators also indicate other technical, informative, or management measures aimed at increasing the acceptance of desalinated water. Regarding techniques, some of the irrigation communities connected to the Águilas-Guadalentín desalination plant (Águilas, Puerto Lumbreras, Pulpí, and Totana) believe that expert technical advice would improve the acceptance of this water source. In addition, in relation to informative actions, four irrigation communities claim that the implementation of information campaigns about benefits and impacts produced by desalinated water would improve its acceptance. In this sense, some irrigators state that it would be a good point to develop marketing campaigns to make visible in Northern Europe, where most of the production is going to, that vegetables and fruits are watered with desalinated water, which is the same water source as that for urban consumption.

Responses to the question of whether desalinated water could substitute other supply sources indicate that there is a division of opinion. On one side, five irrigation communities point out that desalinated water cannot replace any supply source since it is a complementary source to be added to the others. It should be noted that the large irrigation communities (Campo de Cartagena, Lorca, and Riegos de Levante), and those that do not have desalinated water concessions (Librilla and Alhama de Murcia), give this response. On the other side, the rest of the irrigation communities largely agree that desalinated water can replace groundwater, which is the main cause of high water conductivity due to over-exploitation of aquifers. Likewise, the irrigation communities that have their own desalination plant (Águilas and Mazarrón) indicate that in addition to groundwater, desalinated water could replace purified wastewater. It is noteworthy that some irrigating communities that suffer from under-provision and that have been seriously affected by the new TST regulations affirm that desalinated water could replace surface water (Pulpí) and even all sources of supply (Puerto Lumbreras).

Regarding the role of desalinated water as a complementary measure to face the possible impacts of climate change, such as an increase in the frequency and intensity of droughts or a greater irregularity in rainfall, there is a broad consensus. Practically all irrigation communities claim that the use of desalinated water is a useful measure to face a climatically uncertain future; however, some irrigators emphasize that a greater dependence on desalination would feedback climate change due to the high-energy demand and the increase in the emissions. Hence, some of them claim that it is necessary to improve technical performance to reduce energy consumption and promote the use of solar energy in desalination plants.

4.3. Which Driving Factors Are Affecting Irrigation Communities' Decision-Making Processes?

Water availability, ensuring water supply, and the improvement of water quality are the main advantages of using desalinated water indicated by irrigators, while the main drawbacks are diverse: its high price, the high energy consumption and CO_2 emissions, quality problems related with boron and lack of nutrients, the mismatch between production capacity and water demand does not adjust to the seasonal variation, and the increase of vulnerability to shortages due to technical problems in desalination plants. According to the main advantages and disadvantages perceived by the irrigators, the driving factors that may affect the irrigation communities' decision-making processes have been divided into two groups: desalination water quality and environmental impacts; and desalination water price.

4.3.1. Desalination Water Quality and Environmental Impacts

The main parameters in relation to the water quality of relevance to irrigators are conductivity and the presence of boron. In this sense, except for El Saltador and Riegos de Levante, all irrigation communities have their own control system to assess the quality of the desalinated water they receive, the majority of which is a permanent control process. In general, the conductivity values are kept between 400 and 600 µS/cm for the ACUAMED desalination plants, and 900 µS/cm for Escombreras plant, all showing slight seasonal oscillations. It should be noted that the community of irrigators of Águilas, which has and manages its own desalination plant, indicates that the conductivity of the water is variable according to the needs of the crop, with half of the production at 800 µS/cm and the other half at 1500/2000 µS/cm. In fact, apart from Águilas, in the medium or long term none of the irrigation communities plan to request desalinated water quality on-demand according to the crop needs. This option seems to be unfeasible for most of the irrigators since it would require having regulation reservoirs with different qualities for each type of crop.

Regarding boron, three irrigation communities have detected punctual problems, all of them supplied by the Águilas-Guadalentín desalination plant and using a large proportion of desalinated water with respect to the total water resources (Lorca, Pulpí and Puerto Lumbreras). These problems have been identified in long cycle citrus crops and tomatoes, therefore, when it is identified a high level of boron in desalinated water, it is tried to mix with water from other sources.

Apart from the problems associated with boron, the majority opinion among irrigators is that they do not know if there is any environmental impact resulting from the prolonged use of desalinated water in crops. Some irrigation communities indicate that they have perceived that the acidity has been able to produce corrosion problems in the distribution systems, although studies are still being carried out to find out potential problems, as indicated by Campo de Cartagena. Despite not identifying conclusive environmental impacts resulting from the use of desalinated water, 5 out the 11 irrigation communities internally debate the potential impact that desalinated water can have on the soil and crops. Among the aspects with the most agreement are high-energy consumption and CO_2 emissions, which generate a high price. Likewise, the impacts on the soil and crops cannot yet be evaluated since in most irrigation communities it has only been using desalinated water for five years. However, it should be noted that in Águilas and Mazarrón, where they have been using desalinated water for around 20 years, no problems have been identified in this sense. In general, there is a lack of knowledge regarding desalinated water impacts, since in many cases, farmers do not know the origin of the irrigation water and they attribute any problem to conductivity.

4.3.2. Desalination Water Price

As analyzed, there is a widespread consensus that the main obstacle for the use of desalinated water is its price, six times higher than TST water. The desalinated water price vary year-on-year due to investments and maintenance needs of the plants, the electricity price variation, and the updating of tariffs since the supply costs are reviewed annually. However, the subsidies applied to the Torrevieja plant during the drought period between 2015 and 2018 established a fixed price of 0.30 €/m^3. According to some irrigation communities, the fourth additional provision of Law 1/2018, by which urgent measures were adopted to mitigate the effects produced by the drought, this subsidy would be maintained under conditions not subject to drought situations. For this reason, many irrigation communities declare that they did not receive their subsidies at the end of 2019 (Campo de Cartagena or El Saltador). Some irrigation communities, such as Riegos de Levante, instead affirm that the subsidy was eliminated in 2018, so the interpretation of Law 1/2018 is not homogeneous. The problem is that, in the rest of the active desalination plants owned by ACUAMED (Valdelentisco, Águilas-Guadalentín, and Carboneras), this subsidy did not take place, which had the effect that many irrigation communities wanted to participate in the swap system, since the exchange of water allocations was produced with the desalinated water produced in Torrevieja.

It must be considered that the desalinated water supply price is, in almost all cases, much higher than the final affordable price, although mixing with other cheaper sources of water reduces the final price of the water used below this threshold. For most irrigation communities, below 0.30 €/m^3 all crops can be profitable (Table 3). However, if their water supply would depend only on desalinated water, the price of water supply would be between 0.47 and 0.80 €/m^3. This price includes the purchase price of the desalinated water, to which it must be added an increase of 7.5% of transport leakages estimated by the Segura River Basin Authority, 0.24 €/m^3 from the toll of using the distribution infrastructure and 0.07 €/m^3 for the SCRATS rate. Likewise, in some cases, the irrigation communities have their own fees and charges for the use of their infrastructure. This scenario would reduce profitable crop options, with agricultural activity practically unfeasible with water prices above 0.60 €/m^3.

Table 3. Desalination water supply price, final affordable price and types of profitable crops based on water price.

Irrigation Community	Desalinated Water Supply Price (€/m^3)	Final Affordable Price (€/m^3)	Crops that can Cope with a Price <0.30 €/m^3	Crops that Can Cope with a Price 0.30–0.60 €/m^3	Crops that Can Cope with a Price >0.60 €/m^3
Águilas	0.47	0.35	All	Vegetables in hydroponic crops	None
Alhama de Murcia	0.63	0.30	All	Table grape	None
Campo de Cartagena	0.66	0.20	Depends on market prices	Depends on market prices	Greenhouse crops
El Saltador	0.39	0.30	All	Vegetables and some trees	None
Librilla	0.73	0.30	All	Specific crops	None
Lorca	0.47	0.30	Fruit	None	None
Mazarrón	0.50	0.60	All	Vegetables	None
Puerto Lumbreras	0.55	0.60	All	Table grape and lettuce	Table grape
Pulpí	0.68	0.40	All	Citrus and vegetables	None
Riegos de Levante	0.80	0.30	Almost all	None	None
Totana	0.60	0.30	All	Table grape	None

4.4. How Desalination Is Conceived through Newspapers?

4.4.1. Regional Press

From the analysis of the news published in the main newspapers in the area regarding the use of desalinated water for irrigation, five main themes can be highlighted. The price of desalinated water and the expansion of new infrastructures (including the management of associated water concessions) are the two main issues, followed by the management of the Torrevieja desalination plant; concerns about water flows decrease from the TST; and agronomic issues and investigations that are being carried out in this line. Most news items are linked to the desalinated water price to be paid by irrigators [36], although from the end of 2015 to the end of 2018, irrigators received subsidies that have allowed watering at € 0.30/m^3, a price that they consider "reasonable and affordable by the sector" [37]. This issue is directly related to infrastructure expansions, especially those aimed at increasing desalinated flows [38], and new water concessions awarded to the irrigation communities [39]. Likewise, the press has echoed the connection project between Águilas, Valdelentisco, and Torrevieja desalination plants, and with the Azud de Ojós and the post-transfer channels [40,41].

The Torrevieja desalination plant has been the subject of various negative news reports. Reasons are multiple: fraud in contracts committed by the state entity ACUAMED [42], the delay in its start-up at full capacity, and the discontent generated during the allocation of its new concessions [43]. However, the regional press has also highlighted the benefits and positive aspects of its implementation as a complementary water source for both population and the agricultural sector [44]. To a lesser extent, the regional press also reflected the concern of the agricultural sector because of the decrease in freshwater delivery from the TST [45], which has already been one of the triggers for the promotion of desalination. The agronomic aspects associated to the use of desalinated water [46] highlighted the high concentrations of boron [47] as the main issue to be discussed and investigated according to specific research studies carried out in this line [48]. According to the conducted analysis, in just five years the initial reluctance to use desalinated water for irrigation [49] has been reduced [50] and desalination has gained strength to become an essential and stable resource for the sector, despite being considered as a complementary resource and requiring its mixture with other waters [51].

4.4.2. National Press

The analysis of the national press confirmed a matching topic with the concerns reflected at the regional scale, especially regarding the conflict over the price of desalinated water. However, other issues incite complementary interest, such as the political conflict around the management of water resources, the role of ACUAMED, or the need for a water resources alliance between surplus and deficit water resources territories. In general, less attention is paid to the perception of desalinated water, although some interest is put on the social rejection of desalinated water for human supply [52]. Concern about the high price of desalinated water is widespread among irrigators, asking for subsidies [53] and proposing, in many cases, energy savings by renewable energy, such as photovoltaic [54]. Cases of corruption and cost overruns linked to the construction of desalination plants is a recurring theme at the national scale [55], focused on the ACUAMED case [56], very popular during 2016. In addition, the underutilization of a large part of the desalination plants [57] and the political conflict between political parties and regional and national governments related to water resources [58,59], are also recurring themes in the national press. The promotion of a Water Pact, both at the provincial level [60] and at the national level [61], in which desalinated water for irrigation could be promoted and subsidized [62], seeks to solve this problem tacking into account that, in recent years, Spain has become a reference in the construction and operation of desalination plants worldwide [63].

5. Discussion and Conclusions

A steady and assured supply of high-quality water is crucially important in an era when the world at large is embarking on the Sustainable Development Agenda to ensure access to safe water for all by 2030, and for the achievement of Goal 6 to safeguard water supplies for current and future generations [64]. Furthermore, both in academia and in policy-making, it has now been recognized that sustainable food systems need to be assessed in an integrated manner [65]. According to the report "Adapt Now: A global call for leadership on climate resilience", published in 2019 by the Global Commission on Adaptation, adapting the planet's water resources and systems to the Anthropocene and the new climate reality is a formidable task. In this context, desalination has been proclaimed as an almost inexhaustible source of water that can meet growing water demands and buffer arid regions against climate change. In fact, while noting its high-energy costs, the Intergovernmental Panel on Climate Change lists desalination as an 'adaptation option', ensuring how in the near future desalination will possibly become an important source of water supply in semiarid and arid regions. However, a contradiction exists: the benefits of having a 'reliable' and 'rainfall-independent' water source can only be conceived through the application of vast amounts of energy and dismissing associated greenhouse gas emissions [66]. In order to address this gap, this paper expanded the understanding on how irrigation communities from South-East Spain perceive the pros and cons of using desalinated seawater, including current and future scenarios. The obtained results highlighted how:

1. desalinated water concessions tend to be less or equal than the desalinated water demand. According to irrigators, this under-provision can be explained by the existence of a surface water supply (TST). Furthermore, for practically all the irrigation communities, with the exception of those that have their own desalination plant, the average volume of water available at their delivery points is lower than their water concession. To alleviate this situation, irrigators have implemented a series of measures, including the general restriction of water and the establishment of water rights transfers centrally managed by SCRATS. However, the structural under-provision of water for irrigation uses seems non-reversible taking into account that desalinated water concessions requested by irrigators are much higher than the real production capacity of the plants (Torrevieja, Valdelentisco and Escombreras plants accumulate 150.8 MCM/year, while the requested water concessions are of 207.5 MCM/year);
2. those irrigation communities that are using desalinated water in a greater proportion and for a longer time provide the best evaluations of desalinated water quality. Anecdotally, low-quality

standards of desalinated water can be influenced by problems experienced in neighboring irrigation communities rather than the actual use of desalinated water;

3. greater use of desalinated water is explained by three main factors: it is the only source available (due to the prognosis that the TST end up closing and no surface water was supplied); it allows alleviating the structural under-provision of water; and it is a solution to drought situations. To a lesser extent, irrigators point out that the greater use of desalinated water is explained by its subsidized cost, because it allows avoiding the overexploitation of the aquifers during drought scenarios and that it increases the quality of the water used for irrigation;
4. there is no unanimous answer to the question of whether desalinated water could substitute other water supply sources. Large irrigation communities and those without desalinated water concession pointed out that desalinated water cannot replace surface water since it is a complementary source, while the rest largely agree that desalinated water can replace groundwater, which is the main cause of high water conductivity due to over-exploitation of aquifers;
5. the main advantages of using desalinated water are: increasing water availability, ensuring water supply, and improving water quality. On the contrary, the main drawbacks are its high price (six times higher than TST water), the high-energy consumption (the energy cost of the TST is much lower: 1.1 kWh/m^3) and CO_2 emissions, quality problems (conductivity and boron), water demand unadjusted to the seasonal variation, and the increase of vulnerability to shortages due to technical problems in desalination plants. Some of these handicaps have been identified in a recent study conducted by Ricart et al. [67] in which energy cost and water price have been considered the most influencing factors in decision-making processes. Although in the last 30 years the amount of energy required for desalination has fallen precipitously, and taking into account the plant efficiency and energy price increases and fluctuation, energy costs account for between 25% and 50% of the total price of desalinated water [68]. In this scenario, some surveyed irrigators claim that it is necessary to improve technical performance to reduce energy consumption and promote the use of solar energy in desalination plants;
6. for most irrigation communities, below 0.30 €/m^3 all crops can be profitable. This scenario would reduce profitable crop options [69], with agricultural activity practically unfeasible with water prices above 0.60 €/m^3. It should be noted how irrigation is the lowest-valued water use and desalination the highest-cost water source [70]. The price of desalinated water tends to explain why desalination is only affordable in productive and profitable cropping models [71], and why its use is linked to irrigation that is more efficient. Accordingly, the use of desalinated water in producing high-value crops and crop commodities would be another avenue whilst considering the expansion of desalinated water to other sectors [72]. Taking into account that conventional water resources cannot alleviate the water deficit for agricultural use in South-East Spain, seawater desalination appears as a valuable supplement to be added in the water mix used by irrigators [73];
7. both the regional and the national press reflected the concern of the agricultural sector because of the decrease in water delivery from the TST, the water quality problems, and the high-energy prices, which have already been three of the triggers for the promotion of desalination according to irrigation communities' perception. However, at the national level, more emphasis has been put it on corruption and cost overruns, and the political conflict (including Water Pact discussion), in which desalination was presented as a win-win 'scalar fix' to Spain's water challenges with the explicit aim to diffuse political tension through techno-managerial solutions [74]. In addition, investments to promote the integrated management of water resources are also disseminated through the press. According to this last point, by 2021 the Spanish Government declare that ACUAMED plants would be interconnected also with the TST infrastructure, which will provoke that desalinated water could be used by more irrigation communities than those surveyed in this study [75]. The intended water management strategy is that every southeastern irrigation community uses a water mix in which both desalinated water and TST water would be present.

Desalination feasibility is complex and it requires overlaid technical, economic, political, environmental, and societal driving factors. Based on the obtained results, desalination should be considered as a strategic water supply in regional water planning and management for irrigation in water scarcity regions instead of a contingency plan based on emergency demand. However, this asks for ensuring that the benefits and costs of desalinated water are well known, local and current instead of fluctuating, distant, and future [76]. The AGUA program assumed that farmers would turn to desalinated water and pay the government for construction and operating costs. The government faced a choice between selling low volumes of expensive water or subsidizing prices to increase volumes, raise plant efficiency, and perhaps decrease groundwater stress. However, farmers continued to exploit a regulatory loophole on self-supply that gave them access to cheaper, convenient groundwater or surface water, as confirmed in our case study in which irrigators prefer using surface water (from both the Segura basin and from the TST) instead of desalinated water.

The best way to increase farmers' acceptance of desalinated water is by addressing socioeconomic and environmental risks and yuck factor together. Both technical (risks) and social issues (perception) should be considered as the two sides of the same coin which are perceived differently by farmers, irrigation communities, managers, decision-makers, and society [77]. The challenge is to identify farmers' expertise, doubts, fears, and cultural values associated to desalinated water use and combine them with technical and economic issues in order to systematically addressing concerns through a framework of educational, policy, and management strategies. To address this gap, it is essential that engineers and social scientists work together. Engineers can provide the best, safest, and efficient solutions to reduce energy costs and ensuring water quality standards, whereas social scientists can facilitate a better understanding of the reasons that explain rejection or acceptance from farmers' perception of desalinated water for irrigation. Moreover, managers and decision-makers can take profit of this coupled technical-social approach in favor of integrated water resources management in water scarcity regions. Results should be useful to identify how policymakers could use the current concerns shared by the irrigation communities as a social-learning process when they attempt to close the supply-and-demand gap of desalination in water scarcity regions, while addressing the water–energy–food nexus in the medium- and long-term.

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Appendix A

Questionnaire to the irrigation communities
BLOCK 1. IRRIGATION COMMUNITIES' PROFILE

1. Name of the irrigation community

2. Name and charge of the interviewee

3. Year of registration of the irrigation community as a public law corporation

4. Number of irrigators

5. Registered surface with the right to be irrigated (in hectares)

Irrigable surface	
Irrigated surface	

6. Location of irrigated and irrigable surface (municipalities)

7. Average size of the farm (in hectares) (*if different sizes are present, please, indicate as irrigators' profiles as needed)

8. Main crops

9. Irrigation method (select the correct option/s and include the % of use)

Drip irrigation	
Sprinkler irrigation	
Flood irrigation	

10. Technical advisory services offered to the irrigator

BLOCK 2. WATER CONCESSION, SUPPLY SOURCES, USES, PRICE, SURFACE, AND IRRIGATED CROPS

11. Supply source/s and current volume/s (concessional and average supplied volume)

	Concessional volume		Average supplied volume	
Water source	Normal climatic year (m^3/%)	Drought period (m^3/%)	Normal climatic year (m^3/%)	Drought period (m^3/%)
Surface water (river)				
Water transfer (TST)				
Groundwater				
Reclaimed water				
Desalinated water				
Others (*please, specify)				

Water demand to meet the needs of the irrigated area

Total water demand (in m^3)	

Has the amount of water supplied by any source/s ever been insufficient?

Yes	
No	
Do not known/No answer	

If yes, which source/s has/have resulted insufficient?

Surface water (river)	
Water transfer (TST)	
Groundwater	
Reclaimed water	
Desalinated water	
Others (*please, specify)	

If yes, what measure/s has/have been applied?

Water rights transfers	
Temporary authorizations (desalination)	
Controlled overexploitation of aquifers	
Crop restrictions	
General restriction	
Recommendations to irrigators	
Controlled Deficit Watering (CDW)	
Use of emergency wells	
Others (*please, specify)	

12. Name of the desalination plant/s with which the connection is maintained

13. Year and duration of desalinated water concession

Year	
Duration (years)	

14. Reason/s that has/have motivated using desalinated water

Structural under-provision of water	
Temporary under-provision of water	
Need for water quality improvement through mixing with poorer water quality resources	
Others (*please, specify)	

15. Irrigated surface using desalinated water (in hectares, estimated or approximated value)

2018	
2017	
2016	
2015	
2014	
2013	
2012	
2011	
2010	
First year of water concession	

16. Purchased and supplied price of desalinated water (€/m^3)

Purchased	
Supplied	

Is it a fixed or a variable price?

Fixed	
Variable	

If variable, main reason/s that justified it

Has the use of desalinated water benefited from any subsidy?

Yes	
No	
Do not known/No answer	

17. Have you identified a maximum and minimum use of desalinated water?

Yes	
No	
Do not known/No answer	

If yes, in which months is the maximum use of desalinated water?

If yes, what factor/s explain/s a greater use of desalinated water

Drought period	
Subsidized cost	
Only water source available	
Under-provision of water	
Others (*please, specify)	
Do not known/No answer	

18. Do you irrigate directly with desalinated water or a mixture between desalinated water and water from other sources is applied?

Only desalinated water	
Mixed	

If mixed, to what factor/s is/are this mixture due?

Increase the water quality standards	
Take advantage of available conventional water resources	
Reduce the use of desalinated water (save costs)	
Others (*please, specify)	

Once the desalinated water has been received, is it necessary to apply any type of post-treatment process to correct possible imbalances (low mineralization in calcium, magnesium and sulphates) before being used on the plot?

Yes	
No	
Do not know/No answer	

Who should bear the cost of this treatment?

Irrigation communities	
Desalination plant (supplier company)	
Both	
Do not know/No answer	

BLOCK 3. QUALITY, COST, MANAGEMENT, IMPACTS AND BENEFITS

19. Conductivity of the desalinated water supplied (in μ/cm)

20. Assessment of the desalinated water quality standards

Punctuation	Very good	Good	Fair	Bad	Very bad
Current situation					
Evolution					
Future perspectives					

Have you detected any specific problems with boron?

Yes	
No	
Do not know/No answer	

If yes, which problems have been identified and which measures have been promoted to minimize them?

Problem	Measure

21. Are you considering requesting, in the medium-long term, conductivity-quality standards "on demand"?

Yes	
No	
Do not know/No answer	

If yes, what factor/s would be determining to promote conductivity-quality standards "on demand"?

Cost	
Conductivity	
Crop productivity	
Sale price of the food product	
Environmental impact and low water quality standards	
Others (*please, specify)	
Do not know/No answer	

22. Does the irrigation community have its own control system to evaluate the quality of the received desalinated water?

Yes	
No	
Do not know/No answer	

If yes, is it a permanent control process?

Yes	
No	
Do not know/No answer	

23. If the cost of desalinated water is not a determining factor, order the different water sources according to their priority of use (1 = highest priority, 5 = lowest priority)

Surface water (river)	
Water transfer (TST)	
Groundwater	
Reclaimed water	
Desalinated water	

24. How do you assess the exploitation management and services offered by the desalination plant?

Positively	
Negatively	
Do not know/No answer	

If positively, what are the factors that determine this positive assessment?

If negatively, what are the factors that determine this negative assessment?

25. Main advantages and disadvantages of using desalinated water

Advantages	Disadvantages

26. Main environmental impacts identified of prolonged use of desalinated water in crops (more than one option is possible)

Effects caused by high Boron concentration values	
Soil sodification risk	
Acidity and corrosion problems	
Others (*please, specify)	
Do not know/No answer	

BLOCK 4. FUTURE SCENARIO

27. Factor/s that will influence, in the near future, on the acceptance of irrigation with desalinated water

	Positively	Negatively
Water availability (conventional water sources)		
Desalinated water price		
Desalinated water quality		
Environmental impact		
Others (*please, specify)		

28. Are you considering requesting an extension or reduction of the current desalinated water concession?

Yes	
No	
Do not know/No answer	

If yes, what is the reason for this expansion or reduction of desalinated water?

29. What is the final price of desalinated water that the irrigator can assume based on the profile of agricultural exploitation?

≤0.20 €/m^3	
≤0.40 €/m^3	
≤0.60 €/m^3	
>0.60 €/m^3	
Range	

30. Which crops can cope with these ranges of prices? (please specify types of crops according to price categories)

≤0.30 €/m^3	
≤0.60 €/m^3	
>0.60 €/m^3	

31. Is there an internal debate about the environmental impacts that the use of desalinated water can have on the productivity of the soil and/or crops?

Yes	
No	
Do not know/No answer	

If yes, which are the main aspects that generate the most agreement and disagreement options among users?

Agreement	Disagreement

32. Which measures could increase the level of acceptance of the use of desalinated water among the community members?

Subsidies for technical innovation and improve water quality	
Desalinated water price reduction	
Financial bonus according to the volume of water consumed	
Marketing campaigns focused on the consumption of food produced with desalinated water	
Information campaigns about the benefits and impacts of the use of desalinated water	
Expert technical advice	
Institutional and administrative support	
Others (*please, specify)	

33. Do you consider that the use of desalinated water can substitute other sources of water supply?

Yes	
No	
Do not know/No answer	

If yes, which water sources could be substituted?

Surface water (river)	
Water transfer (TST)	
Groundwater	
Reclaimed water	

34. Do you consider that the use of desalinated water is a complementary measure to face any of the possible impacts of climate change such as drought or irregular rainfall patterns?

Yes	
No	
Do not know/No answer	

35. Final assessment of the use of desalinated water for agricultural irrigation and any specific comments.

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