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How to Close the Gap of Desalinated Seawater for Agricultural Irrigation? Confronting Attitudes between Managers and Farmers in Alicante and Murcia (Spain)

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Abstract: Although desalination water cost and quality standards have been widely studied, less attention has been paid to understanding how desalination plant managers and irrigation communities interact to address water scarcity. This paper aims to approach these questions from experience in Alicante and Murcia (Spain). Two specific questionnaires have been applied to (1) three desalination plants managed by the Spanish public company ACUAMED, and (2) 11 irrigation communities who use desalinated seawater. Discursive analysis has been applied in order to deepen understanding on the driving factors, benefits, and barriers of desalination use and management. Results highlighted how (1) irrigation communities consider desalination as a complementary water source to be combined with conventional water resources, (2) both ACUAMED and irrigation communities highlighted two main advantages of desalination: the security/guarantee of supply and water quality parameters, and (3) managers and irrigators disagree on the desalination model of seawater provision and management, since irrigators consider that the Central Union of the Tajo-Segura transfer irrigators (SCRATS) should have a leading role. In addition, the main driving factors and barriers useful for policy makers when closing the gap of desalination have been identified: water price and energy consumption; lack of water storage capacity and regulation; environmental impacts.

Keywords: desalinated seawater; irrigation communities; desalination plant; water-energy cost; perception; Alicante; Murcia; Spain

1. Introduction

Water is one of the key driving factors to ensure sustainable development and is under increasing pressure, with a mismatch between the demand for, and availability of, water across both temporal and geographical scales [1]. Worldwide water consumption continues to grow, and it is estimated that by the year 2030, more than 160% of the total water volume available in the world will be needed to satisfy the global water requirements [2]. Water scarcity is considered one of the most important challenges of our time, constituting an increasing problem in many parts of the world [3]. Agriculture is the sector most affected by water scarcity, as it accounts for 70% of global freshwater withdrawals and more than 90% of the consumption [4,5]. In this context, non-conventional water resources and more specifically, seawater desalination, is considered as an additional water resource to help overcome water scarcity [6,7]. Desalination for sustaining agricultural production is being reported as an alternative water source in some Mediterranean countries faced with the climatological and hydrological constraints [8]. Desalination is broadly considered as a mechanism to deal with the challenge of water resource shortage [9]. The worldwide population relying on desalinated seawater is expected to increase from 7.5% of the world population in 2015, to a projected 18% in 2050 [10]. Furthermore, in the last six years, the world total water desalination capacity, including brackish water and seawater desalination, increased steadily with an annual rate of about 9% [11]. Likewise, the global production capacity of desalinated seawater is expected to double by 2040 [12].

However, some issues can become a barrier to promoting desalination for crop irrigation, including energy cost, electrical conductivity, or farmers' attitudes when accepting or refusing desalinated water use. Water desalination is an energy intensive approach for freshwater production [13], and the rapid increase in installed capacity has resulted in increasing energy consumption. Although technological advances have been made aimed at reducing energy consumption by incorporating new and more efficient energy recoveries or membranes, this issue is still a problem to be taken into consideration [14]. Nevertheless, in some countries, the cost of desalination is progressively dropping, making desalination now more economically competitive and attractive than conventional water resources [15]. The incorporation of desalinated water to agriculture can produce quite different agronomic effects, depending on the quality of the irrigation water that is replaced [16,17]. One of the main concerns about the quality of desalinated water is the lack of essential nutrients and its effect on plant growth, which requires higher fertilization requirements, since is of central importance to greenhouse producers [18]. In addition to its low mineralisation, desalinated water is characterised by a chemical composition quite different from that of conventional water sources that could promote the degradation of the soil structure due to soil sodicity, which highly affects crop yield, and concerns about potential crop toxicity related to high levels of boron and chloride [19]. The correct application and management of specific quality regulations, mixing and management modelling, technical means on the farm, as well as water and soil monitoring can mitigate these risks for agricultural irrigation with desalinated seawater [20]. However, current studies focused on risk evaluation and assessment highlighted two main levels of risk indicators, in which the first-level risks include water intake and outfall risk, processing risk, financial risk and circumstance risk, while the second-level risks include discrepancy in risk perceptions from end-users, such as farmers [21]. Although high costs, lack of essential ions for crop growth, and brine disposal are often cited as limiting factors, the farmers' perspective regarding their relative importance and how to overcome such limitations is currently absent from the literature [22]. 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 [23,24]. Furthermore, perception is directly influenced by environmental impacts of desalination, because desalination has great potential to change the physical, chemical, and ecological characteristics of the marine environments. For example, the salinity of brine discharges from reverse osmosis plants is up to double that of seawater, and these discharges often contain chemicals that may be toxic or induce stress responses to marine organisms [25–27].

In many arid and semi-arid regions, water scarcity is not just a growing environmental concern but also a structural problem [28]. In Spain, and mainly in the Mediterranean area, water scarcity is a significant and well-documented problem that continues to worsen with the increasing demand due to high population growth, economic-development needs, and climate change impacts [29]. In this context, desalination emerged as the solution to water problems, where the construction of dams or the promotion of water transfers have not been outside of interprovincial political disputes and social conflicts [30]. Although desalination started in Spain in 1964 with the construction of the first desalination plant in Lanzarote (Canary Island), the main impulse of desalination was carried out through the modification of the National Hydrological Plan (Law 10/2001) in 2004 (Royal-decree law 2/2004) and 2005 (Law 11/2005) with the approval of the so-called A.G.U.A Program (Actions for the Management and Use of Water) [31]. These new laws involved a fundamental reorientation of the national water management policy that changed from the large water transfer between water basins to a desalination development commitment [32]. Among other actions, the water program promoted the construction of a large number of desalination plants along the Mediterranean arch that would expand the country's desalination capacity by 344.68 hm^3, of which 155.37 hm^3 (46%) would serve to meet the agricultural needs of 244,000 ha [33]. The analysis of the real capacity and production of desalinated water in Spain is a complex calculation due to the large number of small desalinated plants built by the irrigation communities. Regarding the data provided by the AEDyR (Spanish Association of Desalination and Water Reuse) there would be about 800 desalination plants producing about 1800 hm^3/year [34]. Both for the number of plants and for the knowledge and technological advances, plant construction and exploitation, Spain is an international reference in the field of desalination, behind countries such as Saudi Arabia and United Arab Emirates in which this water source has been established as a feasible alternative to overcome water scarcity. Spain has the largest capacity plant in Europe (located in Torrevieja, 80 hm^3/year) and 8 of 20 main companies related to the construction and operation of desalination plants are Spanish. This potential on technological development and implementation of desalination would not have been possible without national regulation. The legislation governing desalination is established in Article 13 of the Consolidate Text of the Water Law, approved by Royal Legislative Decree 1/2001 of July 20. This article establishes that desalination is subject to the general regime for public water resources, so a water concession is required for any desalination operation that has precise authorization and approval in compliance with other specific laws [35].

This paper aims to reveal, from Spanish experiences in Alicante and Murcia, how desalination plants managers and irrigation communities interact in perceiving desalination, in motivating its current use, and in managing their impacts and barriers. Three key questions have been considered: (1) How is desalinated seawater managed and which type of measures have been promoted to overcome current and potential barriers? (2) What are the main factors able to explain the acceptance or rejection of desalinated seawater for agricultural irrigation? (3) Is desalination conceived as a first or alternative option for ensuring climate change adaptation and the replacement of other, conventional water resources?

2. Materials and Methods

2.1. Questionnaire Design

Two questionnaires have been designed to explore desalination plants managers and irrigation communities' perception on desalinated seawater. Each questionnaire included 35 questions (combining multiple choices, open-ended and closed-ended questions) and their structure was divided up into different blocks. The questionnaire given to desalination plants managers was divided up into three blocks according to the pursued objectives. The first block was about technical data (15 questions): year of construction, capacity, desalinated water volume in the last 10 years, energy systems, water and energy cost, and investments and subsidies. The second block was about infrastructures, water capacity and energy cost (11 questions): pumping systems, installations, pre-treatments, and brine and waste management. The last block was about desalination for agricultural irrigation (9 questions): irrigation communities connected to the plant, services offered to the irrigators, water and pumping cost, electrical conductivity, and benefits and risks of using desalinated water for irrigation.

The questionnaire to irrigation communities was divided up into four blocks according to the following topics. The first block contained the profile of the irrigation community (10 questions): year of registration, 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

(8 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 was about impacts and benefits when using desalinated seawater (8 questions): electrical conductivity standards and assessments, identification of problems (boron) and measures of control, priority of use according to different water sources, and main benefits and risks of using desalinated water. The last block contained questions about future scenarios motivating the use of desalinated seawater (9 questions): reasons to increase the use of desalinated water, maximum cost of desalinated water, environmental impacts clearly detected, measures to increase irrigators' acceptance of desalination, and climate change adaptation.

The first version of each questionnaire was reviewed by a group of experts in seawater desalination from both irrigation communities and the Spanish public company *Sociedad Estatal de las Cuencas Mediterrátenas* (hereafter ACUAMED) 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. A third questionnaire was designed to be shared with the irrigation communities that have recently requested the use of desalinated water. Unfortunately, it could not be carried out due to the lack of participation. Finally, and in order to complete the responses of the desalination plants managers, an additional questionnaire to the technical manager of ACUAMED was made, which included several questions about contracts and agreements with irrigation communities, regulation and demand management, acceptance of desalinated water and water cost.

2.2. Survey Methodology

Questionnaires were conducted between March and December 2019. The questionnaires, in Spanish, were sent to each irrigation community secretary and each desalination plant manager before the meeting took place, so that they could prepare some requested data. Each desalination plant facility was visited, and a face-to-face meeting was fixed with each irrigation community in its office. Questionnaires were completed by those responsible for the plant and by the secretary and/or technician of each irrigation community, respectively. 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 desalination plant manager and irrigation community secretary in order to be reviewed.

2.3. Data Analysis

This research develops a discursive analysis of the qualitative information of the questionnaires completed by the managers of the three desalination plants owned by ACUAMED in the Segura River Basin (hereinafter, SRB) (together with the technical director of ACUAMED), 11 irrigation communities, as well as official information on desalinated water concessions provided by the Segura River Basin Authority. In order to complement and contextualize the information provided in the questionnaires, the legislative information provided by the Segura River Basin Authority related to the project competition announcements for the concession of desalinated water volume; the royal drought decrees published between 2015 and 2018; the annual reports of the Central Union of Tajo-Segura transfer Irrigators (SCRATS by its acronym in Spanish) published since 2007 when some of the ACUAMED desalination plants started operating; and the Provisional Schema of Important Issues (PSII) in the SRB, a technical report prior to the drafting of the hydrological planning proposal for the period 2021–2027 have also been consulted.

As the main goals are to deepen understanding on how desalinated water is managed and which measures have been implemented to overcome current and potential barriers, how plants managers and irrigation communities interact in perceiving desalination's acceptability/rejection key factors, and the future prospects of this resource in view of climate change, the discursive analysis has been grouped into three subsections which refer to the research questions: desalination management, motivation and desalinated water use, and future outlook.

3. Case Study

3.1. Location

Alicante and Murcia regions are located in South-eastern (SE) Spain, among the regions with the largest (structural) water deficit in Europe of around 400 hm^3/year [36]. The climatic characteristics of the SRB, in which the study was carried out (Figure 1), correspond to a semiarid Mediterranean climate [37], and according to the water exploitation index, which is the ratio of total fresh water abstraction to the total renewable resource, reaches 130%, ranking this basin with the third highest level of water stress in Europe [38]. The coastal and pre-coastal sectors of Alicante and Murcia are highly specialized in economic activities with high water consumption, mainly residential tourism [39] under the slogan of "sun and beach" [40] and intensive agriculture with an export vocation [41]. In this area, most rivers have a remarkable seasonal regime and streams remain dry most part of the year, except for occasional surface run-off and flash floods.

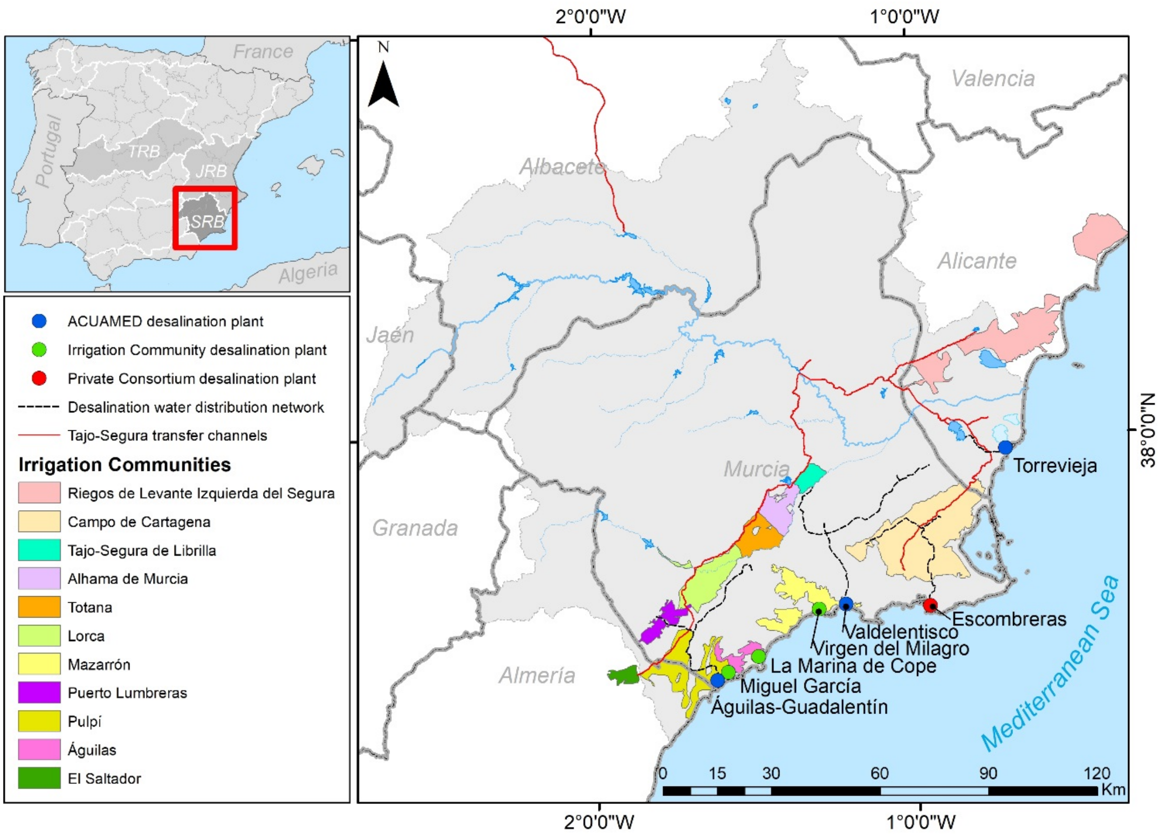

Figure 1. Irrigation communities surveyed, desalination plants according to owners, and the main water distribution network for irrigation uses in the Segura River Basin. Source: own elaboration from irrigation communities' data.

3.2. The Tajo-Segura Transfer

Due to the scarcity of rainfall and surface water, the SRB has been receiving water from the Tajo River thanks to one of the largest engineering hydraulic works in Spain since 1979, the Tajo-Segura Transfer (hereinafter, TST). According to the PSII, the agricultural demand of the subsystem of the irrigable areas of the TST reached an annual demand of 617 hm^3, although the water supply is smaller, around 435 hm^3/year, of which 205 hm^3 came from the TST and 230 hm^3 from other water sources, on average for the period 1980–2012. The TST regulation has been modified recently by the Royal Decree 773/2014 and the fifth additional provision of Law 21/2015, which have restricted water transfers to the SRB. Additionally, in 2019 the Spanish Supreme Court declared the nullity of several articles of the Tajo's River Basin hydrological planning due to the breach of the establishment of ecological flows on the Tajo River. Furthermore, the PSII in the Tajo River Basin (TRB), set an increase in the minimum flow of this river in the city of Aranjuez from 6 m^3/s to 8.52 m^3/s. In addition, the PSII in the SRB considers that this increase would then result in a reduction of 79.38 hm^3/year of TST contributions, since each cubic meter per second of additional water release from Tajo's headwater reservoirs will produce a reduction of up to 31.5 hm^3/year in the availability of water that can be transferred. These new regulations will constrain water transfers between Tajo and Segura River basins, which will result in the need to expand the production of desalinated water for agricultural uses in the SRB.

3.3. Desalination Plants

The three desalination plants owned by ACUAMED, a public company in charge of the construction and exploitation of hydraulic works of general interest, have provided raw water supply services to the SRB irrigation communities from 2008, but especially from 2015, when the plant of Torrevieja started working. In 2008 was opened the desalination plant of Valdelentisco. In this plant, two extensions have been carried out, evolving from a maximum initial production capacity of 25.5 hm^3/year to 46.7 hm^3 in 2010 and 48 hm^3 in 2018, according to the data provided by the plant manager. In 2011 and 2013, the Águilas-Guadalentín and Torrevieja desalination plants construction were finished, respectively. These plants have also undergone an extension of their initial desalinated water production capacity. On the one hand, the desalination plant of Águilas-Guadalentín, after the 11 hm^3 expansion produced in 2019, has reached a production capacity of 70 hm^3/year (200,000 m^3/day). On the other hand, the initial annual production capacity of the desalination plant of Torrevieja was around 40 hm^3 until 2019, when an extension allowed to reach 80 hm^3/year (240,000 m^3/day).

Likewise, according to the data on water concessions provided by the Segura River Basin Authority, in addition to the ACUAMED desalination plants, there are four other seawater desalination plants in the SRB. There are three desalination plants, with a low production capacity, owned by three different irrigation communities. Chronologically, the first seawater desalination plant used for irrigation in the SRB was Virgen del Milagro, owned by the irrigation community of Mazarrón, built in 1995, with a production capacity of 12 hm^3/year. In 2003, the desalination plant of Miguel García was set up, owned by the irrigation community of Águilas, and with a production capacity of 8 hm^3/year. Subsequently, in 2006, the desalination plant of La Marina de Cope was built (5 hm^3/year), owned by the homonymous irrigation community. Furthermore, there is another desalination plant, Escombreras, which has a production capacity of 22.8 hm^3/year and belongs to a private consortium formed by the companies Hydro Management S.L. and Tedagua. This last plant, which began operating in 2009, has only supplied water to the irrigation community of Campo de Cartagena. In summary, in the SRB, there is a desalinated water production capacity of 250.8 hm^3/year, without including the plants dedicated exclusively to urban supply.

3.4. Irrigation Communities

A total of 11 irrigation communities have been selected to conduct the study, which account for more than 58,000 irrigators and 120,000 ha, approximately 82% of the TST total irrigated area (Table 1). It should be noted that, according to SCRATS, this is the first time in which Tajo-Segura irrigation communities have participated in research about desalinated water use. Each irrigation community is currently using desalinated water, directly or by swap, and almost all are connected to a desalination plant managed by ACUAMED. The profile of each irrigation community is contrasted from the year of constitution (irrigation communities with about 70 years of history while others with less than a quarter century) to the irrigable/irrigated surface (irrigation communities such as Campo de Cartagena, Lorca or Riegos de Levante Izquierda del Segura, with several tens of thousands irrigated hectares, and others such as El Saltador or Librilla, with about two thousand hectares). However, in both profiles, at least 60% of the surface is irrigated with desalinated water (with Lorca at 100% and Campo de Cartagena, El Saltador or Riegos de Levante Izquierda del Segura exceeding 90%). The number of irrigators is also balanced: from several thousands (Riegos de Levante Izquierda del Segura, Lorca and Campo de Cartagena) to less than or about one thousand (Puerto Lumbreras and El Saltador), while two main profiles could be identified regarding farm size: those communities with less than or about 1.5 ha (Alhama de Murcia, Librilla, Mazarrón, Totana, Riegos de Levante Izquierda del Segura and Lorca) and those communities that can double, triple or quadruple that surface area (Águilas, Pulpí, El Saltador, Puerto Lumbreras, and Campo de Cartagena). Regarding the main crops, there is a pattern shared by all the irrigation communities of cultivating vegetables and fruits (although some differences exist according to the diversity and dominance of each crop). Lastly, there is a pattern regarding the irrigation system used by irrigation communities: drip irrigation is the main method used by 9 out of 11 communities.

Table 1. Irrigation communities' basic characterization.

Irrigation Community	Year	Irrigable Surface	Irrigated Surface	Irrigators	Average Farm Size (ha)	Main Crops [14]	Irrigation Method
Águilas	1991 [1]	6029	≈4800	1620	3 [7]	Vegetables and fruits	Drip (100%)
Alhama de Murcia	1976 [2]	7200	5096	2318	<1 [8]	Fruits and vegetables	Drip (80%) and flood (20%)
Campo de Cartagena	1952 [3]	41,920	38,319 [5]	9678	4	Vegetables and fruits	Drip (96%), sprinkler (2%), and flood (2%)
El Saltador	1989	2500	2300	≈1000	1.5–4 [9]	Vegetables and fruits	Drip (98%) and sprinkler (2%)
Librilla	1979	2532 [4]	≈1900	1916	<1 [10]	Fruits and vegetables	Drip (40%) and Flood (60%)
Lorca	1978	23,905	23,905 [6]	≈12,000	1.5	Vegetables and fruits	Drip (80%) and Flood (20%)
Mazarrón	1991	4803	3595	1150	<1	Vegetables, vineyards and fruits	Drip (100%)
Puerto Lumbreras	1996	4022	≈3000	880	3–4 [11]	Vegetables and fruits	Drip (90%), sprinkler (2%), and flood (8%)
Pulpí	1991	8451	≈7000	1239	3 [12]	Fruits and vegetables	Drip (70%) and Sprinkler (30%)
Riegos de Levante Izquierda del Segura	1991	≈26,000	≈24,000	≈22,000	1	Fruits and vegetables	Drip (45%) and Flood (55%)
Totana	1979	10,765	6979	4216	<1 [13]	Vegetables, fruits and essences	Drip (80%) and Flood (20%)

Source: own elaboration from the questionnaires. Notes: [1] Petition was on 1986; [2] Latest statutes in 2015; [3] Although the first irrigation campaign with desalinated water was in 1979 with the arrival of the TST; [4] This surface increases until 3515 ha (taking into account the surface currently occupied by the industrial park); [5] This surface is reduced to 32,000 in a dry period; [6] Part of this surface (12,620 ha) corresponds to traditional irrigation (unregulated); [7] Some farms up to 200–300 ha; [8] Some farms up to 400 ha; [9] Some farms up to 40–50 ha; [10] Professional farmer: 20 ha, with 7–8 large fruit and vegetable companies (25–30 ha each one); [11] Some farms up to 50–100 ha; [12] One horticultural company uses 800 ha and a fruit company, about 300 ha; [13] Some horticultural companies up to 150 ha; [14] Vegetables include lettuce, broccoli, artichoke, cauliflower, tomatoes, celery, potato, onion, and pepper; while fruits include citrus, melon, watermelon, grape, and mango.

4. Results

In this section, the perceptions and discourses of desalination plant managers and irrigation communities with reference to desalination and the main measures adopted to solve the current and potential barriers to its implementation, the main factors explaining its acceptance or rejection for agricultural irrigation, and the outlooks considering a climatic change scenario are analysed.

4.1. Desalination Management

4.1.1. Water Concessions

The use of desalinated water requires, in the first place, prior authorization from the corresponding River Basin Authority. Additionally, once this administrative requirement has been formalized, a supply and service contract have been signed between ACUAMED desalination plants and each irrigation community, aimed at formalizing the operational and economic issues related to these infrastructures. With regard to water concessions, the information provided by the Segura River Basin Authority reveals that between 2011 and 2019, only three plants completed the water allocation process (Águilas-Guadalentín, La Marina de Cope, and Miguel García). The rest of the desalinated water concessions are still in the processing status, which reveals that the use of desalinated water is just beginning in some irrigation areas. However, the recurrence of drought situations in the headwaters of the Tajo and Segura River basins has committed the TST, especially since the end of 2015, which has led to an increase in desalinated water use, despite its water concessions not being approved (Figure 2). This situation has been carried out through the adoption of exceptional measures included in the drought decrees approved by the Segura River Basin Authority in May 2015 (Royal Decree 356/2015) and extended to September 2019.

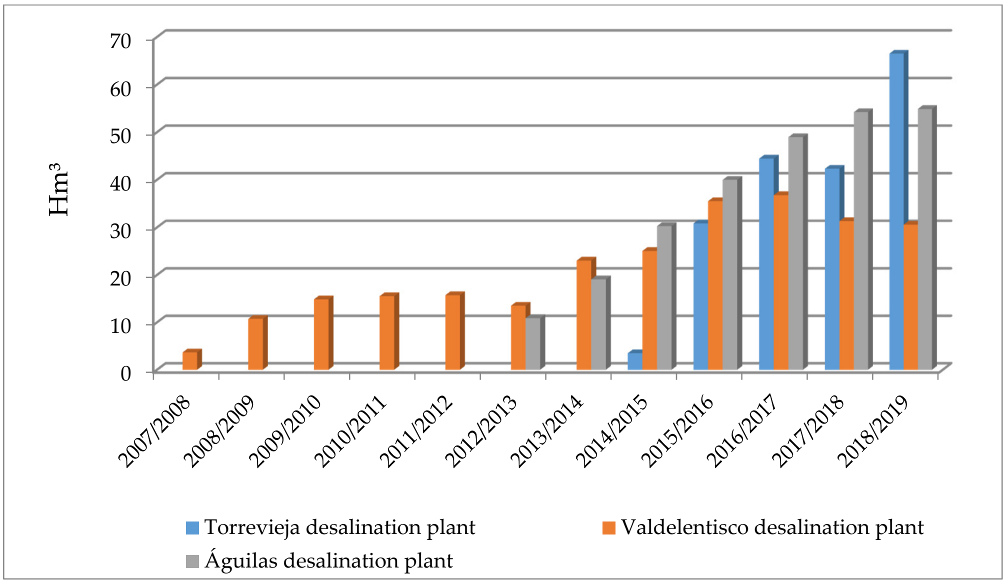

Figure 2. Desalinated water annual production of the plants owned by ACUAMED in the SRB (2007–2019). Source: own elaboration from ACUAMED data.

The enactment of the drought decree was accompanied by an order of the Spanish National Government (Order AAA/2965/2015) in November 2015, which urges that the desalination plants of Torrevieja and Valdelentisco, whose production was not assigned or its immediate use was not foreseen, had to produce 30 hm^3 and 20 hm^3 of desalinated water during the 2015/2016 hydrological year, respectively. Additionally this order arranged that desalinated water from Valdelentisco would experience a price reduction of 0.1 EUR/m^3 during six months in that hydrological year and a fix price of 0.3 EUR/m^3 for the desalinated water from the desalination plant of Torrevieja, to which it would have to add a VAT of 10% and the toll rates for the use of pipeline infrastructures. These subsidized prices for desalinated water lasted until the end of September 2019, when the last extension of the drought decree ended. Likewise, information about the water concessions in processing status unveil that the desalinated water consumption growth is expected to increase. On the one hand, there is an amount of approved desalinated water concessions of 79.2 hm^3/year and, on the other hand, there are 207.5 hm^3/year of water concessions in processing status, adding a total of 286.7 hm^3/year which exceeds the current production capacity (Figure 3).

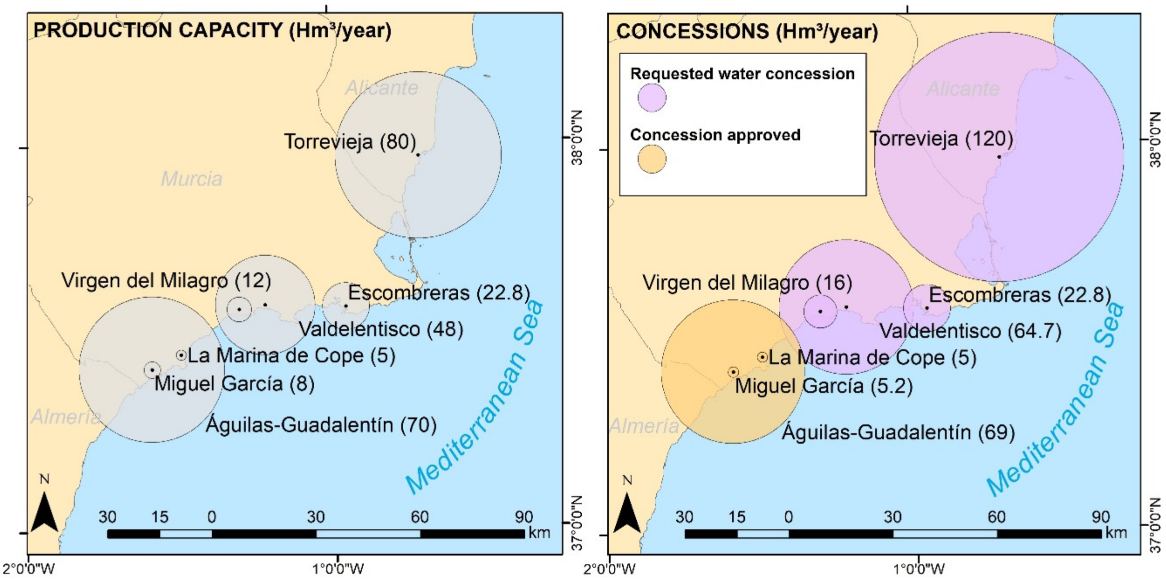

Figure 3. Production capacity of the desalination plants and concessions approved and in process in the SRB for irrigation uses. Source: own elaboration from ACUAMED and SRB data.

According to what is established in the PSII in the SRB for the period 2021–2027, the main reasons for the expansion of desalination is the modification of the TST regulation, the increase in the ecological flows of the Tajo River, and the reducing pressures on groundwater to meet environmental objectives. As a result, the production capacity of the desalination plants of Valdelentisco and Torrevieja is projected to reach in the short term 70 hm^3 and 120 hm^3, respectively. These future extensions are illustrated in the desalinated water concessions in the pipeline.

The irregular situation due to the breach of the legal obligation to grant administrative concessions leads the SRB to initiate various proceedings on this matter. It should be noted that two forms of concessions exist, those granted to collective management entities, such as SCRATS, and the concessions to individual users or irrigation communities. Until the end of the period of validity of the drought decrees, there was a provisional authorization for the use of desalinated water produced in the Torrevieja plant to the SCRATS of 39 hm^3/year until the end of 2018 and up to 79 hm^3/year in 2019, following its production capacity expansion (File number ASV-87/2019). Likewise, procedures were initiated for the concession of the whole production of the Valdelentisco (File number CSR-8/2018), whose production had been assigned through agreements individually between ACUAMED and private irrigation entities, and Escombreras desalination plant (ASV-88/2019). The temporary water concession to SCRATS from the Torrevieja desalination plant ended in November 2019, when an official announcement was made by the Segura River Basin Authority applying for 80 hm^3/year water concessions in the Torrevieja plant on the part of individual users or irrigation communities which receive water from the TST (File number CSR-16/2019), in addition to the 40 hm^3/year concession for urban uses (File number CSR-67/2017). In summary, the approved and pending concessions for the irrigation communities surveyed are detailed in Table 2, with the exception of Torrevieja and Escombreras desalination plants' concessions, which have not yet been allocated.

Table 2. Desalinated Water Concessions (approved and pending) of the irrigation communities surveyed by desalination plants at the end of 2019.

Petitioner (Irrigation Community)	Desalination Plant	Approved Water Concession (hm^3/Year)	Water Concession Being Processed (hm^3/Year)
Águilas	Águilas-Guadalentín	16.5	-
	Miguel García	5.3	-
Alhama de Murcia	Valdelentisco	-	1
	Águilas-Guadalentín	1.2	-
Librilla	Valdelentisco	-	1
Lorca	Águilas-Guadalentín	25.4	-
Mazarrón	Virgen del Milagro	-	16
Puerto Lumbreras	Águilas-Guadalentín	6	-
Pulpí	Águilas-Guadalentín	6	-
Totana	Valdelentisco	-	5
	Águilas-Guadalentín	3.3	-
TST irrigation communities	Torrevieja	-	80
Total		64	103

Source: own elaboration from the questionnaires.

4.1.2. Services and Management Developed by ACUAMED

Apart from water concessions, the irrigation communities establish contracts or agreements with ACUAMED for the use of desalination infrastructure, determine the participation of each user in the payment of the amortization and exploitation rates for cost recovery, as well as operating and maintenance conditions and the responsibility of the parties. Regarding the assessment of the management and services offered by the ACUAMED desalination plants, six irrigation communities offer positive comments, four negative ones, and one of them offers arguments in both ways. It should be noted that the meaning of these assessments is not related to a specific desalination plant, since the irrigation communities supplied by them have identified both positive and negative ratings. In relation to the factors that determine a positive assessment, the most remarkable are the guarantee of water supply (5 out of 11); the direct communication with the desalination plant's staff and technicians of the operating company (3 out of 11); the desalinated water supply speed, and the good water quality (both 2 out of 11). On the contrary, the negative opinions are justified on two issues. On the one hand, some irrigation communities criticize the technical problems linked to the lack of storage capacity and regulation of desalinated water (3 out of 11), which makes it difficult to manage fluctuations in production and water consumption. Furthermore, some irrigation communities highlighted the limitations of the distribution network; the desalinated water production below the design flow rate; the lack of maintenance of hydraulic infrastructure; the failure of desalinated water supply at specific times; or the need to interconnect all desalination plants. On the other, all negative perceptions criticize the contract management signed with ACUAMED. There is a perception that harmful clauses to irrigators are established in these contracts that force to pay for desalinated water, whether they consume it or not. In addition, some irrigation communities remark that some contracts established that if they do not consume the desalinated water agreed, the price of the cubic meter of desalinated water increases in the following month. In general, in those irrigation communities where there is a negative perception of desalination management, ACUAMED is perceived as a closed, rigid, and bureaucratic interlocutor, with which it is difficult to negotiate. Irrigation communities consider that desalination management is not developed in a fair manner, since any agreement is conditioned on the signing of the ACUAMED proposals before knowing the economic conditions, so there is no mediation to solve the needs of the irrigators. This generates the perception among some irrigation communities that ACUAMED seems to only fulfil a money collection function. This vision is reinforced by the fact of the millionaire investment that these plants represented (EUR 762 M) and the cases of corruption associated with various members of ACUAMED. Likewise, in some instances it is pointed out that these contracts should be managed only with the Segura River Basin Authority, so ACUAMED mediation would be unnecessary. In addition, some irrigation communities have the perception that ACUAMED chooses to negotiate individual irrigation communities' agreements for their own benefit instead of negotiating with the SCRATS, which encompasses all the irrigation communities of the TST, which would facilitate desalination management and ensure unity of action. In summary, for most of the irrigation communities, the desalinated water management should be carried out by the SCRATS in consensus with the Segura River Basin Authority who should not be allowed to sign agreements with ACUAMED individually. On the contrary, from the ACUAMED perspective, irrigators' complaints or disagreements are explained by the conflicts of interest of certain users, and their knowledge and experience about the financing and exploitation of infrastructures. Although ACUAMED assumes that costs are usually the most controversial issue, they claim that this is determined by the amount of investments to be recovered and that, therefore, it is not possible to vary operation and maintenance costs.

4.1.3. Regulation

One of the main problems pointed out by the irrigation communities in relation to desalination management is the lack of storage capacity and regulation of desalinated water production, as well as some limitations in the distribution network from the plants to the irrigation communities, especially those which are connected to the Águilas-Guadalentín and Valdelentisco ones. It is worth remarking that the answers received in relation to the connections that each plant maintains diverge in some cases between the information provided by ACUAMED and that offered by the irrigation communities (Figure 4).

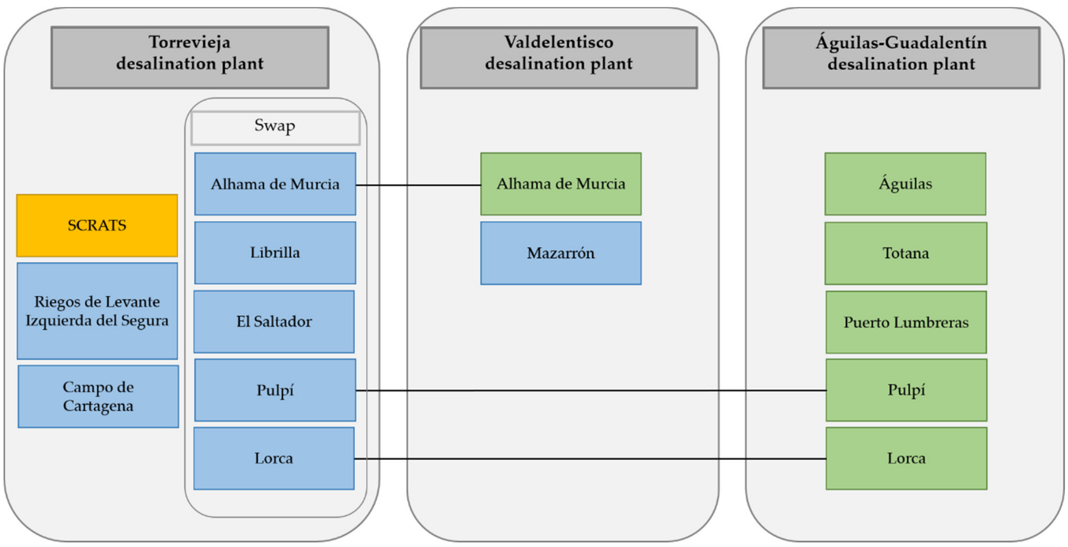

Figure 4. Irrigation communities' connections to each desalination plant. Source: own elaboration from the questionnaires. Legend: In green, the distribution network connection to desalination plant recognized by both irrigation communities and ACUAMED; in blue, the connection only recognized by the irrigation communities; in orange, connection only recognized by ACUAMED.

In this sense, it must be considered that the desalination water distribution network is quite new, and it has been developed especially after the approval of drought decrees. In the case of the Águilas-Guadalentín desalination plant, until the approval of the royal drought decree in 2015, this plant was not been connected to the irrigation communities of Lorca, Puerto Lumbreras and Totana. In fact, all complaints and improvement suggestions related to the limitations of distribution network, storage capacity and regulation come from irrigation communities connected to the Águilas-Guadalentín plant, which are the only ones that have approved desalinated water concessions. In addition, there are other irrigation communities who have requested water from the Águilas-Guadalentín desalination plant, such as Alhama de Murcia and Mazarrón, and the Valdelentisco desalination plant, such as Totana, Mazarrón or Campo de Cartagena, who have not been able to receive water due to infrastructure limitations and the expansion of the solitude process. In the case of the Águilas-Guadalentín plant, according to the irrigation community, there is a regulation capacity of 160,000 m^3 while the Valdelentisco one has a reservoir capacity of 2.6 hm^3 with a total of 124 water delivery points. Nevertheless, only the Torrevieja plant is connected to the post-transfer hydraulic infrastructure, which allows its production to be stored in the *La Pedrera* reservoir, with a storage capacity of 246 hm^3, shared for irrigation and urban uses. That is why the irrigation communities that claim to receive insufficient provision are those connected to the Águilas-Guadalentín plant, presumably due to the technical limitations of regulation and distribution, or those whose concessions to this plant and the Valdelentisco one are in the pipeline.

During the period of validity of the drought decrees, the SCRATS have managed the temporary concessions of desalinated water of the Torrevieja plant. The limitations derived from the desalinated water distribution network and regulatory capacity have been solved from the establishment of a system of exchange of allocations between irrigation communities and also between the SCRATS and the Mancomunidad de Canales del Taibilla (MCT), in charge of urban raw water supply in 80 municipalities of the SRB. These agreements, which were managed and proposed by the SCRATS to the Segura River Basin Authority, have allowed the use of conventional water sources in the irrigation communities not connected to the desalinated water supply network in exchange of desalinated water with the irrigation communities, such as Campo de Cartagena, which were able to use desalinated water from Torrevieja plant. The swap system management contemplates that the irrigation communities which receive additional water from conventional sources have to pay the price difference to the users who have assign their allocations in exchange for desalinated water, which is around 0.35 EUR/m^3, so cedents do not have to suffer any additional expenses (the TST rate for urban water supply is around 0.16 EUR/m^3, while the desalination rate reaches on average 0.51 EUR/m^3). In summary, this action has allowed overcoming one of the main barriers to the use of desalinated water related to the lack of hydraulic infrastructure.

Regarding regulation, from ACUAMED and the plant managers, it is pointed out that there is a preliminary project for the interconnection of all the desalination plants developed by the Segura River Basin Authority, which would allow solving the problems of regulation and storage capacity taking advantage of existing post-transfer hydraulic infrastructure. However, according to the ACUAMED plant managers, at the end of 2019, the distribution network was not being expanded. Likewise, from ACUAMED, it is noted that from the water delivery points to the irrigators, they are not responsible for the operation and maintenance of the pipes which drive water to the points of consumption. Likewise, they pointed out that their responsibility is to deliver the monthly volume of water agreed in the contracts with each user, which will depend on the production capacity of each desalination plant, and that, therefore, demands above this amount will not be guaranteed. Additionally, ACUAMED argue that they are not responsible for integrating desalination into general distribution systems with multiple origins of water, though a possible alternative could be the construction of regulatory elements if they are profitable, analysing the costs derived from their investment and whether there are users interested in promoting them. However, ACUAMED claims that they only perform the actions entrusted to them. Therefore, if any regulation element is considered in any of these actions, ACUAMED signs agreements for the payment of the costs derived from the construction and operation of these infrastructures, even though there may be other infrastructures dependent on other entities.

4.2. Desalination Water Use

4.2.1. Motivation, Demand and Use

For 10 out of 11 irrigation communities, the main reason that motivates the use of desalinated water is suffering from the structural or temporary under-provision of water. In addition, up to four irrigation communities point out that the use of desalinated water is also influenced by the fact that it allows them to improve the water quality through its mixing with other poorer quality water resources.

In some specific irrigation communities, the use of desalinated water is motivated by there being no other alternative. Some of these reasons are shared with those claimed by ACUAMED, since this entity argues that the irrigation communities use desalinated water due to reasons related to security of water supply and on account of its better water quality in comparison with other water sources.

Therefore, the main reason that motivates the use of water is to ensure the water supply, since the structural under-provision of water means that only 3 out of 11 irrigation communities surveyed have a conceded water volume equal to or greater than their water demand (Table 3). In fact, most of them have very pronounced water deficits. For the irrigation communities surveyed, except Riegos de Levante where there is no data about water on withdrawal points, there is an overall water demand of 472 hm^3/year, but the average water volume available is only 230 hm^3/year, and 142 hm^3/year during drought situations. If desalination did not exist, the average water volume on tapping point would be only 127 hm^3/year, and 50 hm^3/year during drought situations. Much of the structural water deficit is due to the under-provision of water from the TST, which represents half the volume of water concessions (265 hm^3/year), but its available volume is reduced to half in normal hydrologic conditions, and to 14% during drought situations.

Table 3. Concessional water volume, average water volume on irrigation tapping point during an average hydrological year and a drought situation, and total water demand by irrigation community.

Irrigation Community	Concession Water Volume (hm^3/Year)		Average Water Volume on Water Withdrawal Points (hm^3/Year)		Average Water Volume on Water Withdrawal Points during Droughts (hm^3/Year)		Water Demand (hm^3/Year)
	Total	**D.W.**	**Total**	**D.W.**	**Total**	**D.W.**	
Águilas	22.8	21.5	22.8	21.5	22.8	21.5	22.8
Alhama de Murcia	16.9	3.3	7.1	1.6	4.5	1.6	22
Campo de Cartagena	137.2	-	98.8	28	37	14	180–200
El Saltador	16	1.5–2	5.3		3.3	2	11
Librilla	14.5	7.2	7.4	1.35–2	2.5–3.8	1.5	5.5
Lorca	71.7	23	50.4	23	39.4	23	110.9
Mazarrón	15.5	14	15.5	14	15.5	14	24
Puerto Lumbreras	9.4	6	8.1	6	7.9–8	6	14
Pulpí	32	10.9	7.6	6.5	7.6	6.5	32–35
Riegos de Levante Izquierda del Segura	167.5	11	The average water volume on withdrawal points is not controlled. Each irrigation community who is part of the General Community is responsible for water distribution.				45–50
Totana	16.1	2.8	7.8	2.8	5.2	2.8	27

Note: D.W.: Desalinated Water. Source: own elaboration from the questionnaires.

This explains why, according to 8 out of 11 of the irrigation communities surveyed, the water deficit is due mainly to the under-provision of water from the TST, while five point to other surface water sources, four to desalinated water, two to purified water, and only one to underground water resources. It is noteworthy that almost three quarters of the irrigation communities have suffered from an under-provision of water from TST, which has led some to claim that it is not only impossible to plan annual water availability, but that they must also pay a fixed annual fee of EUR 220,000 for being water transfer recipients, despite exemption from its payment arranged by royal decree-law 10/2017 and Law 1/2018, by which urgent measures were adopted to mitigate the effects produced by the drought.

In order to solve this under-provision of water, the measures carried out most often are the general restriction of water and the transfer of water rights (pointed out by eight irrigation communities). In the first case, two of the three irrigation communities who do not resort to the general restriction have their own desalination plants. In the second, the irrigators affirm that it is a measure carried out in a centralized way by the SCRATS. Other measures implemented by seven irrigation communities are: the temporary concession of desalinated water; recommendations to the irrigators; and the exploitation of the strategic drought well fields promoted by the Segura River Basin Authority and managed by the SCRATS. Less generally, some irrigation communities resort to controlled deficit irrigation; controlled overexploitation of aquifers; and the formalization of contracts with private users that have wells.

Another issue related to desalinated water use is whether periods of maximum and minimum water demand exist, according to the seasonal variation in irrigation needs. The ACUAMED plant managers have pointed out differentiated patterns. For the Torrevieja plant, the managers indicate that there is no change in water demand, since this plant produces at full capacity. However, the managers of the Águilas-Guadalentín and Valdelentisco plants indicate that there is a maximum demand period between June–August and October–November. However, the irrigation communities claim that the arrival of desalinated water does not vary since they receive a uniform monthly volume. In any case, beyond the variation in irrigation needs determined by the crop type, six irrigation communities coincide in pointing out that during drought situations, there is a higher desalinated water demand due to the closure of the TST. Therefore, higher demand of desalinated water is justified by the fact that is the only water source available, which allows reducing under-provision of water. Moreover, three irrigation communities affirm that a higher desalinated water use is possible because it is subsidized. According to the ACUAMED technical manager, the best strategy that would help the irrigation communities to meet a variable desalinated water demand is the diversification of water supply sources, to be able to use unconventional resources at their maximum capacity for a water consumption baseline. In addition, irrigation communities could use surface and underground resources, which can be stored and have fewer distribution problems, to cover seasonal water consumption peaks.

4.2.2. Water Price, Tax and Cost

According to the ACUAMED desalination plants managers, the water price for agricultural use ranges between 0.38 EUR/m^3 in the Águilas-Guadalentín plant, 0.48 EUR/m^3 in Torrevieja plant and 0.57 EUR/m^3 in Valdelentisco plant. These prices include pumping-distribution costs that are respectively 0.09, 0.08 and 0.13 EUR/m^3. These figures do not match with those indicated by the irrigation communities, which are higher and, in practically all the cases, exceed the final affordable price based on the agricultural holding profile (Figure 5). In this respect, irrigators stressed that in addition to the purchase price, an increase of 7.5% must be added due to transport leakages estimated by the Segura River Basin Authority—0.24 EUR/m^3 from the toll of using the distribution infrastructure and 0.07 EUR/m^3 of the SCRATS surcharge. In addition, some irrigation communities have their own fixed costs related to the financial and operational costs of their infrastructure.

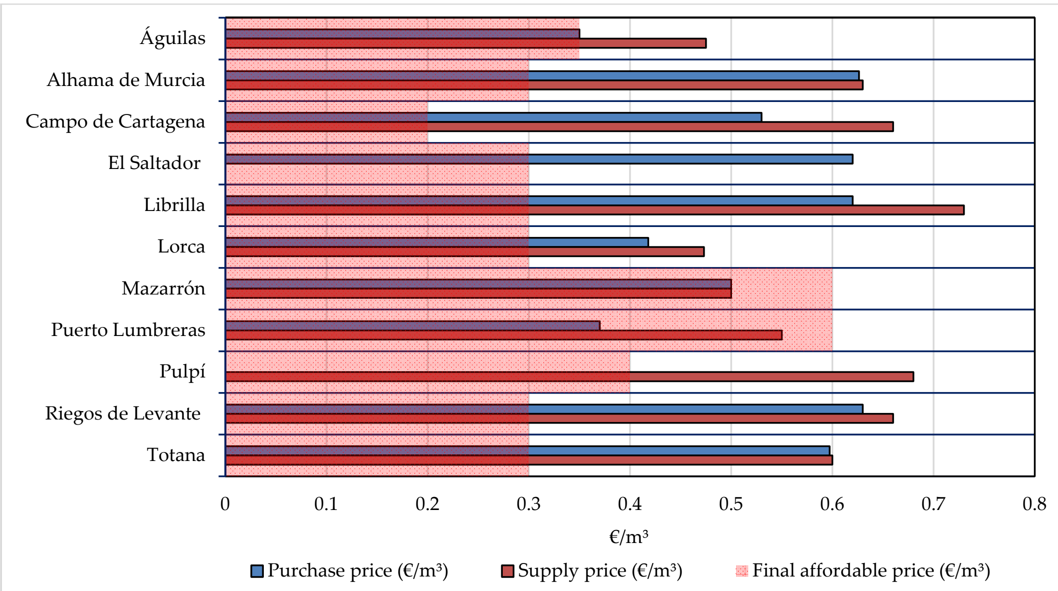

Figure 5. Purchase price, supply price and final affordable price of desalinated water by irrigation community. Source: own elaboration from the questionnaires.

In most cases, the irrigation communities indicate that the price of desalinated water is an inter-annual variable depending on the energy price, the investments made, the maintenance operations and the amount of water that supplied by the TST. In some cases, it is indicated that the price even varies depending on the consumption exerted and the agreements establish with ACUAMED in the desalination management contracts. If the consumption exceeds the allocation of desalinated water provision or does not reach the assigned provision, some irrigation communities pay a surcharge of between 0.12 EUR/m^3 and 0.2 EUR/m^3. Regarding the desalinated water subsidies, there has also been controversy. The subsidies have not been applied uniformly but have only contemplated the water produced in the desalination plants of Valdelentisco and Torrevieja. Some irrigation communities criticize that at the end of 2019, they had not yet received the subsidy, and that the administration owes them money. Generally, according to the irrigators' comments, it is unclear when, for whom, and to what extent the subsidies worked.

If the price of desalinated water were not a determining factor, within the set of possible resources to be used by the irrigators, desalination would be considered in the same order of priority of use as the surface water, after Tajo-Segura water transfer and before purified water and groundwater. However, practically all irrigation communities surveyed agreed to identify the price of desalinated water as the main obstacle to the use of this resource, since it is six times more expensive than the water from the TST. Likewise, irrigators' discourses coincide on the need to establish a common desalinated water price for all and that it should be reduced or, if that were not possible, to only be used if there are subsidies. ACUAMED, for their part, consider that without prejudice to defend their interests in the appropriate instances, complaints/criticisms about the price of desalinated water and the financing and operation costs of the infrastructures depend on the previous experience of the irrigation communities, since those who have already had a desalination plant know them perfectly. However, ACUAMED remarks that the decision to implement a single desalinated water price for all irrigation communities cannot be addressed by them. Neither do they consider that they are responsible for the design and application of the necessary subsidy mechanisms so that the price of desalinated water does not exceed 0.3 EUR/m^3, as stated in the fourth additional provision of Law 1/2018. They also consider that there is no technical/economic threshold that can be assumed by the irrigation communities since, although 0.3 EUR/m^3 has been defined as the standard price, some irrigation communities pay higher prices.

4.2.3. Water Quality Standards

Regarding water quality standards, in addition to the desalinated water quality perception by the irrigators, three issues have been consulted: conductivity, boron concentration, and management measures. Nine of the eleven irrigation communities surveyed have quality control systems in order to implement a permanent quality process control, with weekly analytics or every 15 days, which allows the control of water conductivity levels, among other parameters. According to the irrigators, the conductivity levels present the values indicated by the ACUAMED desalination plants managers, with values between 200 and 500 µS/cm in Torrevieja, 400–600 µS/cm in Valdelentisco and 500–900 µS/cm in Águilas- Guadalentín. In addition, 9 out of 11 irrigation communities (according to the technical profile of the interviewees) value the quality of desalinated water as good or very good (Table 4), which means that the conductivity levels of water does not usually exceed 1300 µS/cm, that is, the level associated with water quality standards suitable for most crops.

Table 4. Main issues related to desalinated water quality by irrigation community.

Irrigation Community	Quality Control Systems	Conductivity of D.W.	Perception of D.W. Quality	Problems with Boron
Águilas	Yes	600–700	Very good	No
Alhama de Murcia	Yes	D.K.	Good	No
Campo de Cartagena	Yes	500	Fair	No
El Saltador	No	500	Good	No
Librilla	Yes	D.K.	Poor	D.K.
Lorca	Yes	400	Very good	Yes
Mazarrón	Yes	600	Good	No
Puerto Lumbreras	Yes	500–600	Good	Yes
Pulpí	Yes	500	Very Good	Yes
Riegos de Levante Izquierda del Segura	No	D.K.	Good	No
Totana	Yes	457	Good	No

Note: D.W.: Desalinated Water. DK: Do not know. Source: own elaboration from the questionnaires.

In general, the irrigation communities have not identified the concentration of boron in desalinated water as a problem. However, in some irrigation communities supplied by the Águilas-Guadalentín plant, they have experienced specific problems of high concentration of boron. It is the case of Lorca, which indicates that sometimes the boron concentration has exceeded 0.5 mg/L, which has caused problems in citric crops. In this case, after been notified by the irrigators, ACUAMED referred to the signed contract that indicated that concentrations in the supplied water of up to 1 mg/L could be reached. Likewise, the irrigation communities of Pulpí and Puerto Lumbreras affirm that boron has generated problems in their farms, especially in long-cycle citrus, table grape, and tomato plantations, which have forced the mixing of desalinated water with water from other sources to reduce its concentration.

All the irrigation communities affirm that it is not necessary to carry out any post-treatment for desalinated water before use. However, all the irrigation communities, except for Mazarrón, some plots of Totana, and Lorca in specific cases, mix desalinated water with water from other sources on their irrigation ponds. The main reasons that justify this mixture are the increase in the water quality (7 out of 11); taking advantage of the available conventional resources (6 out of 11); the cost savings derived from not relying exclusively on desalinated water (5 out of 11). This fact makes it unfeasible to consider requesting, in the medium-long term, a specific desalinated water quality from the plants according to the needs of the crop, since it would require irrigation ponds with different qualities. Furthermore, some irrigation communities point out that the request for water with certain quality standards would increase production costs, so they prefer to continue opting for the mixing of water from different sources to improve the quality. Only two irrigation communities indicate that this option may be considered. In the case of Águilas, it is because they already do so by having their own plant, and in the case of Riegos de Levante Izquierda del Segura, they would only consider it if they only had this water source available and boron levels exceeded limits.

4.3. Future Outlook

4.3.1. Benefits and Impacts

The evaluation of the benefits and disadvantages of using desalinated water for irrigation by ACUAMED desalination plants managers and the irrigation communities offers very similar results. The main advantages identified by ACUAMED refer to a greater availability of water resources and quality, as well as for the irrigators who identify the security/guarantee of supply as the main benefit, and, in second place, the improvement of water quality and the reduction of conductivity by its mix with other water sources. Likewise, some irrigation communities identify other advantages, such as (1) the possibility of using it for all types of crops; (2) the improvement of planning the volume of water available; (3) the reduction of political problems motivated by water transfers between autonomous communities; or (4) the environmental improvement that it entails, since it reduces the exploitation of overexploited aquifers. With regard to the disadvantages, both ACUAMED and the irrigators agree that the main ones are the high price of desalinated water, which is pointed out by all the irrigation communities, and the problems that a high boron concentration could cause, identified by four irrigation communities. However, some irrigation communities pointed out some other problems that were not identified by ACUAMED, such as (1) insufficient water regulation capacity; (2) high level of CO_2 emissions due to high energy consumption; (3) the limitations of desalinated water supply in relation to the seasonal variation of the demand; or (4) possible technical problems related to breakdowns or maintenance.

Furthermore, internally, five irrigation communities claim that the impact of the use of desalinated water on the productivity of soil and crops is debated. This group of irrigators affirms that the prolonged use of desalinated water could produce environmental impacts on the vegetation and soil itself, especially relating to high boron values and infrastructure due to the acidity of the water and corrosion problems. In any case, among this group of irrigators, it is indicated that studies are either being carried out in this regard, or that it is necessary to carry them out, with the objective that they can be given arguments to position themselves with a scientific base. However, most of the responses about the environmental impacts of prolonged use of desalinated water on crops are pronounced in the sense of lack of knowledge (do not know, no answer) or claiming that it has no environmental impact.

4.3.2. Future Scenarios

Looking ahead, irrigation communities agree that the main factors that will influence the acceptance of the use of desalinated water for irrigation will be, first, the price of desalinated water, indicated by all respondents, and secondly, the water availability from conventional sources. Likewise, thirdly, up to six irrigation communities indicate that desalinated water quality will influence its acceptance, although it should be noted that this option is never signalled in a unique way, since the concern for the price always appears. Therefore, the main measure identified unanimously by irrigators to increase the acceptance of the use of desalinated water is the reduction in its price. To a lesser extent, other possible measures to be developed in the future are the promotion of subsidies for the technical innovation necessary to improve water quality, identified by six irrigation communities. Up to four irrigation communities also identify that another series of measures could positively influence the desalinated water use acceptance, such as (1) an economic bonus according to the volume of water consumed; (2) the implementation of information campaigns about the benefits and impacts of the use of desalinated water; (3) expert technical advice; (4) institutional and administrative support.

Despite perceiving water price as the main factor that can limit the acceptance of the use of desalinated water, all irrigation communities, except those of Pulpí and Riegos de Levante Izquierda del Segura, consider requesting further concessions of desalinated water. Among the reasons given to extend their concessions are, mainly, to alleviate the under-provision of water resources and the absence of other water supply sources. Furthermore, in specific cases, it is pointed out that the expected increase in the use of desalinated water is explained by the need to improve water quality mixture, due to the conductivity problems involved in the use of groundwater, and also in order to meet a future increase in water demand. However, practically all the irrigators consider that desalinated water cannot substitute other water sources such as the TST or surface water. In general, irrigation communities believe that desalinated water is a complementary measure to face possible climate change impacts, since irrigation water must be a mixture of different sources, and not just desalinated water. However, the experience lived during the last drought between 2015 and 2018 has led many irrigators to perceive that without desalinated water they would not have been able to continue their activity. For its part, ACUAMED does not provide its vision about future scenarios since they argue that these issues are related to political decisions and that who is capable of making strategic decisions is the National Government through the SRB. In this sense, it would be interesting in future research to complement these results with the vision and perceptions of the political representatives and members of the SRB.

5. Discussion

Conventional water sources are not able to fill the gap between the supply and demand of freshwater, because this growing gap can only be filled by non-conventional water sources such as seawater desalination. Taking into account that almost half of the world's population lives within 100 km of an ocean, and because nearly 70% of major cities are located in this narrow area, seawater virtually represents an infinite freshwater resource with the advantage of being un-exhaustible and climate independent [42]. Desalination plays an important role in the provision of irrigation water in Spain and is being used to alleviate the shortage of water and to preserve freshwater resources [43], besides addressing the water-energy-food nexus with scarcer resources [44]. Our study has been focused on how end users (irrigation communities) and managers (desalination plants) exchange their perception about desalination by addressing three main questions: (1) management and measures promoted to overcome current and potential barriers, (2) main driving-factors of their acceptance or rejection for agricultural irrigation, and (3) the priority (or not) to use desalination for ensuring climate change adaptation.

The first question raised how desalinated seawater is managed and three different models of desalination seawater provision have been identified. Firstly, the ACUAMED desalination plants model, in which irrigation communities have to set contracts or agreements for using their infrastructure and establish the rates in order to comply with the cost recovery principle. Secondly, the swap system proposed and managed by the SCRATS, which enables the exchange of water allocations from conventional water sources for desalinated water produced in the Torrevieja desalination plant between users in the SRB. Thirdly, some irrigation communities have their own desalination plants. Taking into account the diversity of management models and that most of the irrigation communities value the management of the SCRATS very positively, a proposal to improve the current management plan would be that agreements with irrigation communities and future desalinated water allocation process should be centralized through SCRATS and individual agreements between ACUAMED and irrigation communities must be terminated. In this way, it would be easier to solve the problem of fixed production of desalinated water, since the distribution infrastructure and regulation of the post-transfer could be used, which would allow for optimizing the distribution of water based on technical and operational criteria, guaranteeing water quality and the lowest possible price and minimizing the infrastructure to be carried out. Moreover, a centralized management would solve conflicts related to abusive clauses in the contracts signed between ACUAMED and irrigators, and competence between irrigation communities.

Regarding current and potential barriers, two main issues have been identified: water price and energy consumption [45]. Notwithstanding these, there are others barriers identified by the irrigators, such as (1) technical problems in some plants [46], by which despite the advancements made, seawater desalination for irrigation is still expensive compared to traditional freshwater sources; (2) hydraulic infrastructure constraints, such as the lack of regulation and storage capacity [47], and, in some plants, (3) the limitations imposed by the lack of water distribution networks [48]. All these issues could be faced by applying the PSII for the 2021–2027 planning cycle in the SRB. The PSII states, in its Theme 13 of "Allocation and economic-financial regime of desalination resources", the full distribution of the current production capacity of desalination plants, and even the expansion of the desalination capacity of ACUAMED desalination plants (an additional of 63 hm^3/year), to replace resources from over-exploited aquifers and those water subsystems in situations of a lack of water guarantee, such as those of the TST. However, this extension may be insufficient, since dealing with structural water deficit and the hypothetical closure of the TST would require adding around 400 hm^3/year of desalinated water for the irrigation communities surveyed, alone. Additionally, to ensure the use of these resources it would be necessary the exemption of the cost recovery principle stipulated in the European Water Framework Directive, as allows in the case of certain hydrological conditions, such as drought situations. The economic issue tends to be in line with the management issue and, according to the irrigation communities answers, the management carried out by ACUAMED must be improved, as most irrigation communities consider that it would be preferable that the agreements for the use of desalinated water were negotiated not individually, but in common between the SCRATS and the Segura River Basin Authority. The evident lack of cooperation and communication between ACUAMED and the Segura River Basin Authority has led to a situation in which desalinated water concessions could not be made effectively, and in which economic issues have not been studied in advance.

In relation to the second question, three main issues have been highlighted as the benefits of using desalination: (1) the fact that seawater is the only water source available for irrigation when (severe) drought periods occur [49]; (2) the subsidized costs which have contributed to the growing use of this alternative water source [50]; (3) the increase in the water quality mixture used by irrigators [51]. In relation to rejection of desalinated water use, the main factors are (1) high cost (including high energy consumption) [52], and (2) environmental impacts, such as brine discharges and the impact of boron over crops and soil [53]. It should be noted that in order to minimize the first issue, the national government approved urgent measures during the drought period between 2015 and 2018 that included the subsidy of desalinated water price for irrigation, the expansion of desalination hydraulic infrastructure, the approval of temporary concessions or a project of future interconnection of the desalination plants. Beyond being a reactive measure against an adverse scenario, the underlying issue is how to achieve an agreement at European and national level that guarantees a desalinated water price below 0.30 EUR/m^3 (which is the most profitable limit set by irrigation communities and to whose compliance the Government committed in the fourth additional provision of Law 1/2018) and duly comply with the cost recovery principle fixed by the Water Framework Directive.

Lastly, in response to the third question, desalination is conceived as an alternative option concerning climate change adaptation and not the first option, because seawater represents a supplement to their irrigation needs [54]. The high cost of seawater is identified as the main barrier for irrigators to only relying on this source, since in the great majority of cases, the delivery price of seawater is much greater than the affordable price by irrigators. Almost all the irrigation communities use a mixture of water from different conventional and non-conventional water sources in order to comply with quality standards and affordable costs. Therefore, desalination seems to be an alternative option, of which development is encouraged by the impossibility to satisfy water demand with other water sources. In this regard, a large part of the irrigation communities pointed out that the use of water transferred from other Spanish river basins cannot be rejected, although some of them have the perception that it is likely that the TST may be closed permanently. Given this situation, a strategy could be to replace the current water concessions focused on water transfer for desalinated water, where the SCRATS would play a fundamental role.

6. Conclusions

Desalination challenges (water and energy cost, infrastructures network, environmental impacts, integrated water management, and climate change scenarios) require understanding both technical and social driving factors, and to this end, it is essential that end users (irrigators) and managers can work together to go deeper into most water-energy-efficient solutions but also in ensuring the acceptance of using desalination among irrigators. This paper aimed to understand the concerns and challenges of desalinated seawater for agricultural irrigation and the relevance of water cost and quality standards, by exchanging perceptions from desalination plant managers and irrigation communities from Alicante and Murcia (Spain). Combining technical data and behavioural issues through discursive analysis, driving factors on the benefits and barriers of desalination use and management have been identified. Results highlighted how (1) irrigation communities consider desalination as a complementary water source to be combined with conventional water resources, (2) both ACUAMED and irrigation communities agree on highlighting two main advantages of using desalinated water: the security/guarantee of supply and water quality parameters, while the main disadvantage for irrigators is the high water cost, and (3) managers and irrigators disagree on the desalination management model, since irrigators consider that the Central Union of the Tajo-Segura transfer irrigators (SCRATS) should have a leading role. The obtained results should be useful in future attempts to identify how the current concerns shared by the irrigation communities could be addressed by desalination plant managers, while putting attention on the main driving factors and barriers, such as different models of desalination seawater provision, water price and energy consumption as main barriers, lack of storage capacity and regulation, and environmental impacts. Overcoming these issues is key to turning current barriers into future best practices in desalination use and management. Furthermore, policy makers should take this social-learning process between users and managers into account when they attempt to close the supply-and-demand gap of desalination in the medium and long term, which is especially significant in regions of water scarcity and confronted water use.

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