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Review

Extending Natural Limits to Address Water Scarcity? The Role of Non-Conventional Water Fluxes in Climate Change Adaptation Capacity: A Review

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Abstract: Water consumption continues to grow globally, and it is estimated that more than 160% of the total global water volume will be needed to satisfy the water requirements in ten years. In this context, non-conventional water resources are being considered to overcome water scarcity and reduce water conflicts between regions and sectors. A bibliometric analysis and literature review of 81 papers published between 2000 and 2020 focused on south-east Spain were conducted. The aim was to examine and re-think the benefits and concerns, and the inter-connections, of using reclaimed and desalinated water for agricultural and urban-tourist uses to address water scarcity and climate change impacts. Results highlight that: (1) water use, cost, quality, management, and perception are the main topics debated by both reclaimed and desalinated water users; (2) water governance schemes could be improved by including local stakeholders and water users in decision-making; and (3) rainwater is not recognized as a complementary option to increase water supply in semi-arid regions. Furthermore, the strengths–weaknesses–opportunities–threats (SWOT) analysis identifies complementary concerns such as acceptability and investment in reclaimed water, regulation (cost recovery principle), and environmental impacts of desalinated water.

Keywords: water scarcity; water cost; water quality; water management; desalination; reclaimed water; rainwater; climate change; adaptation; south-east Spain

1. Introduction

Water scarcity, defined as long-term water imbalances occurring when the level of water demand exceeds natural water availability and supply capacity, is expected to pose high risks to both societies and economies in the next decade [1]. According to Mehta [2], water scarcity is both 'real' and 'constructed', in which socio-political and institutional factors are at interplay. The constructive perspective fits well with a coexisting double narrative. On the one side, the water insufficiency narrative identifies the reasons for water scarcity in the limited supply or decreasing water resources and the factors increasing the demand side. This narrative comprises population growth, water transfers with neighboring regions, and climate change pressures [3]. On the other side, the water mismanagement narrative attributes water scarcity primarily to poor management and bad governance, and the lack of economic investment and development in water resources infrastructure [4]. Nevertheless, increasing water use due to population and economic growth is usually recognized as the primary driver of water scarcity because both factors lead to a growing demand for water-intensive goods and services (e.g., agro-food products) [5]. Moreover, hydroclimatic extremes (e.g., heat waves, droughts) intensify high consumptive water use [6]. The last three decades have successively been the hottest on the earth's surface compared to all the previous decades since 1850 [7]. Furthermore, rising temperatures have changed the balance of water resource revenue and expenditure, which, in turn, has caused widespread water scarcity and an uneven distribution of water resources. Land-use and land-cover changes [8], and changes in characteristics and patterns of precipitation and evaporation [9], have also contributed to maximizing the imbalance between water supply and demand, requiring investment in water infrastructures or water transfers to ensure water security [10].

Climate change will have a significant influence on water scarcity and water supply, both quantitatively and qualitatively. Severe impacts are reported to be water-related, with river ecosystems and agriculture often highlighted as sectors highly sensitive to change [11]. Agriculture, the world's largest water-consuming sector, accounts for 70% of water use on average, although it is estimated that the consumption of freshwater for agricultural irrigation accounts for 60%–90% of all water use, depending on the level of economic development and the climate of the area [12]. At the current growth rate of population and urbanization, the agriculture sector will have to produce 60% more food globally and 100% more in low-income nations [13]. However, a year with an anomalous rainfall regime, sudden temperature changes, or extreme weather events, have harmful effects on the performance in agricultural and livestock activities [14]. Consequently, ensuring food security and sustainable agricultural development is an urgent challenge because declining water availability or increasing water demand can harm cropland productivity [15]. Furthermore, although domestic and tourism water demands are relatively low compared to agricultural activity, tourism is heavily water-dependent, and the quantity and quality of water affect multiple facets of tourism sustainability [16]. At first glance, tourism appears to have a negligible impact on water resources, because global figures suggest that international tourism accounts for less than 1% of national water use in most countries, although in some others, such as Spain, this percentage could exceed 10% [17]. Nevertheless, tourism tends to be concentrated in dry and warm places and seasons, coinciding with high water demand from urban and agriculture users [18].

The competing water-related interests and the varying physical and socioeconomic drivers impacting specific sectors are increasing the challenge to address water supply in the near future [19]. In addition, water-related extreme events maximized by climate change will have indirect implications on social, economic, and environmental systems, thereby changing the spatial management and allocation of land and water resources [20]. This situation is particularly enhanced over semi-arid regions, where average precipitation is between one-fifth and one-half of the potential plant water demand [21]. Consequently, drying trends may occur most significantly in these regions, impacting the hydrological cycle, leading to changes in system response and increased drought risk and water scarcity [22]. According to Haghighi et al. [23], drought in semi-arid regions often starts with a meteorological drought (defined by lack of precipitation, possibly aggravated by hot temperatures, causing high evapotranspiration rates) [24], which leads directly to a hydrological drought (defined as a persistently decreasing discharge volume in streams and reservoirs over months or years) [25]. However, if the use of water resources exceeds the renewal of surface and groundwater, or if water demand outstrips supply, both agricultural and socio-economic droughts occur [26,27]. Exacerbating matters, a recent satellite-based study of Earth's freshwater resources demonstrated that this scenario based on drought severity was predicted for the end of the 21st century by the Intergovernmental Panel on Climate Change [28].

Although a consensus on long-term drought dynamics and their main drivers has not been achieved due to the complexity and difficulty with defining drought, different drought types, and difficulty providing an absolute assessment of the drought severity phenomenon [29], it is predicted that the frequency and intensity of droughts will increase under future climate change scenarios at the regional level, particularly in southern Europe [30]. Droughts are expected to be more severe over time and enduring, which poses a challenge for agricultural and urban-tourist water management in the Mediterranean region [31]. Mediterranean basins have a strong climate seasonality due to being dominated by alternating high- and low-pressure systems, and by depending on the water resources generated in other areas [32]. Future projections of climate trends show that Mediterranean countries will become drier and hotter, which might result in a severe decrease in agricultural productivity [33]. The need for irrigation water increases in these basins during the summer months as the growing season progresses, and the fluctuations in out-of-phase water availability and demands results in temporary or permanent water scarcity in the region [34]. Consequently, the Mediterranean region is one of the most vulnerable regions to climatic and anthropogenic changes, and hence it is a climate change hotspot due to the expected warming and drying of the region [35].

The problem facing society today goes beyond the lack of water resources to meet the world's growing needs and requires a change in the way that water is used, managed, and shared according to conflicting interests between water uses and functions [36,37]. This means considering water as both a biophysical and a social resource because water and society are (re)making each other: social conflict over water resource allocation affects the resource, and the hydrological features affect who has access to water, when, where, and at what cost [38]. Therefore, the strong competition between agriculture and urban-tourism water demands indicates the existence of 'structural' or 'permanent' water scarcity [39]. This scenario has motivated scientific communities to search for different (and complementary) solutions to increase water supply for both water-related sectors [40]. There are multiple environmental benefits associated with the agricultural use of reclaimed water, including: (a) reduced pressures on overstressed aquifers; (b) successful groundwater recharge; (c) reductions in fertilizer applications and expenses due to nutrients remaining in reclaimed water; and (d) higher crop yields for some crop types that are grown with reused water [41].

Conversely, lack of widespread public support (addressing the displeasure related to the perceived risk to human health and the environment), and technical and economic implementation (ensuring quality standards and energy efficiency at low cost), are some of the main barriers identified by reclaimed wastewater promoters [42]. Similarly, desalination is controversial because of its direct environmental consequences (high energy consumption and impacts on marine ecosystems) and for its consideration as a supply-oriented solution (creating a sense of security based on an unlimited resource that can reduce attention to water demand, enabling further consumption and pressuring local water systems) [43,44]. However, desalination provides a high-quality water supply [45] and is climate-independent, although this can thereby be seen as shifting problems from one scarcity (freshwater) to another (energy), thus postponing problem-solving [46]. On the contrary, the use of reclaimed (also called recycled) water for indirect potable reuse is mainly focused on landscaping (urban wetlands to improve water quality, green areas to mitigate the urban heat island effect, and better living environments for residents) [47], although the main obstacle for landscape water replenishment is its high nutrient concentration. Furthermore, potable reuse is limited to those contexts with severe water scarcity patterns, in which water is too precious to use just once [48]; for example, in 2002, Singapore became the first country to blend reclaimed water with fresh water in a reservoir to be used as recycled drinking water, called NeWater [49]. Similar efforts have been proposed in other water scarcity regions and cities to achieve net-zero urban water (conceived as the ability to sustain a population's water needs by replacing unsustainable practices with alternative, long term, locally sustainable sources). However, public perception, rather than water quality, has halted these projects [50].

In urban-tourist contexts and parallel to the use of reclaimed and desalinated water, rainwater is still an under-utilized, renewable alternative water source for water-stressed cities around the world. Nonetheless, since the late 1990s, rainwater harvesting has been increasing in countries such as the United States, Australia, the United Kingdom, Sweden, and France [51], or countries of the Mediterranean region such as Spain, Italy, or Greece [52–54]. By collecting and storing rainwater from land surface catchments, rainwater harvesting can be used for potable and non-potable purposes to have a significant role in reducing water consumption and as a flood management strategy [55]. In technical terms, water harvesting could be a system that collects rainwater from where it falls around its periphery instead of allowing it to travel as runoff [56]. Easy maintenance, cost-effectiveness, and communities' preference over recycled water have turned rainwater into a water supply alternative [57]. However, rainwater is a resource that must be gathered in decentralized interventions, rather than one large public works construction, as occurs when addressing agricultural water demand [58]. According to Cousins [59], a transition towards water-sensitive cities is needed: (1) to collect the water, and transport and store it as long as possible to slow the runoff and facilitate its infiltration to recharge the aquifers and mitigate floods; (2) to prevent the collapse of sewage systems and treatment plants (reclaimed water) and, in turn, prevent discharged pollution from degrading water bodies; and (3) its subsequent use based on the principle of fit-for-purpose for certain urban (watering gardens, street cleaning, etc.) and tourism (accommodation facilities, toilet flushing, cooling towers, etc.) purposes [60].

This study extensively reviews the relevant literature from the past two decades guided by the following research question: What are the challenges posed by the use of non-conventional water resources when addressing water scarcity in semi-arid regions, assuming that usually adopted solutions and strategies should be motivated by different technical and social narratives? Furthermore, this contribution aims to re-think the benefits and concerns, and the inter-connections of reclaimed and desalinated water, as an adaptive strategy to address climate change and increase the resilience of agricultural and urban-tourist water demands in semi-arid regions. A special focus was placed on south-east Spain to highlight: (1) the practical implications of using reclaimed and desalinated water; (2) the circumstances and attitudes under which non-conventional water resources are used and accepted; and (3) the (current) role and potential use of rainwater.

2. Water Scarcity in South-East Spain

The region of south-east Spain has one of the largest structural water deficits in Europe. This is partly due to its semi-arid climatic characteristics, with mean annual rainfall values less than 400 mm, a great intra-annual variability, with a marked dry season in summer, in addition to inter-annual variability, with the occurrence of frequent episodes of drought and punctual episodes of intense precipitation. In this region, therefore, there is low availability of surface water resources because most of the rivers have a marked seasonal regime and their channels remain dry for most of the year. In addition, urban-tourist development, especially linked to residential tourism in coastal areas, and, above all, the development of an export-oriented irrigation model, explains not only the pressure on water resources but also the competition for water resources between agriculture and urban-tourist users [61]. This high-water demand has been fueled for decades by the Tajo-Segura transfer (TST) water flows, which since 1979 have conveyed water to the south-east from the Tajo River Basin headwaters located in the Iberian Peninsula hinterland. However, the volume transferred has not fulfilled users' expectations because the operation of this infrastructure has not prevented the irrigable surface from extending beyond the water availability limits [45]. This water deficit has been partially solved thanks to the extraction of underground water resources and the overexploitation of most of the aquifers in south-east Spain. Moreover, the need to diversify supply sources to guarantee demands has driven the development of non-conventional water resources in this region. In this sense, it should be noted that for several decades the reuse of wastewater has been especially intense in the south-east of Spain, where are located the highest percentages of wastewater treatment and reclaimed water use at the national level, mainly for agricultural irrigation [62].

Similarly, during the past two decades, desalination has also played a key role in guaranteeing water demand. In 2004 there was a change of direction in the Spanish water policy, which entailed the dismissal of future inter-regional water transfer projects for the benefit of desalination development in those Mediterranean regions that presented water deficit problems, such as south-east Spain, which experienced the greatest development of this infrastructure [63]. Although the use of this water source was initially focused on urban uses, recently the demand for desalinated water for agricultural irrigation has undergone significant growth. This expansion in desalinated water use has been driven by the modification of the TST legislation between 2014 and 2015 (Royal Decree 773/2014 and Law 21/2015) and the establishment of greater ecological flows on the Tajo River, which further restricted the approval conditions to enable water transfers to the south-east [45]. Faced with this situation, there has been an escalating trend in the consumption of desalinated water for agricultural uses that will continue in the future, according to the recent applications for desalinated water concessions by irrigators, which exceed the current production capacity of desalination plants [61].

3. Materials and Methods

A bibliometric analysis and literature review were combined to provide deeper and state-of-the-art knowledge of the use, management, and perception of non-conventional water resources. The bibliometric analysis provides a descriptive and statistical evaluation of scientific publications for tracking progress and identifying areas for future research [64], and the literature review identifies the manifest and latent background to a challenging topic from qualitative data [65]. The following sections describe the nature and the source of the data collected and the main methods used to analyze them.

3.1. Data Collection: Search Terms and Process

The systematic literature review and the corresponding bibliometric and literature analysis were focused on two scientific databases, Thomson Reuters' Web of Science (WOS) database and Elsevier's Scopus database. Both databases provide peer-reviewed literature with high standards of availability, updating, scientific relevance, and comprehensiveness. However, the inclusion of the Scopus database was motivated by its stronger international/non-English coverage, in addition to more extensive coverage of social science [66].

The relevant literature was identified by defining a temporal scale (period from 2000 to 2020) and a spatial scale (south-east Spain) to determine the case study area. Search terms were selected considering their ability to ensure a search string that combines both the conceptual and the technical/social terms associated with the use and management of non-conventional water resources. Consequently, the combination of keywords included conceptual terms such as desalinat*, non-conventional water resources*, reclaimed water, wastewater reuse*, and technical/social terms such as adapt*, advantage*, climate change, cost*, drought*, environment*, impact*, irrigat*, qualit*, management, percept*, planning, polic*, resilience, risk*, scarc*, sustainabilit*, transfer*, urban, water supply, and water demand. The search process in the WOS database was guided by the fixed use of the OR operator for non-conventional water resources terms concepts as part of the title of the paper, the AND operator to include the word "Spain" as part of the abstract, and another AND to contain in the abstract at least one of the technical/social terms listed previously, which were all included in the search string also separated with an OR operator. Accordingly, the search string for the WOS database was:

> TI = (desalinat* OR non-conventional water resources OR reclaimed water OR wastewater reuse) AND AB= (Spain) AND AB= (adapt* OR advantage* OR climate change OR cost* OR drought OR environment* OR impact* OR irrigat* OR qualit* OR management OR percept*OR planning OR polic* OR resilience OR risk* OR scarc* OR sustainability* OR transfer* OR urban OR water supply OR water demand).

Furthermore, the search process in the Scopus database was guided by the fixed use of the OR operator for non-conventional water resources conceptual terms, the AND operator to include the word “Spain”, and another AND to contain at least one of the technical/social terms, which were all included in the search string also separated with the OR operator. For each of the three components (non-conventional water resources, Spain, and technical/social) the search process in the Scopus database was undertaken as part of the title of the paper, the abstract, or the keywords. Accordingly, the search string for the Scopus database was:

> TITLE-ABS-KEY (desalinat* OR “non-conventional water resources” OR “reclaimed water” OR “wastewater reuse”) AND TITLE-ABS-KEY (Spain) AND TITLE-ABS-KEY (adapt* OR advantage* OR “climate change” OR cost* OR drought OR environment* OR impact* OR irrigat* OR qualit* OR management OR percept* OR planning OR polic* OR resilience OR risk* OR scarc* OR sustainability* OR transfer* OR urban OR water supply OR water demand).

Similarly, the same search analysis was carried out including rainwater, considering the following search string for both the WOS and Scopus databases, respectively:

> TI = (rainwater) AND AB= (Spain) AND AB= (adapt* OR advantage* OR climate change OR cost* OR drought OR environment* OR impact* OR irrigat* OR qualit* OR management OR percept*OR planning OR polic* OR resilience OR risk* OR scarc* OR sustainabilit* OR transfer* OR urban OR water supply OR water demand).

> TITLE-ABS-KEY (rainwater) AND TITLE-ABS-KEY (Spain) AND TITLE-ABS-KEY (adapt* OR advantage* OR “climate change” OR cost* OR drought OR environment* OR impact* OR irrigat* OR qualit* OR management OR percept* OR planning OR polic* OR resilience OR risk* OR scarc* OR sustainabilit* OR transfer* OR urban OR “water supply” OR “water demand”).

3.2. Screening and Selection

The papers returned from the different databases were positively considered for both the bibliometric analysis and the literature review based on an inclusion criterion applied to three successive levels: title, abstract, and full text. Furthermore, additional aspects were considered: The investigations should be scientific articles written in English or Spanish, published between 2000 and 2020, and centered in south-east Spain, where the use of non-conventional water resources is more widespread than in other Spanish Mediterranean regions. Moreover, content inclusion criteria were considered, focusing on researches related to the use of non-conventional water resources (e.g., driving factors that limit or favor their use) and their social, economic, or environmental impacts, in addition to the repercussions for water resources management. Consequently, studies focused solely on technical issues, such as analysis of different desalination methods or wastewater treatment options, were dismissed. However, the selection was not made based on the research category. Similarly, after the full-text analysis, the relevance of the contribution was considered, and those papers that do not make any substantial contribution or whose content is very similar to that of another investigation were rejected. In this case, priority was given to maintaining the most recent articles in the bibliographic review.

The initial search in both databases returned 670 papers on reclaimed and desalinated water, of which two-thirds were from Scopus. However, the title analysis equaled the initial dominance of Elsevier’s database. After eliminating 30 duplicate papers and conducting abstract analysis, a total of 81 papers were included for a full-text and literature review (Table 1). In addition, the search for rainwater papers initially returned 147 papers (87.8% from Scopus), of which only seven were considered for full-text analysis (Table 2). Due to the small size of the sample, these papers were not considered for the literature review.

Table 1. Papers on reclaimed and desalinated water returned by databases.

Database	Initial Search	Title Analysis	Duplicated Papers	Abstract Analysis	Full-Text Analysis
WOS	237	64	-	64	51
Scopus	433	69	30	39	30
TOTAL	670	133	30	103	81

Table 2. Papers on rainwater returned by databases.

Database	Initial Search	Title Analysis	Duplicated Papers	Abstract Analysis	Full-Text Analysis
WOS	18	7	-	7	1
Scopus	129	25	7	18	6
TOTAL	147	32	7	25	7

3.3. Data Analysis

After compiling an inventory with the retrieved publications from the above search engines and criteria, the 81 papers were reviewed, classified, and analyzed following a bibliometric approach. Performance analysis is one of the main procedures used in a bibliometric analysis and was conducted to evaluate the characteristics of publication outputs, identifying popular topics or variation trends of the non-conventional water resources research [67]. A codebook of the main parameters used for the literature review was defined. Included references were limited to those in the English language (n = 72) to avoid translating some themes and sub-themes (such as title or keywords) that could affect the meaning of the original words used. The coding process was focused on 5 main themes composed of 15 sub-themes (data columns) that were able to provide three main information topics: article, author(s), and research (Table 3). Data was organized using Microsoft Excel© (Microsoft, Redmond, Washington, USA).

Table 3. Codebook of main themes/sub-themes used for the bibliometric analysis.

Theme	Sub-Theme	Codes
General info	DOI, Journal, Year of publication	3
Authorship	Author(s)'s name, Author(s)' affiliation(s), Author(s)' country	3
Case study	Region(s), Case study(s)	2
Analysis	Research topic(s), Research method, Research tool(s)	3
Content	Title, Keywords, Aim, Conclusions	4

Note: The sub-themes Research topic(s) and Research tool(s) can be described using a maximum of three items. The Research method typologies were adapted from [68]. For those themes containing sub-themes with more than one answer option that was hierarchical, the first or main option was highlighted and distinguished from the whole option' analysis. Author(s)' affiliation(s) contains both the department and the university of reference. When one publication also included a case study outside south-east Spain, this example was not analyzed. The Content sub-themes were abstracted from the original text. Geographical references were excluded from the analysis of the Keywords to focus the attention on the conceptual topics.

As a first step for the literature review, the bibliometric analysis included the examination of the linkages among terms used in non-conventional water resources literature. VOSviewer software v1.6.16 (Centre for Science and Technology Studies, Leiden, The Netherlands) [69] was used to create a network map of the co-occurrence of terms extracted from papers' abstracts. VOSviewer uses a visualization of similarities algorithm to display the relationship between entities in a way in which both direct and indirect connections result in placing those entities closer together on a map [70]. A term network map was created to show co-occurrence and linkages among the terms. The content analysis of the literature review is described below. This process was organized in two blocks, reclaimed and desalinated water, and for each block, five issues were identified and analyzed: water use, water cost, water quality, water management, and water perception/acceptance.

In addition, two issues were identified for the desalinated water analysis: environmental impacts and the political ecology approach.

4. Results

4.1. Bibliometrics

The field of non-conventional water resources gained significant academic interest from 2012 onwards when 64 of 72 papers (88.8%) were published. Since two articles were published in 2005, the number of publications multiplied by more than eight within 15 years; 2019 had the highest publication index, with 19 papers. The scholars who published most articles were Victoriano Martínez-Álvarez and Juan José Alarcón (nine articles each) followed by Bernardo Martín Górriz and Antonio M. Rico Amorós (eight articles each). Fifty authors published at least two articles as main author or co-author, and 119 persons were named in no more than one publication. Spanish authors were present in 69 of 72 papers, and non- Spanish authors were from the UK, Chile, Italy, Israel, France, Czechia, and Oman.

A total of 52 institutions were identified considering a dual profile: research (mainly universities and research centers, 36 institutions) or end-users (including irrigation communities, water partnerships or foundations, 16 organizations). The University of Alicante was the institution with the greatest participation (18 papers), followed by the Technical University of Cartagena (11 papers), the CEBAS-CSIC (nine papers), and the University of Murcia and the University of Almería (eight papers each). End-users did not publish individually but always in collaboration with research institutions.

Most articles were published in a transdisciplinary journal such as Water (10 publications), followed by two more specific journals such as Desalination (nine publications) and Desalination and Water Treatment (six publications). In the analyzed 20-year period, 15 of 31 journals contained between two and ten publications related to the non-conventional water resources topic, and 16 journals contained only a single article. The range of journal fields appears to be almost infinite, ranging, e.g., from sustainability and ecology to the energy/pollution field, to the management and policy field. This corresponds with the interdisciplinary nature of the subject, which provides it with a wide spectrum of publication outlets.

Regarding the framework of the analysis, Murcia is the region in which more papers were focused (31 papers, 43.1%), followed by Alicante (18 papers, 25%) and Almeria (10 papers, 13.9%). Furthermore, five papers were focused on more than one region and eight papers in the Segura River Basin or the whole Spanish context (e.g., state of the art). Furthermore, 42 of 72 papers included a case study mainly focused on desalination processes and farmers’ perception of water quality standards or water/energy cost, whereas only nine papers were focused on reclaimed water issues. This imbalance between desalinated and reclaimed water interest was also in line with the nature of the journals most used to publish the results of the research, in which desalination provided two of the three most-cited journals.

Eleven topics were used to characterize the research focus of each publication: Agronomy, Economy, Environment, Management-Planning, Perception, Policy, Technology, Tourism, Water consumption, and Water quality (physicochemical standards). Up to three research topics were identified for each of the publications. Papers were mainly focused on desalination management and planning (34 papers), agronomy and water quality standards (26 and 21 papers, respectively), and economy (22 papers) and environment (21 papers). Only four papers were focused on a single topic, and 42 of 72 papers included three topics as a mechanism to address multi-objective aims. Topics were analyzed using a wide range of methods, including qualitative, quantitative, and a mixed qualitative–quantitative nature. More than half of the studies (41 of 72 papers, 56.9%) were mainly quantitative, whereas 17 papers provided a literature review and 14 papers were mainly qualitative. Qualitative and quantitative methods were applied according to different aims. The qualitative analysis aimed to understand, explore, and collect data to explore a single case study or a regional casuistic. Conversely, quantitative methods were used to provide numerical data and indicators based on experimental plots, which also can be analyzed using statistical and modelling techniques to reveal patterns and extrapolate the obtained results. More than one-third of the papers (26 of 72 papers, 36.1%) were reviews and 22 of 72 were experimental. Interviews and surveys were used in 21 of the 72 papers, and economic analysis (cost-benefit analysis, contingent valuation method) were applied in 12 papers.

VOSviewer was used to identify the terms that co-occurred more than five times based on their relevance score. Starting from the entire text of the abstracts, including 14,788 total terms, those words with fewer than five-word occurrences were excluded, reducing the sample to 2137 items. Only 127 terms met this threshold, of which 60% (76 terms) are automatically selected according to the relevance scores for which a word was considered informative. The terms were then manually screened to remove words that discussed the research process (e.g., data, research, article, aim, case study) and remove synonyms (e.g., actor and stakeholder). Figure 1 shows the relevant terms and their network of co-occurrence. This term co-occurrence network can help us understand the knowledge components and knowledge structure of reclaimed and desalinated water research.

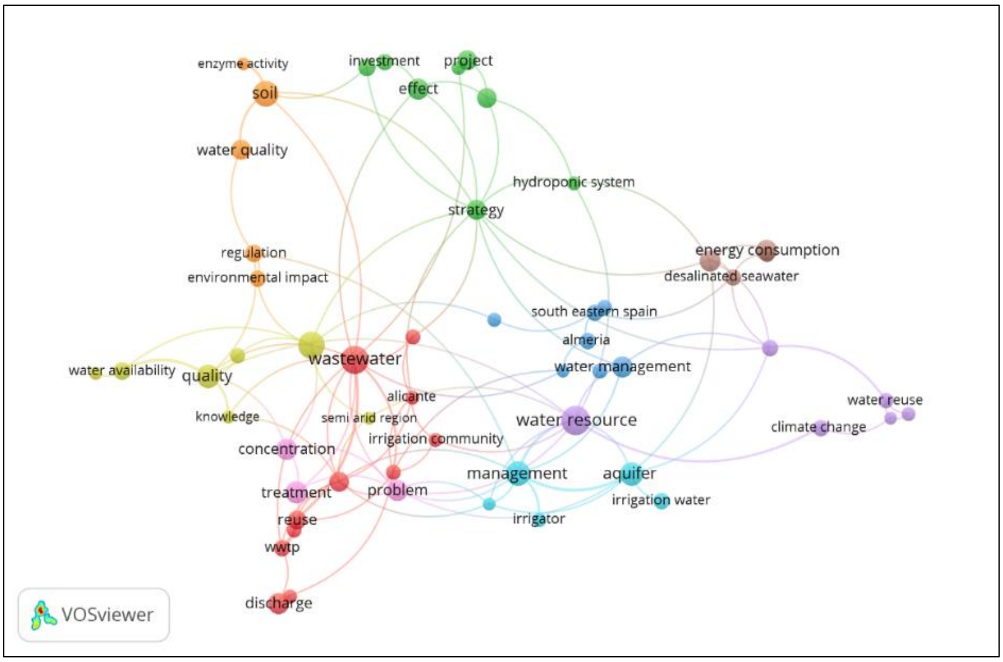

Figure 1. Co-occurrence of words selected from abstracts.

VOSviewer identifies knowledge components (words) as nodes to be included in one cluster, with the number of clusters determined by a resolution parameter. The size of nodes indicates the frequency of occurrence. The curves between the nodes represent their co-occurrence in the same abstract. The shorter the distance between two nodes, the larger the co-occurrence number of the two words. The color indicates the intensity of the co-occurrence: red, blue, green, and yellow clusters are those including more words co-occurring by abstract. The higher the value of the parameter, the larger the number of clusters. In this case, nine clusters were identified, of which four (red, blue, green, and yellow) concentrated the higher number of co-occurring words. The red cluster is focused on reclaimed water experimental contributions, whereas the blue cluster is focused on water management, the green cluster on water infrastructure and investment, and the yellow cluster on water quality standards. In addition, the knowledge structure is based on the position, connection, and distance between clusters and nodes. The closest nodes and central positions illustrate a close nexus between topics: the red and blue clusters are central and close to nodes about reclaimed and desalinated problems (pink cluster), and irrigation use (teal cluster), or energy consumption (brown cluster), but far from topics such as climate change (lilac cluster) or soil analysis (orange cluster). A deeper analysis of the literature review is provided for each topic in the following section.

4.2. Reclaimed Water

4.2.1. Reclaimed Water Use

Since the end of the twentieth century, the increase in reclaimed water consumption in south-east Spain has been strongly linked to the adaptation of the national regulatory framework to meet European requirements. Compliance with the European Water Framework Directive and the Directives 91/271/EEC and 98/15/EC on urban wastewater treatment influence the increase in the availability of this resource in the study area [71,72]. In Spain, the legal framework for reclaimed water used was established in 2007 (Royal Decree 1620/2007), and establishes the criteria on maximum permissible values and quality analysis to be adopted for the intended uses [73], which are grouped into five categories: urban, industrial, agricultural, recreational, and environmental (Figure 2). The increase in reclaimed water use in addition to wastewater treatment improvement has contributed to restored water quality natural water bodies and diminished groundwater extraction, contributing to recovery from overexploitation of numerous aquifers [74].

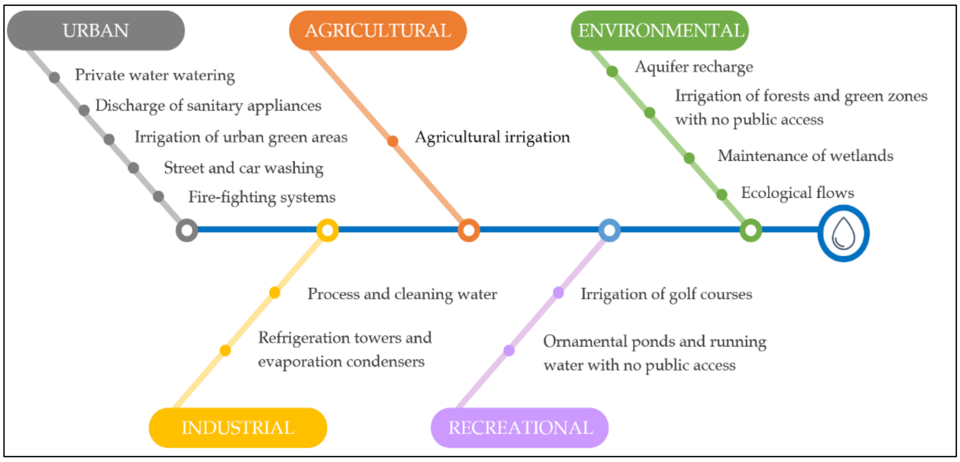

Figure 2. Groups of uses and applications for reclaimed water legally approved in Spain.

In the Segura River Basin, which covers most of south-east Spain, reclaimed water comprises up to 10% of the total available water resource, of around 110 million cubic meters (MCM) per year [75]. This has been possible due to the high levels of waste water treatment and regeneration, which are currently 99.5% and 97%, respectively [75]. However, there is still a margin for potential growth in the use of reclaimed water because it reuses almost 70% of treated wastewater [72]. In the region of Murcia, 89% of the volume of reclaimed water concessions is for agrarian uses, 9.7% for irrigation of golf courses, 0.9% for irrigation of parks and other urban uses, and the remaining 0.005% for ecological and industrial uses [75]. Moreover, in some irrigation communities, this water source represents all water consumed, although it usually represents around one-quarter of the total water resources used by irrigators. The amount of reclaimed water used for agricultural irrigation depends both on the availability of conventional water sources with adequate quality for irrigation and on the availability of wastewater treated at the urban scale. Regarding recreational uses, during the most recent period of intense real-estate development, which was drastically halted by the 2008 economic crisis, a large number of golf courses were created in in south-eastern Spain, which in most cases are irrigated with reclaimed water produced in external wastewater treatment plants [76]. In addition, reclaimed water use has been gradually introduced in some of the large coastal cities to cope with the scarcity of water resources in southeastern Spain, allowing freshwater to be saved in municipal uses, such as street-cleaning or the irrigation of public parks, and private gardens [72,77].

Nevertheless, one of the most controversial issues regarding reclaimed water uses are the environmental uses or the establishment of minimum stream flows to achieve the so-called good ecological status of water bodies, as stated in the European Water Framework Directive (WFD) [78]. The Spanish legislation does not specify quantitative or qualitative parameters in this respect [73], but they are specified in the corresponding river basin management plans. The potential rise of minimum flow rate requirements using reclaimed water has been critically analyzed for south-east Spain study cases; because its quantification is a discretionary decision, its setting may have an impact on other environmental issues and involve legal conflicts if its implementation limits or cancels other water rights [78]. In this study case, this measure has been applied to non-permanent hydrological rivers which characterized semi-arid environments. Hence, some authors critically determine that compliance with this measure will have the opposite effect than expected because the use of reclaimed water for these purposes will reduce the flows for agricultural use, which translates into the maintenance of groundwater extraction and worsens the overexploitation of aquifers. Similarly, it should be borne in mind that changes in river flows may affect original biodiversity in semi-arid and non-permanent rivers, creating a new ecosystem instead of maintaining existing ones.

4.2.2. Reclaimed Water Cost

A group of investigations focused on comparing cost-benefit analyses between reclaimed water and other sources of water for agricultural uses was identified [79–82]. Results indicate that crops irrigated with a mixture of water sources are the most productive and present higher profitability, followed by those irrigated only with transferred water and, finally, by those watered exclusively with reclaimed water [80]. Nevertheless, considering non-market or environmental benefits associated with the use of reclaimed water in the cost-benefit analysis, the use of a mix of water sources is still the best option, but reclaimed water is better than transferred water [80]. Non-market or environmental benefits represent the society welfare improvement produced by the use of reclaimed water and the preservation of the ecological status of water bodies through the reduction of water footprint and the eutrophication processes [79,80,82].

In economics, non-market valuation of environmental resources and services may be measured in monetary terms using the concept of individuals' willingness to pay (WTP). Hence, the monetary WTP measure shows whether changes in the level of provision of environmental goods impact individual welfare, and aggregating individual changes in welfare provides an indicator of the total economic value of the change [79–82]. In these studies, a large proportion of the surveyed population, between 70% and 80%, was willing to pay an increase in their monthly water bill for the supply of reclaimed water for agricultural and ecological flows [79,82]. The average increase that people were willing to pay translated to 0.33 €/m^3, which was greater than the range of treatment cost for reclaimed water (0.16–0.26 €/m^3). This result could be interpreted as the non-market benefits of reuse reclaimed water being larger than the investment and operational costs of wastewater treatment plants [79].

However, it should be considered that most of the respondents did not know that reclaimed water costs were already assumed by urban users and that this willingness to pay varied according to sociodemographic characteristics, because older respondents, populations with a lower educational level, and larger households presented a lower WTP, whereas the WTP was greater in females and people who use the river for recreational uses [79,82]. Nevertheless, there was no consensus among the results of different studies, because some indicated that the lower-income population was more likely to pay more for the supply of reclaimed water [82], whereas other investigations note that higher-income households presented a higher WTP [79]. Another relevant outcome is that people who were more aware regarding the price they were already paying for reclaimed water in their water bills were less willing to increase the amount paid. In addition, people who were more satisfied with their current payment were more willing to pay. This is a key point in

Spanish Mediterranean coast municipalities, in which are located the higher water tariffs at the national level, partly due to the effect of the introduction of desalinated water, which can be a brake on the growth of non-conventional water resources. All of these results may have policy implications regarding new tools to improve public acceptance of reclaimed water and increase the perception of welfare impact.

4.2.3. Reclaimed Water Quality

One of the main advantages of the agricultural use of reclaimed water is saving of fertilization costs because the water contains a large part of the essential nutrients required by crops [83–85]. However, this water source also has some drawbacks related to its quality and chemical composition which involve some agronomic issues, such as the accumulation of chloride, sodium, and boron that can affect both soils and crop production in the medium term [84,86]. Some studies have examined the impact that irrigation with this water source may have on the supply of essential nutrients, the effect of salinity on the crop yield, the crop toxicity, the soil sodicity risk, and the economic inflow-outflow analysis of different types of crops [86]. Other research has evaluated the effects of using reclaimed water on agronomic and microbiological parameters [87], physiological and soil structural properties [88], and other factors such as crop growth, leaf mineral content, plant and soil water status, and fruit quality [89]. Results indicate that the use of reclaimed water allows health standards to be complied with and thus does not represent a microbial risk [87], or affect plant water status, fruit quality [89], or crop yield [90]. Furthermore, reclaimed water supplies a large portion of the crop nutrient requirements, especially for tree crops such as lemon or peach [86]. Similarly, soil sodicity risks were low, and reclaimed water nutrients may substantially save fertilizer costs. However, high electrical conductivity may reduce yields by up to 23% in peach crops and 19% in tomatoes, which may offset economic savings associated with fertigation [86]. In addition, reclaimed water can increase the risk of chlorosis and toxicity effects of sodium and boron in some tree crops, which may result in soil salt accumulation and infiltration, and leaf boron concentration exceeding the phytotoxic limit, which could pose a risk for production in the medium and long terms [86,89,91].

Other studies have analyzed the impacts of using reclaimed water simultaneously with the implementation of regulated deficit irrigation on soil productivity [92] and soil microbial community, a critical component of the soil quality [93,94]. The outcomes indicate that this strategy intensifies the development of salinity accumulation even when using freshwater, so a soil water deficit should be avoided to prevent sodicity risk [92]. In addition, even though, at first, the diversity of the microbial community and soil respiration is reduced temporally, the re-establishment of full irrigation is accompanied by an enhancement of ecological soil attributes which can contribute to the maintenance of soil fertility and crop productivity [94]. Thus, the use of reclaimed water, unlike transferred water, promotes a more resilient salt-adapted microbial community that recovers quickly after the end of the water restriction [90,93]. It would appear that microbial responses are probably shaped by the specific plant physiology, rootstock sensitivity to salinity, and water relations of the crop [90].

Finally, some recent research has focused on the existence of emerging pollutants in reclaimed water, including pharmaceutical compounds that are not fully removed after wastewater treatment, which may be eventually released into agricultural systems and can also reach the food chain [95,96]. According to the results, wastewater treatment plants are highly efficient at eliminating conventional pollutants, but only partially remove pharmaceutical pollutants, even after tertiary treatment. Taking this into account, pollutant concentrations of the effluent should be decreased to acceptable levels by blending freshwater with reclaimed water for agricultural uses in a ratio of 2 to 1 [96]. The analysis of pharmaceutical content in lettuce tissues (roots and leaves) irrigated with reclaimed water concludes that the concentrations identified do not present any health risk because they are relatively low [95].

4.2.4. Reclaimed Water Management

In Spain, reclaimed water ownership is public, and must be operated under a concession regime which is managed by each River Basin Authority. Although reclaimed water is generated at the municipal level, its management is carried out by each regional government, through regional water sanitation entities such as Entidad de Saneamiento de Aguas (EPSAR) in the Valencian Community, or Entidad de Saneamiento y Depuración de Aguas Residuales de la Region de Murcia (ESAMUR). To cover the costs of operating and maintaining sanitation and treatment facilities, in addition to conveyance and storage infrastructure for irrigators [75], a new tax, the sanitation fee, was created by these regional entities, which is paid by urban users in their water bills for the discharge of wastewater into the public sewage system [71,73].

Regarding management practices, the Spanish legal framework determines that public health authorities are required to provide a binding report confirming that the proposed uses are appropriate from a technical point of view, and including self-monitoring and risk management programs presented by the applicant for the reclaimed water concession [73]. In addition, according to the new European reclaimed water regulation, a new actor, called the Reclaimed Water Manager, is a key player responsible for implementing the risk management plans, thus ensuring environmental and health safety for using reclaimed water [85]. These regulations are aimed at maintaining the current situation, in which it is ensured that crops irrigated with reclaimed water do not pose any microbiological or toxicity hazard for human health [86]. In this regard, concerns about reclaimed water quality-related negative effects on crop yields and soil sustainability, grouped as agronomical risks, are controlled with irrigation management strategies such as salt leaching, the introduction of calcium amendment, or blending reclaimed water with other water sources [87]. Other specific water management strategies, such as periodic controls of nutrients in the soil and the leaf tissues, are also implemented to avoid food safety problems and salinization or deterioration of agro-systems [84]. In some cases, discharges of brackish water or seawater intrusions into the urban sewerage network can increase the salinity of the effluent produced in the wastewater treatment plants, preventing its reuse for agricultural uses due to its high conductivity [61,77]. In such cases, it is necessary to incorporate desalination plants into the wastewater treatment plants, to ensure the high quality of the reclaimed water [97]. This situation has led to complaints from irrigators about the non-compliance of the polluter pays principle, because it affirms that urban end users should also assume environmental and resource costs, which would include the extra costs of the desalination processes of the reclaimed water [61].

Reclaimed water urban uses are less widespread because they require high investment in the creation of separate distribution infrastructure. However, there are some examples, such as that of the city of Alicante, where this non-conventional water source is used for both municipal (cleaning streets and irrigation of green areas) and domestic uses (irrigation of private gardens in some low-density urban areas) [72,77]. This initiative has allowed the irrigation of more than 80% of public green zones with reclaimed water, which allows more than one million cubic meters per year of freshwater savings [72].

Finally, in the south-east of Spain, the Marina Baja region case study stands out as an original management option that has been reached between urban-tourist and agricultural users concerning the use of reclaimed water and the adaptation to drought situations [61,77,98–100]. Through the leadership of the Water Consortium of the Marina Baja, a public entity responsible for the raw water supply to both irrigators and municipalities, several agreements have been established between local stakeholders by which irrigators exchange their conventional water sources to the urban-tourist users by reclaimed water during drought situations, obtaining various economic compensations in return, in addition to a subsidized reclaimed water price [61,100]. This example illustrates how the inclusion of non-conventional water resources should be accompanied by new modes of water governance which must include local stakeholders and seek mutual benefit configurations through cooperation among users because it is key to adapting to water availability [101]. This dynamic water governance configuration allows guaranteeing water supply for urban, tourist, and agricultural users, thus harmonizing different interests and demands. However, this configuration of agreements is not exempt from threats, which require the continuous review of the agreements adopted between the interested parties, and the renewal of infrastructure [61].

4.2.5. Reclaimed Water Perception and Acceptance

Although non-conventional water resources may represent a promising solution for a future characterized by higher water scarcity problems, user's acceptability and perceptions have been identified as a novel and understudied research topic which may help to implement policy options and water resources management. Usually, these studies have focused on farmers' perceptions [45,102,103], although some research has also been carried out for home users [104].

Among irrigators, in addition to the price, in a theoretical scenario in which all water sources have the same price, the most valued options were surface and reclaimed water [102,103]. The main advantages of using this source are its high availability, as it is less affected than conventional resources by uncertainty, and its high nutrient content, which allows farmers to reduce the amount of chemical fertilizer needed to sustain profitable crop yields [102]. Similarly, its positive effects on the environment are recognized, such as the control of wastewater discharge or the development of practices such as artificial recharge of aquifers. Nevertheless, some main barriers or rejection factors for the use of reclaimed water are also identified [103]. One of these is water quality because, despite its generally good valuation, in some cases reclaimed water presents high levels of conductivity or high concentrations of chlorine, sodium, or boron [102]. Concerning the price, there is no clear position among the irrigators, because there is not a very wide knowledge of the price. Furthermore, the lack of adequate distribution and regulation infrastructure for the use of reclaimed water is one of the main barriers, in addition to the related energy costs. Similarly, for irrigators, the ambiguity which surrounded the reclaimed water legal framework represents an obstacle to the use of this water source because the quality and food safety of the crops is a central concern among irrigators [103]. Therefore, issues related to emerging pollutants are one of the main concerns of irrigators relating to the use of reclaimed water.

For residential users, reclaimed water is the least valued option, with the exception of desalination, among all the water supply options [104]. However, the main barriers and drawbacks identified by urban users for the use of reclaimed water are, surprisingly, not the potential health risks, which are identified as the third-ranked problem in order of importance. Ranked first and second are energy requirements and economic costs, respecitvely. For urban users, this source is conceived to be used principally for outdoor water uses (garden irrigation) and public uses (public parks irrigation, golf courses, irrigation of sports facilities, and street-cleaning); to a lesser extent, there is a general acceptance for its use in toilet flushing and agricultural irrigation [104]. It is worth noting that the level of education and income are directly related to the acceptability of the use of reclaimed water. In general, higher-income households tend to have a lower risk perception about the use of reclaimed water, both in terms of human health and economic costs.

4.3. Desalinated Water

4.3.1. Desalinated Water Use

Spain accounts for more than half of all of Europe's desalination capacity, most of which is located on the Mediterranean coast [105]. Urban users have been using desalinated water both for domestic uses [77] and to water green areas and urban parks from small brackish desalination plants [81]. The development of desalination for urban uses has been possible due to the existence of large regional water supply systems, such as those managed by the public entity Mancomunidad de los Canales del Taibilla (henceforth MCT). MCT supplies raw water to 80 municipalities in south-east Spain, which has a permanent population of almost 2.5 million inhabitants [63]. Since 2003, desalinated water has been incorporated into the blending of water sources managed by the MCT, which owns four desalination plants with a total operational capacity of 96 million cubic meters (MCM) per year. However, the percentage of desalinated water use in the water blending varies according to the hydrological situation, which makes it a strategic resource to adapt to drought situations [106,107]. This conception is especially evident in the case of the Marina Baja region, which is connected through an emergency pipeline (Rabasa-Fenollar-Amadorio) to a desalination plant located 35 km to the southwest (the state-owned Muchamiel desalination plant) to guarantee water supply during extraordinary drought situations [72,77,97,99].

Similarly, in the case of agricultural uses, desalinated water demand has been linked to the availability of other water supply sources, so during drought periods its use has increased enormously [72]. Despite this, Spain is considered to be one of the world-leading countries in the use of desalinated water for irrigation [108]. Desalinated water consumption for irrigation uses started in the south-east of Spain in the mid-1990s, when after an intense drought period some irrigation communities invested in private desalination plants [109]. Throughout the 2000s, the consumption of desalinated water for irrigation grew slowly. However, it was in the following decade when consumption skyrocketed, especially from 2013 and 2014 with the start-up of most of the state-owned large desalination plants [110], coinciding with the start of another intense period of drought and the new operating rules of the Tajo-Segura transfer, which limited the arrival of the transferred water [106]. In the Segura River Basin, desalinated water amounts to 150 MCM per year, which represents 10% of agricultural demand [110]. At the end of 2017, seawater desalination plants were supplying water in the Segura River Basin almost at full capacity, surpassing the volume of reclaimed water used for the first time. During the past five years (2015–2020), desalinated water demand for agricultural uses has been greater than that finally supplied because the priority of guaranteeing urban water supply prevented all agricultural demand from being satisfied [110]. As a result, several irrigation communities are promoting the construction of new private desalination plants and extensions in the production capacity of existing state-owned desalination plants are planned [44]. The modification of the Tajo-Segura transfer regulation and the planned reduction of pressure on groundwater bodies to meet environmental objectives are two of the main reasons for this projected further expansion of seawater desalination production capacity [44].

4.3.2. Desalinated Water Cost

A wide body of research has analyzed issues related to energy consumption and the desalinated water price. An essential aspect that allows contextualizing these analyses is the intensification of the water–energy nexus derived from the use of non-conventional water resources because most of the difference in water price between water sources is due to specific energy consumption [111]. Despite the energy-efficiency improvements in osmosis technology seawater desalination, energy requirements are still much higher than those of other water sources [97,110]. A common measure of energy use is specific energy consumption, expressed in kWh/m^3, which has been analyzed for different desalination stages and other water sources in south-east Spain (Table 4). Variations in desalination energy consumption are due to different factors such as plant altitude, the age of the plant, the salinity of the feed water, targeted desalinated water quality, the production capacity, the use of energy recovery systems, and the type of membrane technology [110,112]. Additionally, further energy requirements for desalination post-treatments (boron removal), the allocation to irrigation plots, and the on-farm specific energy consumption [113] should also be considered.

Table 4. Energy consumption according to seawater desalination stage and other water sources in south-east Spain.

Desalination Stage/Water Source	Energy Consumption (kWh/m^3)
Seawater intake pumping	0.12–0.62
Desalination processes	2.78–3.38
Pumping to an elevated regulating reservoir	0.43–1.04
Seawater Desalination (Total)	3.49–4.84
Surface water	0.06
Groundwater	0.48
Reclaimed water	0.72
Brackish Desalination	1.21
Transferred water	0.95

Source: [110,113].

High energy consumption greatly influences the total cost of desalinated water, which can be divided into three parts. First, capital costs, which include the amortization and financial costs related to the initial investment, and considering the lifespan of the plant, the variable interest, and the production rate, have a significant influence on the final cost [110,113]. Second, the operation and maintenance costs, which are the main component of the desalinated water price, are closely related to energy consumption, and represent between 50% and 66% of the total cost [110,113]. Finally, allocation costs include both the cost of water conveyance from desalination plants to the irrigation districts or urban water supply systems and the distribution costs [110]. Full cost analyses in the Segura River Basin established that desalinated water costs may range between 0.63 and 0.80 €/m^3 [113,114].

This price range contrasts with the average rates of different water sources for agricultural uses in the Segura River Basin, which are 0.02–0.09 €/m^3 for surface water; 0.05–0.1 €/m^3 for reclaimed water; 0.12 €/m^3 for Tajo-Segura transfer; 0.16–0.42 €/m^3 for groundwater; and 0.26–0.56 €/m^3 for desalinated brackish water [113], although this last water source shows high price fluctuations between plants [108,115]. Thus, the final cost of water is highly dependent on the proportion of each water source used in the water blending. The increase in the use of desalinated water has led to a sustained increase in water prices. For urban users, as the MCT exemplifies, water tariffs have experienced an increase of 91% between 2005 and 2017, from 0.36 to 0.69 €/m^3 [72]. In the case of agricultural uses, the price that farmers paid for desalinated water in 2017 was made up of several components (Table 5). In addition to the desalination purchase price, irrigators pay a consumption tax, a transfer toll if water conveyance to irrigator districts requires the use of infrastructure not owned by the plant or the irrigators, and the irrigation district rate [110].

Table 5. Composition and range of the desalinated water price supplied to farmers in south-east Spain.

Concept	Price Ranges (€/m^3)
Production price	0.4–0.62
VAT (10% Taxes)	0.04–0.06
Conveyance to Irrigation Districts	0–0.02
Distribution within Irrigation Districts	0.02–0.09
Final price to farmers	0.47–0.63

Source: [110].

These figures also indicate that desalinated water selling prices for farmers are lower than the full cost, which reflects both the existence of direct and indirect subsidies, in addition to the long-term price agreements established between plants' concessionaire companies and irrigators before the electricity price hike in Spain set prices lower than current costs [113]. However, despite presenting a price lower than the cost of production, desalinated water is still the most expensive water source, which could jeopardize crop profitability. However, profitability depends highly on the type of crop [110]. Although greenhouse crops can cope with desalinated water costs over 0.6 €/m^3 [79,116,117], the most representative crops in south-east Spain present a lower mean net margin of water, which ranges between 0.3 €/m^3 and 0.6 €/m^3, thus the price of desalinated water compromises its profitability [110,118,119].

4.3.3. Desalinated Water Quality

As in the case of reclaimed water, a large number of studies have focused on issues related to the quality of desalinated water. One of the strengths of desalination water quality is its low conductivity values, at least in south-east Spain, where reported values are maintained between 400 and 600 µS/cm for the state-owned seawater desalinated plants [45]. This makes it possible to expand the type of crops, especially in areas where groundwater is usually used for irrigation [116,120], because the high levels of salinity restrict the potential crops to those less sensitive to high levels of conductivity, such as tomato [102]. Nevertheless, brackish desalinated water may present higher salinity levels, which may produce lower yields in the majority of crops, soil salinization, and an increase in the leachable fraction needed, which results in greater irrigation requirements [121].

Although salt content in desalinated water is generally lower than that in surface water, its chemical content generates some drawbacks. Reduced content of calcium, magnesium, and sulfates may affect plant quality and crop yields, therefore, the remineralization of desalinated water must be undertaken [113]. This issue may modify the organoleptic characteristics of the urban water supply, which can lead to identifying a medicinal taste and bad odor in desalinated water [122]. For agricultural uses, the need for additional fertilization when using desalinated water, which depends on the level of replacement of conventional water resources, is a key aspect for irrigators because it increases costs and may affect farming profitability [123]. Furthermore, its high concentration of sodium, chloride, and boron may produce phytotoxicity, affecting plant growth and crop yields, and damaging soil structure [109]. One potential indirect effect of using desalinated water is the soil sodicity risk, resulting in the structural collapse of soil aggregates, decreasing hydraulic conductivity, leading to soil erosion and compaction, and decreasing aeration [113]. Another quality-related problem is the high concentration of boron, which may cause toxicity problems for several crops, especially citrus and tree crops [109]. Some irrigation communities have identified timing problems in long cycle citrus crops and tomato related to boron concentrations, but only in those where desalinated water represents a high proportion of the water mix used [45]. However, in other irrigation communities that have a privately-owned desalination plant, none of these agronomic problems in soils and crops have occurred after 20 years of using desalinated water [45]. Other studies have analyzed the short-term agronomic and economic effects of using desalinated water in citrus crops, concluding that symptoms of toxicity were not observed, or a reduction in crop yield or fruit quality [124]. Nevertheless, the effect of introducing desalinated water highly depends on the quality of the replaced irrigation water and on the quality of other water sources that may be used in the blending [113].

Finally, another relevant parameter related to desalinated water quality is chemical stability, controlled by the alkalinity value, which measures the buffering capacity of the water to withstand changes in pH, and the Langelier Index, which indicates the propensity of water to precipitate $CaCO_3$ [113]. Waters with high alkalinity are less sensitive to sudden changes in pH, resisting the addition of liquid fertilizer solutions, which could have a positive impact on agricultural productivity and minimize corrosion and pipe rusting in distribution systems [113]. Therefore, the possibility that desalinated water results in corrosion problems in distribution systems may be related to acidic pH values [45]. The relevance of the control of the carbonate precipitation/dilution potential of desalinated water relates to the potential risk that the introduction of this new water source may have in detaching $CaCO_3$ scales that accumulated for decades in the pipeline systems, which can affect the functioning of valves, filters, and flowmeters [113]. However, results in south-east Spain desalination water guarantee a lack of precipitation of new carbonate scales or the release of the existing scales.

4.3.4. Desalinated Water Environmental Impacts

In addition to agronomic effects on soil and plants, another body of research has focused on desalination's environmental impacts [125,126]. Several environmental life cycle assessments determine that desalinated water use for irrigation leads to higher environmental impacts in several categories such as global warming, energy use, soil quality, and aquatic ecotoxicity [91]. In Spain, the main energy sources rely on fossil fuels, which enormously increase the energy footprint of desalination plants and the greenhouse gas emissions [127]. The energy costs of replacing conventional water resources with desalinated water were calculated for agricultural uses in the Campo de Cartagena region in a scenario of high desalinated water use, which represents 26.5% of water resources. Results showed increases in energy consumption and GHG emissions of 50% and 30.3%, respectively [128]. Therefore, although technological advances have made it possible to reduce the costs of desalination, the expectation that ecological costs would be fully incorporated into the total cost of this water source may have the opposite effect [105]. Considering the Spanish energy mix for a typical desalination plant, the average cost of its related greenhouse gas emissions translated into an increase in the desalinated water price of 0.03 €/m^3 [114]. The high energy consumption derived from the use of desalinated water reinforces the analysis of the different impacts associated with different agricultural production systems [129]. Higher yields and energy use efficiency in hydroponic cultivations makes them an option with a lower environmental impact than conventional soil cultivation, in terms of greenhouse gas emissions.

Based on a life-cycle assessment methodology, another type of research analyzes whether environmental impacts of reverse osmosis desalination are reduced if brackish groundwater is used instead of seawater [130]. Results indicate that, considering the limitations due to the availability of groundwater, brackish desalination resulted in less environmental impact, which were mainly related to lower electricity consumption and brine discharge [130]. Unlike seawater desalination, brackish water desalination is a user-preferred option; it does not require a powerful filtering system or remineralization of water because destination is the only agricultural use [107]. The long-term effect of pumping saline groundwater from a coastal aquifer feeding a desalinated plant was demonstrated through electrical conductivity profile data, which indicate that the fresh–saline water interface was deepened, freshening the aquifer and reducing groundwater salinity by 16%. This highlights the effectiveness of this use against seawater intrusion [131]. However, the extension of small desalination plants may induce other environmental problems such as exhaustion of groundwater, uncontrolled brine discharges, and the proliferation of illegal or unregistered plants [109]. Similarly, groundwater may contain high levels of chemicals, mainly pesticides, pharmaceuticals, and surfactants derived from wastewater effluents or of urban origin, which could present an environmental risk. Thus, they need to be removed before use because they could compromise microbiological water quality for irrigation and produce changes in soil-aquifer media and hydraulic parameters [132].

Third, some papers have focused on the analysis of marine brine discharge. Research includes both pre-operation environmental impact analysis, which comprises a monitoring program to determine previous marine environmental conditions and the potential environmental affects due to the construction work [133], and analysis of the potential impact of brine in marine ecosystems after the commencement of operations [134,135]. Some results indicate that the construction of a marine pipeline and brine discharge have not affected the marine environment [133,135], even in long-term monitored brine discharge studies [136]. However, in other research, changes have been identified in the vitality of oceanic *Posidonia oceanica* meadows and marine communities, such as the disappearance of echinoderms, organisms sensitive to high salinity, in the areas close to the brine discharge [134]. The differences in these results may be related to the specific characteristics of the brine dilution and its related infrastructure, consequently, it is necessary to develop further research to analyze this environmental impact [137]. Nevertheless, these studies usually note that these marine ecosystems have already been affected by other activities near the coast, such as trawling and other fishing techniques, marine wastewater discharges, beach regeneration activities, and the expansion of the city's harbor activities, so it is sometimes difficult to determine the true impact of brine spills [133,134].

4.3.5. Desalinated Water Management

Many investigations have indirectly analyzed issues related to desalination management, on both regional and local scales. On the regional scale, to prevent the underutilization of desalinated water when cheaper water sources are available, long term take-or-pay contracts were signed between agricultural and urban users and desalination plant managers [113]. The intention is to reduce the significant variability in the desalinated water cost that depends on the production rate of the plant, guaranteeing the payment for the amount agreed in the contract and the operation of the plant at the projected capacity [110]. However, in some cases, agricultural users have complained about clauses in these contracts that impose surcharges if the consumption exceeds or does not reach the assigned provision, about the variability of the desalinated water price, and, also, concerning the lack of suitability of the desalinated monthly water supply, which is a uniform volume, for the seasonal variation in the irrigation needs [44,45].

Various studies have stressed the importance of management measures aimed at foster desalinated water supply among farmers, through indirect subsidies established for agricultural use, which is exempt from pay capital costs, and direct subsidies reducing the water price for in some plants. These measures were established in the so-called Drought Decree in the Segura River Basin between 2016 and 2019 as an extraordinary measure to reduce the effects of the water scarcity derived from a drought situation and the closure of the Tajo-Segura transfer [44,110,113,138]. These economic measures were adopted in parallel to temporal authorizations for the use of desalinated water because the desalination water concession process had not been completed for most of the plants [45]. Another management problem experienced by most desalination plants has been not reaching their maximum production capacity due to the lack of the required electrical power or an incomplete distribution system [113]. Thus, the Drought Decree also allowed necessary funding for the development of the distribution network, storage capacity, and regulation infrastructure for each desalination plant to be provided, although further investment is still required for the interconnection of the main desalinated water plants in south-east Spain [44,139]. In this respect, during recent years, some desalination plants have constructed their distribution network with irrigation hydrants to supply desalinated water directly to farmers [110]. In other cases, the water conveyance and regulation infrastructure of conventional water resources have been used, especially for those plants whose production is totally or partially destined for urban uses [44]. The experience obtained in desalination management has emphasized that the involvement of the main stakeholders in decision-making is crucial [44]. To avoid water scarcity during the most recent drought situation, and considering the limitations of the desalinated water conveyance and regulation infrastructure, a system of allocation exchanges between agricultural users was established in the Segura River Basin. These agreements, proposed and managed by the SCRATS (the Central Union of Tajo-Segura transfer irrigators), allowed the use of conventional water resources by inland agricultural users not connected to the desalinated water supply network in exchange for their temporary desalinated water concessions, which were effectively consumed by coastal urban and agricultural users [44]. This swap system stipulated that inland irrigators should pay for the reallocated water as if it were desalinated so that the coastal users would not suffer additional costs.

On the local scale, other desalinated water management actions have also been identified as being implemented by the irrigation communities or directly by the farmers. As with reclaimed water, the usual practice carried out by farmers to offset agronomic concerns and ensure the economic viability of the farms by reducing the final water price is the strategy of mixing different water sources [45,61,108,110,140]. Furthermore, most of the irrigation communities monitor water quality and soil content to control water conductivity and other agronomic issues, such as soil sodicity risk [44,113]. Similarly, those who only have access to desalinated water have installed on-farm facilities for boron removal [113]. Finally, some studies have focused on the development of smart fertigation tools that may help to develop better blending strategies and fertigation programs, considering key agro-economic factors in an agricultural setting and allowing the most efficient energy use [113,123,141,142].

4.3.6. Desalinated Water Perception and Acceptance

Another research topic addressed by studies carried out in south-eastern Spain is the perception and acceptance of the use of desalinated water, especially among agricultural users. In general, the level of acceptability regarding the use of desalinated water is very low among farmers which have not yet used this water source [102] and residential users [104]. However, this perception changed a few years later because irrigators which already used these sources evaluated desalinated water as the third best option after surface water and water transfers, and ahead of reclaimed water and groundwater, which was the least-favored option [45]. The best valuations of desalinated water are made by irrigation communities where desalinated water represents a large portion of the total volume of water used and where this water source has been used the longest [45]. Therefore, there is a contrast in the perception of water quality between those irrigators who have not used this source and those who have. As a result, irrigators who do not know the quality of the water are reluctant to use it.

The main perceived advantage of using this water source among irrigators is its availability, because it ensures water supply and overcomes structural and temporary under-provision of water, which increase during drought situations. In this regard, the experiences of drought and water availability uncertainty may overcome drawbacks and barriers for the acceptance of use of this water source by irrigators [45,105]. Similarly, the need for water with higher quality to be mixed with that of poorer quality also increases the acceptability of desalinated water because it provides an opportunity to cultivate crop types sensitive to water salinization, such as pepper, courgette, or aubergine [120]. Although information campaigns are the least-valued measure to increase the acceptance level, field experience has shown that focusing on critical issues (price, fertilization, crop yield and quality, water consumption, and soil quality), the participation of local stakeholders and technical experts, and the use of appropriate dissemination channels, such as those which already employ farmers when learning about technical agricultural issues, have strong and more positive impacts on the willingness of farmers to use desalinated water [45,102].

Farmers who have not used this water source identify as the main barriers its price [102,103] and the lack of economic measures, such as direct subsidies to reduce desalinated water prices and foster technical investments to connect farms with main supply systems, or indirect subsidies, such as tax reliefs for the use of desalinated water or volume discounts according to the volume consumed [45]. In addition, price variation throughout the year due to several reasons, such as infrastructural investments and maintenance needs or variation in electricity price, is another economic drawback for the use of desalinated water. Thus, acceptability not only depends on the desalinated water price but also on the desalinated water supply price, which may include purchase price, transport leakages, the toll of using distribution infrastructure, and other tariffs and rates for the use of the irrigation communities' infrastructure, in addition to the final affordable price, which depends on the profitability of the crop options [45]. Other reasons related to desalinated water quality have also been noted, such as the need for additional fertilization, which involves extra costs and difficult irrigation management. Additionally, potential effects on yield, crop quality, and plant growth due to the concentrations of boron are identified as another drawback of using desalinated water [102,103].

4.3.7. Desalinated Water and Political Ecology

A body of research has analyzed the evolution of desalination in south-east Spain and the changes associated with water governance from a historical and critical perspective, in some cases following the theoretical framework of political ecology. Following the development of regional initiatives in the mid-1990s for the promotion of brackish desalination, and small private-owned desalination plants with government subsidies [44,72,109], the development of seawater desalination on the Spanish Mediterranean coast occurred following the approval of the Actuaciones para la Gestión y la Utilización del Agua (AGUA) program in 2005 [112]. This program conceived of seawater desalination as the alternative to inter-regional water transfers and indicates a policy shift in Spanish water management, avoiding further inter-regional political conflicts related to water, as occurred with the Tajo-Segura transfer [46]. However, this commitment for desalination development occurred in the context of the Spanish real estate boom, which had repercussions on the oversizing of some plants and in the approach to construction, much of which was based on projected upward urban growth trends [112]. In addition to the unfulfilled demand expectation due to the collapse of the real estate market and the economic crisis, some important issues, such as high energy demand and its repercussions for the water price, were not planned for correctly [46]. Furthermore, in 2008 the reform of the electricity market in Spain resulted in a 75% increase in the electricity price between 2008 and 2012, which, coupled with the underutilization of the maximum production capacity in desalination plants, increased the price of desalinated water [113]. As a result, for many years the prospects for the use of desalinated water were not fulfilled, especially by the agricultural sector, due to its high price. This situation caused the plants to be underused, increasing the expected price of desalinated water due to not working at full capacity, and having to pay the fixed costs, which increased the debt incurred by the public administrations [63]. In addition, Acuamed, the public entity responsible for the management of desalination projects, was involved in corruption scandals related to cost over-runs in the awarding of contracts [105].

The introduction of desalination has generated new conceptual frameworks to define the new characteristics of water governance and its associated problems, new stakeholders involved, and future challenges [46,105]. This new water governance model is based on the persistence of capital-intensive supply-side solutions to simultaneously satisfy permanently growing water demands and opening-up spaces for capital accumulation. This implies an increasing role of multinational private capital, that is, multi-scalar financial flows, in water governance. Furthermore, investment in desalination is not only driven by the need to increase water security, but also by the rise of private finance as a factor shaping infrastructure decisions. As a result of the increasing development of desalination due to the AGUA program, Spain ranks fourth in desalination capacity globally, strengthening the role of private capital in water management [46]. Thus, Spanish companies and water utilities are amongst the world's largest engineering, procurement, and construction contractors for desalination, a market that comprises few companies [46,63,105]. Some of the twenty largest global desalination water contractors by water production volume are Spanish companies, in many cases subsidiaries of a large parent company in the construction sector: Acciona Agua, ACS-Tedagua, Befesa, FCC-Aqualia, Ferrovial-Cadagua, Inima, Sacyr-Sadyt, and SETA [63].

5. Discussion and Conclusions

In areas such as south-east Spain, where irrigated agriculture accounts for the greatest water demand, a cross-reference between the use of reclaimed and desalinated water will become a key alternative strategy in the future due to the expected lower availability of conventional water resources and longer drought periods resulting from climate change [143]. However, the analysis of the literature review highlights some further future challenges regarding the use of reclaimed water (Figure 3). One of the main challenges is increasing the volume of reclaimed water use, which still has significant potential for growth [72,73]. This goal will require exploring new water governance schemes that actively involve local stakeholders and water users in water decision-making to guarantee the success of the proposed initiatives [143]. Similarly, further reclaimed water use should adapt to the requirements of new European regulations to prevent contamination of soils and aquifers through the release of pesticides in reclaimed water [144]. Reclaimed water growth will further reduce pollution problems by eutrophication of natural ecosystems, guaranteeing of ecological river flows, reduction of fertilizer expenditure, reduction of groundwater abstraction, and improvement of aquifer recharge, which is a vital measure to adapt to climate change and manage drought cycles. In this respect, the use of geographic information system tools and multi-criteria analysis, which includes technical, environmental, and economic criteria, will allow optimal areas for aquifer recharge with reclaimed water to be evaluated [145]. To meet the expected increase in reclaimed water use, further investment in wastewater treatment plants (WWTPs), in addition to distribution and regulation infrastructure, is necessary to guarantee the quality of the water claimed and its potential use by agricultural, recreational, or urban users. These investments will clearly result in higher urban water tariffs to comply with the fulfillment of the full-price water recovery principle, and the "polluter should pay" principle that emerged from European Union Water Framework Directive [127]. Although the research carried out to date indicates that, in general, urban users show a willingness to pay to sustain increases in the price of water associated with the use of reclaimed water and the environmental benefits it generates, it will be necessary to evaluate the application of these tariff mechanisms to guarantee that their application is socially sustainable to prevent situations of water poverty.

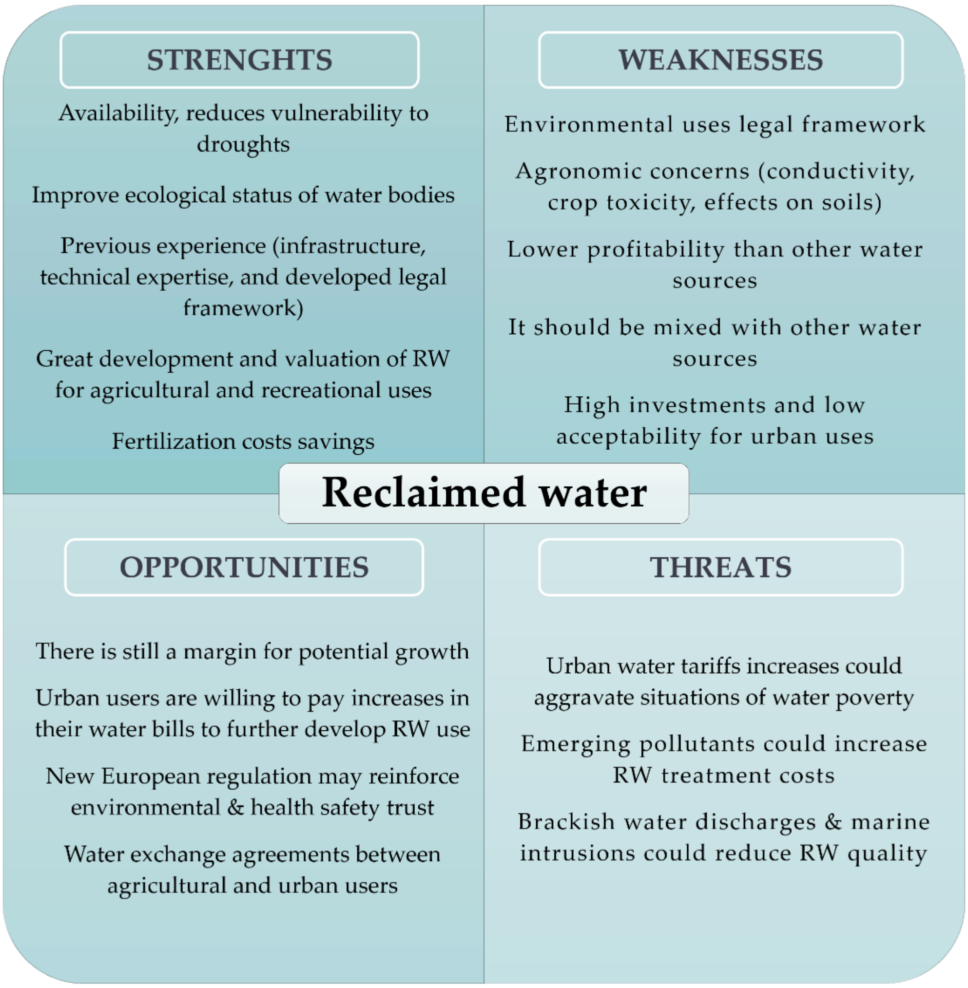

Figure 3. Strengths–weaknesses–opportunities–threats (SWOT) analysis for reclaimed water.

Some of these issues have been included in the draft version of the Climate Change and Energy Strategy 2030 promoted by the regional government (Valencian Community) and currently under public consultancy, which is committed to non-conventional water resources (reclaimed and desalinated water) in the face of transfers. The strategy includes specific measures (items 73–76) related to the improvement of sewerage networks to maximize water network efficiency, in addition to the use of coastal treatment plants as a solution to address the overexploitation of the river basin resources. However, the most prominent measure is the review of the water treatment plan for the whole of the region to increase the quality standards of the effluent and ensure total effluent reuse for different uses, mainly agricultural. Furthermore, the Vega Renhace Plan to improve the capacity to adapt to extreme atmospheric events (floods and droughts) is also committed to, among other measures, the renewal of all of the WWTPs in the region (tertiary systems and desalination). Both regional and local strategies are in line with the European commitment to increase the role of non-conventional water resources, especially in semi-arid regions, and exemplified by Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020, regarding the minimum requirements for the reuse of water. The regulation is mainly aimed at establishing the minimum requirements for the agricultural reuse of water (without ruling out other purposes by the Member States) and in accordance with Directive 91/271/EEC, which highlights in its preamble that the reuse of properly treated water, for example from urban WWTPs, has less environmental impact than other alternative supply methods of water, such as transfers or desalination. However, it is necessary to increase confidence in the reuse of water, for which the public must be provided with "clear, complete, and updated information on water reuse (. . .) so that all interested agents are aware of the benefits of these resources".

Furthermore, and despite its highest environmental impacts, desalination has been identified as an important option to reduce vulnerability to climate change and reduce the current overexploitation of aquifers [125,126,143]. The literature review highlighted how the perception of irrigators is that desalinated water, even with subsidized prices, could not act as a substitute for other water sources because they play a fundamental role in reducing the final price of the water used, improving the quality of the mix, and reducing the most relevant agronomic concerns [106,123] (Figure 4). However, it is conceived as a complementary source to be added to the others and a clear measure to face possible impacts of climate change, such as the increase in drought events [45]. In some cases, some irrigation communities indicate that desalination could replace groundwater in the future, which in this region is the main cause of high-water conductivity due to over-exploitation of aquifers [45,117,146]. Moreover, some economic analysis reveals that subsidizing desalinated water prices would reduce but not eliminate groundwater use and aquifer overexploitation, due to the high-water demand in this area, which suggest that irrigators value groundwater due to its lower cost [146].

These issues delineate the future challenges facing desalination in the south-east of Spain. Firstly, further research must confirm the results obtained to date on the effects of mid- and long-term desalinated water use on different crop yields and soils, to promote its use by irrigators [124]. However, one of the most relevant challenges is the need to address the reduction of the energy footprint of desalinated water production, fostering renewable energy sources, and ensuring the full capacity operation of plants to reduce greenhouse emissions, maximize energy efficiency, and reduce water prices [143]. In regions with a structural water deficit, such as south-east Spain, the incorporation of non-conventional resources does not imply reducing the water deficit because it is related to the unsustainability of the legal (and illegal) extension of the irrigable surface [127,143]. For this reason, some authors suggest other measures should be considered, for example, establishing limits to the increase in irrigable area, favoring a territorial model based on its available resources, or increasing social resilience to provide better adaption to drought situations [104]. In addition, despite the great development experienced in desalination in south-east Spain, further expansion of the production capacity in existing plants is planned and new plants are under construction [143,147]. This foreseeable increase in desalination use indicates a continuous increase in the water price in the future, especially for urban users, who are not subject to exemptions to the cost of water services. However, in a future scenario in which the price of desalinated water is not reduced, the choice of crops would be modified in favor of those with lower water requirements, shorter cycles, and winter flooding suitability, which would ensure the economic sustainability of farms [123].

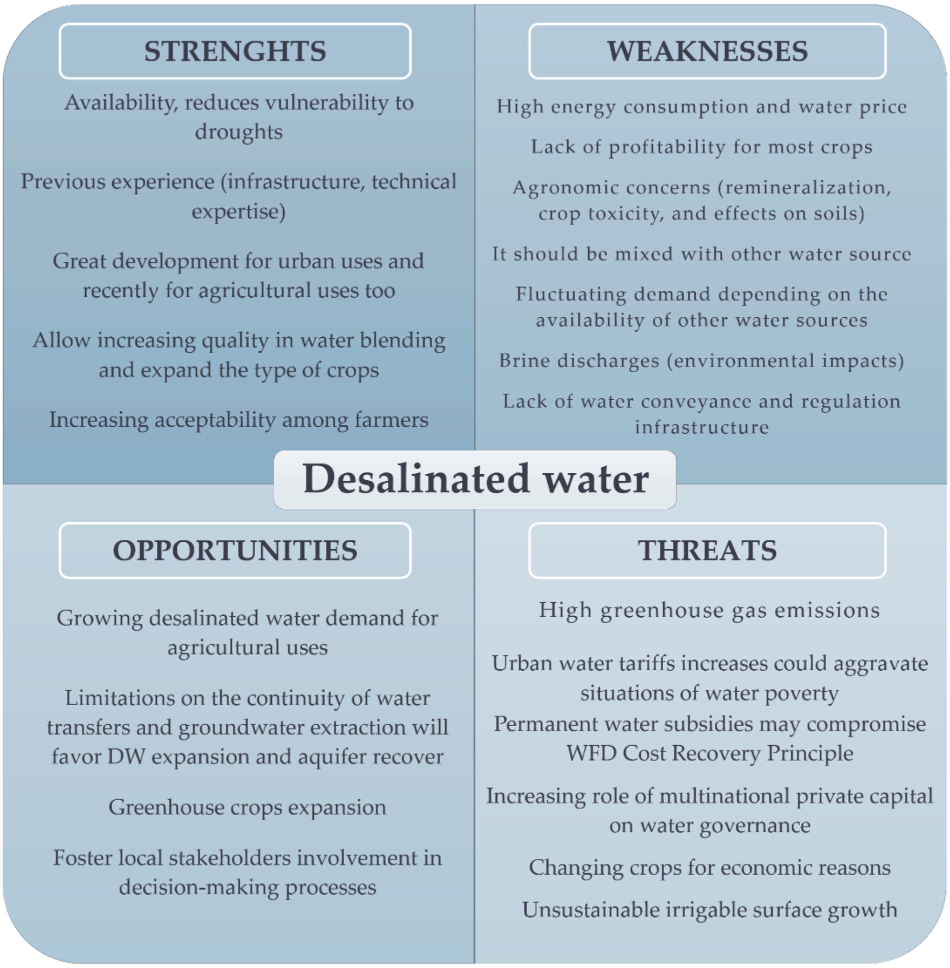

Figure 4. SWOT analysis for desalinated water.

Following the "Greek tradition" of emphasizing a multiplicity of supply sources, each as a safeguard against the failure of others [148], rainwater could be considered as the third source of discussion and, more specifically, as a complementary source for wastewater treatment plants. Although many semi-arid areas suffer from water scarcity, paradoxically, a local source of water such as rainwater is mostly treated as a risk (in the form of weather extremes such as floods) rather than a valuable resource [52]. Many views from political, technical, and citizen spheres indicate a paradigm shift that explores the potential resource dimension that these unwanted flows could now play. In recent years, local initiatives focused on rainwater harvesting have proliferated to mitigate the effects of global heating [149]. In the city of Alicante, two examples that utilize stormwater have been consolidated: an anti-pollution tank and The Marjal Floodplain Park. In both cases, although their main function is to reduce the flooding risk of specific urban areas and prevent seawater pollution from the first stormwater runoff, the stored flows can be driven to the sewage plants so that, once treated, they can be reused. Urban water flows that were previously unknown, ignored, or considered dangerous are developing new functions as assets that attract the interest of water suppliers or large users. The use of rainwater provides other advantages, including: (1) its renewable nature; (2) its collection on a local level, reducing conflicts between territories over the use of conventional water resources; and (3) its relative ease of access and availability, provided that water harvesting and sustainable urban drainage strategies are adopted on a household level [150]. Consequently, in addition to the consolidated use of reclaimed and desalinated water, the use of rainwater could be a valuable alternative to promote the integrated management of non-conventional water resources, alleviate the pressure on conventional water resources, and increase the resilience of semi-arid and water scarcity regions to climate change.

Most of the 17 Sustainable Development Goals (SDGs) agreed by the United Nations in 2015 to balance the social, economic, and environmental dimensions of sustainable development are affected, either directly or indirectly, by growing water scarcity problems [151]. Consequently, the proposal to combine the use of reclaimed and desalinated water, and the promotion of rainwater, is in line with the goal of SDG6: Ensure availability and sustainable management of water and sanitation for all. This goal includes global targets that should be addressed at the regional scale as highlighted in the literature review, including those based on a technical perspective (water quality standards and water efficiency), and a social perspective (water management and governance): treatment and reuse of wastewater and ambient water quality (6.3), water-use efficiency and scarcity (6.4), Integrated Water Resources Management (6.5), and participation in water and sanitation management (6.b) [152]. According to the last two points, although SDG6 represents high-level agenda setting for water cooperation and social participation at the international level, some issues can be highlighted at the regional scale by encompassing the complexities of hydropolitics, and the promotion of agreements and good partnerships between water users in water scarcity regions [153]. For example, the obtained results identified how some of the concerns have been resolved by promoting the cooperation between water users, such as the agreements promoted by the Water Consortium of the Marina Baja between irrigators and urban-tourist water users.

Further research should be focused on the viability of this type of agreement, considering that cooperation is not exempt from threats [154], and could be motivated by the nature of the water scarcity narrative to be (mutually) addressed: water insufficiency and water mismanagement. Based on the main challenges identified from the literature review, both narratives coexist in south-east Spain among agriculture and urban-tourist water users. Each of the challenges identified will require specific solutions from a technical point of view, however, the results highlighted that, to face these challenges, it will be equally important to propose new approaches to water governance and water management that may allow the avoidance of conflicts of interest between users at different scales (both local, regional, and even national). These results can be extrapolated to other case studies of the Mediterranean coast, especially those with a semi-arid climate, where urban, tourism, and irrigation development have threatened the fragile balance between water resources availability and water demand. These regions, affected by the overexploitation of aquifers and dependent on water transfers, such as south-east Spain, will require the introduction and development of non-conventional water resources. Therefore, it may be expected that challenges similar to those identified in this work will arise regarding the use and management of non-conventional water sources. This could require defining specific indicators to monitor how technical (water insufficiency) and social (mismanagement) narratives are addressed in the decision-making processes relating to water scarcity management.

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