agronomy

Article

Farmers' Attitudes towards Irrigating Crops with Reclaimed Water in the Framework of a Circular Economy

María. J. López-Serrano *, Juan F. Velasco-Muñoz, José A. Aznar-Sánchez and Isabel M. Román-Sánchez

Department of Economics and Business, University of Almería, 04120 Almería, Spain; jfvelasco@ual.es (J.F.V.-M.); jaznar@ual.es (J.A.A.-S.); iroman@ual.es (I.M.R.-S.)
* Correspondence: mjlopezserrano@ual.es

Abstract: In a global situation where water constraints are a daily concern and expected to worsen in the upcoming years, finding new water alternatives to guarantee its supply is of critical importance. Against this background, reclaimed water has proved to be a sustainable alternative that recycles wastewater from a circular economy approach, thus enhancing water availability for key sectors such as agriculture. In such a context where public policies should encourage the implementation of this sustainable resource that helps reduce climate change by allowing wastewater reuse, there is too often a lack of knowledge of farmers' perceptions, thus resulting in them being ineffective. In this sense, studying and analyzing agriculturalists' perceptions is of interest for the development of appropriate policies that truly foster reclaimed water use in agriculture and enhance its shift from waste to resource. For this research 231 farmers, both long-time users of reclaimed water and non-users, were surveyed to find common and differing attitudes and perceptions. Results show how once farmers start irrigating their crops with this alternative resource there is a marked improvement in their opinion. The high price is the most widespread barrier, which can be tempered with public subsidies that absorb part of this cost. The insights obtained from this research may be of interest to other regions, especially for those in arid and semi-arid climates where water scarcity is a critical problem and sustainability a growing concern.

Keywords: reclaimed water; tertiary water; treated wastewater; circular economy; sustainable agriculture; perceptions; farmers

Citation: López-Serrano, M.J.; Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; Román-Sánchez, I.M. Farmers' Attitudes towards Irrigating Crops with Reclaimed Water in the Framework of a Circular Economy. *Agronomy* **2022**, *12*, 435. https://doi.org/10.3390/agronomy12020435

Academic Editor: Angela Libutti

Received: 20 January 2022
Accepted: 8 February 2022
Published: 9 February 2022

1. Introduction

Even distribution of water, a dwindling resource, is currently a major issue when one considers that over 4 billion people suffer from severe water scarcity for a minimum of a month every year [1,2]. In light of this, the role of agriculture should be underlined, as it is the world's major water consumer, reaching a consumption of up to 90% of the total water supplies in some areas, with this figure expected to worsen in many places [3–7]. Agriculture is also of crucial importance with regard to climate change, one of the greatest threats to both humans and the environment; in addition to its high vulnerability because of extreme and unpredicted weather conditions that increase water scarcity, agriculture contributes up to 14% of greenhouse gas emissions [8–12]. Against this background and taking into account the inherent relationship between water and land use, agriculture plays a key role in the global task of guaranteeing water supply from a sustainability perspective [13–16]. The importance of agriculture in meeting the demand of an ever-growing population relies on the search for and implementation of a successful, lasting and sustainable water source to irrigate crops [17]. Moreover, this irrigation alternative should be able to ensure economic, environmental and social development [18].

To fight against this concerning situation, tertiary water use has been further implemented over the last decades, and even more considerably in recent years, as it is a resource that, apart from being cheap, enhances the preservation of essential water supplies when used for irrigation purposes [19,20]. Tertiary water, which can also be referred to as reclaimed water or treated wastewater, requires handling urban wastewater in treatment plants in order to develop an alternative water source to irrigate crops [21]. This treatment should be adequate and controlled before irrigating crops to avoid microbiological or physicochemical soil alterations or high heavy metal concentrations that may damage human health [22–24]. Reclaimed water implementation for irrigation, as well as reducing freshwater extractions, reduces the possibility of wastewater spilling into water bodies, preventing the deterioration of aquatic ecosystems and lessening environmental pollution [25–27]. Reclaimed water helps the whole of society with the ever-more-difficult task of meeting global water demand for irrigation whilst enhancing economic development in a sustainable way [28–30]. Treated wastewater also contributes positively to those crop soils irrigated with it, since this resource has proved to be an excellent fertilizer that improves soil quality due to the high quantity of essential nutrients it contains [31–33]. Furthermore, productivity in crops irrigated with tertiary water has been proved to be boosted by using this water source. These advantages enable environmental sustainability and cost savings and growth revenue for the farmer [34].

Another aspect of using treated wastewater to irrigate crops in agriculture that deserves special attention due to its relevance and great potential is its contribution to the circular economy (CE), since the process of treating wastewater enhances its shift from waste to resource through reusing and recycling [35,36]. As a very important element in the process towards the implementation of the CE model is enabling waste management through sustainable practices, considering treated wastewater within the framework of CE has a fundamental role because of the high number of interconnections between CE and sustainability, which result in an integrated approach [37]. In this context, potentiating the use of reclaimed water in agriculture plays a key role in connecting a circular economy with the water sector, since this industry, which is highly dependent on water resources, is critical for the supply of raw materials and food [38–41]. This relationship between the implementation of tertiary water in agriculture and the circular economy, apart from promoting the sustainable approach of water reuse, positively contributes to decreasing the negative impact that raw wastewater would have on the environment, and it improves the efficiency of the water resources as well [42].

Promoting and implementing circular economy policies in the water sector, apart from guaranteeing water supply, has been proved to make national and local economies more competitive, independent and protected from other areas with abundant water resources [43]. Furthermore, channelling wastewater affluents from waste to resource following the principles of the CE model will help communities cope with future water demands necessitated by current global population increase predictions [44]. In fact, since its beginning as a concept in the 1970s, CE has increasingly been considered a major driver in reclaimed water management as its reuse not only maximizes the recovery of freshwater but also encourages the correction of problems that arise from current patterns of production and consumption [45,46]. This being said, reaching the goal of sustainability through the CE approach and water reuse is a pressing need taking into account the proved ineffectiveness of the traditional water management approach, which has led to the existing water stress [47,48].

Nevertheless, and despite the increase in its worldwide use on account of its widely proved environmental, social and economic benefits, reclaimed water implementation for irrigation is still at low levels due to poor social acceptance [49–51]. Although every sector of society is important in terms of perceptions, the role of farmers should be highlighted, as they have the final decision regarding supporting and accepting or declining tertiary water use [52–54]. This low level of acceptance seems to stem from farmers' scepticism, as they are only aware of this sustainable source of irrigation's capacity to fertilize and provide nutrients once they have implemented it and seen the benefits for themselves, despite vast research published in this field [55]. Furthermore, this negative standpoint is often influenced by the flawed belief that due to the inadequate regulation of its treatment, using tertiary water affects soil and crop quality and productivity in a negative way [56,57].

Despite the popularization of treated wastewater use for several purposes, many misperceptions about current policies affecting the treatment of wastewater for irrigation, which are often perceived as too weak, limit its implementation [58]. Although regulation is increasing, it is true that there are still many areas in the world, particularly in less-developed nations, where there is a lack of adequate protocol and proper treatment of wastewater [59]. So much so that more than 20 million ha (hectares), which represents 7% of the total irrigated land, is watered with raw wastewater [60,61]. However, a year after the World Health Organisation (WHO, Geneva, Switzerland) published standard regulations for the reuse of wastewater to properly ensure human health, there was a milestone event that changed the face of water reutilization [62]. When the World Water Assessment Program (WWAP) stated treated wastewater as a reliable and sustainable water resource, the national and international landscape started to change, and since then, the development of regulations on this issue has been ever more frequent in national and international institutions to ensure high standards of water quality [63]. The European Union developed specific regulation (EU 2020/741) where minimum requirements for using reused water in agriculture guarantee a high level of quality in order to protect the environment and human health and foster a circular economy [64]. For its part, the World Health Organisation (WHO) has also evolved regulations regarding the reuse of wastewater to properly ensure human safety [62].

In consideration of increasing utilization and regulation, it is vital to address farmers' perceptions, which have been frequently sidelined despite them being key stakeholders [65]. Their importance is due to the crucial role they play in supporting and accepting programs and policies that promote reused water and in taking the action to properly, safely and effectively implement it in their farms [66–68]. To cover the aforementioned gaps in previous research, the following questions have been addressed in the present study: (1) Can a characterization of farmers' profiles in an area of study be established?; (2) How far does farmers' acceptance extend towards the use of tertiary water for irrigation compared to other water alternatives?; (3) Why do long-time users of treated wastewater use it to irrigate crops?; (4) What are the main perceived benefits and drawbacks derived from this use?; (5) Are non-users less willing to use tertiary water than users? Why?; and (6) Which measures are seen as the most effective to promote reclaimed water implementation from farmers' points of view?

This research introduces an important novelty for the first time by considering the perceptions, understood as a subjective way of identifying and interpretating something based on personal beliefs and experiences, of long-time users of tertiary water and comparing them with those of non-users. After studying farmers' perspectives from both sides, these empirical results shine a light on the reality of those who have the final decision regarding using tertiary water with the CE approach, thus enabling the development of adequate, adapted and realistic regulations, which, unfortunately, are currently far from being a reality. Moreover, the results are particularly significant considering that in the EU, Spain stands out as one of the main practitioners of wastewater reclamation so the insights obtained from this research may be of help to those countries or areas where the construction of appropriate distribution channels from treatment wastewater plants to irrigation communities or farms is being considered [69].

2. Materials and Methods

2.1. Study Area

The present study was conducted in the province of Almería because of its representativity in the area. As it can be seen in Figure 1, it is a Mediterranean area located in southeastern Spain, because of its representativity. Its scarce annual rainfall, which is lower than 200 m, combined with a mean annual temperature of 18 °C, makes it a semi-arid area marked by high solar radiation [70]. Furthermore, available water for irrigation conditions its production and acts as one of the main limiting factors in one of the driest spots in Europe [71,72]. This area is well known for its key agricultural role, so much so that it has the highest concentration of greenhouses in the world and is the biggest exporter of fruits and vegetables in the whole of the European Union [73–76]. The constant growing demand on its agricultural products along with the already scarce water resources has led the province to a water deficit sustained over time [77]. Despite its characteristic high water productivity and the presence of a significant number of aquifers, due to the lack of constant water streams that enhance water collection, local aquifers have suffered much pressure after many years of being the main water resource used to irrigate [71]. With 60,699 total hectares cultivated in the 2019/2020 agricultural season and a medium surface of 3 hectares per farm, the overall number of farms in the area amounts to 20,233. Crops grown in the area are based on conductivity limitations in some irrigated areas since the high conductivity levels in some wells and aquifers narrow the possibilities. The system used to irrigate crops in the region has suffered an intense modernization in recent years due to localized irrigation, automated fertigation and tensiometers use, all of which improve the efficiency of the water in the area [74]. Irrigated areas are geographically divided among irrigation communities, which have different sources of water. This semi-arid region deserves special attention, as its case study can be extrapolated to other countries in a similar situation, especially those situated in arid and semi-arid climates, which also have several limitations regarding their water resources [78–82].

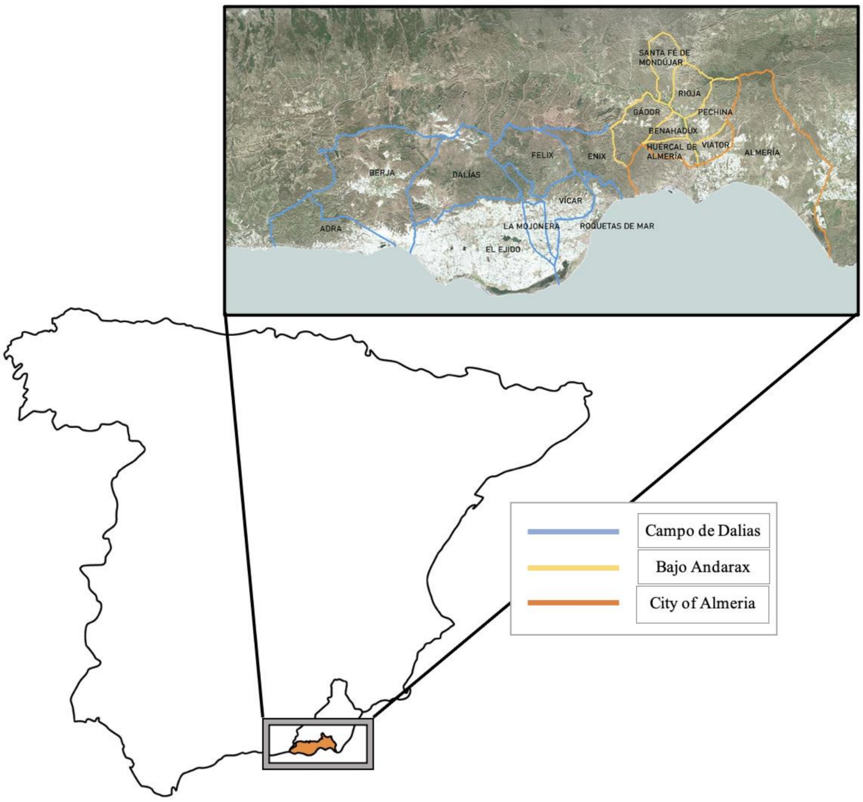

Figure 1. Area of study adapted from Fototeca Digital CNIG.

The province is made up of six main subareas, two of which stand out for holding more than 77% of the greenhouse concentration of the province [83]. These two areas, Campo de Dalias and Bajo Andarax (which includes Almeria City), are significantly important to this study as in Campo de Dalias the use of tertiary water for irrigation is nonexistent, as the main water resource is groundwater, whereas Bajo Andarax has been using treated wastewater for irrigation since 1997 [84]. Water management in both areas is organized by the aforementioned irrigation communities, which are in charge of supplying the amount of water needed by irrigators for their crops. In Campo de Dalias, the Users Central Board is composed of many irrigation communities that have signed an agreement to enable the recovery of Beninar Reservoir. Since then, the water price of this reservoir, 0.02 €/m^3, has been combined with the cost of desalinated water, at the cost of 0.60 €/m^3, in order to establish a balanced price, so the cost charged to farmers for the water is 0.3 0€/m^3 regardless of where the water comes from. The impossibility of using reclaimed water in Campo de Dalias stems from the lack of a distribution channel from the wastewater treatment plant to the irrigation communities. Conversely, most farmers from Bajo Andarax use reclaimed water from the wastewater treatment plant located in Almeria city where raw urban wastewater coming from industries and households undergo primary, secondary and tertiary treatments. Reclaimed water resulting from the treatments has a homogeneous quality and meets the parameters stipulated by the EU. Its cost varies from 0.44 €/m^3 to 0.62 €/m^3 depending on where the farm is located because of distribution costs. Although tertiary water is a commonly used resource in the area, chosen by 60% of local farmers, there are other alternatives available, such as underground water from the Bajo Andarax Reservoir. There are also various nearby irrigation communities that manage wells from which underground water is drawn. The coexistence of these two areas, both of which have board agricultural experience but use completely different irrigation resources, makes it the most suitable place for this study where new water alternatives should be implemented to cope with depleting aquifers, which results in increasing water conductivity and salinity and decreasing water quality.

2.2. Qualitative Research: Questionnaire Design

In view of the methodologies implemented in other studies that aimed to evaluate similar water-related perceptions, the research conducted has both qualitative and quantitative analyses [51,85,86]. Before carrying out the first part of the qualitative analysis, a thorough bibliographical review was conducted to establish the state of the art in order to determine the current priorities, trends and methodologies within the perceptions of reclaimed water used for irrigation. This analysis enhanced the decision to use combined media for the survey where questions have been both distributed online using the platform Google Forms and with person-to-person semi-structured interviews in places of interest to farmers such as irrigation communities, supply depots or other facilities linked to the agricultural holding [85,87–90]. The locations of farmers surveyed through in-person interviews were selected so as to ensure the representativity of the whole range of agricultural holdings in the area of study. A total of 159 in-person interviews were conducted with a duration of 15–20 min each, and 72 online surveys were collected with an estimated individual length of around 10 min. The questionnaire was in Spanish. Moreover, and in order to guarantee the inclusion of all the main aspects of further research needed among the group of questions initially proposed, questions included in the questionnaire were based on previous investigations [66,71,74,87,89,90]. Furthermore, previous studies in the same province with clear results allowed the discarding of some groups of questions such as those related to greenhouse irrigation technology, type of soil or greenhouse type, among others, as extensive answers had previously been obtained [71,74,75]. Finally, all people surveyed were informed that there were no correct answers and anonymity was ensured.

For the qualitative study, a total of 5 people with deep expertise in agriculture in the area of study were interviewed: a full-time professor of agriculture, the president of an irrigation community, the president of an agricultural cooperative and two farmers with more than 40 years of experience. In these first five interviews, a concise guide was used for obtaining the farmers' initial responses. The first part of this guide was a presentation on the topic and was followed by an open debate to set burning issues that needed to be tackled in the personal interviews. Then, three different set of questions were purposed by a general agreement. Stakeholders, in consensus with the researchers of this study, finally decided on three sets of questions about farmers' details, characteristics of the agricultural holding and crop-related aspects. From the interview, the most relevant topics were extracted to be used during the next steps of the research. Then, twelve farmers, forming the focus group, were reunited to develop a focus group discussion where the main water issues addressed by the experts in the previous interviews were tackled. Furthermore, the objective was posing the questions for the three sets in an easily understandable way for the farmers to avoid the maximum number of doubts, uncertainties and biased answers. This group was made up of six farmers with extensive experience in tertiary water irrigation in agriculture and six farmers that had never used this water resource before. Once representative key stakeholders had been initially surveyed, the initial questionnaire to consolidate the most important information obtained was formulated. In order to pretest it before its launch, a pilot survey with eight farmers, four of whom were users of reclaimed water and the other four non-users, was carried out [27,91]. As the same questionnaire was given to both users and non-users, it contained conditioned questions that led down different paths for both groups, so depending on the respondent there might have been 17 to 22 questions. Different types of questions were used: open-ended answer, short answer, Likert-type scale (5 or 3 points scale) and multiple choice, some having the possibility of more than one option [85,88,92]. Furthermore, and in order to avoid survey bias, answers in closed-response questions were randomized and presented to each respondent in a different order in both onsite and online formats [93]. The questionnaire was grouped into four sections:

1. Featuring farmers and their agricultural holdings. Three sets of questions were asked, referring to: (a) farmer's details (age, level of education, specialized agricultural training courses, years of experience and annual median gross income); (b) characteristics of agricultural holding (surface area of the agricultural holding, year of the greenhouse construction, greenhouse type, climatic system, total workers, number of family members working in the holding, water consumption per hectare and type of water used to irrigate); and (c) crop-related decisions (crop variety decision maker and buyer).
2. Attitudes towards diverse alternatives of water resources. In this part of the questionnaire two topics were addressed by the farmer; water alternatives and water characteristics. Firstly, an evaluation of four different water alternatives (surface water, underground water, desalinated water, reclaimed water) using a Likert-type scale was requested. To keep the survey concise and avoid lengthy scales that have proved to induce fatigue and unmotivated respondents, Likert-type scale values to score options from -2 to 2 were used; negative numbers reflect negative perceptions, 0 indifference, and positive numbers indicate positive perceptions [94].
3. Perceptions and acceptance towards reclaimed water use. In this part of the survey, every respondent was asked if he had ever used tertiary water for irrigation and as this was a conditioned question depending on the answer, it led to different questions. If the farmer had used reclaimed water to irrigate crops, then he was asked if he had continued using this resource. In case of an affirmative answer, the next aspect to be covered would be the estimated percentage of its use taking into account other water alternatives used in the holding. Then, reasons why the farmer uses reclaimed water and its perceived benefits and drawbacks would be surveyed. Lastly, if the agriculturalist complemented reclaimed water with other alternatives, the differences perceived among them had to be clarified. On the other hand, if the farmer had never used this alternative resource, his willingness to use it if he could would be evaluated. In the case of a negative or dubitative response, the reasons for this reluctance would be requested, and one or more answers could be chosen (the idea of reusing human waste is disgusting, high prices, fear of soil quality loss, fear of a reduction in production, fear of product quality loss, fear that its use for irrigation results in the consumer becoming ill, I need more information about advantages and disadvantages and I would only use it if I had no other alternative). A negative answer in the question about continuity would also lead to an option to choose the reason for use cessation.

4. Measures to promote tertiary water use in irrigation. Six different actions were measured using Likert-type scale values from 1 to 3 from less to more effective (subsidies for those irrigation communities that implement this irrigation method, direct subsidies to farmers that implement it, price reduction for users, volume discounts, information campaigns about its economic and environmental benefits and more stringent regulation that assures water quality).

2.3. Quantitative Research: Sample Size and Selection

The second part of the present research comprises a quantitative approach for which a data collection process was required. In order to determine the sample size needed, a confidence level of 95% and a maximum error level of 5% were set on the basis of hectares. From the greenhouse area of Campo de Dalias, which accounts for 21,801 hectares with no reclaimed water users, 378 hectares had to be surveyed to meet statistical requirements. For its part, the group of reclaimed water users accounts for 3069 hectares; nevertheless, only 1800 of them are regular users of Cuatro Vegas Irrigation Community, which is the irrigation community that provides treated wastewater to its farmers. For this reason, the 1800 hectares were evaluated as a total in order to assure the representativity of the farmers that use this alternative water resource. Then, and in order to meet already stated statistical requirements a total of 317 hectares were evaluated. This sample guarantees representativity among the research group. In total 231 farmers were surveyed from April to June 2021.

2.4. Data Analysis

Once data had been collected from all the questionnaires, they were compiled and tabulated in Microsoft Office Excel to then be submitted to a statistical analysis program that classified the main characteristics of the farmers surveyed and their agricultural holdings. The analysis was performed using SPSS software (version 23). From the study of the data gathered, a profiling of the farmers and their agricultural holdings was carried out. Subsequently, an in-depth examination was undertaken to approximate water preferences to farmers' socioeconomical profiles with a statistical analysis where maximum, minimum, mean, mode, standard deviation and coefficient of variation were calculated. Differences in water preferences among water users were evaluated using Friedman's test separately for each water user type. Friedman's test looks for differences in the ratings of the 4 separate categories where each person gives a rating for the 4 categories. So, the test verifies if there are significantly different ratings for the four categories across all people in the dataset. In this case, the categories were the water sources, and the people were those surveyed from a water user group. When the dependent variable being measured is ordinal, this analysis is used to examine differences between groups. This test was run separately for each group of water users. In other words, it answered the question: "Do water users from the same group have a preference for any of the water sources?" On the other hand, differences in water ratings across different users were evaluated separately for each water source using a Kruskal–Wallis test. This non-parametric alternative to the one-way ANOVA is used for differences in the ratings of one water source among different water user groups. In other words, it answered the question: "Do water users from the same group have a preference for any of the water sources?". Then, the survey responses studied from the qualitative analyses were extensively analyzed based on mean, median and mode to find out acceptance and perceptions of the use of reclaimed water. Lastly, the evaluation of how farmers perceived different actions to promote the use of reclaimed water for irrigation and the influence their socioeconomical conditions may have had on their answers was conducted. This evaluation was carried out through a statistical analysis using SPSS software to try to find statistical patterns, correlations and groupings. A K-Means cluster analysis was performed for this purpose with the unlabelled data to detect direct relationships among variables and group those that are directly related based on feature similarity through this unsupervised learning algorithm. Numerical answers and statistical analysis results were measured using tables. Graphs were mainly based on the frequency of the answers to explain the high concentration of some responses. The relationship between water source perceptions and water source used was evaluated in a combined graph of a line and bar chart using Excel. Short questions were analyzed and grouped so the top 3 perceived advantages and disadvantages of using reclaimed water could be represented in a graph bar. Willingness to implement reclaimed water is shown in a pie chart. Likert-type scale and multiple answer questions are detailed in spider graphs.

3. Results and Discussion

Data resulting from the survey has been divided into three different sections: farmer profiles, preferences and attitudes regarding tertiary water of users and non-users, as well as incentives for boosting the implementation of reclaimed water to irrigate agricultural crops.

3.1. Farmers Profiles

Table 1 shows the variables that have been statistically studied and for which the minimum, maximum, average, standard deviation and coefficient of variation have been calculated. These variables, elaborated with data from 231 farmers, have been grouped into three areas:

Farmers' details. A total of 71% of the farmers surveyed are over 40 years old, and the average age in the sample is 48 years. Experience is also high in this traditional profession with an average of 25 years. If average age is compared with mean experience, it can be seen that most agriculturalists started farming in their early twenties, which provided them with deep expertise. In terms of education level, despite 62% of the agriculturalists having basic levels of education (primary or secondary), 69% of the total sample attended specialized agricultural training courses, which shows high levels of specialization. In terms of gross turnover, the average is EUR 226,811with a minimum of EUR 10,000 and a maximum of EUR 2,000,000.

Characteristics of the agricultural holding. The mean surface area of the farms surveyed is 3.05 ha, which, if compared with the annual gross income, an approximate gross yield of EUR 74,364 per hectare was obtained for every agricultural campaign. Average data resulting from the greenhouse construction year show that medium holding age is 18 years. The most common greenhouse type is a sloping roof, found on 66% of the greenhouses. This was followed by the flat-arch type, representing 28% of the sample. The residual 4% for other types shows a clear prevalence of two main types in the area of study. Only a marginal percentage of the farms, around 6%, have a climate monitoring system. As employed labour may vary significantly depending on the time of the year and the seasonal tasks to be completed, only full-season workers were considered. A little over half of the farmer labour is provided by family members, with numbers increasing with decreasing farm size. Whereas in agricultural holdings up to 1 ha family members working represent 74% of the total labour, in those larger than 2 ha family labour represents 33%.

Crop-related aspects. Although crop selection varies deeply depending on the area, agricultural holding characteristics are a deciding factor when deciding which crop to sow for 43% of the farmers. It must be highlighted that depending on the area, driving forces vary considerably. In Almeria and Bajo Andarax, where conductivity levels are an increasing problem, the crop selection is weighted in favour of water limitations or tradition, which is based on many years with high levels of salinity. In Campo de Dalias, the pervious campaign prices and recommendations suggested by cooperatives have a more important role. Wholesalers and agricultural cooperatives stand out, accounting for 78% of the trading channels used by the agriculturalists surveyed.

As seen in the standard deviation results, a great majority of the variables have a coefficient of variation higher than 30%, which is not acceptable as this shows a great extent of variability of the data dispersion around the sample in relation to the mean. This can also be observed when analysing the coefficient of variation, which is the ratio of the standard deviation to the mean. The higher the coefficient is, the greater the level of mean sample dispersion is. Both statistics analyses prove that the dispersion is too widespread in the sample and thus impedes cluster grouping with acceptable errors to test its significance.

Table 1. Features of farmers surveyed and their agricultural holdings.

Field	Variable	Description	Min.	Max.	Average	Standard Deviation	Coefficient of Variation
Farmers' details	V_1	Farmer's age (years old)	20	82	47.52	12.16	25.59%
	V_2	Years of farming experience (years)	1	69	25.34	14.5	57.20%
	V_3	Level of education: (1) primary education, (2) secondary education, (3) upper-secondary school or vocational training, (4) university degree	1	4	2.13	*	*
	V_4	Specialized agricultural training courses: (1) yes, (2) no	1	2	1.31	*	*
	V_5	Annual median gross income (EUR)	10,000	2,000,000	226,811	310,466	136.88%
Characteristics of agricultural holding	V_6	Surface area of the agricultural holding (hectares)	0.2	32	3.05	3.57	117.09%
	V_7	Year of the greenhouse construction (4-digit)	1970	2021	2003	10.77	0.54%
	V_8	Greenhouse type: (1) sloping roof, (2) flat arch, (3) multi-tunnel, (4) others	1	4	1.4	*	*
	V_9	Climatic system: (1) yes, (2) no	1	2	1.94	*	*
	V_{10}	Percentage of family-based workforce	0%	100%	52%	0.35	67%
Crop-related aspects	V_{11}	Crop selection: (1) It's my own decision based on my agricultural holding characteristics. (2) It's my own decision based on tradition. (3) It's my decision based on water limitations such as conductivity, consumption or salinity. (4) It's my own decision based on the previous campaign prices. (5) The cooperative where I am a member suggests what to sow. (6) Others	1	6	2.86	*	*
	V_{12}	Trading channel: (1) wholesalers, (2) agricultural cooperative, (3) intermediary companies, (4) others	1	4	1.95	*	*

* Cannot be calculated on qualitative variables.

3.2. Preferences and Attitudes towards Tertiary Water

3.2.1. General Perceptions towards Different Water Alternatives

Once farmers had been evaluated four different water alternatives, including underground, surface, desalinated and reclaimed sources, various connections could be drawn. Before analysing the results, the fact that responses were based on perceptions must be highlighted. These responses were based on the subjective, biased and personal experiences of the farmers with different water resources. This perceived evaluation is of great importance since the main barrier to achieving an integral implementation of reclaimed water in agriculture is the refusal of the farmers based on their negative perception.

According to the Friedman test ($p < 0.001$) each water user ranked the alternative water sources significantly different. Nevertheless, differences in water preference by water use type was significant only for underground water sources ($p < 0.001$) and insignificant for the remaining water sources ($p > 0.20$). K-Means cluster analysis results are inconsistent and not significant, as any direct relationship may be proved across most variables with acceptable errors to test significance and therefore, to extrapolate results with a reasonable degree of certainty, it was excluded from the research.

As can be seen in Figure 2, every alternative received its highest score in terms of desirability from its users. This evaluation of an everyday used resource shows the positive relationship between the use of a water alternative and its perceived quality and benefits, as in all cases its users are those who give the highest rating to each resource. This is in line with previous research but contrasts a study where users had a more negative perspective about reclaimed water after using it than the one they had used before [52,54,65]. In terms of general desirability, surface water is the most preferable alternative, contrary to reclaimed water, which is the least. Such a negative assessment by farmers contrasts with other research where the desirability of tertiary water is higher than that of other alternatives such as underground and desalinated water [95]. Despite its low levels of popularity among general farmers, its irrigators see it as the second most desirable alternative for them. The low rating of underground water given by tertiary water users, the second lowest in terms of desirability for most farmers surveyed, is based on the fact that in Almeria and Bajo Andarax water wells and aquifers often have levels of conductivity and salinity that are too high, which impede its use for irrigation. On the other hand, Campo de Dalias agriculturalists evaluated underground water positively as their wells are of a much higher quality. Moreover, it must be noted that when asking farmers about desalinated water, their negative perceptions towards it were often connected to its negative environmental consequences and its high price. Last but not least, it should be highlighted that although differences seem to be low, they are significant as they show a whole point out of five points of difference between different alternatives. This means that there is an important variation in the quality perceived before and after using a water resource.

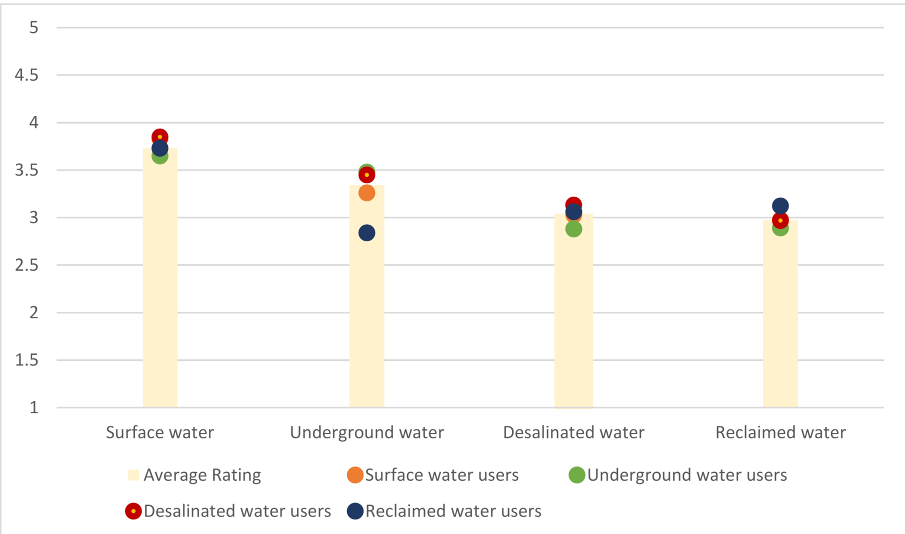

Figure 2. Farmers' perceived water sources desirability.

3.2.2. Users' Perceptions of Reclaimed Water

Initially, the distribution channel with water from the wastewater treatment plant to the local irrigation community was created to develop an auxiliary resource that guaranteed water supply in the area due to the increasing aquifer and water well depletion and salinization. Nevertheless, things have worsened in recent decades to the point where hundreds of farmers are able to irrigate exclusively thanks to reclaimed water, from which they obtain all of the water their crops need. In addition, because of the increasing salinity and conductivity levels in water wells that up until the time of the study had been used for the irrigation of some crops such as tomatoes, this water is no longer suitable by itself and needs to be mixed with reclaimed water to reduce these levels. The tomato is the most representative crop in Almeria and Bajo Andarax as it supports higher levels of conductivity compared to other crops such as peppers or zucchinis. This situation, which is much worse than anticipated, is expected to be further aggravated by the desalination plant located in Almeria, which, instead of obtaining water from the sea, acquires it from local water wells and aquifers to save money in the process of desalinating, as the salt concentration to be eliminated is much lower and thus the process is much cheaper. The plant plans to put a new frame into operation that increases its desalination capacity, thus reducing local water reserves in aquifers and water wells even more. All of this has escalated due to the passivity of the local politicians and despite the despair of the local farmers who see their natural resources depleting and reclaimed water already suffering occasional shutdowns.

The situation mentioned above was constantly referred to by the farmers surveyed during the part of the interview where they were asked about the reasons why they use reclaimed water. Their concern about whether this sustainable resource would be enough for all the farmer due to the depletion of underground water and its quality at unusable levels and the lack of any other water alternatives is highlighted in Figure 3, which shows the number of respondents that chose that answer. The most frequently chosen option for the reason they use reclaimed water was the absence of any other alternatives to irrigate crops. The next two options in terms of representativeness are also linked with the lack of alternatives, as what the irrigation community offers in the area, which is only reclaimed water, is due to the absence of other available options. Furthermore, there was a significant number of farmers that claimed that the reason they use tertiary water is to mix it with water from the water well, thus reducing conductivity or pH levels. These three reasons that justify the use of reclaimed water in the area are a very clear representation of the current situation, which is expected to worsen because of the lack of political support given to the agricultural holdings located in the area.

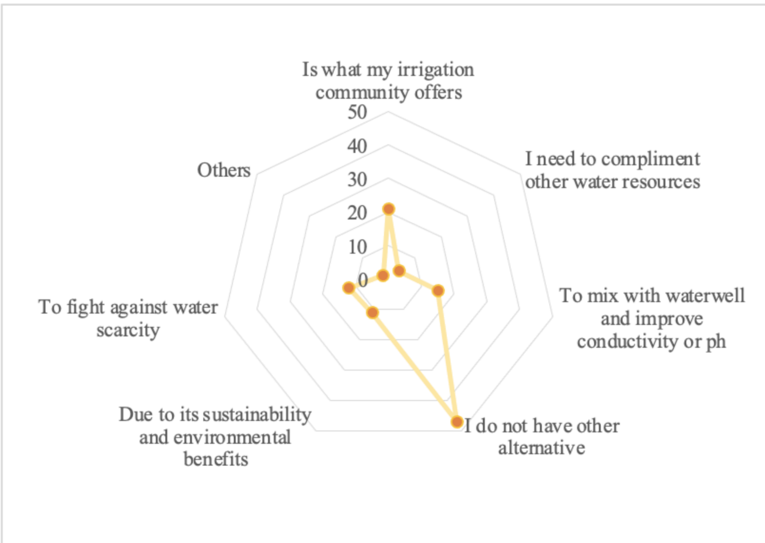

Figure 3. Farmers' initial reasons for using reclaimed water.

Farmers were also asked to mention perceived benefits and drawbacks of the use of tertiary water to irrigate agricultural corps and results, as shown in Figures 4 and 5, which refer to the total number of farmers that has chosen that option. Although the repetition rate in the three options represented in both figures proves extended perceived beliefs by farmers, they are not always based on reliable studies or data since they are often biased by personal situations or experiences. Figure 4 shows that the most frequently repeated answer was the guarantee of having water available to irrigate their crops, a positive aspect derived from using reclaimed water, as has already been found in other research [54,65,95]. Sustainability and water reutilization are very close in terms of perceived importance, sustainability being understood as the implementation of a circular economy in the agriculture through the use of sustainable and respectful environmental practices. These two factors are directly connected, as reusing water instead of discharging it into water bodies is a sustainable practice that fosters the sustainability of natural resources. Other aspects that are also often noticed by users are the saving in fertilizers using reclaimed water and low levels of conductivity, compared with local water alternatives, that allow farmers to sow any crop. The levels of conductivity in reclaimed water in the local wastewater treatment plant were around 2.5 dS/m, while most water wells in the area had levels from 5 to 7 dS/m. It should be clarified that the ideal conductivity for the crops grown in that area is between 2 and 3 dS/m, as tomatoes, which is the most common crop in the area of study, needs higher levels than cucumbers or peppers.

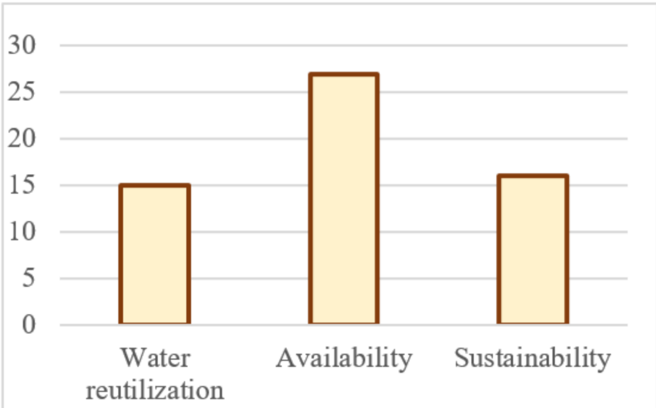

Figure 4. Combined data of the most beneficial advantages of using reclaimed water perceived by farmers.

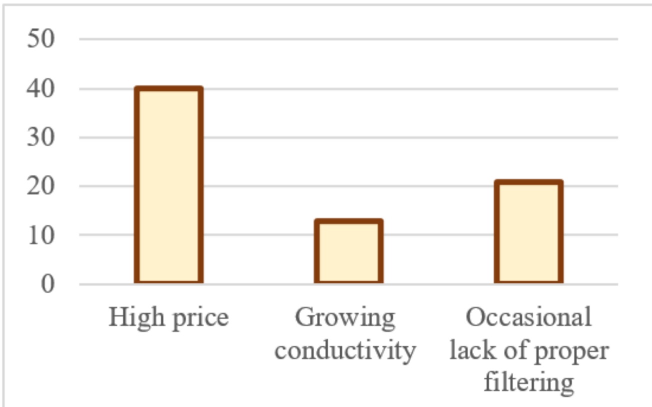

Figure 5. Combined data of the most disadvantageous drawbacks of using reclaimed water perceived by farmers.

Drawbacks were also assessed by farmers, as shown in Figure 5, and the prevailing opinion is related with the high price of reclaimed water when compared with groundwater in the area of study, a problem already widely perceived by users in other studies [30,96]. Many agriculturalists refer to the importance of subsidising part of the cost of this resource to make it more attractive to new users. This is has already been accomplished with other water alternatives as many desalinated plants are the property of the government so it subsidises the price of desalinated water, making it lower for the farmer. Subsidising the price of reclaimed water for agricultural use is already implemented in other countries, such as Cyprus or the USA (California) where the public administration front a great part of the water price [97]. Respondents also referred to the occasional lack of proper filtering, which, although becoming less and less frequent, still affects some agricultural holdings by clogging their filters. Lastly, increasing conductivity was referred to as a significant drawback by those farmers who mix water from the water well with reclaimed water to obtain conductivity levels suitable for the crop. Nevertheless, although current reclaimed water conductivity levels are adequate for all the crops sown in the area, farmers with their agricultural holdings nearby water wells with excessively high levels of conductivity need another water source with very low levels that would compensate for this factor.

3.2.3. Non-Users' Attitudes about the Utilization of Tertiary Water to Irrigate Agricultural Crops

The willingness to use reclaimed water of those farmers surveyed that had never used it because their agricultural holdings are located in areas where this option does not exist was evaluated in order to study general perceptions coming from non-users. With nearly three out of four farmers willing to use it, fully or partially, the results illustrated in Figure 6 are encouraging in terms of farmers' acceptance. The key group are hesitant farmers who comprise exactly half of the sample. Their importance lies in the fact that they are certainly open to this new water alternative, as long as the reasons that make them doubtful of its use are addressed; therefore, further investigation is needed in order to overcome these factors and tilt this balance in favour of tertiary water.

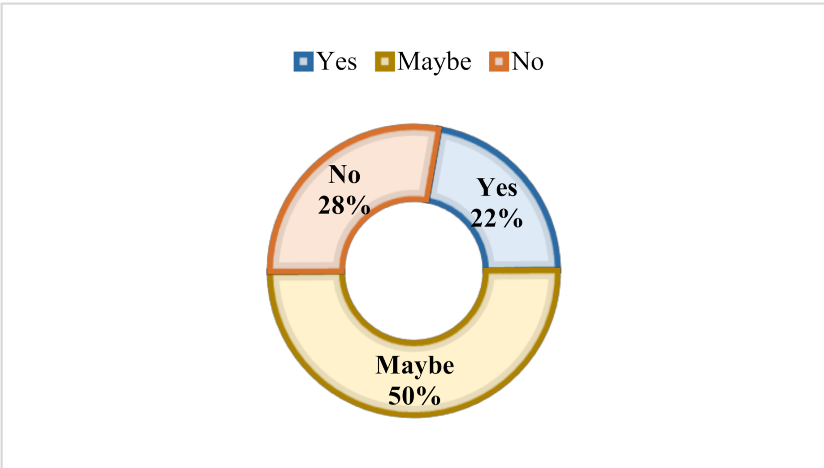

Figure 6. Non-users' percentage of willingness to use reclaimed water to irrigate their crops.

Figure 7, which refers to the total number of farmers that chose that option, compares the reasons given by hesitant users that make them uncertain about whether to use reclaimed water or not with arguments from reluctant users that justify their refusal to use this sustainable resource if they could. The first group of users also referred to the high price of this water alternative. While a great number of hesitant users would probably change their minds with proper information about advantages and disadvantages or would simply use it in the case of the absence of alternatives, reluctant users' hesitations are based on fear. The idea of losing soil or product quality or diseases derived from the consumption of a product irrigated with reclaimed water are the most recurrent worries. To eliminate as well as prevent fears and misconceptions, informational campaigns have already been stated as key in the role of encouraging farmers to use tertiary water [50,57]. It has to be underlined that the yuck factor mentioned in many articles, which refers to the disgusting image that reusing human waste may have, is of minimum importance to these farmers as they are used to applying organic fertilizer from animal disposals [55].

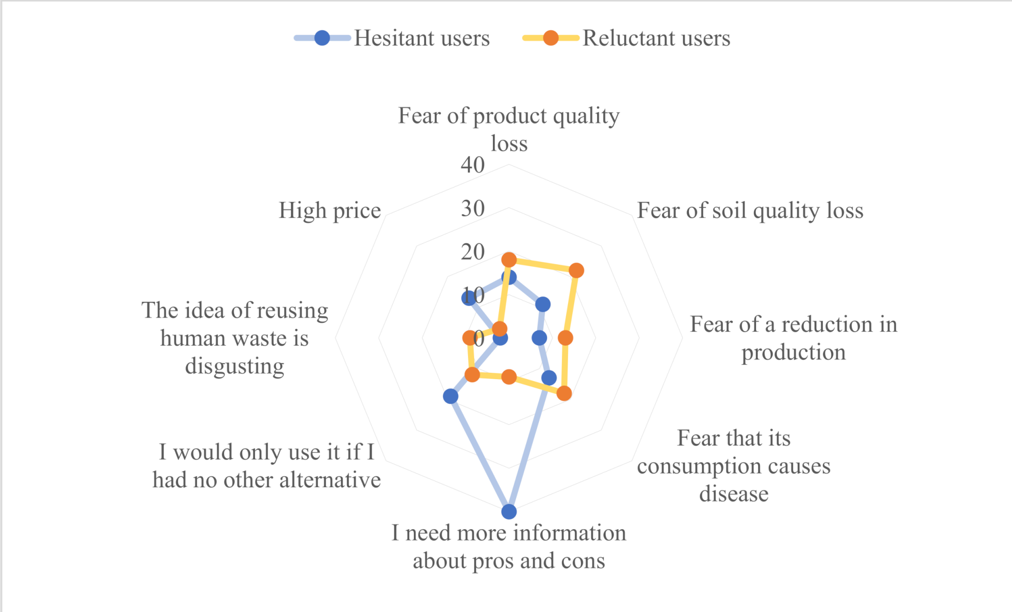

Figure 7. Farmers' reasons for hesitating or rejecting the idea of using reclaimed water.

3.3. Perceived Effectiveness of Diverse Incentives That May Boost the Implementation of Reclaimed Water in Agriculture

At the end of the questionnaire, the farmers surveyed were asked to evaluate the effectiveness of different incentives that could be put into effect in order to promote the use of reclaimed water to irrigate agricultural crops. Similar patterns of opinions are shown in Figure 8, which existed regardless of whether the farmer had or had not previously used reclaimed water for irrigation. This figure shows in terms of importance, from 1 to 3 (1—not important at all and 3—really important) with intervals of 0.5, how users perceive certain policies and their capacity to promote the implementation of reclaimed water for watering crops. In terms of cost reduction, the option of a price decrease overruled subsidies, whether it be for farmers or irrigation communities. Information campaigns about the benefits derived from its use, along with price reduction, were the options chosen by the greatest number of farmers. Both aspects have already been stated in previous research [66,67]. For its part, the volume discount was the least desirable measure for fostering the use of reclaimed water as farmers see the proposal as a disadvantage for farms with small surface areas and for those focused on saving water, as this measure would lead to its wasteful consumption to receive volume discounts. Nevertheless, although opinions are quite similar between the two groups studied, there is an aspect where there is a greater discrepancy. While agriculturalists who have never used reclaimed water believe that more stringent regulation is necessary, users have more knowledge about how strict the regulation already is. This difference confirms and reinforces the already perceived idea that information campaigns are a key measure of progress in the task of promoting reclaimed water for crop irrigation.

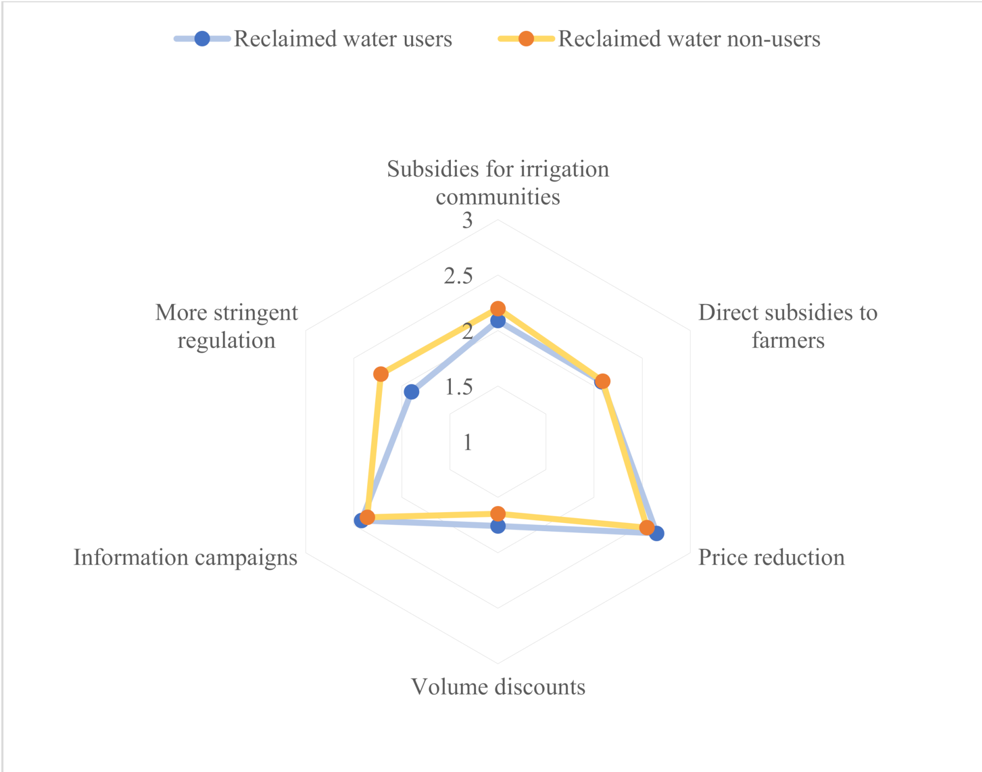

Figure 8. Farmers' perceived effectiveness about different measures to boost reclaimed water use.

4. Conclusions

Statistical analyses carried out in this study illustrate that there are differences in the quality between the water resources surveyed perceived by farmers. Since these differences might be influenced by their experiences, this research may also prove the variation in the level of satisfaction of farmers after using tertiary water for irrigating their crops, which increases after its use. Users interviewed awarded this alternative water resource the highest rating above other alternatives, including groundwater or desalinated water. This improvement in the assessment of reclaimed water shows how the most common incorrect and negative beliefs about the consequences of irrigating with this water alternative diminish or even disappear once it is implemented. Despite its use, usually starting in locations where other water bodies are depleting or in bad conditions in terms of quality, treated wastewater has been demonstrated as being a sustainable alternative that channels wastewater into a productive use that boosts and strengthens such key sectors such as agriculture by using the circular economy approach. Apart from it being water reutilization rather than requiring disposal into water bodies, its availability is guaranteed. These are both benefits clearly perceived by farmers, who also value its capacity to greatly reduce the cost of fertilizers.

In spite of already strict regulation of treated wastewater, farmers sometimes perceive a lack of compliancy from the irrigation community, which, as they continuously referenced during the interviews, should not be in charge of controlling water quality as they are not trained for this task, which instead should be carried out by the public administration. Because of the high and prohibitive price of reclaimed water along with increasingly narrower profit margins, far from making the primary sector attractive, it creates a negative image as one of the least advantageous to invest in. Apart from deterring potential new investors or entrepreneurs, this negatively affects the revitalization of an already ageing sector. This could be tackled by investing in nationalizing wastewater treatment plants to boost its use, as has already been accomplished with some desalination plants in Spain, or through public subsidies that reduce the cost for farmer.

One figure that deserves special attention is that over 70% of the farmers surveyed are open to the idea of using reclaimed water if adequate information is provided to them. The importance of informational campaigns that prove environmental benefits and the quality and safety of this resource was perceived by all the groups interviewed. Furthermore, they are the most effective measure to raise awareness among those farmers that are currently reluctant about its implementation because of wrongly perceived fears, which would be reduced or eliminated by these campaigns. Moreover, these informational campaigns would probably be welcomed by farmers due to the high number of those with specialized training in agriculture, which implies high interest levels in their field. These campaigns should be launched not only for non-users but also for users to show them the economic benefits that often go unnoticed and answer further questions as some still have a misleading picture of regulation and its strictness.

These findings confirm that there is great potential for fostering farmers' willingness to use reclaimed water to irrigate their crops and that once farmers start using it their opinions about its quality and benefits improve. Furthermore, in a global context where water resources are depleting and irrigated areas are increasing every day to feed an unceasingly growing population, managing waste and limited resources using the CE approach has been proved in this study to be a widely accepted alternative to fight against water scarcity while pursuing the goal of reaching a circular economy thanks to which many hectares in Almeria and Bajo Andarax have been irrigated every agricultural year since 1997. Setting differences aside, insights derived from the present research can be of great interest to other areas where water constraints and the implementation of a circular economy is a reality, especially in arid and semi-arid climates, due to their similarity with the area studied.

Author Contributions: M.J.L.-S.: Conceptualization, Methodology, Formal analysis, Investigation, Writing—original draft preparation, Writing—Review and Editing. J.F.V.-M.: Conceptualization, Methodology, Investigation, Validation, Writing—Review and Editing, Supervision. J.A.A.-S.: Methodology, Investigation, Writing—Review and Editing. I.M.R.-S.: Methodology, Investigation, Writing—Review and Editing. All authors have read and agreed to the submitted version of the manuscript.

Funding: This work was partially supported by the Spanish Ministry of Education, Science and Universities by the FPU18/01778 predoctoral contract granted to María José López Serrano.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: We gratefully acknowledge all the farmers interviewed in this research for their time and disinterested assistance.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. WWAP. UNESCO World Water Assessment Programme. In *The United Nations World Water Development Report 2019, Leaving No One Behind*; UNESCO: Paris, France, 2019.
2. Deviller, G.; Lundy, L.; Fatta-Kassinos, D. Recommendations to derive quality standards for chemical pollutants in reclaimed water intended for reuse in agricultural irrigation. *Chemosphere* **2020**, *240*, 124911. [CrossRef] [PubMed]
3. Becerra-Castro, C.; Lopes, A.R.; Vaz-Moreira, I.; Silva, E.F.; Manaia, C.M.; Nunes, O.C. Wastewater reuse in irrigation: A microbiological perspective on implications in soil fertility and human and environmental health. *Environ. Int.* **2015**, *75*, 117–135. [CrossRef] [PubMed]
4. Martínez-Alvarez, V.; Maestre-Valero, J.F.; González-Ortega, M.J.; Gallego-Elvira, B.; Martin-Gorriz, B. Characterization of the Agricultural Supply of Desalinated Seawater in Southeastern Spain. *Water* **2019**, *11*, 1233. [CrossRef]
5. Contreras, J.; Roldán-Cañas, J.; Moreno-Pérez, M.; Gavilán, P.; Lozano, D.; Baeza, R. Distribution Uniformity in Intensive Horticultural Systems of Almería and Influence of the Production System and Water Quality. *Water* **2021**, *13*, 233. [CrossRef]
6. Wang, X.; Müller, C.; Elliot, J.; Mueller, N.D.; Ciais, P.; Jägermeyr, J.; Gerber, J.; Dumas, P.; Wang, C.; Yang, H.; et al. Global irrigation contribution to wheat and maize yield. *Nat. Commun.* **2021**, *12*, 1235. [CrossRef]

7. Kourgialas, N.N. A critical review of water resources in Greece: The key role of agricultural adaptation to climate-water effects. *Sci. Total Environ.* **2021**, *775*, 145857. [CrossRef]
8. Melián-Navarro, A.; Ruiz-Canales, A. Evaluation in Carbon Dioxide Equivalent and CHG Emissions for Water and Energy Management in Water Users Associations: A Case Study in the Southeast of Spain. *Water* **2020**, *12*, 3536. [CrossRef]
9. Ashu, A.B.; Lee, S.-I. The Effects of Climate Change on the Reuse of Agricultural Drainage Water in Irrigation. *KSCE J. Civ. Eng.* **2021**, *25*, 1116–1129. [CrossRef]
10. Al-Agele, H.; Nackley, L.; Higgins, C. A Pathway for Sustainable Agriculture. *Sustainability* **2021**, *13*, 4328. [CrossRef]
11. Arellano-Gonzalez, J.; AghaKouchak, A.; Levy, M.C.; Qin, Y.; A Burney, J.; Davis, S.J.; Moore, F.C. The adaptive benefits of agricultural water markets in California. *Environ. Res. Lett.* **2021**, *16*, 044036. [CrossRef]
12. Xin, Y.; Tao, F. Have the agricultural production systems in the North China Plain changed towards to climate smart agriculture since 2000? *J. Clean. Prod.* **2021**, *299*, 126940. [CrossRef]
13. Pretty, J.; Sutherland, W.J.; Ashby, J.; Auburn, J.; Baulcombe, D.; Bell, M.; Bentley, J.; Bickersteth, S.; Brown, K.; Burke, J.; et al. The top 100 questions of importance to the future of global agriculture. *Int. J. Agric. Sustain.* **2010**, *8*, 219–236. [CrossRef]
14. Hoang, L.T.; Roshetko, J.M.; Huu, T.P.; Pagella, T.; Mai, P.N.; Pham, T. Agroforestry—The Most Resilient Farming System for the Hilly Northwest of Vietnam. *Int. J. Agric. Syst.* **2017**, *5*, 1–23. [CrossRef]
15. Villarejo, V.C.; López, C.M. Water use in arid rural systems and the integration of water and agricultural policies in Europe: The case of Andarax river basin. *Environ. Dev. Sustain.* **2014**, *16*, 957–975. [CrossRef]
16. Runhaar, H. Four critical conditions for agroecological transitions in Europe. *Int. J. Agric. Sustain.* **2021**, *19*, 227–233. [CrossRef]
17. Fields, C.M.; Labadie, J.W.; Rohmat, F.I.; Johnson, L.E. Geospatial decision support system for ameliorating adverse impacts of irrigated agriculture on aquatic ecosystems. *Agric. Water Manag.* **2021**, *252*, 106877. [CrossRef]
18. Hristov, J.; Barreiro-Hurle, J.; Salputra, G.; Blanco, M.; Witzke, P. Reuse of treated water in European agriculture: Potential to address water scarcity under climate change. *Agric. Water Manag.* **2021**, *251*, 106872. [CrossRef]
19. Tociu, C.; Ciobotaru, I.-E.; Maria, C.; Déak, G.; Ivanov, A.-A.; Marcu, E.; Marinescu, F.; Savin, I.; Noor, N.M. Exhaustive approach to livestock wastewater treatment in irrigation purposes for a better acceptability by the public. *AIP Conf. Proc.* **2019**, *2129*, 020066. [CrossRef]
20. Dhiman, J.; Prasher, S.O.; ElSayed, E.; Patel, R.M.; Nzediegwu, C.; Mawof, A.; Dhiman, J.; Prasher, S.O.; ElSayed, E.; Patel, R.M.; et al. Heavy metal uptake by wastewater irrigated potato plants grown on contaminated soil treated with hydrogel based amendments. *Environ. Technol. Innov.* **2020**, *19*, 100952. [CrossRef]
21. Truchado, P.; Gil, M.I.; López, C.; Garre, A.; López-Aragón, R.F.; Böhme, K.; Allende, A. New standards at European Union level on water reuse for agricultural irrigation: Are the Spanish wastewater treatment plants ready to produce and distribute reclaimed water within the minimum quality requirements? *Int. J. Food Microbiol.* **2021**, *356*, 109352. [CrossRef]
22. Shannag, H.K.; Al-Mefleh, N.K.; Freihat, N.M. Reuse of wastewaters in irrigation of broad bean and their effect on plant-aphid interaction. *Agric. Water Manag.* **2021**, *257*, 107156. [CrossRef]
23. Oubane, M.; Khadra, A.; Ezzariai, A.; Kouisni, L.; Hafidi, M. Heavy metal accumulation and genotoxic effect of long-term wastewater irrigated peri-urban agricultural soils in semiarid climate. *Sci. Total Environ.* **2021**, *794*, 148611. [CrossRef]
24. Guedes, P.; Martins, C.; Couto, N.; Silva, J.; Mateus, E.P.; Ribeiro, A.B.; Pereira, C.S. Irrigation of soil with reclaimed wastewater acts as a buffer of microbial taxonomic and functional biodiversity. *Sci. Total Environ.* **2021**, *802*, 149671. [CrossRef]
25. Lavrnić, S.; Zapater-Pereyra, M.; Mancini, M. Water Scarcity and Wastewater Reuse Standards in Southern Europe: Focus on Agriculture. *Water Air Soil Pollut.* **2017**, *228*, 251. [CrossRef]
26. Rehman, F.; Subyani, A.M.; Cheema, T.; Harbi, H.M.; Azeem, T.; Naseem, A.A.; Ullah, M.F.; Riaz, O.; Rehman, S.U. Correction to: Contribution to the comparative study of treated and untreated wastewater: A case study (Wadi Fatima and Al Misk Lake) in Saudi Arabia. *Arab. J. Geosci.* **2020**, *13*, 1042. [CrossRef]
27. Haldar, K.; Kujawa-Roeleveld, K.; Schoenmakers, M.; Datta, D.K.; Rijnaarts, H.; Vos, J. Institutional challenges and stakeholder perception towards planned water reuse in peri-urban agriculture of the Bengal delta. *J. Environ. Manag.* **2021**, *283*, 111974. [CrossRef]
28. Ayuso-Gabella, N.; Page, D.; Masciopinto, C.; Aharoni, A.; Salgot, M.; Wintgens, T. Quantifying the effect of Managed Aquifer Recharge on the microbiological human health risks of irrigating crops with recycled water. *Agric. Water Manag.* **2011**, *99*, 93–102. [CrossRef]
29. Cherfi, A.; Achour, M.; Cherfi, M.; Otmani, S.; Morsli, A. Health risk assessment of heavy metals through consumption of vegetables irrigated with reclaimed urban wastewater in Algeria. *Process Saf. Environ. Prot.* **2015**, *98*, 245–252. [CrossRef]
30. Garcia-Cuerva, L.; Berglund, E.Z.; Binder, A.R. Public perceptions of water shortages, conservation behaviors, and support for water reuse in the U.S. *Resour. Conserv. Recycl.* **2016**, *113*, 106–115. [CrossRef]
31. Moazeni, M.; Nikaeen, M.; Hadi, M.; Moghim, S.; Mouhebat, L.; Hatamzadeh, M.; Hassanzadeh, A. Estimation of health risks caused by exposure to enteroviruses from agricultural application of wastewater effluents. *Water Res.* **2017**, *125*, 104–113. [CrossRef] [PubMed]
32. Ezzat, S.M.; Elkorashey, R.M. Wastewater as a Non-conventional Resource: Impact of Trace Metals and Bacteria on Soil, Plants, and Human Health. *Hum. Ecol. Risk Assess. Int. J.* **2020**, *26*, 2245–2265. [CrossRef]
33. Ofori, S.; Puškáčová, A.; Růžičková, I.; Wanner, J. Treated wastewater reuse for irrigation: Pros and cons. *Sci. Total Environ.* **2021**, *760*, 144026. [CrossRef] [PubMed]

34. Anjum, M.A.; Hussain, S.; Arshad, P.; Hassan, A. Irrigation water of different sources affects fruit quality attributes and heavy metals contents of un-grafted and commercial mango cultivars. *J. Environ. Manag.* **2020**, *281*, 111895. [CrossRef] [PubMed]
35. Morales, M.E.; Belmonte-Urena, L.J. Theoretical research on circular economy and sustainability trade-offs and synergies: A bibliometric analysis. In Proceedings of the 2021 IEEE International Conference on Technology and Entrepreneurship (ICTE), Kaunas, Lithuania, 24–27 August 2021; pp. 1–6. [CrossRef]
36. Preisner, M.; Smol, M.; Horttanainen, M.; Deviatkin, I.; Havukainen, J.; Klavins, M.; Ozola-Davidane, R.; Kruopienė, J.; Szatkowska, B.; Appels, L.; et al. Indicators for resource recovery monitoring within the circular economy model implementation in the wastewater sector. *J. Environ. Manag.* **2022**, *304*, 114261. [CrossRef]
37. Smol, M.; Adam, C.; Preisner, M. Circular economy model framework in the European water and wastewater sector. *J. Mater. Cycles Waste Manag.* **2020**, *22*, 682–697. [CrossRef]
38. Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; Batlles-Delafuente, A.; Fidelibus, M.D. Rainwater Harvesting for Agricultural Irrigation: An Analysis of Global Research. *Water* **2019**, *11*, 1320. [CrossRef]
39. Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; Batlles-Delafuente, A.; Fidelibus, M.D. Sustainable Irrigation in Agriculture: An Analysis of Global Research. *Water* **2019**, *11*, 1758. [CrossRef]
40. Guerra-Rodríguez, S.; Oulego, P.; Rodríguez, E.; Singh, D.N.; Rodríguez-Chueca, J. Towards the Implementation of Circular Economy in the Wastewater Sector: Challenges and Opportunities. *Water* **2020**, *12*, 1431. [CrossRef]
41. Rodríguez-Villanueva, P.; Sauri, D. Wastewater Treatment Plants in Mediterranean Spain: An Exploration of Relations between Water Treatments, Water Reuse, and Governance. *Water* **2021**, *13*, 1710. [CrossRef]
42. Abad-Segura, E.; Batlles-Delafuente, A.; González-Zamar, M.-D.; Belmonte-Ureña, L. Implications for Sustainability of the Joint Application of Bioeconomy and Circular Economy: A Worldwide Trend Study. *Sustainability* **2021**, *13*, 7182. [CrossRef]
43. Abad-Segura, E.; Fuente, A.; González-Zamar, M.-D.; Belmonte-Ureña, L. Effects of Circular Economy Policies on the Environment and Sustainable Growth: Worldwide Research. *Sustainability* **2020**, *12*, 5792. [CrossRef]
44. UNESCO; WSSM. *Water Reuse within a Circular Economy Context*; UNESCO: Paris, France, 2020; ISBN 978-92-3-100413-1.
45. Gherghel, A.; Teodosiu, C.; De Gisi, S. A review on wastewater sludge valorisation and its challenges in the context of circular economy. *J. Clean. Prod.* **2019**, *228*, 244–263. [CrossRef]
46. Salminen, J.; Määttä, K.; Haimi, H.; Maidell, M.; Karjalainen, A.; Noro, K.; Koskiaho, J.; Tikkanen, S.; Pohjola, J. Water-smart circular economy—Conceptualisation, transitional policy instruments and stakeholder perception. *J. Clean. Prod.* **2021**, *334*, 130065. [CrossRef]
47. Bellver-Domingo, Á.; Hernández-Sancho, F. Circular economy and payment for ecosystem services: A framework proposal based on water reuse. *J. Environ. Manag.* **2022**, *305*, 114416. [CrossRef]
48. Zhang, X.; Liu, Y. Circular economy is game-changing municipal wastewater treatment technology towards energy and carbon neutrality. *Chem. Eng. J.* **2021**, *429*, 132114. [CrossRef]
49. Chhipi-Shrestha, G.; Hewage, K.; Sadiq, R. Fit-for-purpose wastewater treatment: Testing to implementation of decision support tool (II). *Sci. Total Environ.* **2017**, *607–608*, 403–412. [CrossRef]
50. Michetti, M.; Raggi, M.; Guerra, E.; Viaggi, D. Interpreting Farmers' Perceptions of Risks and Benefits Concerning Wastewater Reuse for Irrigation: A Case Study in Emilia-Romagna (Italy). *Water* **2019**, *11*, 108. [CrossRef]
51. Baawain, M.S.; Al-Mamun, A.; Omidvarborna, H.; Al-Sabti, A.; Choudri, B.S. Public perceptions of reusing treated wastewater for urban and industrial applications: Challenges and opportunities. *Environ. Dev. Sustain.* **2018**, *22*, 1859–1871. [CrossRef]
52. Petousi, I.; Fountoulakis, M.; Stentiford, E.; Manios, T. Farmers' Experience, Concerns and Perspectives in Using Reclaimed Water for Irrigation in a Semi-Arid Region of Crete, Greece. *Irrig. Drain.* **2015**, *64*, 647–654. [CrossRef]
53. Urquijo, J.; De Stefano, L. Perception of Drought and Local Responses by Farmers: A Perspective from the Jucar River Basin, Spain. *Water Resour. Manag.* **2016**, *30*, 577–591. [CrossRef]
54. Khanpae, M.; Karami, E.; Maleksaeidi, H.; Keshavarz, M. Farmers' attitude towards using treated wastewater for irrigation: The question of sustainability. *J. Clean. Prod.* **2020**, *243*, 118541. [CrossRef]
55. Ricart, S.; Rico, A.M.; Ribas, A. Risk-Yuck Factor Nexus in Reclaimed Wastewater for Irrigation: Comparing Farmers' Attitudes and Public Perception. *Water* **2019**, *11*, 187. [CrossRef]
56. McClaran, N.; Behe, B.K.; Huddleston, P.; Fernandez, R.T. Recycled or reclaimed? The effect of terminology on water reuse perceptions. *J. Environ. Manag.* **2020**, *261*, 110144. [CrossRef]
57. Chauhan, J.S.; Kumar, S. Wastewater ferti-irrigation: An eco-technology for sustainable agriculture. *Sustain. Water Resour. Manag.* **2020**, *6*, 31. [CrossRef]
58. Olivieri, A.W.; Seto, E.; Cooper, R.C.; Cahn, M.D.; Colford, J.; Crook, J.; Debroux, J.-F.; Mandrell, R.; Suslow, T.; Tchobanoglous, G.; et al. Risk-Based Review of California's Water-Recycling Criteria for Agricultural Irrigation. *J. Environ. Eng.* **2014**, *140*, 04014015. [CrossRef]
59. Natasha; Shahid, M.; Khalid, S.; Niazi, N.K.; Murtaza, B.; Ahmad, N.; Farooq, A.; Zakir, A.; Imran, M.; Abbas, G. Health risks of arsenic buildup in soil and food crops after wastewater irrigation. *Sci. Total Environ.* **2021**, *772*, 145266. [CrossRef]
60. Guadie, A.; Yesigat, A.; Gatew, S.; Worku, A.; Liu, W.; Ajibade, F.O.; Wang, A. Evaluating the health risks of heavy metals from vegetables grown on soil irrigated with untreated and treated wastewater in Arba Minch, Ethiopia. *Sci. Total Environ.* **2020**, *761*, 143302. [CrossRef]
61. Tariq, F. Heavy metals concentration in vegetables irrigated with municipal wastewater and their human daily intake in Erbil city. *Environ. Nanotechnol. Monit. Manag.* **2021**, *16*, 100475. [CrossRef]

62. Antwi-Agyei, P.; Peasey, A.; Biran, A.; Bruce, J.; Ensink, J. Risk Perceptions of Wastewater Use for Urban Agriculture in Accra, Ghana. *PLoS ONE* **2016**, *11*, e0150603. [CrossRef]
63. WWAP. UNESCO World Water Assessment Programme. In *The United Nations World Water Development Report 2017*; Wastewater: The Untapped Resource; UNESCO: Paris, France, 2017.
64. Ponce-Robles, L.; Masdemont-Hernández, B.; Munuera-Pérez, T.; Pagán-Muñoz, A.; Lara-Guillén, A.J.; García-García, A.J.; Pedrero-Salcedo, F.; Nortes-Tortosa, P.A.; Alarcón-Cabañero, J.J. WWTP Effluent Quality Improvement for Agricultural Reuse Using an Autonomous Prototype. *Water* **2020**, *12*, 2240. [CrossRef]
65. Carr, G.; Potter, R.B.; Nortcliff, S. Water reuse for irrigation in Jordan: Perceptions of water quality among farmers. *Agric. Water Manag.* **2011**, *98*, 847–854. [CrossRef]
66. Chen, W.; Bai, Y.; Zhang, W.; Lyu, S.; Jiao, W. Perceptions of Different Stakeholders on Reclaimed Water Reuse: The Case of Beijing, China. *Sustainability* **2015**, *7*, 9696–9710. [CrossRef]
67. Aznar-Crespo, P.; Aledo, A.; Melgarejo, J. Factors of uncertainty in the integrated management of water resources: The case of water reuse. *Int. J. Sustain. Dev. Plan.* **2019**, *14*, 141–151. [CrossRef]
68. Yadav, L.P.; Smith, D.; Aziz, A.A.; Le Thuy, C.T.; Thao, H.X.; Le, H.H.; Nicetic, O.; Quyen, L.N.; Vagneron, I. Can traders help farmers transition towards more sustainable maize based farming systems? Evidence from the Lao-Vietnamese border. *Int. J. Agric. Sustain.* **2021**, *19*, 234–254. [CrossRef]
69. Troldborg, M.; Duckett, D.; Allan, R.; Hastings, E.; Hough, R.L. A risk-based approach for developing standards for irrigation with reclaimed water. *Water Res.* **2017**, *126*, 372–384. [CrossRef] [PubMed]
70. Toro Sánchez, F. El uso del agua en Nijar: Implicaciones ambientales del modelo actual de gestión. *Rev. Estud. Reg.* **2008**, *7585*, 145–176.
71. Aznar-Sánchez, J.A.; Belmonte-Ureña, L.J.; Valera, D.L. Perceptions and Acceptance of Desalinated Seawater for Irrigation: A Case Study in the Níjar District (Southeast Spain). *Water* **2017**, *9*, 408. [CrossRef]
72. Jiménez-Buendía, M.; Soto-Valles, F.; Blaya-Ros, P.; Toledo-Moreo, A.; Domingo-Miguel, R.; Torres-Sánchez, R. High-Density Wi-Fi Based Sensor Network for Efficient Irrigation Management in Precision Agriculture. *Appl. Sci.* **2021**, *11*, 1628. [CrossRef]
73. Egea, F.J.; Torrente, R.G.; Aguilar, A. An efficient agro-industrial complex in Almería (Spain): Towards an integrated and sustainable bioeconomy model. *New Biotechnol.* **2018**, *40*, 103–112. [CrossRef]
74. Aznar-Sánchez, J.A.; Belmonte-Ureña, L.J.; Velasco-Muñoz, J.F.; Valera, D.L. Farmers' profiles and behaviours toward desalinated seawater for irrigation: Insights from South-east Spain. *J. Clean. Prod.* **2021**, *296*, 126568. [CrossRef]
75. Aznar-Sánchez, J.A.; Belmonte-Ureña, L.J.; Velasco-Muñoz, J.F.; Valera, D.L. Aquifer Sustainability and the Use of Desalinated Seawater for Greenhouse Irrigation in the Campo de Níjar, Southeast Spain. *Int. J. Environ. Res. Public Health* **2019**, *16*, 898. [CrossRef]
76. Lo-Iacono-Ferreira, V.G.; Viñoles-Cebolla, R.; Bastante-Ceca, M.J.; Capuz-Rizo, S.F. Transport of Spanish fruit and vegetables in cardboard boxes: A carbon footprint analysis. *J. Clean. Prod.* **2020**, *244*, 118784. [CrossRef]
77. Maestre-Valero, J.F.; González-Ortega, M.J.; Martínez-Álvarez, V.; Martin-Gorriz, B. The role of reclaimed water for crop irrigation in southeast Spain. *Water Supply* **2019**, *19*, 1555–1562. [CrossRef]
78. Martín, J.R.; Ramos-Miras, J.; Boluda, R.; Gil de Carrasco, C. Spatial relations of heavy metals in arable and greenhouse soils of a Mediterranean environment region (Spain). *Geoderma* **2013**, *200–201*, 180–188. [CrossRef]
79. Reca, J.; Trillo, C.; Sánchez, J.; Martínez, J.; Valera, D. Optimization model for on-farm irrigation management of Mediterranean greenhouse crops using desalinated and saline water from different sources. *Agric. Syst.* **2018**, *166*, 173–183. [CrossRef]
80. Honoré, M.N.; Belmonte-Ureña, L.J.; Navarro-Velasco, A.; Camacho-Ferre, F. Profit Analysis of Papaya Crops under Greenhouses as an Alternative to Traditional Intensive Horticulture in Southeast Spain. *Int. J. Environ. Res. Public Health* **2019**, *16*, 2908. [CrossRef]
81. Thompson, R.; Thompson, R.; Padilla, F.; Padilla, F.; Peña-Fleitas, M.; Peña-Fleitas, M.; Gallardo, M.; Gallardo, M.; Thompson, R.; Thompson, R.; et al. Reducing nitrate leaching losses from vegetable production in Mediterranean greenhouses. *Acta Hortic.* **2020**, *1268*, 105–117. [CrossRef]
82. Cajamar. Análisis de la Campaña Hortofrutícola de Almería.Campaña 2019/2020. Cajamar. 2020. Available online: https://www.plataformatierra.es/detalle/analisis-campana-hortofruticola (accessed on 19 June 2021).
83. Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible de la Junta de Andalucía. Secretaría General de Agricultura y Alimentación. Cartografía de Invernaderos en Almería, Granada y Málaga. 2019. Available online: https://www.juntadeandalucia.es/export/drupaljda/producto_estadistica/19/06/Cartografia%20_inv_AL_GR_MA_190926.pdf (accessed on 19 April 2021).
84. Garcia-Caparros, P.; Contreras, J.I.; Baeza, R.; Segura, M.L.; Lao, M.T. Integral Management of Irrigation Water in Intensive Horticultural Systems of Almería. *Sustainability* **2017**, *9*, 2271. [CrossRef]
85. Rey, D.; Holman, I.P.; Knox, J.W. Developing drought resilience in irrigated agriculture in the face of increasing water scarcity. *Reg. Environ. Chang.* **2017**, *17*, 1527–1540. [CrossRef]
86. Akpan, V.E.; Omole, D.O.; Bassey, D.E. Assessing the public perceptions of treated wastewater reuse: Opportunities and implications for urban communities in developing countries. *Heliyon* **2020**, *6*, e05246. [CrossRef]
87. Attari, S.Z. Perceptions of water use. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 5129–5134. [CrossRef]

88. Suri, M.R.; Dery, J.L.; Pérodin, J.; Brassill, N.; He, X.; Ammons, S.; Gerdes, M.E.; Rock, C.; Goldstein, R.E.R. U.S. farmers' opinions on the use of nontraditional water sources for agricultural activities. *Environ. Res.* **2019**, *172*, 345–357. [CrossRef]
89. Dery, J.L.; Rock, C.M.; Goldstein, R.R.; Onumajuru, C.; Brassill, N.; Zozaya, S.; Suri, M.R. Understanding grower perceptions and attitudes on the use of nontraditional water sources, including reclaimed or recycled water, in the semi-arid Southwest United States. *Environ. Res.* **2018**, *170*, 500–509. [CrossRef]
90. Wade, M.; Peppler, R.; Person, A. Community education and perceptions of water reuse: A case study in Norman, Oklahoma. *J. Environ. Stud. Sci.* **2021**, *11*, 266–273. [CrossRef]
91. Zhu, Z.; Li, A.; Wang, H. Public perception and acceptability of reclaimed water: The case of Shandong province, China. *J. Water Reuse Desalination* **2017**, *8*, 308–330. [CrossRef]
92. O'Donnell, E.; Netusil, N.; Chan, F.; Dolman, N.; Gosling, S. International Perceptions of Urban Blue-Green Infrastructure: A Comparison across Four Cities. *Water* **2021**, *13*, 544. [CrossRef]
93. Walters, W.H. Survey design, sampling, and significance testing: Key issues. *J. Acad. Libr.* **2021**, *47*, 102344. [CrossRef]
94. Kock, F.; Berbekova, A.; Assaf, A.G. Understanding and managing the threat of common method bias: Detection, prevention and control. *Tour. Manag.* **2021**, *86*, 104330. [CrossRef]
95. Ricart, S.; Villar-Navascués, R.; Hernández-Hernández, M.; Rico-Amorós, A.; Olcina-Cantos, J.; Moltó-Mantero, E. Extending Natural Limits to Address Water Scarcity? The Role of Non-Conventional Water Fluxes in Climate Change Adaptation Capacity: A Review. *Sustainability* **2021**, *13*, 2473. [CrossRef]
96. Mesa-Pérez, E.; Berbel, J. Analysis of Barriers and Opportunities for Reclaimed Wastewater Use for Agriculture in Europe. *Water* **2020**, *12*, 2308. [CrossRef]
97. Gul, S.; Gani, K.M.; Govender, I.; Bux, F. Reclaimed wastewater as an ally to global freshwater sources: A PESTEL evaluation of the barriers. *J. Water Supply Res. Technol.* **2021**, *70*, 123–137. [CrossRef]