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Economic Assessment of Irrigation with Desalinated Seawater in Greenhouse Tomato Production in SE Spain

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Abstract: This study assesses the impact of irrigating with desalinated seawater (DSW) on the profitability of greenhouse tomato in south-eastern Spain, comparing different water-quality sources in both traditional sanding cultivation and soilless hydroponic production. The assessment is based on the combination of partial crop budgeting techniques with field data from the LIFE DESEACROP Project experimental activities. Our results show that the exclusive use of DSW for tomato production increases fertilization costs by 20% in soilless systems and by 34% in traditional sanding cultivation, and water costs by 30% in soilless systems and by 48% in traditional soil cultivation. As a result, production costs increase by 5% in soilless cultivation and 3% in soil cultivation, increases that are reduced when DSW is blended with brackish water. However, the lower salinity of DSW, compared with conventional water resources in the area, increases both crop yield and profitability. Soilless cultivation would also increase tomato profitability but only if good quality water is available. The materialization of the potential benefits of soilless production requires improving water quality through the increased use of DSW. Otherwise, the traditional sanding production system, better adapted to the area's poor soils and bad quality water, would be more profitable.

Keywords: desalination; protected cultivation; hydroponic; soilless cultivation; irrigation water quality; production costs; crop profitability; partial crop budgeting

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1. Introduction

South-eastern Spain is one of the most water-scarce regions in Europe. The high profitability of agricultural activity, coupled with semi-arid climatic conditions, means that the demand for irrigation water far exceeds the availability of water resources [1], generating a situation of chronic shortage that mainly impacts agriculture. Responses to this situation have been multiple. First, water scarcity has encouraged the widespread adoption of pressurized irrigation systems, together with the modernization of water distribution infrastructures, maximizing its efficiency to levels that are difficult to improve from a technical point of view [2] and generating significant benefits for irrigated agriculture [3]. Second, another traditional response to water scarcity in south-eastern Spain has been the transfer of water resources from other areas, first through the Tajo–Segura transfer and later through the Negratín–Almanzora transfer, both of which provide significant volumes for both urban supply and irrigation [4]. Third, there has been an important development of non-conventional water resources, including a high level of reuse of domestic wastewater for irrigation purposes [5–7], as well as the recent and growing use of seawater desalination for irrigation [8,9].

Despite all these actions, the scarcity of water resources continues to be a reality in south-eastern Spain. Moreover, it will likely intensify in the future as a result of climate change, with scenarios that forecast a reduction in the average water runoff in the natural regime of between 5% and 11% [6,10]. At the farm level, adaptive responses include the use of more sustainable irrigation strategies based on regulated deficit irrigation techniques and remote-control systems to optimize irrigation management and the shift to less water-demanding crops or varieties [11–13]. At the institutional level, there is little margin for improving the distribution of water, increasing the resources from wastewater reuse (limited by urban and industrial consumption) or constructing new water transfers. In addition, future scenarios of water availability in the basins of origin forecast a reduction in the contributions of these transfers [14]. All this reduces the feasible policy alternatives for increasing the resilience of irrigated agriculture in the face of the progressive depletion of hydrological systems and for dealing with the current and future water shortages in the area.

Against other options for managing water demand through economic mechanisms, the main commitment of the Spanish national hydrological authorities has been the development of the availability of desalinated seawater (DSW). Indeed, through the AGUA Program, Spain has invested heavily in the construction of seawater desalination plants (SWDP) over the last two decades in order to cover the structural water deficit, meet the demand for irrigation and guarantee urban supply [15]. In this sense, Spain is the only country in the world, together with Israel, to commit to this water planning strategy [8].

Currently, there exist eleven SWDPs that supply water for irrigation in south-eastern Spain, with a joint production capacity of 362 Mm^3/year, of which up to 268.3 Mm^3/year are available for use in irrigation [16]. During the first years of operation of the SWDPs, the demand for DSW for agricultural use was low, between 20 and 25 hm^3/year. From 2013 onwards, when several large public SWDPs started to operate, the agricultural use of DSW rapidly increased, reaching 177.3 Mm^3/year in 2017 [16]. This boom in the use of DSW is explained by several favorable circumstances: a large number of SWDP financed by the public AGUA Program, which also use modern and quite efficient desalination technologies that reduce the cost of DSW production; the growing need to provide new water resources to help alleviate the structural water deficit; and the high profitability of irrigated agriculture in many irrigated areas. It also coincides with the 2013 policy agreement that changed the operation rules of the Tagus–Segura Transfer (the main source of water supply in SE Spain), resulting in lower transferred volumes and reducing the water supply reliability for agricultural users [17]. Nowadays, the volume of DSW resources supplied for irrigation is remarkable, supplying more water for irrigation than the reuse of wastewater and approaching the historical average irrigation water volumes supplied from the headwaters of the Tagus [16]. Based on the existing demand and the downward trends in other sources of water supply, the agricultural use of DSW in SE Spain is likely to increase in the future.

This large availability of DSW resources has undoubted advantages for irrigation, some of which are precisely those that have justified the significant public investment that has allowed its development in south-eastern Spain. On the one hand, DSW is a new source of water supply, which increases total water availability for irrigation in a specifically water-stressed area where highly profitable export-oriented crops are grown. Alternatively, new DSW resources can be used to replace groundwater from depleted and/or salinized systems, of which numerous examples exist in south-eastern Spain, thus helping to recover degraded aquifers and reducing the impact of balancing aquifer pumping/recharge rates [18,19]. DSW is also a stable and inexhaustible source of water, without the climatological and hydrological uncertainties associated with conventional water resources, whose incorporation into the pool of resources increases water supply reliability [20], encouraging productive investments and allowing better production planning.

Another potential advantage of DSW is related to the improvement in the quality of irrigation water in some areas resulting from the use of DSW. The quality of DSW is significantly better than that in many Mediterranean coastal areas, where groundwater resources have significant levels of electrical conductivity. The reduced salinity of DSW increases crop yields with respect to low-quality water, as shown in different Mediterranean horticultural crops by [7,21,22]. Water salinity reduces water uptake and plant transpiration because of the physiological adaptation of roots to water stress and the reduction in root density [23]. Using less saline water, such as DSW, changes the spatial distribution of the rates of root water uptake, which increases transpiration [24]. This also reduces vertical hydraulic fluxes, thus reducing the water leaching fraction [25] and nitrate leaching below the root zone [24,25]. In addition to increasing crop yields and reducing water and nitrate leaching, lower electrical conductivity allows the development of crops that are more sensitive to water salinity. For example, in the Campo de Níjar area in the Almería province, where poor groundwater quality has traditionally led to a predominance of tomato cultivation, the improvement in water quality due to the incorporation of DSW is allowing more crop diversification.

On the other hand, the main disadvantage of DSW is the high cost of its supply, including its production and its transportation to irrigable areas, which reduces the profitability of agricultural activity. The final cost of DSW for farmers can double or, in some cases, even triple the cost of the standard water pool, depending on the SWDP production costs, the transportation costs to each irrigated area and the level of public subsidy to DSW [16].

DSW also may cause agronomic problems that arise from its particular physicochemical characteristics, which might affect crop yields, fertilization needs and the conservation of agricultural soils [26]. One of these problems is derived from its low concentration of nutrients, such as calcium, magnesium and sulfate, which are essential for crop development, and whose presence in continental waters makes their supply through fertilization unnecessary [21,26,27]. These deficiencies force adding these nutrients, what increases fertilization costs and impacts farm profitability [28]. Likewise, its high boron and chloride content can generate toxicity in sensitive crops, such as citrus [26]. However, all these impacts are significantly reduced when DSW is blended with resources from other origins. The nutritional imbalances that DSW has for its agricultural use can be corrected by blending with other inland waters, remineralization post-treatments in SWDPs and by reprogramming in-plot fertigation [26]. The first option is the most economical and most frequently used. When DSW is almost the only available resource and blending is not an option, incorporating the nutrients in the SWDP is less costly than reprogramming fertigation, but it is barely done as SWDPs are not interested in further increasing the cost of DSW.

Reprogramming fertigation can increase fertilization costs. Experimental studies in south-eastern Spain's horticulture report increases in fertilization costs ranging between 6% and 22% when irrigating with DSW, depending on the crop and cropping system [28,29]. However, the negative impact of reprogramming fertilization on-farm profitability is reduced when compared to that of the cost of DSW. For instance, [28] calculates a reduction in farmer's profit for soil lettuce cultivation of 26% using a 50% DSW mixture and 55% irrigating exclusively with DSW, most of it caused by the higher cost of DSW. The authors of [29] find that changes in fertilization for several horticultural crops in SE Spain would reduce crop profit by 1–3% in soil production systems and by 4–18% in soilless production systems, depending on the crop considered and that such impact is small when compared to that of the cost of DSW. They also show that if DSW was blended with other sources of water, fertilization costs would not increase at all for soil production systems.

In this sense, the aim of this study is to analyze the economic impact of using desalinated seawater in greenhouse tomato cultivation, one of the main horticultural crops in south-eastern Spain, looking at both the implications in terms of both changes in input use and prices and in terms of improved water quality. This study considers both conventional sanding cultivation and hydroponic systems with reuse of drainage, which are the major production systems used in the area. Apart from the cost for farmers themselves, seawater desalination can also impose costs on society as a whole; the most relevant ones are its environmental impact due to the high energy consumption required for its production, around 4 kWh/m^3, and the associated GHG emissions [30]. Consequently, this study also looks at the implications in terms of GHG emissions but also in terms of nutrient lixiviation, a major problem in aquifers across the Mediterranean area.

Agricultural use of DSW is a relatively recent topic for agronomic research, and scientific evidence is still limited to a few published references and crops, mainly from Israel and Spain, where several research groups are developing projects to generate a better understanding of the physiological and agronomic response of crops irrigated with DSW and its impacts on soil, aquifers and crop profitability. This paper contributes to this growing literature by looking at the economic impact of irrigation with DSW in Spanish greenhouse tomato production using very detailed experimental data. Previous studies have looked at this issue in other horticultural crops [21,28,29]. This paper builds on [31,32], which look at the environmental and food quality implications of using DSW on greenhouse tomato production by using data and results from the same experimental activities. The study follows with a detailed description of the methodology used and the results obtained, to finish with the major conclusions that can be drawn.

2. Materials and Methods

This study looks at the impact on farm profitability and input productivity of the changes in the tomato production process resulting from the use of DSW under two alternative production technologies, basically changes in input use, input cost and crop yields. The approach for such assessment is based on the combination of partial crop budgeting techniques with experimental field data. Partial crop budgeting consists of calculating the effect on the profitability of changes in the crop production process, either in terms of changes in production costs, crop yields or farm prices. It is the most common tool used to analyze the profitability of alternative farming practices and agricultural technologies [33]. The basis for any partial budgeting is the elaboration of a detailed technical-economic characterization of the standard crop production process in terms of farming practices, crop yields, input use and production costs, from which detailed budgets can be built to integrate changes in input use and output for their comparison.

2.1. Analyzed Productive Strategies and Experimental Data

Data on the response of greenhouse tomato to irrigation with DSW, both on traditional soil cultivation and hydroponic soilless cultivation, comes from experiments carried out within the LIFE+ DESEACROP project, which deals with the use of desalinated seawater in soilless tomato production systems in south-eastern Spain. These experiments consider both different sources of water and greenhouse tomato production technologies. A detailed description of the experimental design and set-up can be found in [31,32].

To analyze the effect of irrigation with desalinated seawater, three types of irrigation treatments with different water salinity were considered:

- T1: Desalinated seawater (DSW) from the Carboneras SWDP, with a 0.5 dS/m electric conductivity;
- T2: A mix of 83.36% of DSW and 16.64% of saline water, with a final electric conductivity of 1.5 dS/m.
- T3: A mix of 44.56% of DSW and 55.44% of saline water, with a final electric conductivity of 3 dS/m, similar to the usual source of supply in the area (brackish groundwater).

Two different greenhouse tomato production systems were considered to analyze the effect of the cultivation system:

- H: Hydroponic soilless cultivation system with recirculation and reuse of drainage flows using coconut fiber substrate bags, the most commonly used substrate in SE Spain protected horticulture;
- S: Traditional soil cultivation using a sanded soil ("enarenado") without the reuse of drainage flows, which percolate to the subsoil. The "enarenado" consists of three layers of clay or gravel, manure and sand that allow cultivating over the commonly very poor soils of the area using low-quality water.

Experimental plots were set up in a greenhouse located in Retamar (Almería) in SE Spain. The greenhouse is a traditional Almerian-type plastic greenhouse without heating and with automated natural rooftop and lateral ventilation. The experiment consisted of eighteen demonstrative subplots with an area of 80.8 m^2, each with a plantation density of two plants per m^2. The experimental setting consisted of six repetitions per type of water (T1, T2 and T3), three of them for each productive system (H and S) on a random block design. Each repetition included four rows of plants with two additional rows in the borders of the repetitions to avoid possible border effects in the measurements. The experiment was carried out between September 2018 and June 2020 and included four sequential short productive cycles (4–5 months long): two autumn–winter cycles of tomato (*Solanum lycopersicum* L. cv. Ramyle) and two spring–summer cycles of tomato (*Solanum lycopersicum* L. cv. Racymo).

The results presented in this study correspond to the average values for the four tomato experimental production cycles. Crop yield variability has already been analyzed by [32], which concluded that differences in tomato yield across experimental treatments (water source and cultivation system) are statistically significant. Additionally, tomato quality was not considered in the present study, as [31] did not find a statistically significant relationship between tomato quality and the experimental irrigation treatments for any of the production processes considered using data from the same experiment.

2.2. Technical-Economic Characterization of the Standard Production Processes

The first step is characterizing the crop production processes, for both production systems, in technical terms. To that end, the productive process is defined on the basis of the natural crop cycle in order to obtain the income and production costs associated with each production activity in a more direct and realistic manner [34]. Moreover, the production cycle/process for each crop would be considered in isolation, even if the farms have more than one crop or production process. Therefore, based on these methodological criteria, the production cycle must be understood as a double process, both agronomic and economic.

The technical characterization of the standard production processes requires collecting detailed information on all the different farming operations implemented along the temporal sequence of the productive cycle. To that end, the farming operations were organized sequentially, starting right after harvesting of the previous crop cycle and ending in the harvesting of the crop, and per type of farming operation (plowing, irrigation, fertilization, weed and pest control, pruning, harvesting, etc.). Each farming operation can imply the use of labor and machinery, consumption of water and energy or the use of different materials. Such information is expressed in physical units to characterize output and input use (hours, m^3, liters, kilograms, etc.).

In this study, the standard technical characterization of both tomato production processes was based on the farming operations performed in the experimental plots, cross-validated with the relevant literature [7,35–37] and consultation with technical agricultural experts from the area. Technical data from the experimental plots used in the analysis include: (1) quantity of tomato production; (2) use of inputs such as fertilizers, pesticides and other agrochemicals, energy and irrigation water (type of input, quantity applied, hours/number of applications); (3) farm machinery used (type of machinery, crop operations, hours of use, fuel consumption, etc.); and (4) labor (crop operations, working hours/days per operation, etc.). Because of the different nature of the two productive systems considered, which involve the traditional soil cultivation ("enarenado") and hydroponic substrate cultivation, technical data collection includes both variable inputs (consumed in each crop cycle) and fixed inputs (used in different crop cycles). This allows both a more accurate assessment of crop profitability for each experimental treatment and the comparison of both cultivation systems.

Next, the economic characterization of the production processes was built to define the standard cost structure and crop budget. The standardization of costs allows the reduction of biases and variabilities resulting from differences in the prices of inputs and eases the analysis of water use and the comparison of the different alternatives analyzed. The standard economic characterization was obtained from the technical characterization using input market prices and average market product prices to allow for the standardization of production costs. Therefore, only technical information was collected from experimental plots, while economic information (such as wages, cost of inputs, O&M costs of machinery or irrigation equipment, crop selling price, input prices, labor cost, etc.) were obtained from public statistics and market prices from commercial input suppliers. The definition of the cost structure follows the crop production cost assessment methodology and cost items used by the Spanish Ministry of Agriculture [35], in accordance with standards set for the European Farm Accountancy Data Network.

The standard direct cost structure includes the following cost items: raw materials (plants and seeds, fertilizers, plant protection products and herbicides, other materials); irrigation, if applicable (water, energy, maintenance and repair); machinery, if applicable (consumables, such as fuel and lubricants, maintenance and repair, external contracting); labor; other miscellaneous. Similarly, the standard indirect costs structure for each productive system was defined based on the characterization of the productive structure of the standard greenhouse farm in the area of study in terms of equipment and infrastructures (greenhouse, cropping system, irrigation systems, etc.).

Direct costs arise from the use of inputs that are used in only one crop cycle. These include tomato seeds and seedling trays, fertilizers, pesticides, irrigation water, electricity, labor, a plastic soil cover for weed control used in traditional soil cultivation, pollinators (*Bombus terrestis*), tutoring ropes and natural predators (*Nesidiocoris tenuis*) for the main tomato pests in the area. Table 1 presents the inventory of the productive inputs used in each crop cycle plus the average crop yields obtained and the environmental impacts considered in the analysis, while Table 2 details the unitary prices of variable inputs. More detail on the data used on crop yields, water use and drainage, fertilizers, manure and pesticide use, substrate materials, etc., and on the environmental impacts considered can be consulted in [32]. Direct costs do not include any machinery item, as machinery is only used in the preparation of traditional sanded soil and substrate and, therefore, is included in the cost of these operations, which, as they concern several years and productive cycles, are accounted for as indirect costs.

Table 1. Inventory of variable inputs, crop yields and environmental impacts per crop cycle.

Item	Unit	Strategies					
		H-T1	**H-T2**	**H-T3**	**S-T1**	**S-T2**	**S-T3**
Seeds	packets/ha	21	21	21	21	21	21
Seedling trays	Units/ha	140	140	140	140	140	140
Fertilizers:							
Ammonium nitrate	kg/ha	69	114	48	45	66	30
Potassium nitrate	kg/ha	478	1348	1252	319	766	753
Calcium nitrate	kg/ha	1254	798	628	828	514	325
Magnesium nitrate	kg/ha	387	109	0	255	82	0
Monopotassium phosphate	kg/ha	418	289	310	277	187	201
Potassium sulphate	kg/ha	765	332	0	511	252	0
Nitric acid	kg/ha	129	129	129	129	129	129
Phosphoric acid	kg/ha	0	135	249	0	72	124
Aminoacids	kg/ha	0.46	0.46	0.46	0.46	0.46	0.46
Others	kg/ha	3.44	3.44	3.44	3.44	3.44	3.44
Pesticides:							
Insecticides	kg/ha	12.94	12.94	12.94	12.94	12.94	12.94
Fungicides	kg/ha	175.83	175.83	175.83	175.83	175.83	175.83
Net water used	m^3/ha	2390	2610	2670	1950	1950	1920
Reused drainage water	m^3/ha	600	650	670	-	-	-

Table 1. *Cont.*

Item	Unit	Strategies					
		H-T1	H-T2	H-T3	S-T1	S-T2	S-T3
Electricity	kWh/ha	1948	2115	2175	488	488	480
Labor	Hours/ha	2260	2211	2119	2155	2159	2112
Plastic base for weed control	Kg	-	-	-	256.46	256.46	256.46
Tutoring ropes	Units	14,511	14,511	14,511	14,511	14,511	14,511
Pollinators	Box/ha	8	8	8	8	8	8
Natural pest predators	Box/ha	10	10	10	10	10	120
Average crop yield	kg/ha	66,300	59,000	45,400	50,700	51,300	44,300
CO_2 net balance	kg CO_2/ha	13.371	13.148	10.232	7.730	6.848	4.669
Eutrophication potential	kg PO_4^{3-} eq/ha	40.39	39.96	35.51	143.50	140.32	137.39

Source: Own elaboration with data collected from experimental plots and [32].

Table 2. Unitary costs of variable productive inputs.

Item	Unit	Unitary Cost	Source of Data
Seeds	EUR/packets	323	Market price
Seedling trays	EUR/tray	6.38	Market price
Fertilizers			
Ammonium nitrate	EUR/kg	0.438	Market price
Potassium nitrate	EUR/kg	0.920	Market price
Calcium nitrate	EUR/kg	0.440	Market price
Magnesium nitrate	EUR/kg	0.560	Market price
Monopotassium phosphate	EUR/kg	1.520	Market price
Potassium sulphate	EUR/kg	0.820	Market price
Nitric acid	EUR/kg	0.330	Market price
Phosphoric acid	EUR/kg	0.610	Market price
Aminoacids	EUR/kg	15.15	Market price
Others	EUR/kg	3.73	Market price
Pesticides			
Insecticides	EUR/kg	71.94	Market price
Fungicides	EUR/kg	2.37	Market price
Irrigation water			
T1	EUR/m^3	0.553	Calculated from the official water tariffs
T2	EUR/m^3	0.501	Calculated from the official water tariffs
T3	EUR/m^3	0.379	Calculated from the official water tariffs
Electricity	EUR/kWh	0.1127	Average retail price for Spain in 2020
Labor	EUR/h	8	[38]
Plastic base for weed control	EUR/kg	1.81	Market price
Tutoring ropes	EUR/unit	0.15	Market price
Pollinators	EUR/box	22.0	Market price
Natural pest predators	EUR/box	19.38	Market price

Source: Own elaboration.

Indirect costs arise from the use of productive inputs that are used in more than one crop cycle. In our case, these include the following:

- Common to both cultivation systems: the greenhouse, including both the structure and the plastic cover; the irrigation water reservoir; and the shed for the irrigation system.
- The irrigation system, which is different for the hydroponic (H) and for the traditional soil cultivation system (S).
- The sanded soil ("enarenado") in the traditional soil cultivation system (S).
- The substrate in the hydroponic system (H), which includes the substrate sachets and the sachets holders.
- A plastic soil cover for the control of weeds in hydroponic cultivation (H).

The total cost of the equipment and infrastructures considered and their imputation per crop cycle are shown in Table 3. The cost of the traditional sanded soil includes both the cost of materials and the cost of building the "enarenado" structure. However, it does not include the cost of the manure layer because the amortization period is different as it is replaced every three years. The cost of the manure layer of the "enarenado" includes both the cost of the manure itself and the cost of substituting it every three years. The cost of the hydroponic substrate corresponds to 4837 sachets of coconut fiber substrate per hectare with a unitary cost of 2.27 EUR/sachet. Sachets are used, on average, for two years. The cost of the base of the hydroponic substrate corresponds to the cost of the substrate holders (4837 units at a unitary price of 1.94 EUR/unit). Last, the cost of the plastic base for weed control used in hydroponic production, which is substituted every two years, corresponds to 680.64 kg of plastic with a unitary price of 2.29 EUR/kg.

Table 3. Cost of equipment and infrastructures considered in the calculation of indirect costs.

Item	Total Cost (EUR)	Area (ha)	Lifetime (Years)	Crop Cycles per Year	Cost per Cycle (EUR/ha)	Source of Data
Greenhouse structure and plastic cover	100,000	1	25	2	2000	Market price
Irrigation water reservoir	11,200	1	50	2	112	Market price
Shed for irrigation system	4259	1	20	2	106	Market price
Irrigation system (S)	26,991	1	20	2	675	Market price
Irrigation system (H)	51,485	1	20	2	1287	Market price
Traditional sanded soil (S)	65,000	1	25	2	1300	Market price
Manure soil layer (S)	4522	1	3	2	754	Market price
Hydroponic substrate (H)	11,003	1	2	2	2751	Market price
Hydroponic substrate base (H)	9379	1	30	2	156	Market price
Plastic base for weed control (H)	1559	1	2	2	390	Market price
Insurance	380	1	1	2	190	[35]
Maintenance of infrastructures and equipment	296	1	1	2	148	[35]
Land rent	812	1	1	2	406	[39]

Source: own elaboration based on data from the indicated sources. Values are equal for both soil cultivation (S) and hydroponic cultivation (H) unless otherwise stated.

The standard crop budget includes both costs and revenues. To calculate farm revenue, the market crop price was calculated as the average detrended yearly crop price calculated using data from the official agricultural databases. The results from the experimental plots were integrated into the standard crop budget for each productive process. The different experimental treatments imply changes in farming operations, input use and crop yields (Table 1) that result in changes in production costs and revenues. The integration of such changes in the standard crop budget results in a separate cost structure and budget for each experimental treatment.

2.3. Economic Assessment of the Experimental Treatments

The assessment of the impact of the different experimental treatments on crop profitability and input productivity for each tomato productive system is based on the calculation of several financial and economic indicators from the standard crop budgets built, indicators that are then used to compare the different experimental treatments and production systems. First, cost measures were calculated based on the data collected on the crop's production process, being expressed in average per hectare values and in average unitary values per kilogram of tomato production (Unitary production cost or break-even price). Second, crop profitability was measured through the farm profit, calculated by subtracting direct costs, assets depreciation and other indirect costs (e.g., the land rent) from farm revenue, following the methodology in [35]. Third, different relevant partial productivity measures were calculated, such as average land productivity (revenue per hectare), average water productivity (revenue per unit of irrigation water), average labor productivity (revenue per unit of labor) and average energy productivity (revenue per unit of energy consumed). Fourth, some indicators, such as labor use per input use (land, water, energy), were calculated to account for the social profitability of the resources used in tomato production.

Last, in addition to assessing the impact of the analyzed productive strategies in terms of crop profitability and partial input productivity, the environmental implications of the different production processes and experimental treatments were also analyzed. More specifically, we look at the environmental impact in terms of the balance of CO_2 emissions and the eutrophication potential, which are identified, together with water use, as the most relevant environmental issues related to seawater desalinization and intensive horticultural production. In this sense, partial productivity and labor use measures per unit of CO_2 emissions and per unit of eutrophication potential were calculated. Both CO_2 emissions and eutrophication potential for each water source and productive system are those calculated by [32] and are shown in Table 1. The balance of CO_2 emissions is measured in kilograms of CO_2. Eutrophication potential is measured as kilograms of equivalent phosphate anion (kg ${PO_4}^{3-}{}_{eq}$), and its main contributors are ammonia, nitrogen oxides, nitrate and chemical oxygen demand.

All the indicators calculated were used to assess the social and economic implications of the use of DSW for tomato cultivation under both traditional soil and hydroponic production, alternatives that, as commented, also have environmental implications. For example, greater productivity of water or higher use of labor per kg of CO_2 emitted imply a more efficient use of scarce resources.

3. Results and Discussion

The average **crop yields** in Table 1 show a positive impact of both water quality and of the use of soilless productive systems. The reduced conductivity of water increases average crop yields by 15% in traditional sanded soil and by 46% in soilless cultivation with respect to using the worst-quality water. This is consistent with [40], who obtained a 44% yield increase in greenhouse tomato when using DSW against using brackish groundwater. The differences in the average crop yields between T3 and T2 are significant, while the difference between T2 and T1 is smaller (but statistically significant, as shown by [32]). In the case of traditional soil production, the average crop yield is slightly greater for T2 than for T3. It must be noted that the increase in average crop yield when irrigating with less saline water is significantly greater for soilless production with the recirculation of drainage flows (H) than with traditional sanded soil cultivation (S). The greater difference in crop yields between T2 and T3 for soilless cultivation (H) with respect to soil cultivation (S) can be explained by the different nature of both cultivation technologies. Traditional soil production systems in the area were developed to accommodate poor soils and bad quality water, therefore, the use of soilless cultivation barely increases crop yields if saline water is used.

Table 4 summarizes the average cost structure calculated for each experimental treatment and presents profitability indicators, while Table 5 summarizes all the productivity and social indicators calculated. Both direct and indirect **production costs** are greater for soilless cultivation (H) than for traditional soil cultivation (S), as shown in Table 4, while only direct costs increase with the use of DSW (T1 > T2 > T3). Differences in direct costs are explained by the higher cost of DSW, the higher water, energy and fertilizer consumption of soilless production (H) and the harvesting cost that depends on crop yield. The soilless production system has the advantage of avoiding the percolation of nutrients to the soil, as drainage is recirculated, but at the same time consumes more water, fertilizers and energy.

On the other hand, soilless production also increases crop yield. Differences in indirect costs are explained by the amortization cost of the substrate and the water recirculation system. Because of the above, unitary production costs per kilogram are lower for soilless production (H) in T1 and T2, while they are greater for more saline water (T3) because of the lower yields obtained (Table 4).

Table 4. Production cost structure and crop profitability for the different strategies (euros/ha).

	Strategies					
	H-T1	**H-T2**	**H-T3**	**S-T1**	**S-T2**	**S-T3**
Seeds	7672	7672	7672	7672	7672	7672
Fertilizers	2563	2558	2134	1723	1603	1292
Pesticides and herbicides	1348	1348	1348	1348	1348	1348
Other materials	2540	2540	2540	3004	3004	3004
Raw materials (subtotal)	14,123	14,118	13,694	13,747	13,627	13,316
Cost of water	1322	1307	1013	1078	977	729
Cost of energy for irrigation	219	238	245	55	55	54
Maintenance	580	580	580	200	200	200
Irrigation (subtotal)	2121	2126	1838	1333	1232	983
Labor	18,080	17,687	16,954	17,241	17,272	16,895
DIRECT COSTS	34,324	33,931	32,486	32,321	32,131	31,194
Depreciations	6802	6802	6802	4947	4947	4947
Other indirect costs	743	743	743	743	743	743
INDIRECT COSTS	7546	7546	7546	5690	5690	5690
TOTAL COSTS	41,869	41,477	40,032	38,011	37,822	36,884
REVENUE	55,029	48,970	37,682	42,081	42,579	36,769
PROFIT	13,160	7493	−2350	4070	4757	−115
Unitary production cost (break-even price) (EUR/kg)	0.632	0703	0.882	0.750	0.737	0.833

Source: own elaboration. Data in euros per hectare unless otherwise stated.

Looking at the cost of fertilization, a major concern when irrigating with DSW, it can be seen that reprogramming fertigation because of the nutritional deficiencies of DSW increases fertilization costs (T1 > T2 > T3). Fertilization costs increase when using DSW by 20% for soilless cultivation (H) and by 33% for traditional soil cultivation (S). These figures are greater than those in [28], which obtained fertilization cost increases of 10% in open-air lettuce and 6% in hydroponically grown greenhouse lettuce, but in a similar range to those evidenced in [29], which estimated fertilization cost increases of 15% in lettuce, both hydroponically and in soil, 12% in soil-grown sweet pepper and 22% in hydroponically grown sweet pepper.

With respect to **profitability**, Table 4 shows that per-hectare farm profit increases significantly with water quality in the case of soilless production (T1 > T2 > T3) but not in the case of traditional soil cultivation, where profit increases from T3 to T2 but not from T2 to T1. The comparison between soilless (H) and soil cultivation (S) shows that farm profit is greater for soilless cultivation for better quality water (T1 and T2) but not for lower-quality water (T3), where the opposite occurs because the small impact that improving water quality has on crop yields for soilless production does not compensate the greater production costs. Additionally, it can be seen that differences in farm profit between soilless and soil production are greater for T1 than for T2 and T3. Again, this result shows that the benefits of DSW in terms of improved water quality are greater in soilless production but also that the benefits of hydroponic production with respect to traditional sanded soil cultivation require high-quality water to be reached.

Table 5. Average values of productivity measures and social indicators for the different strategies.

Item	Indicator	Strategies					
		H-T1	H-T2	H-T3	S-T1	S-T2	S-T3
Partial productivity measures	Land productivity (EUR/ha)	55,029	48,970	37,682	42,081	42,579	36,769
	Water productivity (EUR/m^3)	23.02	18.76	14.11	21.58	21.84	19.15
	Labor productivity (EUR/day)	182.62	166.12	133.36	146.45	147.91	130.58
	Energy productivity (EUR/kWh)	27.69	22.69	16.98	84.60	85.60	75.08
	Productivity per kg of $CO_{2\,eq}$ (EUR/kg)	4.12	3.72	3.68	5.44	6.22	7.88
	Productivity per kg of PO_4^{3-} equivalent (EUR/kg $PO_4^{3-}{}_{eq}$)	1362	1226	1061	293	303	268
Social indicators	Labor use per hectare (days/ha)	301	295	283	287	288	282
	Labor use per m^3 of water (days/m^3)	0.1261	0.1129	0.1058	0.1474	0.1476	0.1467
	Labor use per kWh (days/kWh)	0.1516	0.1366	0.1273	0.5777	0.5788	0.5750
	Labor use per kg of CO_2 (days/kg)	0.0225	0.0224	0.0276	0.0372	0.0420	0.0603
	Labor use per kg of PO_4^{3-} equivalent (days/kg)	7.46	7.38	7.96	2.00	2.05	2.05

Source: own elaboration.

It is difficult to frame these results within previous studies (e.g., [28,29]), as these authors compare the use of DSW with fair-quality surface resources and do not consider the effect on crop yields of improving water quality. However, our results are consistent with previous findings in terms of the increased cost of fertilization and water use when using increasing proportions of DSW, both impacts being greater in hydroponic production systems.

Looking at **partial productivity** measures, Table 5 first shows that partial input productivities increase with water quality for soilless production (T1 > T2 > T3) but not for traditional soil cultivation, where productivities increase from T3 to T2 but not from T2 to T1. Second, comparing productive systems, it can be seen that both land and labor productivity are greater for soilless production (H > S) for all water qualities. However, differences between soilless production and traditional soil production for low-quality water (T3) are small because of the above-mentioned similar crop yields. On the contrary, both water and energy productivities are greater for traditional soil production for T2 and T3 because of the greater water and energy requirements of soilless production. Only in the case of T1 does the increase in crop yields provided by hydroponic production compensate for the associated increase in water consumption and, therefore, water productivity for H surpasses that for S.

Turning to the social indicators that look at labor demand per unit of the different inputs, Table 5 shows that the improvement of water quality through the use of DSW and the use of soilless productive systems with drainage recirculation results in a slight increase in labor use per hectare, but with very small differences for the different water sources (T1, T2 and T3). On the contrary, the more intensive use of water and energy in soilless cropping systems (H) reduces labor use per m^3 and per kWh with respect to soil cultivation (S). Labor use per unit of water and energy consumption increase with water quality for soilless cultivation (H) but barely has an impact for conventional soil cultivation (S).

Moving to the environmental impact in terms of GHG emissions, because of the greater energy, water and fertilizer consumption of soilless production (H), the associated CO_2 emissions balance is greater than for traditional soil cultivation (S) (Table 1). This causes both the productivity per kg of CO_2 and the demand for labor per kg of CO_2 to be significantly lower for soilless production than for conventional soil cultivation (Table 5). Likewise, the CO_2 emissions balance increases with the use of DSW for both productive systems (Table 1). However, the productivity per kg of CO_2 increases with water quality in soilless production (H), despite the increasing use of more energy-demanding and CO_2^- emitting DSW, because of the increases in crop yield that the use of better-quality water allows (Table 5). Regarding labor demand per kg of CO_2, it is barely affected by the use of DSW. In the case of traditional soil production (S), both the productivity per kg of CO_2 and labor use per kg of CO_2 sharply decreases with water quality because the resulting increases in crop yields and labor requirements do not compensate for the increase in CO_2 emissions that the increasing use of DSW causes.

Last, the reduced lixiviation and associated eutrophication potential that soilless cropping systems allow for (Table 1) results in significantly higher productivities and labor use per kg of equivalent phosphate anion with respect to traditional soil production (Table 5). The impact of the use of DSW on the eutrophication potential is relatively limited (caused by the higher fertilization needs) and, because of its positive effect on crop yields, the productivity per kg of equivalent phosphate anion slightly increases with the use of DSW, i.e., with water quality, for both soil and soilless production. However, the differences between T2 and T3 are not significant.

4. Conclusions

The Spanish national water authorities have made a clear commitment to desalination as a reliable source of resources for the continuity of irrigation in south-eastern Spain, where conventional water resources are already compromised. This commitment is materialized in investments to increase the production of DSW and interconnect infrastructures for its distribution. In addition to being a new source of water supply, DSW may, in some areas, reduce water salinity and increase crop yields. However, its higher cost and the need for more specialized and expensive fertilization to cover nutritional deficiencies increase production costs and thus impact farm profitability. In that sense, this study has assessed the economic impact of the use of desalinated seawater (DSW) for tomato production in soilless greenhouse cropping systems of the Almería province, based on the results of the LIFE DESEACROP Project experimental activities, and comparing the use of different water sources in both traditional soil and soilless protected agricultural production systems.

Our results first show that the use of DSW increases tomato production costs but also crop yields, as water salinity gets reduced, resulting in higher crop profitability. Using only DSW for tomato production increases fertilization costs by 20% in soilless systems and by 34% in soil cultivation, and water costs by 30% in soilless systems and by 48% in traditional soil cultivation. This results in an increase in production costs of 5% in soilless cultivations and 3% in soil cultivation, increases that are smaller when DSW in blended with saline groundwater. Despite this, the use of DSW in tomato production in the area is profitable. Additionally, all input productivities increase with the use of better-quality water.

Secondly, regarding the effect of the cultivation system, soilless cropping systems are more intensive in terms of input use, especially water, energy and fertilizers, which results in higher production costs that, in this specific case, are compensated by higher crop yields and higher crop profitability. However, crop profitability when more saline water is used is greater for the traditional soil production system. Additionally, the use of soilless production systems increases land and labor productivity with respect to traditional soil systems but results in lower productivity of water and energy.

In sum, both the use of DSW and soilless production systems would increase the profitability of protected tomato production in SE Spain. However, the materialization of the potential benefits of soilless production requires the use of better-quality water resources. In the study area, where available natural water resources are highly saline, improving irrigation water quality implies using DSW. Otherwise, the traditional soil production system, which is better adapted to poor soils and low-quality water, would be more profitable.

However, from the societal perspective, the advantages of irrigating with DSW are more ambiguous. The use of DSW improves input productivity, and thus resource use efficiency and the demand for labor, but significantly increases CO_2 emissions. However, despite this, the productivity of CO_2 emissions increases with water quality for soilless production but conversely decreases for traditional soil production, as the increase in tomato production is not compensated by the increase in CO_2 emissions. The use of DSW also increases nutrient lixiviation due to the higher fertilization needs. However, because of its positive effect on crop yields, productivity per kg of equivalent phosphate anion slightly increases with the use of DSW for both productive systems.

Our results suggest that the benefits, both private and social, of using DSW for irrigation are linked to an improvement in the quality of water resources that might improve crop yields. The deficient quality of water resources in the area of study results in significant increases in crop yield when better quality water (i.e., DSW) is used. In other areas without this positive effect, the use of DSW would definitively increase production costs; the cheaper conventional water resources are, the more the increase. In general, only high-value, intensive fruit and vegetable crops could withstand the increased costs of irrigating with DSW, which would be unbearable for other crops, which makes integrated management of DSW with other sources of supply necessary in order to maintain their economic viability.

A similar conflict arises with the use of hydroponic systems. If conventional water resources available present a high electrical conductivity, soilless systems seem to take greater advantage of the water quality improvement that DSW provides than conventional soil systems and, in any case, soilless systems increase farm profitability and labor demand. However, in environmental terms, they drastically reduce lixiviation, and thus soil and water pollution, but at the cost of increasing the use of very limiting productive resources (water and energy) and CO_2 emissions.

To finish, we highlight that this study has presented results based, as other previous studies in other areas and crops, on experimental activities on the use of DSW for irrigation. As a relatively novel issue, there are few but increasing experimental studies on the issue. However, we think that in order to allow for more complete economic assessments, there is a need for more research on the modeling of root water uptake and plant transpiration and on the optimization of water consumption when irrigating with DSW.

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References

1. 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]
2. Soto-García, M.; Martínez-Alvarez, V.; García-Bastida, P.A.; Alcon, F.; Martin-Gorriz, B. Effect of Water Scarcity and Modernisation on the Performance of Irrigation Districts in South-Eastern Spain. *Agric. Water Manag.* **2013**, *124*, 11–19. [CrossRef]
3. Berbel, J.; Gutierrez-Martín, C. *Efectos de la Modernización de Regadíos en España*; Berbel, J., Gutierrez-Martín, C., Eds.; Cajamar Caja Rural: Almería, Spain, 2017; ISBN 978-84-95531-83-4.
4. Calatrava, J.; Gómez-Limón, J.A. Mercados de Agua y Eficiencia Económica. In *Los Mercados de Agua en España: Presente y Perspectivas*; Gómez-Limón, J.A., Calatrava, J., Eds.; Cajamar Caja Rural: Almería, Spain, 2016; pp. 125–155, ISBN 9788495531735.
5. CHJ. *Plan Hidrológico de la Demarcación Hidrográfica del Júcar. Ciclo de Planificación Hidrológica 2015–2021*; Confederación Hidrográfica del Júcar: Valencia, Spain, 2015.
6. CHS. *Plan Hidrológico de la Cuenca del Segura 2015–2021*; Confederación Hidrográfica del Segura: Murcia, Spain, 2015.
7. Valera-Martínez, D.L.; Belmonte-Ureña, L.J.; Molina-Aiz, F.D.; López-Martínez, A. *Greenhouse Agriculture in Almería. A Comprehensive Techno-Economic Analysis*; Cajamar Caja Rural: Almería, Spain, 2016; ISBN 978-84-955531-75-9.
8. Martínez-Alvarez, V.; González-Ortega, M.J.; Martin-Gorriz, B.; Soto-García, M.; Maestre-Valero, J.F. The Use of Desalinated Seawater for Crop Irrigation in the Segura River Basin (South-Eastern Spain). *Desalination* **2017**, *422*, 153–164. [CrossRef]

9. Melgarejo-Moreno, J.; López-Ortiz, M.I.; Fernández-Aracil, P. Water Distribution Management in South-East Spain: A Guaranteed System in a Context of Scarce Resources. *Sci. Total Environ.* **2019**, *648*, 1384–1393. [CrossRef]
10. CEDEX. *Evaluación del Cambio Climático en los Recursos Hídricos en Régimen Natural en España*; Centro de Estudios y Experimentación de Obras Públicas: Madrid, Spain, 2012.
11. Fereres, E.; Soriano, M.A. Deficit Irrigation for Reducing Agricultural Water Use. *J. Exp. Bot.* **2007**, *58*, 147–159. [CrossRef] [PubMed]
12. Ruiz-Sanchez, M.; Domingo, R.; Castel, J. Review. Deficit Irrigation in Fruit Trees and Vines in Spain. *Span. J. Agric. Res.* **2010**, *8*, S5–S20. [CrossRef]
13. Galindo, A.; Collado-González, J.; Griñán, I.; Corell, M.; Centeno, A.; Martín-Palomo, M.J.; Girón, I.F.; Rodríguez, P.; Cruz, Z.N.; Memmi, H.; et al. Deficit Irrigation and Emerging Fruit Crops as a Strategy to Save Water in Mediterranean Semiarid Agrosystems. *Agric. Water Manag.* **2018**, *202*, 311–324. [CrossRef]
14. Senent-Aparicio, J.; López-Ballesteros, A.; Cabezas, F.; Pérez-Sánchez, J.; Molina-Navarro, E. A Modelling Approach to Forecast the Effect of Climate Change on the Tagus-Segura Interbasin Water Transfer. *Water Resour. Manag.* **2021**, *35*, 3791–3808. [CrossRef]
15. Downward, S.R.; Taylor, R. An Assessment of Spain's Programa AGUA and Its Implications for Sustainable Water Management in the Province of Almería, Southeast Spain. *J. Environ. Manag.* **2007**, *82*, 277–289. [CrossRef]
16. 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]
17. Rey, D.; Garrido, A.; Calatrava, J. An Innovative Option Contract for Allocating Water in Inter-Basin Transfers: The Case of the Tagus-Segura Transfer in Spain. *Water Resour. Manag.* **2016**, *30*, 1165–1182. [CrossRef]
18. Martínez-Granados, D.; Calatrava, J. The Role of Desalinisation to Address Aquifer Overdraft in SE Spain. *J. Environ. Manag.* **2014**, *144*, 247–257. [CrossRef]
19. Martínez-Granados, D.; Calatrava, J. Combining Economic Policy Instruments with Desalinisation to Reduce Overdraft in the Spanish Alto Guadalentín Aquifer. *Water Policy* **2017**, *19*, 341–357. [CrossRef]
20. Rey, D.; Calatrava, J.; Garrido, A. Optimisation of Water Procurement Decisions in an Irrigation District: The Role of Option Contracts. *Aust. J. Agric. Resour. Econ.* **2016**, *60*, 130–154. [CrossRef]
21. Ben-Gal, A.; Yermiyahu, U.; Cohen, S. Fertilization and Blending Alternatives for Irrigation with Desalinated Water. *J. Environ. Qual.* **2009**, *38*, 529–536. [CrossRef] [PubMed]
22. Zarzo, D.; Campos, E.; Terrero, P. Spanish Experience in Desalination for Agriculture. *Desalin. Water Treat.* **2013**, *51*, 53–66. [CrossRef]
23. Coppola, A.; Chaali, N.; Dragonetti, G.; Lamaddalena, N.; Comegna, A. Root Uptake under Non-Uniform Root-Zone Salinity. *Ecohydrology* **2015**, *8*, 1363–1379. [CrossRef]
24. Russo, D.; Kurtzman, D. Using Desalinated Water for Irrigation: Its Effect on Field Scalewater Flow and Contaminant Transport under Cropped Conditions. *Water* **2019**, *11*, 687. [CrossRef]
25. Yasuor, H.; Yermiyahu, U.; Ben-Gal, A. Consequences of Irrigation and Fertigation of Vegetable Crops with Variable Quality Water: Israel as a Case Study. *Agric. Water Manag.* **2020**, *242*, 106362. [CrossRef]
26. Martínez-Alvarez, V.; Martin-Gorriz, B.; Soto-García, M. Seawater Desalination for Crop Irrigation—A Review of Current Experiences and Revealed Key Issues. *Desalination* **2016**, *381*, 58–70. [CrossRef]
27. Yermiyahu, U.; Tal, A.; Ben-Gal, A.; Bar-Tal, A.; Tarchitzky, J.; Lahav, O. Rethinking Desalinated Water Quality and Agriculture. *Science* **2007**, *318*, 920–921. [CrossRef]
28. Maestre-Valero, J.F.; Martin-Gorriz, B.; Soto-García, M.; Martinez-Mate, M.A.; Martinez-Alvarez, V. Producing Lettuce in Soil-Based or in Soilless Outdoor Systems. Which Is More Economically Profitable? *Agric. Water Manag.* **2018**, *206*, 48–55. [CrossRef]
29. Martínez-Alvarez, V.; Gallego-Elvira, B.; Maestre-Valero, J.F.; Martin-Gorriz, B.; Soto-Garcia, M. Assessing Concerns about Fertigation Costs with Desalinated Seawater in South-Eastern Spain. *Agric. Water Manag.* **2020**, *239*, 106257. [CrossRef]
30. Martin-Gorriz, B.; Soto-García, M.; Martínez-Alvarez, V. Energy and Greenhouse-Gas Emissions in Irrigated Agriculture of SE (Southeast) Spain. Effects of Alternative Water Supply Scenarios. *Energy* **2014**, *77*, 478–488. [CrossRef]
31. Antolinos, V.; Sánchez-Martínez, M.J.; Maestre-Valero, J.F.; López-Gómez, A.; Martínez-Hernández, G.B. Effects of Irrigation with Desalinated Seawater and Hydroponic System on Tomato Quality. *Water* **2020**, *12*, 518. [CrossRef]
32. Martin-Gorriz, B.; Maestre-Valero, J.F.; Gallego-Elvira, B.; Marín-Membrive, P.; Terrero, P.; Martínez-Alvarez, V. Recycling Drainage Effluents Using Reverse Osmosis Powered by Photovoltaic Solar Energy in Hydroponic Tomato Production: Environmental Footprint Analysis. *J. Environ. Manag.* **2021**, *297*, 113326. [CrossRef]
33. Swinton, S.M.; Lowenberg-DeBoer, J. Evaluating the Profitability of Site-Specific Farming. *J. Prod. Agric.* **1998**, *11*, 439–446. [CrossRef]
34. Ballestero, E. *Economía de la Empresa Agraria y Alimentaria*, 2nd ed.; Ediciones Mundi-Prensa: Madrid, Spain, 2000.
35. MAPA. *Estudios de Costes y Rentas de las Explotaciones Agrarias: Resultados Técnico-Económicos. Cultivos Hortícolas 2016*; Ministerio de Agricultura, Pesca y Alimentación: Madrid, Spain, 2020.
36. Junta de Andalucía. *Anuario de Estadísticas Agrarias y Pesqueras de Andalucía*; Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible, Junta de Andalucía: Sevilla, Spain, 2018.

37. Calatrava, J.; Martínez-Granados, D. La Productividad Económica En Los Sistemas Agrarios Intensivos Del Mediterráneo. In *El Regadío en el Mediterráneo Español. Una Aproximación Multidimensional*; Garrido, A., Pérez-Pastor, A., Eds.; Cajamar Caja Rural: Almería, Spain, 2019; pp. 97–124, ISBN 9788495531933.
38. BOPA. *Convenio Colectivo Provincial de Trabajo en el Campo 2012–2015*; Boletín Oficial de la Provincia de Almería Número 77, de miércoles 24 de abril de 2013; Diputación Provincial de Almería: Almería, Spain, 2013.
39. Junta de Andalucía. *Resultados de la Encuesta de Cánones de Arrendamientos Rústicos en Andalucía Año 2019*; Consejería de Agricultura, Ganadería, Pesca y Desarrollo Sostenible, Junta de Andalucía: Sevilla, Spain, 2020.
40. Valera, D.L.; Marín, P.; Camacho, F.; Belmonte, L.J.; Molina-Aiz, F.; López, A. Agua de Mar Desalinizada Para Riego En Los Invernaderos de Almería. *Vida Rural* **2018**, *447*, 38–42.