

## Article

# Economic Analysis of the Use of Reclaimed Water in Agriculture in Southeastern Spain, A Mediterranean Region

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**Abstract:** In a global context where agriculture is the major consumer of water, there is a pressing need to look for alternative water resources. In light of there being a lack of studies that compare the use of diverse water alternatives in different crops, the overall objective of this research is to evaluate the impact generated by the use of tertiary water from an economic and financial perspective and compare it with groundwater and desalinated water. To reach this objective, a detailed study of the cost structure of greenhouse investment has been developed. Furthermore, the most traditional indicators for investment profitability have been calculated for the three different water alternatives: tertiary water, groundwater and desalinated water. The cost analyses demonstrate the relative short reach that the price of water has in an area of greenhouse agriculture exploitation, which provides a margin of increasing water costs while still allowing for economic profit. Taking into account the three water resources considered, evidence shows that the use of tertiary water is not only financially and economically viable but is also the best alternative water resource above desalinated water in terms of profitability and sustainability.

**Keywords:** tertiary water; reclaimed water; treated wastewater; agriculture; irrigation; greenhouse



**Citation:** López-Serrano, M.J.; Velasco-Muñoz, J.F.; Aznar-Sánchez, J.A.; Román-Sánchez, I.M. Economic Analysis of the Use of Reclaimed Water in Agriculture in Southeastern Spain, A Mediterranean Region. *Agronomy* **2021**, *11*, 2218. <https://doi.org/10.3390/agronomy11112218>

Academic Editors: Alejandro Lopez-Martinez and Magdalena Sobocińska

Received: 1 October 2021  
Accepted: 31 October 2021  
Published: 2 November 2021

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## 1. Introduction

Water is a critical resource since it establishes a basis for humans from a subsistence, economic, social and environmental perspective [1,2]. Such a vital asset being jeopardized for decades by climate change, unceasing demand and pollution, has resulted in a decline in water quality and quantity [3–5]. Furthermore, forecasts predict substantial worsening brought with further biofuel production, growing population, rapid urbanization and expanding agriculture [6–9]. For the ninth year in a row, the World Economic Forum has reported water crises as one of the top five global risks that may affect society [10]. Estimations claim that already 10% of the population does not have access to fresh drinking water [11]. The upcoming situation is expected to be exacerbated, with at least 25% of the global population having to deal with water shortages in the near future and facing a water deficit of 40% in less than a decade [9,12]. Due to its essentiality, guaranteeing the supply of this dwindling resource is one of the most relevant challenges currently faced by humanity [10,11]. Within the framework of water consumption, agriculture is in the spotlight for being the major user worldwide, with an uptake between 60% and 90%, depending on the region [12–14]. As the main water consumer and in such context of great strain caused by water use for irrigation, agriculture plays a key role in enhancing environmental sustainability and ensuring water resources [11,15,16].

Managing hazards that may endanger water quality and supply requires making farming decisions that enhance horticultural production in a sustainable way [17]. In this sense, the Mediterranean region plays an essential role not only as being one of the most important agricultural areas in the world, but also because it already has scarce water resources under high stress [18,19]. Furthermore, this pressure adds to the fact that agriculture in Southern Europe is the main consumer of water and that there is

expected to be a reduction in river flow in the upcoming years [20,21]. Among all the Mediterranean countries, Spain stands out for having more than 30% of the whole of the irrigated area of the EU, and this is mainly due to a region in the South East that deserves special consideration [22]. Almeria is well-known for being the main fruit and vegetable exporter in the European Union and for having the highest greenhouse concentration in the world [23–26]. Despite its highly productive agricultural sector allowing rapid economic development in the region, there have also been negative consequences [27–29]. Because of such production levels, water resources have been overexploited for years to meet demand, resulting in salinity problems in depleting aquifers, which highlights the need to look for alternatives to gradually reduce and eventually eliminate this constraint factor [30].

With water being a key driver for crops and in a social and environmental situation where increasing demand and decreasing quality attract attention, the incorporation of unconventional sources as an alternative for obtaining irrigation water is of vital importance [31–34]. Reclaimed water stands out for being a resource with few risks to humans or the environment, thus why its ever more frequent implementation is evident, especially in arid and semi-arid climate as Mediterranean [35–38]. Reclaimed water, which can be also referred as tertiary water or treated wastewater, consists of handling urban wastewater in treatment plants in order to develop an alternative water source to irrigate [39]. This treatment should be regulated, controlled and adequate before irrigating crops to avoid microbiological or physicochemical soil alterations that may jeopardize the environment or high heavy metal concentrations that may endanger human health [40–42]. Tertiary water significance is emphasized by the 2030 Agenda for Sustainable Development, where the need for increasing global treated wastewater is stated as a desired target [43]. This sustainable and cost-effective alternative may change the water supply landscape, considering that around 60% of irrigated farming worldwide takes place close to a wastewater treatment plant [44]. Furthermore, research has proved that its use provides overall benefits [45]. Against this background, using reclaimed wastewater for irrigation has been shown to be mutually profitable for all growers, nature and society [33,46].

From a sustainability perspective, as well as helping with water stress reduction and aquifer recovery, reclaimed wastewater use in agriculture decreases water pollution by providing a solution for the disposal of wastewater, instead of it being discharged into waterways without any treatment, which is currently over 80% [47–52]. Another relevant example of tertiary water helping farmers to increase economic profit is with fertilizers, which can be reduced by up to 66%, helping to improve soil fertility and fruit quality [53,54]. The supply of essential organic and inorganic nutrients, along with nitrate pollution control are also among the benefits that positively influence crops irrigated by treated wastewater [55–58]. Due to the proven benefits and limited risks, which can remain unnoticeable with preventive barriers in place, international institutions have been boosting reclaimed wastewater implementation for irrigation [43,59].

Notwithstanding, many positive aspects derived from the use of treated wastewater to irrigate crops, its still low implementation worldwide seems to be connected to farmers' perceptions [60]. This is due to the frequent inability to receive the economic, social and environmental benefits normally derived from its use [61,62]. Despite the vast research carried out on wastewater use in agriculture, particularly over the last few years, there is a lack of studies that compare the use of various water alternatives. This is indicative of the clear research gap existing in this field, which impedes the widespread implementation of an alternative water resource as reclaimed water in a context of water depletion worldwide and where agriculture is consuming up to 90% of water resources in some areas. Moreover, it is important to illustrate to farmers the need to put wastewater irrigation into effect and therefore, it is key to show them that the economic benefits derived after using this alternative water resource are not only realistic but also will enhance the sustainability of their agriculture exploitations in the long run; this would not be possible at the current rates of underground water usage. Therefore, the overall objective of this research is to evaluate the impact generated by the use of tertiary water, economically and financially,

which will show potential users convincing reasons for its implementation and will help researchers in future studies where this economic and financial perspective may be used as a basis. This objective will be fulfilled through a detailed study of the cost structure of greenhouse investment and with different indicators of profitability.

## 2. Materials and Methods

With the main goal of analyzing the impact generated by the use of treated wastewater on the profitability of agricultural holdings, economically and financially, the paradigmatic case of Southeast Spain was studied. The results of this work have important practical implications, since they show the impact that the implementation of this irrigation alternative may have on the profitability of farms. In this context, tertiary water, apart from having proved its indispensability in the management of water disposal, has also been widely demonstrated as being the most effective alternative for dealing with water supply and demand, providing remarkable benefits for crops, humans and the environment. In addition, lessons learned from this case study could be useful to other regions that are already facing increasing scarcity of water for use in agriculture and are considering using reclaimed wastewater.

### 2.1. Study Region

The province of Almeria is located in Southeastern Spain and is well known for its agricultural production. With more than 3,764,735 tons harvested in the 2018/2019 agricultural season, of which 80% are exported, it is the leading exporter of many fruits and vegetables in the European Union [26,63]. With an export value of 2684 million euros, the agricultural sector in the area has developed a consistent auxiliary industry of 1367 million [64]. Almeria is made up of six main sub-areas; Campo de Dalías and Bajo Andarax (including Almeria City) stand out among them for having the highest concentration of greenhouses with a surface area covering more than 77% of the total [65].

In view of its role as an economic engine, it is vital to ensure water availability for crop irrigation in an area where structural water deficit is a major problem [66]. Despite having one of the most efficient agricultural systems in terms of water consumption, it remains the largest water consumer in the province with more than 80% of groundwater uptake [67]. In this context, the fast development of agriculture has led to pollution from aquifers and overexploitation, the storage volume of reservoirs has been greatly reduced and nearly all greenhouse areas have been declared as Nitrate Vulnerable Zones by the European Union [29,68]. This issue has added to the already existing problems with seawater intrusion for being in a coastal area [54,69]. To tackle these drawbacks and face current and coming needs, desalinated and reclaimed wastewater are thus far considered the most suitable alternatives [70].

### 2.2. Data Analysis

Due to all of the unprecedented alterations undergone by food systems worldwide during the 2019/2020 agricultural season, and to avoid bias from the great economic fluctuations and severe GDP declines caused by COVID-19, this study has been developed using the 2018/2019 crop season as a basis [71–73]. The current research was carried out in two phases in order to meet the objectives stated in the introduction. The first phase focused on qualitative research. To begin, an exploration of the existing literature in this field of study was carried out where articles, reports, research projects and public institution studies were analysed. Moreover, a group of professionals with expertise in the agricultural and irrigation sector were consulted and interviewed throughout the entire process with the aim of checking the information and data compiled. Process evaluations by experts in qualitative studies have proved to be the most worthwhile method in outlining the research, ensuring the reliability of the study and managing flaws or unexpected circumstances [74]. Furthermore, agriculturalists have provided primary data from their farms regarding the water consumption of the diverse crops studied.

During the second phase, quantitative analysis was carried out. In this section, the traditional analytical methods used to financially evaluate investments were applied [75,76]. Net present value and internal rate of return were used to determine the viability of an outlay. These indicators of project profitability were complemented with a detailed study of the cost structure and the influence of the cost of water on the profitability of the farms. To conclude the analysis, the apparent productivity of water, and shutdown and breakeven points were also calculated in order to show the maximum payment capacity for water. The results show the farmers' ability to pay for the use of different water resources on their farms.

### 3. Results and Discussion

#### 3.1. Area of Cultivation and Crop Distribution

The province of Almeria was composed of 31,614 real hectares in the 2018/2019 agricultural season [65]. Nevertheless, and to account for the fact that more than 44% of crops are planted in two short cycles instead of one large cycle, the total number of effective hectares studied to value production properly was 45,668 [63]. As can be seen in Table 1, peppers, watermelons and tomatoes are the crops that occupy the largest part of this area with 11,125, 10,524 and 9555 hectares. In terms of production, these three crops also lead, with 785,043, 548,677 and 888,389 tons produced, respectively. However, in terms of economic value, the leading crop is the pepper with 604.483 million euros, which is followed by tomatoes, cucumbers and zucchinis, with 582.783; 266.313 and 245.330 million euros respectively.

**Table 1.** Major aspects of greenhouse cultivation in the province of Almeria.

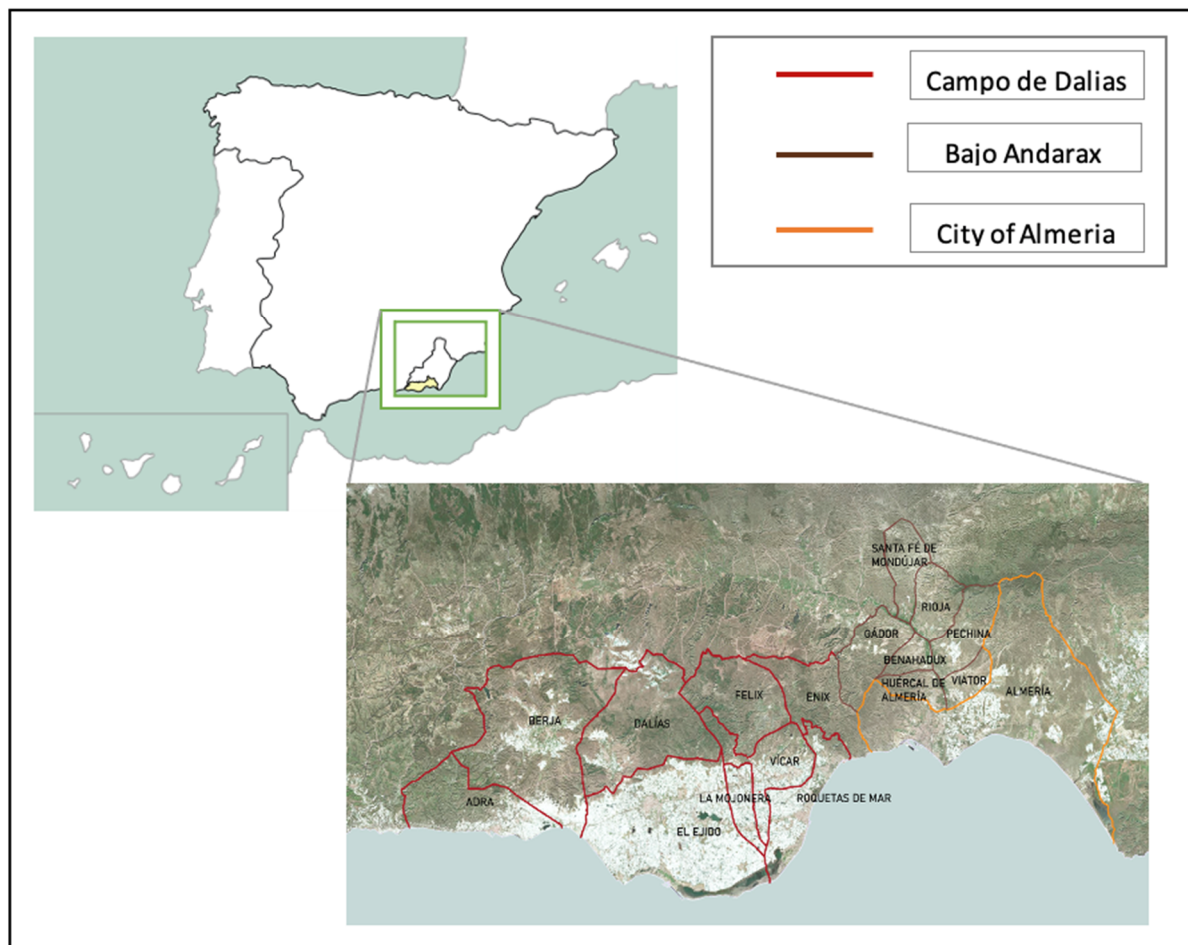
Crop	Cultivated Area (Hectares)	Production (Tons)	Farmers' Income Value (Million Euros)
Tomato	9555	888,389	582.783
Pepper	11,125	785,043	604.483
Watermelon	10,524	548,677	160.214
Zucchini	7439	459,420	245.33
Cucumber	4677	527,352	266.313
Aubergine	2164	190,614	112.272
Melon	2589	121,344	55.818
Green Bean	290	4347	7.081

Data: Cajamar from its Analysis of 2018/2019 crop season (*Análisis de la campaña hortofrutícola 2018/2019*).

The surface area comprises different crops depending on the sub-area. In Figure 1, represented with different colours, are the three sub-areas that have been studied in this research. Red represents Campo de Dalías, orange is the city of Almeria and brown is Bajo Andarax.

Campo de Dalías, as Table 2 shows, is well known for its pepper production with 30% of the area focused on this crop. Next in importance are zucchinis and cucumbers with 16% and 14% of the area respectively. Almeria city's farming is focused mainly on tomatoes, which take up 75% of the area, followed far behind by watermelons and melons, with 10% and 7%. With respect to Bajo Andarax, the tomato has a clear lead again with 82% of the area dedicated to this fruit, followed by cucumbers and peppers with a much lower 12% and 3%. Crop differentiation in different areas depends mainly on water and soil characteristics, which make an area suitable for a certain crop.

Due to their close proximity and similarities in terms of crops and that both water supplies come from the same sources, Bajo Andarax and Almeria will be considered herein as the same sub-area for this study.



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

**Table 2.** Crop distribution in each of the study areas.

<i>Campo de Dalias</i>		<i>Almeria</i>		<i>Bajo Andarax</i>	
Crop	Surface Area	Crop	Surface Area	Crop	Surface Area
Pepper	30%	Tomato	75%	Tomato	87%
Zucchini	16%	Watermelon	10%	Cucumber	12%
Cucumber	14%	Melon	7%	Pepper	3%
Watermelon	12%	Cucumber	3%	Zucchini	3%
Melon	11%	Zucchini	3%	Green Bean	2%
Tomato	9%	Pepper	2%	Watermelon	2%
Aubergine	5%			Melon	1%

Data: COEXPHAL internal reports.

### 3.2. Structure Cost: Initial Investment and Regular Expenses

#### 3.2.1. Initial Investment

With the objective of calculating the relevance of water in farmers' expenditures, it is necessary to develop an initial cost structure based on start-up costs that are required for economic activity in a greenhouse, as represented in Table 3. The investment needed at the beginning of greenhouse implementation has been defined by diverse influences that are a compilation of local banks' adjustments for loans to this end, previous governmental studies, research, farmers with experience and local companies dedicated to each item. The initial cost structure has been divided into three main sections: structural elements, retrofit and irrigation system. Costs are calculated for one hectare of greenhouse. Moreover, investment costs have been estimated for a greenhouse structure of "Raspa y Amagado"



on the basis it is the most representative structure in the study area, being used for more than 75% of the greenhouses in the province [77,78].

**Table 3.** Initial Investment for a Greenhouse Hectare.

Initial Investment	EUR
<i>Structural Elements</i>	
Windows	11,200
Corridors	4000
Storage construction	9000
Walls	8000
Wiring	3000
Tillage and Levelling	8000
Greenhouse Construction	82,000
<i>Retrofit</i>	
Topsoil Contribution	15,000
Sanding	18,000
Treatment installation	2000
Manure	5000
<i>Irrigation System</i>	
Watering head	9000
Watering distribution system	6500
Irrigation pond building	10,000
<b>Total</b>	<b>190,700</b>

Primary data obtained from agriculturalists.

### 3.2.2. Fixed Costs

With the goal of calculating some important figures from an accounting perspective, such as the shutdown and breakeven costs, the development of an annual fixed cost structure, such as the one in Table 4, was necessary. For this study, a useful life for the investment of 20 years has been considered, which is the most common loan term for greenhouse investment in Almeria. Despite some fixed costs not being yearly (some may be every 2 to 3 years or more) the total costs for the entire period have been divided to obtain annual fixed costs.

**Table 4.** Annual Fixed Costs for a Greenhouse Hectare.

Annual Fixed Costs	EUR
Solarisation	1600
Bleaching	500
Maintenance of Structures	500
Plastic	3800
Manure	1000
Pond	350
	<b>7400</b>

Primary data obtained from agriculturalists.

### 3.2.3. Variable Costs, Production and Intakes

Costs that are neither related to the initial investment nor fixed every period are highly significant, as depending on certain crops may vary greatly. To include the most representative crops in the areas of study in relation to surface area, production and value, and to represent the alternatives that are more common in Campo de Dalías and Bajo Andarax, three different crop alternatives were studied (Table 5). First, the tomato, which is the most important fruit in the province in terms of surface area cultivated and production. The tomato crop is essentially sown in long-cycle, which may comprise from eight to nine months of harvesting. The selected variety is “Larga Vida (Long Life)”. The second alternative that has been chosen is the combination of “California (Californian)” pepper and “Galia” melon, in two short-cycles. The pepper leads the ranking in terms of reported

incomes of farmers, and based on its latest trends, may take the lead in the other categories in the near future. Finally, “Almería” cucumbers and zucchinis have been considered as an example due to their extensive use in the province and because they are the third and fourth most valuable crops regarding landowners’ revenues.

**Table 5.** Variable Costs of an Agricultural Holding (per hectare) \*.

	Tomato “Larga Vida”	Pepper “California”/ Melon “Galia”	Cucumber “Almería” /Zucchini
Salaried-worker labour	12,770	12,470	16,160
Seeds + Seedbed	3460	12,940	7440
Fertilizers	3970	2650	5910
Plan-protection (insects included)	5580	4770	4570
Energy	2200	1430	2090
Supplies	800	700	900
External Services	800	800	300
Water (groundwater)	1800	2295	2100
<b>Total</b>	<b>31,380</b>	<b>38,055</b>	<b>39,470</b>

\* Household labour is not evaluated; Data: Prices and Markets Andalusian Observatory (Observatorio de Precios y Mercados de la Junta de Andalucía).

In terms of variable costs, the most significant item is salaried-worker labour, representing between 33–41% of the total. The importance of fertilizers also has to be highlighted, as they comprise between 7% and 15% of the total variable costs. This is quite relevant as far as the implementation of treated wastewater for irrigation is concerned, as it has been proven that expenditure in fertilizers can be reduced by up to 45% in this area [79]. For its part, water makes up no more than 6% of the total variable costs among crops studied, despite the inclusion of water used for irrigation and disinfection.

### 3.2.4. Variable Costs, Production and Intakes

There are other aspects from an agricultural holding, such as efficiency, crop water consumption and total income that are directly related to the cost structure and therefore must be calculated to develop a deeper financial assessment (see Table 6). Tomatoes have the highest efficiency in terms of water consumption with 6000 m<sup>3</sup>/he and peppers and melons lead the ranking of less labour with 339 working days per hectare. Valuing medium prices at which the different crops were sold in the 2018/2019 agricultural season, cucumbers and zucchinis reach the highest costs and the greatest gross margin per hectare with EUR 83,475 and EUR 27,070, respectively. This crop alternative also has the highest efficiency levels with 175,000 tons harvested per hectare.

**Table 6.** Relevant Indicators for the Three Crop Alternatives Studied.

	Tomato “Larga Vida”	Pepper “California”/Melon “Galia”	Cucumber “Almería” /Zucchini
Efficiency (kg/he)	130,000	130,000	175,000
Water (m <sup>3</sup> /he)	6000	7650	7000
Labour (working days/he)	432	339	471
Income (€/he)	65,780	80,000	83,475
Gross Margin (€/he)	<b>17,465</b>	<b>25,010</b>	<b>27,070</b>

Data: Markets and Prices Andalusian Observatory & Primary Data.

### 3.3. Financial Indicators: Shutdown and Breakeven Points and Apparent Productivity of Water (APW)

In order to assess water productivity in the area, which has already proved in various studies to be one of the highest in Spain, the APW has been calculated in Table 7 [80–82]. Results of APW calculations in the area prove the efficiency of the agricultural sector in

Almeria and its potential. Therefore, it reinforces the growing need for developing and potentiating alternative water resources in order to face a demand that is acquiring greater importance every day in terms of a growing cultivation area and production.

**Table 7.** Apparent Productivity and Shutdown and Breakeven Points.

	Selling Price	APW	BP	SP
Tomato	Min: 0.196	4.25	−2.22	−0.68
	Med: 0.506	10.96	4.5	6.03
	Max: 0.763	16.53	10.07	11.6
Cucumber/Zucchini	Min: 0.186/0.196	4.76	−1.94	−0.58
	Med: 0.432/0.537	11.93	5.23	6.59
	Max: 0.927/1.446	28.74	22.04	23.4
Pepper/Melon	Min: 0.444/0.358	6.98	1.04	2.31
	Med: 0.705/0.472	10.46	4.52	5.78
	Max: 1.005/0.742	15.36	9.42	10.68

APW: Apparent productivity of water; BP: Breakeven Point; SP: Shutdown Point.

Breakeven point is when the total income equals the total costs, which means that the level of profits is exactly zero, with neither benefits nor losses [83]. At this point, when the agricultural holding breaks even, any increase in cost would lead to the surpassing of the breakeven and therefore the farmer may be inclined to stop production rather than continuing to produce at a point where costs are not covered. Results show that with medium prices there is still a margin to increase the price of water and provide economic benefits for the grower. This means that groundwater could be substituted for other water alternatives, even if their price is higher, and still prove desirable.

Lastly, and in order to complete an assessment of the maximum payment capacity of farmers for water, the shutdown point has been calculated. This refers to the level at which total variable costs are equal to total income. For this reason, the grower would be incurring losses under this point, which would be the same as fixed costs. It can be defined as the maximum water repayment capacity that can be faced in the short term because fixed costs are incurred even with zero production [30]. That means that the shutdown point shows the minimum price and quantity needed to keep economic activity going. Below this point, the farmer would not be interested in continuing production as it would be impossible to cover total variable costs.

Having analysed the three different price scenarios where minimum, medium and maximum prices during the agricultural season studied have been considered for each crop alternative or combination, it can be claimed that apart from tomatoes and the combination of cucumbers and zucchinis with minimum prices as a model, the rest of the crops show high shutdown points in the different price scenarios, which guarantees short-term repayment capacity for the growers.

### 3.4. Financial Profitability of Three Different Investment Alternatives: Desalinated, Ground and Tertiary Water

To determine the viability of the alternatives provided, a financial analysis has been developed with the traditional most used indicators to determine profitability. As previously mentioned in Section 3.3, minimum, maximum and medium prices have been considered based on the fact that there is a great price variation in every agricultural season. A 20-year lifetime of the investment has been taken into account and using the Spanish Official Credit Institute as a reference, an interest rate of 4.852% has been used for the calculations [84]. In terms of water price, different alternatives have been evaluated; all of them based on the most widespread prices for each resource in the area of study. For groundwater a price of 0.3 EUR/m<sup>3</sup>, which is most common among local irrigation associations, has been used. For desalinated water, a price range has been chosen for developing precise and unbiased analysis, as the price of desalinated water varies depending on the area. This variation depends mainly on two factors. The first is that some desalination plants are



owned by the government which subsidizes part of the cost for the agriculture, while in other areas the grower has to face the entire cost of the water. On the other hand, the cause of inequality among areas is due to natural resources, as in Campo de Dalias where there is a reservoir from which water use for irrigation has a cost of 0.02 EUR/m<sup>3</sup>. As a result of its depletion, irrigation associations from the area have developed a plan where the real cost of desalinated water coming from public desalination plants, which is 0.60 EUR/m<sup>3</sup>, is compensated with the cost of Beninar Reservoir water, so agriculturists use a mixture of both resources and a price of 0.30 EUR/m<sup>3</sup> is charged indistinctly. The price of desalinated water where plants are private is 1 EUR/m<sup>3</sup> (which is the most common scenario for other Mediterranean areas). Reclaimed water in the area of study comes from the wastewater treatment plant located in Almeria city where raw urban wastewater coming from industries and households gets primary, secondary and tertiary treatments. Treated wastewater resulting from these treatments has homogeneous quality and meets the parameters stipulated by the EU, which protect both human health and the environment. Its costs depend on where the farm is located, as a result of a variation in distribution costs. Therefore, in the area of study where this resource can be used for irrigation its prices vary from 0.44 EUR/m<sup>3</sup> to 0.62 EUR/m<sup>3</sup>. Furthermore, it was necessary to consider that when using tertiary water, the reduction of fertilizers has proved to be of 45% in this area, as claimed in 3.2.4. As a consequence, when evaluating reclaimed water, these costs have been adapted and this fluctuation has been considered.

#### 3.4.1. Net Present Value (NPV)

NPV, presented in Table 8, evaluates the absolute return of an investment. If future cash flows are known, this indicator calculates the present value of a future stream of payments, which are the projected earnings of the investment [85]. When the NPV of an outlay is positive, this means it is profitable and therefore, desirable.

**Table 8.** NPV of three different crop alternatives with diverse water alternatives.

		NPV <sub>GW</sub> (EUR)		NPV <sub>DW</sub> (EUR)		NPV <sub>TW</sub> (EUR)	
	Selling Price	WP (EUR/m <sup>3</sup> )	0.3	0.3	1	0.44	0.62
Tomato	Min: 0.196		−288,180	−288,180	−341,184	−298,781	−312,410
	Med: 0.506		29,710	29,710	−23,294	19,109	5479
	Max: 0.763		642,047	642,047	589,043	631,446	617,817
Cucumber/Zucchini	Min: 0.186/0.196		−291,587	−291,587	−353,426	−303,955	−319,856
	Med: 0.432/0.537		150,926	150,926	57,348	138,558	122,657
	Max: 0.927/1.446		1,826,695	1,826,695	1,764,857	1,814,328	1,798,426
Pepper/Melon	Min: 0.444/0.358		−19,814	−19,814	−87,394	−33,330	−50,708
	Med: 0.705/0.472		124,929	124,929	89,087	111,412	94,035
	Max: 1.005/0.742		788,882	788,882	721,301	775,366	757,988

NPV: Net Present Value; WP: Water Price depending on the source; NPV<sub>GW</sub>: Net Present Value with Groundwater; NPV<sub>DW</sub>: Net Present Value with Desalinated Water; NPV<sub>TW</sub>: Net Present Value with Treated Wastewater.

In this area of study, the start-up of a greenhouse will result in benefits as long as medium prices are maintained. The analysis shows, with only one exception, how all three water alternatives maintain positive levels of profitability. The only time, when under circumstances of medium prices, the investment would not be profitable, is in the case of the tomato crop and only in the most expensive scenario with desalinated water. It should also be emphasized that considering the scenarios for the three alternatives in terms of water costs and selling prices, the use of treated wastewater for irrigation shows in all cases better economic results in all the crops evaluated compared with those for desalinated water. In consideration of the analysis, it can be claimed that the extra costs that represent the use of treated wastewater instead of groundwater do not involve a threat to profitability for the grower and that it is more than compensated due to the reduction in fertilizer costs. Other aspects, such as volatility of prices, which in the agricultural campaign studied were

high with several peaks and a deep variability between them in both senses, have been shown to have a much higher importance than water price.

### 3.4.2. Internal Rate of Return (IRR)

A discounted cash flow analysis equal to the NPV of all cash flows to zero results in IRR [86]. This discount rate estimation helps to cost the profitability of potential investments, delivering the expected compound annual rate of return that will be earned.

In all cases, except for those of minimum prices, the return rate is positive and therefore desirable (see Table 9). The most important aspect of this internal rate of return analysis is that under no circumstances is tertiary water rate lower than desalinated rate, which reinforces the idea that reclaimed water is the most profitable alternative for groundwater. Furthermore, it stands out that there is only a very slight difference between groundwater and tertiary water rates, which in the cheapest scenario for tertiary water are higher than or equal to the groundwater, but never lower. Furthermore, the very slight difference in the return rate of groundwater and treated wastewater in the most expensive scenario for this last resource should be noted, as it is in no case higher than 0.9%. With this analysis, as happens with NPV, the worst case scenario for treated wastewater is in all cases better than that of desalinated water regardless of price or crop.

**Table 9.** IRR of three different crop alternatives with diverse water alternatives.

	Selling Price	WP (€/m <sup>3</sup> )	IRR <sub>GW</sub>	IRR <sub>DW</sub>		IRR <sub>TW</sub>	
			0.3	0.3	1	0.44	0.62
<b>Tomato</b>	Min: 0.196		-	-	-	-	-
	Med: 0.506		6.6%	6.6%	3.4%	6.0%	5.2%
	Max: 0.763		26.4%	26.4%	24.2%	26.0%	25.4%
<b>Cucumber/Zucchini</b>	Min: 0.186/0.196		-	-	-	-	-
	Med: 0.432/0.537		13.0%	13.0%	9.8%	12.3%	11.6%
	Max: 0.927/1.446		75.9%	75.9%	73.3%	75.4%	74.7%
<b>Pepper/Melon</b>	Min: 0.444/0.358		-	-	-	-	-
	Med: 0.705/0.472		11.7%	11.7%	8.2%	11.0%	10.1%
	Max: 1.005/0.742		32.7%	32.7%	29.8%	32.1%	31.4%

IRR: Internal Rate of Return; WP: Water Price depending on the source; IRR<sub>GW</sub>: Internal Rate of Return with Groundwater; IRR<sub>DW</sub>: Internal Rate of Return with Desalinated Water; IRR<sub>TW</sub>: Internal Rate of Return with Treated Wastewater.

### 3.4.3. Payback Period (PP)

PP reflects the time it will take for an investment to be recovered, and suggests that the shorter the payback, the more profitable it will be [87]. In the case of the three alternatives studied, considering medium prices during the 2018/2019 crop season and the fact that the useful life of a greenhouse is at least 20 years, all water sources evaluated are profitable and have enough benefits to face the investment required. The payback period among the water alternatives shown in Table 10, deserves special attention given that in the cheapest scenario for all of them the PP is quite similar, with a maximum variation of 1.3 years in only one situation and little or no variation in the rest (between 0 and 0.4). It is also important to highlight that valuing the least desirable situations for the grower facing the highest prices for each resource, treated wastewater has in all scenarios a shorter PP and would be more interesting from a financial point of view than desalinated water.

**Table 10.** PP of three different crop alternatives with diverse water alternatives.

	Selling Price	WP (€/m <sup>3</sup> )	PP <sub>GW</sub> (Years)		PP <sub>DW</sub> (Years)		PP <sub>TW</sub> (Years)	
			0.3		0.3	1.0	0.4	0.6
<b>Tomato</b>	Min: 0.196		-		-	-	-	-
	Med: 0.506		9.1		9.1	14.4	11.5	12.3
	Max: 0.763		3.7		3.7	4.1	3.8	4.0
<b>Cucumber/Zucchini</b>	Min: 0.186/0.196		-		-	-	-	-
	Med: 0.432/0.537		7.0		7.0	8.6	7.3	7.7
	Max: 0.927/1.446		1.3		1.3	1.4	1.3	1.7
<b>Pepper/Melon</b>	Min: 0.444/0.358		-		-	-	-	-
	Med: 0.705/0.472		7.6		7.6	9.7	8.0	8.5
	Max: 1.005/0.742		3.1		3.1	3.3	3.1	3.8

PP: Payback Period; WP: Water Price depending on the source; PP<sub>GW</sub>: Payback Period with Groundwater; PP<sub>DW</sub>: Payback Period with Desalinated Water; PP<sub>TW</sub>: Payback Period with Treated Wastewater.

#### 4. Conclusions

The use of properly treated wastewater has widely shown that its implementation in agriculture enhances the reduction of freshwater resource depletion and sea spills. Moreover, it helps in achieving the recovery of aquifers and soil quality improvement. Despite the previously stated benefits, putting this alternative resource into effect is proving to be too slow a process if present and future needs in terms of water demand are taken into account. In the case of Almeria, a Mediterranean region with an intensive agricultural system known worldwide for its efficiency and its vastly cultivated area as a reference, can help many countries to learn from its example. The results of this research where tertiary water has been constantly used in an area since 1997 show the environmental and economic benefits of its implementation.

After studying a surface area of more than 31,000 hectares from a financial perspective, highlighting the importance of water, analyses have proved how expenditures directly related to water use in an area of greenhouse agriculture exploitation have a relatively short reach. Apparent productivity in terms of water efficiency in the diverse crops studied, and shutdown and breakeven points show how efficient crops are in terms of water consumption. This also implies that there is still a wide margin for using tertiary water to maintain the economic viability of farms. Analyses developed in this research prove that costs associated with water and how they differ to the alternatives provided are of secondary importance, due to almost insignificant role that water has in a greenhouse cost structure. Furthermore, it has been demonstrated that water costs, depending on the source, have only a minimal effect in terms of recovery of the investment and project profitability. Despite some numbers may slightly change in the future if there is a variation in any of the raw materials needed for the greenhouse construction or for growing the agricultural crops, data trends in the last decades show stability and gradual and minimum price fluctuation, which would not change the conclusions derived from this research.

Analysing the results, it is possible to arrive at the conclusion that there is virtually no difference in the alternatives provided for the research in terms of costs, which could mean that both desalinated and tertiary water use are much the same. Nevertheless, the worst case scenario for treated wastewater is in the analyses developed preferable to the worst for desalinated water, which is probably the most common situation in other semi-arid areas where desalinated water is not subsidised. This strengthens the idea that tertiary water is in all cases the best alternative to face water depletion derived from irrigation. Furthermore, its superiority in terms of benefits reinforces the need for developing infrastructures to potentiate the implementation of reclaimed water, a resource that has proven to be a sustainable and cost-effective alternative, more so than competing alternatives.

This Spanish case is of importance as it can be extrapolated to other countries where desalinated water gets subsidies. The company Acuamed, which owns many of the most important desalination plants in the areas where agriculture has a more relevant role,

belongs to the government. This public ownership means that farmers avoid having to pay the real cost of desalinated water, as at least 40% of it is assumed by subsidies. These subsidies, provided in order to reduce the cost of this water alternative for farmers, have deep economic consequences, as in 2018 Acuamed incurred direct losses calculated at EUR 582,000. Apart from increasing inequality amongst farmers who have their crops only a few kilometers away and need to use private desalination plants due to their location, this positive reinforcement is providing economic advantages only for some, for apparently no reason. In order not only to eliminate this imbalance, but also to promote the alternative that is more environmentally sensitive and cost efficient, iniquitous subsidies that result in losses of thousands of euros could be eradicated. Therefore, money once used for this purpose could be channeled into adequate infrastructure investment that guarantees an appropriate distribution channel from wastewater treatment plants to farms.

**Author Contributions:** M.J.L.-S.: Conceptualization, Methodology, Formal analysis, Investigation, Writing—original draft preparation, Writing—Review & Editing. J.A.A.-S.: Conceptualization, Methodology, Investigation, Validation, Writing—Review & Editing, Supervision. J.F.V.-M.: Methodology, Investigation, Writing—Review & Editing. I.M.R.-S.: Methodology, Investigation, Writing—Review & Editing. All authors have read and agreed to the published 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 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 the following collaborators for the helpful data provided for the present research: José Antonio Fernández Maldonado, Antonia García Marco and Carmen María Prieto Clares from Tierras de Almería irrigation association, José Antonio Pérez Sánchez from Cuatro Vegas irrigation association, Tamara María González Hernández from Coexphal and Ramon Gil Pérez from Grupo Cooperativo Cajamar.

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

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