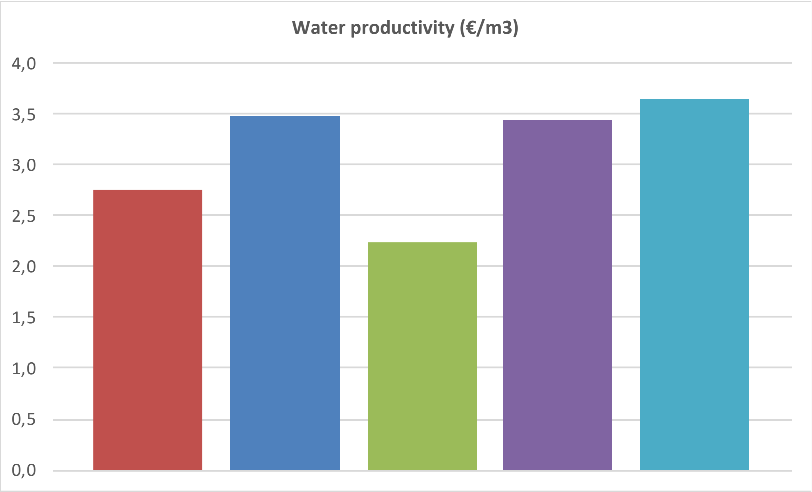
PROPOSAL LIFE 16-ENV-ES-000341

“DESALINATED SEAWATER FOR ALTERNATIVE AND SUSTAINABLE SOILLESS CROP PRODUCTION”



ACCIÓN C2. “Monitoring the socioeconomic impact of irrigation with desalinated seawater”

Deliverable C.2.2: “Comparative socio-economic assessment of the impact of the implemented agricultural practices on farm profitability and input productivity”

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Abstract

This deliverable presents the results of the assessment of the socio-economic impact of the use of desalinated seawater (DSW) for tomato production in soilless greenhouse cropping systems of the Almería province, based on the DESEACROP project's experimental activities. Results suggest that both the use of DSW and soilless production systems would increase the profitability of tomato in the study area. However, the materialization of the potential benefits of soilless production would require irrigating with better quality water resources through the increased use of DSW. Otherwise, the traditional soil production system, which is better adapted to the area's poor soils and bad quality water, would be more profitable. From the society perspective, the advantages of soilless production are ambiguous, as it increases both the use of very limiting productive resources (water and energy) and of CO_2 emissions without the resulting increase in production and job creation compensating it.

Resumen

En este entregable se presentan los resultados de la evaluación del impacto socio-económico del uso de agua marina desalinizada (AMD) para la producción de tomate en sistemas de cultivo sin suelo de la provincia de Almería, en base a los resultados de las actividades experimentales del proyecto DESEACROP. Los resultados obtenidos sugieren que tanto el uso de AMD como el cultivo sin suelo incrementarían la rentabilidad de la producción de tomate en la zona. Sin embargo, la materialización de los beneficios potenciales del cultivo sin suelo requiere de recursos hídricos de mejor calidad, lo que, en la zona de estudio, supone incorporar cantidades crecientes de AMD. En caso contrario, el sistema tradicional de cultivo en suelo, mejor adaptado a los suelos pobres y la mala calidad del agua de la zona, resultaría más rentable. Desde el punto de vista de la sociedad, las ventajas de la producción sin suelo son ambiguos, ya que se incrementa el uso de recursos limitantes (agua y energía) y las emisiones de CO_2, sin que el incremento de la producción y la creación de empleo lo compense.

Introduction

DESEACROP aims to promote more efficient and sustainable management of desalinated seawater (DSW) for tomato production in soilless systems in the area selected for demonstration. With that objective in mind, experimental activities in the project include different irrigation treatments using different types of water both in soil and soilless protected agricultural production systems.

C2 action aims to demonstrate that the implemented farming practices provide positive socio-economic and environmental impacts in the area of study. Major expected direct socio-economic impacts are: the increase in input productivity (water, fertilizers and energy) and resource use efficiency; the reduction of the environmental impacts of irrigation (use of water, fertilizers, energy and CO_2 emissions); the increase and improvement in the knowledge and training of farmers and technical consultants; and an increased potential for the diffusion of the proposed farming practices.

These potential impacts will be assessed within the action's two tasks:

- Task C2.1. Monitoring the social and economic implications.
- Task C2.2. Monitoring the impacts on the stakeholders' perceptions.

The main goal of these tasks is to demonstrate the positive socio-economic impacts of the innovative agricultural practices implemented and the increased potential for their diffusion at the local or regional scale based on adequate communication and dissemination activities. Consequently, task C2.1 focuses on the analysis of the socio-economic impact of the implemented actions, whereas task C2.2) focuses on the assessment of the impact of communication and dissemination activities. UPCT is the partner in charge of action C2, with the support of UAL and the input of previous actions, mostly B3 and C1.

Action C2 spanned from January 2018 to June 2020 and produced three deliverables. The present one presents the results for task C2.1 (Monitoring the social and economic implications).

Methodology of task C2.1

Task C2.1 consists on the evaluation of the socio-economic impact of the tested agricultural practices and technologies in terms of increased farm profitability, increased input productivity and resource use efficiency and increased productivity of the measured environmental impacts. This assessment is based on the calculation of different economic ratios and indices using: (i) primary data generated in the experimental actions B3 and C1; and (ii) secondary data from previous studies on crop production costs (conventional greenhouse and hydroponic systems) in the area of study and from agricultural statistical databases.

Data collection and codification process

The primary and secondary data collected was used to establish a technical-economic characterisation of the standard crop production processes and farming practices in terms of quantity and quality of production, input use, production costs, environmental outcomes, dynamics of the production process, etc. Such characterisation serves as a benchmark for comparison with the experimental plots where the different sustainable agricultural strategies will be tested.

The technical-economic characterization of the crops' production processes requires collecting detailed information on the different crop operations along the productive cycle. To obtain such information, crop operations are organised on a monthly basis, starting right after harvesting and ending in the harvesting of the following crop season, and per type of operations (ploughing, irrigation, fertilisation, weed and pest control, pruning, harvesting, etc.). Technical data from the experimental plots was collected by Patricia Marín Membrive from the University of Almería and codified by UPCT using an Excel spreadsheet developed ad-hoc by UPCT and is compatible with the technical-economic characteristics of the standard production processes identified.

Data collected on each crop's production process include: (1) quantity and quality of tomato production; (2) use of inputs such as fertilisers, herbicides and other agrochemicals, energy and irrigation water (type of input, quantity applied, hours/number of applications, price of inputs); (3) farm machinery used (type of machinery, crop operations, hours of use, fuel consumption, cost, etc.); and (4) labour (crop operations, working hours/days per operation, costs, etc.). CO_2 emissions for each water quality and productive systems have been taken from UPCT (2020).

Once all the data from experimental plots was collected, validated and codified, it was standardized to define a standard characterization of the crop production process, in order to allow for comparison between the different farming practices tested. Each production process was characterized in terms of the standard productive process, defined by the different crop operations on a monthly basis.

Experimental activities and productive strategies

Part of the data used in this analysis comes from the experimental activities in DESEACROP, which focus on the comparison of different sources of water and greenhouse tomato production technologies.

Two different production systems were considered (2018a):

- H: Soilless cultivation with recirculation of drainage flows, using coconut fibre substrate which is the most commonly used one in SE Spain protected horticulture;
- S: Traditional soil cultivation without the reuse of drainage flows that percolate to the subsoil;

Three different water supply sources were tested (UAL, 2018b):

- T1: Desalinated seawater (DSW) from the Carboneras desalination plant, 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.

Experimental plots were set up in a greenhouse located in Almería in SE Spain. The greenhouse is a traditional Almerian type greenhouse without heating and with automated natural rooftop ventilation. The experiment consisted of 18 demonstrative subplots with an area of 80.8 m^2 each with a plantation density of 2 plants per m^2. The experimental setting consisted of 6 repetitions per type of water (T1, T2 and T3), 3 of them for each productive system (H and S) on a random block design. Each repetition included 4 rows of plants with two additional rows in the borders of the repetitions to avoid possible border effects in the measurements.

Results in this report correspond to four short productive cycles of tomato (*Solanum lycopersicum L.*) carried out between September 2018 and June 2020, more precisely two autumn-winter cycles and two spring-summer cycles.

Socio-economic assessment of farming practices

The analysis of the collected data will be based on the calculation of social and economic indicators and ratios for the agricultural practices implemented. The objective is to assess the impact of the different farming practices on each crop's profitability and productivity. Such assessment will be based on the technical-economic characterization of crops' production processes. The technical and economic characterization of standard crop production processes will be the basis for the definition of the cost structure for each crop, following the methodology and cost items used by the Spanish Ministry of Agriculture (MAGRAMA, several years), in accordance with standards set for the European Farm Accountancy Data Network.

For the standardization of direct production costs, input market prices and average market product prices were used. Indirect production costs were calculated based on secondary sources of information (MAGRAMA, 2015; Junta de Andalucía, 2018; Calatrava and Martínez-Granados, 2019). Market crop prices were calculated as the average yearly price for each crop calculated using data from official agricultural database. The standardization of costs allows to reduce biases and variabilities resulting from differences in the prices of inputs and eases the analysis of water use and the comparison of different irrigation strategies. Once the standard production costs were calculated, the socioeconomic analysis was completed for the different productive cycles.

The social and economic indicators used focus on the analysis of the impact on crop profitability and input productivity of the different farming practices considered. More specifically, the indicators calculated are shown in **Table 1**.

Table 1. Indicators used in the analysis

ITEM	INDICATOR	UNITS	CALCULATION
Cost measures	Production cost	€/ha	Based on data from experimental plots following methodology in in MAGRAMA (several years)
	Unitary production costs	€/kg	Production cost divided by crop yield
	Unitary cost of major inputs (water, energy, etc.)	€/kg	Cost of input divided by crop yield
Productivity measures	Land productivity	€/ha	Farm revenue (crop yield multiplied by its selling price) divided by cultivated area
	Water productivity	€/m3	Farm revenue divided by irrigation water applied
	Labour productivity	€/day	Farm revenue divided by labour use
	Energy productivity	€/kWh	Farm revenue divided by power use
	Productivity per tonne of CO_2	€/t	Farm revenue divided by the balance of CO^2 emissions
Profitability measures	Crop gross margin per hectare	€/ha	Crop gross margin divided by irrigated area
	Farm net margin per hectare	€/ha	Farm net margin divided by irrigated area
	Gross margin per unit of irrigation water	€/m^3	Farm net margin divided by water use
	Net margin per unit of irrigation water	€/m^3	Farm net margin divided by water use
Social indicators	Labour use per hectare	Days/ha	Labour use divided by the cultivated area
	Labour use per unit of irrigation water	Days/m^3	Labour use divided by irrigation water applied
	Labour use per unit kWh	Days/kWh	Labour use divided by power use
	Labour use per kg of CO_2	Days/kg	Labour use divided by CO^2 emissions

First, cost measures were calculated based on the data collected on the crop's production process. Direct and indirect costs have been defined based on the crop production cost assessment methodology used by the Spanish Government (MAGRAMA, several years). The different cost items considered are expressed in per hectare values and in unitary values per kilogram of production.

Second, different relevant productivity measures were calculated, such as land productivity (revenue per hectare), water productivity (revenue per unit of irrigation water), labour productivity (revenue per unit of labour), energy productivity (revenue per unit of energy consumed) and total factor productivity (revenue/total cost).

Third, different crop profitability measures were calculated. In this report both crop gross margin and farm are presented. Gross margin was calculated by subtracting direct costs and labour costs from farm revenue, while farm net margin was calculated by subtracting direct costs, machinery costs, labour costs, indirect costs and asset depreciation from farm revenue, following the methodology in MAGRAMA (several years). Farm net margin still includes the opportunity costs of farm-owned inputs (unpaid family labour, land and capital), which are very case-specific and therefore difficult to estimate to compute the farm profit. Consequently, farm net profit is used as a proxy for farm profit (Ballesteros, 2000). Unitary profitability indices were calculated for both land and water inputs: per hectare gross/net margin and gross/net margin per unit of irrigation water.

Fourth, social indicators, such as labour use per input use (land, water, energy), were calculated to account for the social profitability of resources used in the production processes.

Last, the environmental impact in terms of CO2 emissions was consider through the calculation of a productivity measure (Crop productivity per kg of CO_2) and a social indicator (labour use per kg of CO_2).

These indicators allow to assess the social and economic implications of the analysed farming practices, which have also environmental implications, as a greater productivity of water of a higher use of labour per kg of CO_2 emitted imply a more efficient use of scarce resources.

Results

Table 2 summarizes the average values of the indicators calculated. In order to correctly interpret them, it is important to consider that the crop yields obtained in the experimental activities of the project are below normal tomato yields in Almería. This is due to the need to incorporate more than two productive cycles in the project’s lifetime, what led to the decision to plant four short productive cycles instead of two long ones. Additionally, the need to fit two tomato productive cycles in one year lead to finishing the crop’s harvesting before than usual practice in commercial farms, to give room and time for the preparation of the following experimental cycle. This has resulted in a lower annual average crop yield (11 kg/m^2) than the usual in the area that is 19 kg/m^2 per year according to Valera et al. (2014).

Average crop yields in **Table 2** show a positive impact of water quality and of the use of soilless productive systems. The increase in the average crop yields when passing from T3 to T2 is significant, while the difference between T2 and T1 is smaller. The increase in crop yield when irrigating with less saline water is significantly greater for soilless production with recirculation of drainage flows (H). 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 more technique nature of soilless cultivation. Traditional soil production systems in the area were developed to accommodate to poor soils and bad quality water resources and therefore yields are less affected by water salinity, which significantly reduces yields in soilless cultivation.

Cost measures

Both direct and indirect production costs are greater for soilless cultivation (H) than for traditional soil cultivation (S) and increase with the use of DSW (T1>T2>T3), as shown in **Table 2**. Differences in direct costs are explained by the higher cost of DSW, the higher water, energy and fertilizers consumption of soilless production (H) and the harvesting cost that depends on crop yield. The soilless production system has the advantage to avoid 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, crop yields also increase with soilless production. Differences in indirect costs are explained by the amortization cost of the substrate and the recirculation system.

Because of the above commented, 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. A similar pattern is observed when looking to the unitary cost of labour. On the other hand, the unitary costs of water, energy and fertilization are greater for soilless production (H) than for soil production (S). This is caused by the significantly higher consumption of water, energy and fertilizers in soilless production, despite of the greater yields that this productive system provides. However, the cost of these inputs is relatively small compared to other inputs such as capital and labour and are compensated, in general, by the higher crop yields that soilless systems provide.

Productivity measures

Table 2 first shows that both land and labour productivity are greater for soilless production (H) for water qualities T1 and T2. Again, results for T3 in soilless production are worse than in traditional soil production because of the above mentioned differences in crop yield. For each productive system, both land and labour productivities increase with water quality (T1>T2>T3).

Second, and because of the greater water and energy requirements of soilless production, both water and energy productivities are greater for traditional soil production. Again, for a given productive system, productivities increase with water quality (T1>T2>T3).

Table 2. Values of the indicators for the different strategies

ITEM	INDICATOR	ESTRATEGIES					
		H-T1	**H-T2**	**H-T3**	**S-T1**	**S-T2**	**S-T3**
Crop yield	Average crop yield (kg/ha)	66.438	64.375	44.675	55.378	54.311	47.353
Cost measures	Direct costs (€/ha)	39,837	39,712	37,458	36,577	36,494	35,280
	Indirect costs (€/ha)	11,897	11,897	11,897	10,158	10,158	10,158
	Total production costs (€/ha)	51,734	51,609	49,355	46,735	46,652	45,438
	Unitary production costs (€/kg)	0.7787	0.8017	1.1048	0.8439	0.8590	0.9596
	Unitary water costs (€/kg)	0.0169	0.0166	0.0169	0.0148	0.0138	0.0112
	Unitary energy costs (€/kg)	0.0173	0.0185	0.0239	0.0009	0.0009	0.0009
	Unitary fertilization costs (€/kg)	0.0415	0.0435	0.0591	0.0328	0.0348	0.0336
	Unitary labour cost (€/kg)	0.3509	0.3597	0.4813	0.4046	0.4109	0.4566
Productivity measures	Land productivity (€/ha)	55,458	53,736	37,292	46,226	45,336	39,528
	Water productivity (€/m^3)	23.60	22.01	17.06	27.03	26.58	25.82
	Labour productivity (€/day)	142.7	139.2	104.1	123.8	121.9	109.7
	Energy productivity (€/kWh)	5.34	4.98	3.86	108.12	106.31	103.28
	Productivity per tonne of CO_2 (€/tonne)	4.15	4.09	3.64	5.98	6.62	8.47
Profitability measures	Crop gross margin per hectare (€/ha)	15,621	14,024	-166	9,649	8,842	4,247
	Farm net margin per hectare (€/ha)	4,451	2,854	-11,336	218	-589	-5,184
	Gross margin per unit of irrigation water (€/m^3)	6.65	5.74	-0.08	5.64	5.18	2.77
	Net margin per unit of irrigation water (€/m^3)	1.89	1.17	-5.19	0.13	-0.35	-3.39
	Crop gross margin per power use (€/kWh)	1.50	1.30	-0.02	22.57	20.73	11.10
	Farm net margin per power use (€/kWh)	0.43	0.26	-1.17	0.51	-1.38	-13.54
	Gross margin per unit tonne of CO_2 (€/tonne)	1.17	1.07	-0.02	1.25	1.29	0.91
	Net margin per tonne of CO_2 (€/tonne)	0.33	0.22	-1.11	0.03	-0.09	-1.11
Social indicators	Labour use per hectare (days/ha)	389	386	358	373	372	360
	Labour use per unit of irrigation water (days/m^3)	0.1653	0.1581	0.1640	0.2183	0.2180	0.2354
	Labour use per kWh (days/kWh)	0.0374	0.0358	0.0371	0.8733	0.8721	0.9415
	Labour use per tonne of CO_2 (days/tonne)	0.0291	0.0294	0.0350	0.0483	0.0543	0.0772

Last, because of the greater energy, water and fertilizers consumption of soilless production, the associated CO_2 emissions balance are greater, what causes the productivity per tonne of CO_2 emitted to be significantly lower for soilless production. The productivity per tonne of CO_2 increases with water quality in soilless production, despite the increasing use of DSW, more energy demanding, because of the increases in crop yield that the use of better quality water allows. In the case of soil production, the productivity per tonne of CO_2 decreases with water quality because the resulting increases in crop yields do not compensate the increase in CO_2 emissions that the increasing use of DSW causes.

Profitability measures

With respect to the different profitability measures calculated, their interpretation must consider that some of them take negative values because of the above-commented lower-than-usual yields obtained in the project's experiments. For all profitability measures considered (land, water, energy and CO_2 emissions), profitability per unit increases with water quality (T1>T2>T3). All profitability measures are also greater for soilless production for T1 and T2 but the opposite for T3, because of the impact of low water quality of crop yields for soilless production (**Table 2**).

Social indicators

Turning to the social indicators that look at labour demand per unit of the different inputs, **Table 2** 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 labour 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 reduces labour use per m^3, per kWh and per tonne of CO_2 emitted with respect to conventional soil cultivation.

Conclusions

This report presents the results of the assessment of the socio-economic impact of the use of desalinated seawater (DSW) for tomato production in soilless greenhouse cropping systems of the Almería province. The results presented focuses on the analysis of the different strategies analysed in the project's experimental activities, which have compared the use of different water sources in both traditional soil and soilless protected agricultural production systems.

The main conclusions reached are:

- The use of DSW results in greater production costs but also in higher crop yields, as water salinity gets reduced, and in higher crop profitability.
- Soilless cropping systems are more intensive in terms of input use, especially water, energy and fertilizers, what results in higher production costs that are compensated by higher crop yields and higher crop profitability. However, crop yields and crop profitability when more saline water is used are greater for the traditional soil production system. The materialization of the potential benefits of soilless production in terms of crop yields and crop profit therefore requires the use of better quality water resources.
- The use of soilless production systems increases land and labour productivity with respect to traditional soil systems but result in lower productivities of water, energy and CO_2 emissions.
- All productivities calculated increase with the improvement in water quality through the increased use of DSW.
- The productivity of CO_2 emissions increases with water quality for soilless production, despite the increased CO_2 emissions that the use of DSW causes, but decreases for traditional soil production, as the increase in yields is not compensated by the increase in CO_2 emissions.
- The use of soilless production systems and DSW slightly increase labour use per hectare but reduce labour use per m^3, per kWh and per tonne of CO_2 emitted.
- Results are affected quantitatively by specific restrictions of the experimental setting that resulted in crop yields that are below average yields in the area, but still hold qualitatively.

To summarize, the results of the project's experimental activities suggest that both the use of DSW and soilless production systems would increase farm profitability in the study area. 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 bad quality water, would be more profitable.

However, from the society perspective, the advantages of soilless production and DSW are ambiguous. While the use of DSW improves input productivity and thus resource use efficiency, the use of soilless production systems reduces the productivity of water, energy and CO_2 emissions. If we look at labour generation, both soilless production and DSW generate less labour per water and energy use and per CO_2 emissions. The intensification of tomato production through the use of soilless production technologies increases the use of very limiting productive resources (water and energy) and CO_2 emissions without the resulting increase in production and employment generation compensating it.

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