Quantification of production inefficiencies as a cost-savings tool for increasing the viability of traditional olive farms

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Abstract

Just like any other businesspeople, farmers have to take decisions every day that are crucial for the survival of their farms. They often wonder "Is the structure of my farm competitive and sustainable in time? Should I expand its size or modify the management? And if so, by how much? However, in many cases they do not have the necessary information to take good decisions. In this paper, we develop a methodology to estimate the production costs of farms as a means of assessing the impact of several structural inefficiencies. In this way, we show how changes in farm management can reduce costs, so increasing farm sustainability. Results show that significant economies of scale can be achieved in production, and that downtimes, farm fragmentation and dispersion have a substantial effect on production costs and profit margins. Furthermore, through cooperative forms of production and management, traditional farms can become more sustainable, while at the same time fostering rural and territorial development.

Keywords*: Production costs, Farm structure, Smallholdings, Cooperation, Farm sustainability, Olive groves.*

1. Introduction

In a globalized world with a globalized market in which commodity prices are fixed at a worldwide level, producers must adhere to a model of competitiveness and efficiency in which it is vitally important to monitor production costs so as to ensure continuous improvement (Vargas-Hernández *et al.*, 2018; Dachin, 2016). The olive oil production sector is no exception to this rule. More efficient production models with lower costs are appearing all over the world, including intensive and super-intensive systems. These are marginalizing traditional farms, as happened in the past with cotton, vineyards and fruit trees (Barea Barea and Ruiz Avilés, 2009). This process of intensification and greater efficiency of production is not possible in all areas as it depends on the availability of water and natural resources, fertile soils, gentle slopes and production structures of sufficient size and limited fragmentation (Sanchez-Martínez and Gallego-Simón, 2011). Proof of this is that in all the olive oil-producing countries the vast majority of farms still follow the traditional model (IOC, 2015). As a

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result, there are numerous farms with a traditional management system, which have to survive in an increasingly demanding competitive environment and which are currently at risk of abandonment (Rocamora-Montiel *et al.*, 2014a; Lasanta *et al.*, 2016). Despite this, traditional olive farming remains the main source of economic, social, environmental and cultural wealth in the olive growing areas (CAPDR, 2017a) and the continuity of the traditional productive model is therefore essential for their survival. For traditional farms to thrive and compete, they must be managed more efficiently. In this paper, we analyse the production process in the traditional olive farming areas, so as to identify existing inefficiencies and propose alternatives that could help improve the competitiveness of these businesses. This improved competitiveness must go hand in hand with a concerted drive towards the economic and environmental sustainability of farming, given the increasing demands within society for sustainable agricultural production systems (Rocamora-Montiel *et al.*, 2014b; Capone *et al.*, 2021).

With this in mind, the first stage of our research was to identify the production costs on traditional farms and uncover the inefficiencies that make them unprofitable and ultimately unsustainable. In the specific case of olive oil production, previous research studies approached the question of calculating costs from two main perspectives. The first involved quantifying the costs by means of farm surveys. Although studies of this kind provide detailed information about production costs, they are sensitive to the particular decisions taken by the farmers that participate in the survey and the specific circumstances of each farm, so making the results difficult to generalize. Amongst these studies, the European Commission Report on Olive Farms (2012) compares the production costs of the three main EU producers: Spain, Italy and Greece. Results indicate that in all three Member States, high income is associated with large olive groves, a low input from family labour as a percentage of total labour, higher total direct payments and above all, high labour productivity. They also found that the economic situation of olive oil farms has been deteriorating significantly over recent years, especially due to low labour productivity. Other studies, at a national level, include those by the Ministry of Agriculture, Fishing and Food (MAPA, 2017), by the Regional Government of Andalusia (CAPDR, 2017b) in Spain and by the Institute of Services for the Agricultural and Food Market (ISMEA, 2012) in Italy. These studies found that farming costs were often higher than the sales price. They also confirmed the social importance of olive growing as a source of employment and the contribution made by family labour in ensuring the viability of traditional olive farms.

A second group of studies quantified production costs on the basis of expert opinions. These studies calculated the production costs for theoretical “representative” farms”, based on a previous classification of different cultivation models such as for example traditional mountain, traditional machine-workable, intensive and super-intensive farms. These studies include those by the Economic and Social Council of the Province of Jaén (CES, 2011), which has a provincial remit, the one by AEMO (2020) at a national level, and the one by the International Olive Oil Council (IOC, 2015) at international level. Apart from these studies, there are also research papers that quantify production costs by focusing above all on the change in the production model from a traditional to an intensive model (Ruz-Carmona, 2012) or by comparing them (Rodríguez-Entrena *et al.*, 2016; Vilar *et al.*, 2010). In some cases, their analysis is centred on just one kind of olive grove, as happens in the research by García-Brenes and Sanz-Cañada (2012) and Sánchez Martínez and Garrido Almonacid (2017), who focus on mountain olive groves. These studies reached similar conclusions in that they argued that it would be difficult for the traditional olive grove to remain viable unless it underwent profound structural changes, such as the intensification of olive farming, the search for alternative products with higher added value or significant changes in the management of the farms.

The main limitation of these studies is that their cost estimates do not cover the farm characteristics that have most impact on profitability, such as the size of the farm, the numbers, shapes and areas of the fields that make it up, how scattered they are (the distances between them), the downtimes in production and other aspects of farm management such as the unpaid work done by the owner or the technological and machinery pool available to them. As a result, they are of little practical value for farmers wishing to identify the changes they need to introduce to make their businesses more profitable. For example, even though in reality olive farms in Spain have an average size of 7.04 ha, the production-cost study by AEMO (2020) assumed a field size of 30 ha when pricing outsourced services, while the study by the Spanish Ministry of Agriculture was based on an average farm size in Andalusia of 33 hectares for irrigated olive groves and 39 for rainfed (MAPA, 2017).

Many studies worldwide analysed the relationships between farm size and production costs. Results are mixed and differ according to countries, crops and from one case to another. Some papers observed that small farms are more efficient than larger ones (Maqbool *et al.*, 2012); while others found that the relationship between size and efficiency is non-linear (Helfand and Edward, 2004), more complex than is normally believed (Nkengne, 2010) and positive, i.e. as size increases so does efficiency (Delord *et al.*, 2015). Nonetheless, in the case of olive growing, it has been demonstrated that significant economies of scale can be achieved, especially via an increase in size. In research on olive farms in Greece, Giannakas *et al.* (2000) linked the low level of technical efficiency with small size and extensive fragmentation; FAOSTAT (2014) observed that small farms (<5 ha) operate with losses, medium farms (5-50 ha) make small profits and larger farms (>50 ha) make larger profits. In Spain, Colombo *et al.* (2018) found significant economies of scale in production, especially in farmed areas of up to 30 ha.

Apart from size, the fragmentation of farmland increases production costs because it hampers agricultural mechanization, requires more intensive management and involves additional costs associated with the extra time and fuel required to travel between the fields (Latruffe and Piet, 2014). This was also observed in olive farming by Colombo and Perujo-Villanueva (2017a), who showed how land fragmentation reduces work efficiency along the edges of fields and by Perujo-Villanueva and Colombo (2017), who calculated the extra costs incurred due to the spatial dispersion of fields[1].

These aspects are often ignored in research on this question and may explain the mixed results obtained so far. When these aspects are omitted from the calculations, this could also lead to results that do not offer an accurate picture of the real situation and could cause farmers to take incorrect decisions.

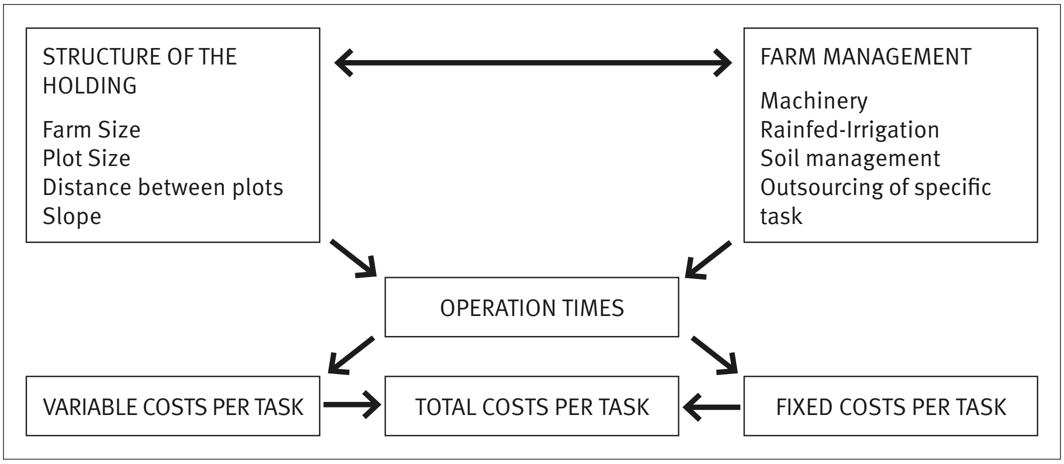
Owners of small farms are often unaware of the exact production costs they have to bear and take idiosyncratic, individualistic production decisions, principally on the basis of local uses and customs that have proved effective over time and in past experience. This makes it difficult for them to implement the changes required to make production more efficient, in spite of the fact that these changes may be fundamental for their survival, especially in a free-market production context in which the competition from larger, more efficient companies is putting the continuity of small farms at risk (Stringer *et al.*, 2020).

This paper has four main objectives. Firstly, it proposes a methodology for estimating production costs, identifying the impact of production inefficiencies in relation to farm size, farm structure (in terms of the number, shapes and areas of the fields that make it up and the distance between them), the downtimes in production and other aspects of farm management such as the unpaid work done by the owner or the technological and machinery pool available to farmers. Secondly, it quantifies in monetary terms the cost of possible inefficiencies in the different tasks involved in olive farming. Thirdly, it estimates the costs of more efficient alternative production methods, based on cooperation between farmers (Parrilla González and Ortega Alonso, 2022), which could enhance not only the profitability of the farm, but also its sustainability. Lastly, it discusses the results so as to enable the public authorities to design policies to incentivise the adoption of more efficient production systems on traditional farms.

The paper is structured as follows. We begin by

[1] Field fragmentation and dispersion also reduce the real estate value of the land belonging to a farm, so reducing the value of farm assets as a whole and therefore profitability as shown by Perujo-Villanueva and Colombo, 2021.

Figure 1 - Methodology used to calculate the costs involved in each task.



describing the methodology used for data analysis. In the next section, we outline the results, before going on to discuss their implications for private and public decision-making. We then bring the article to an end by setting out our conclusions.

2. Materials and methods

The flexible quantification of production costs requires a precise definition of the production process and the ability to vary all the parameters involved in line with the characteristics of each farm. To this end, we began by identifying the main tasks carried out by olive farmers in line with existing bibliography on olive groves (Barranco *et al.*, 2017). In our estimation of production costs, we adopted a new approach which involved calculating all the fixed and variable costs based on the time the farmer needs to carry out each production task. Our working hypothesis is that the time it takes to perform each task is a common variable to all farms regardless of their production structure. Thus, our proposed calculation method is based on relating the unit cost of the resources used with the time required to carry out the different tasks. Farms that are technologically more advanced, with better machinery and a more efficient production structure, can perform the different tasks more quickly than less mechanized farms with a fragmented, scattered field structure. Therefore, by quantifying the total production time (defined as the total number of hours worked over the course of the annual production cycle to produce the final product), we can determine the production costs in a comparable way across different farms and analyse how changes in the production process could reduce production times and therefore costs.

To this end, we designed a purpose-built tool (OlivGest)[2] which calculates the times involved in each task according to the structural characteristics (size, fragmentation, slope), production model (rainfed or irrigated), and management system (machinery and resources available, use of external labour and services, self-employment, administrative costs etc.) of each farm. It then uses these times to estimate the fixed and variable production costs as detailed in section 2.2. Figure 1 shows a diagram of the methodology used.

2.1. *Task times*

The time required to perform each task was initially calculated on the basis of the theoretical time it would take, assuming a situation of maximum efficiency. By means of a sequential process we then add to these theoretical minimum times, the

[2] OlivGest is a spreadsheet linked to a web interface where users can insert their own data to obtain individual production costs. We are currently finalising the web interface and access to the program is expected to be available to users by mid-2024, once program registration has been completed.

extra time incurred due to inefficiencies arising from the real production structure of the farms.

The theoretical production times represent the minimum time required to carry out task *i* in the theoretical situation of a long, perfectly straight field. In this case, the calculation is based on the speed at which task *i* is carried out and the width of the operation. It is calculated using the following formula,

$$TTi = \frac{10}{WSi*WWi} \quad (1)$$

where TT*i* (h/ha) is the theoretical time required to carry out task *i*, WS*i* is the Work Speed (km/h) and WW*i* is the Working Width (metres).

In practice, any farming task *i* will begin with an initial period of preparation of the necessary tools and machinery. This period must be added to the TT*i*. In general terms, this task will take the same time regardless of the size of the farm. This initial period is referred to as the Initial Operation Time (IOT*i*) and is measured in hours. Its impact on the time spent on the task per unit of area of the farm (IOTha*i*) can be quantified with the following formula,

$$\text{IOTha}i = \frac{IOTi}{\text{AF}} \quad (2)$$

In which AF is the Area of the Farm in ha. Clearly, the smaller the farm the larger the impact of this inefficiency.

Apart from the IOT*i*, there are various farming tasks that require certain specific actions in order for the farmer to be able to carry out or continue with the task. For example, during a phytosanitary treatment, the barrel must be refilled. Likewise, during fertilizing the farmer must stop to refill the fertilizer spreader. The time taken to perform each specific action is referred to as the Specific Operating Time (SOT*i*) and its value per hectare for a task *i* (SOThai) is calculated as follows:

$$SOThai = \frac{SOTi}{\text{AA}i} \quad (3)$$

where AA*i* corresponds to the Autonomy Area i.e., the maximum area (in ha) that the farmer can cover without having to refill for task i:

$$\text{AA}i = \frac{CCi}{\text{DOSES}i} \quad (4)$$

CC*i* is the Capacity of the Container (barrel etc.) used in task *i*, in litres or kg, and DOSES*i* is the amount of product (litres or kg) used per ha for task *i*.

These factors are then added together to produce what we refer to as the Initial Operation Time*i* (h/ha), i.e., the time required to carry out tasks regardless of the "physical" structure of the farm.

$$ITi = TTi + IOThai + SOThai \quad (5)$$

The fragmentation and shape of the fields have a negative effect on the time it takes to do each task, giving rise to inefficiencies due to the reduction of the working width at the edges. This is because in the centre of the field, farmers can drive their tractor between two rows of olives, treating both rows at the same time, while at the edge of the field only one row can be treated. Time is also lost every time the tractor has to turn, as it has to slow down. These inefficiencies have been defined as the Time Lost due to the Edge Effect (TLEE) and the Time Lost due to the Turn Effect (TLTE). The TLEE for task i, is calculated as follows:[3]

$$TLEEi = \frac{\sqrt{PS}*WWi}{50*PS} * TTi \quad (6)$$

where PS represents the plot size in ha.

The TLTEi depends on the Number of Turns (NT) and the time lost in each lap (TL), which is 0.0083 h/turn (IDAE, 2006). The formula used to calculate this for task i is:

$$TLTEi = NTi * TL \quad (7)$$

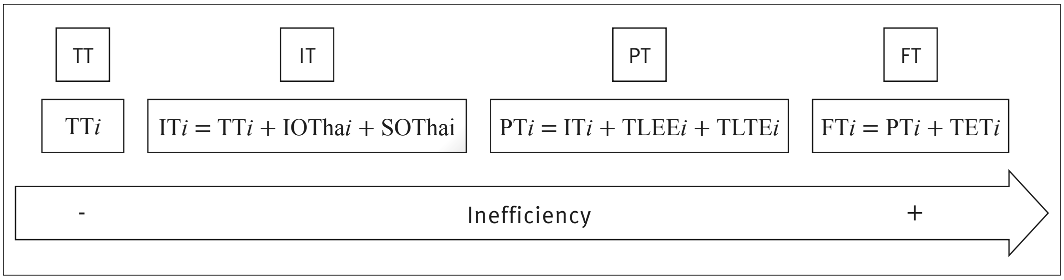
$$NTi = \frac{100*\sqrt{PS}}{WWi*PS} \quad (8)$$

By adding TLEE and TLTE to Initial Time, we obtain the Practical Time required for task i (PTi):

$$\text{PT}i = \text{IT}i + \text{TLEE}i + \text{TLTE}i \quad (9)$$

[3] Previous researchers have calculated the impact of this factor for different shapes of field (Gónzalez et al., 2007). However, in order to be able to make a more generalized calculation, we assumed a square-shaped field when estimating the TLEE and TLTE.

Figure 2 - Summary of the times spent on the various aspects of task *i*.



Another factor that generates inefficiencies in work time is the dispersion of the plots which make up the farm, due to the time spent travelling between the different fields. The impact of the travel time, or Transfer Effect Time (TET), is calculated as follows:

$$TETi = \frac{MTi * NMi}{DSi} = \qquad (10)$$

where MTi is the average time spent moving between fields (in hours) NMi is the number of movements made in one day and DSi is the maximum surface area covered in one day (Daily Surface area) when performing task i (ha).

If we add the time lost due to these movements between fields to the PTi, we obtain the Final Time for task *i* (FT*i*)

$$FTi = PTi + +TETi \qquad (10)$$

As a summary, in Figure 2, we present the different times obtained for task i.

2.2. *Calculation of the cost of each task*

The production costs for each task are obtained by taking into account the variable costs arising from the use of resources, labour costs, and the proportion of the fixed costs corresponding to it. By calculating the exact time that staff and machinery devote to each task, we can then establish the exact distribution of the fixed and variable costs involved in each task.

The fixed costs can be distributed between each task by calculating the costs per hour of the machinery used in each task. Depreciation of the machinery is calculated assuming that each machine has a functional timespan that can be expressed in years, (e.g., 20 years for a sprayer) or in the maximum use time (expressed in hours, e.g., 1000 hours for a sprayer). Both values were obtained from the machinery manufacturers and confirmed in interviews with farmers (Table 1). The fixed cost per hour of use was calculated by dividing the cost of the machinery by the time it is used, under the assumption that a machine is fully depreciated when it has reached the end of its functional lifespan. A tractor, for instance, is expected to last either 20 years or 12000 hours of use (Table 1). If it is used for more than 600 hours a year, it means that the tractor would be fully depreciated before the end of the maximum-use period (20 years). Thus, use time is important when calculating the depreciation period. If a tractor is used for less than 600 hours a year, full depreciation will be considered to have been reached at the end of its 20-year maximum functional lifespan. In this calculation, the real machinery-use time is considered, for which purpose the downtimes (initial periods of preparation (IOT*i*ha), the specific operating times (SOT*hai*) and the movement times (TET*i*) must be subtracted from the FT*i*, as there is no wear on the machinery when it is not in use. The sum of all these times of use of the different pieces of machinery pulled by the tractor indicates the time for which the tractor itself is used, a figure that can also be used to calculate the depreciation of the tractor.[4] When a farmer decides to outsource a particular task, the market costs are attributed directly to total costs.[5]

[4] As explained below, on small farms we assume that farmers use a 4x4 vehicle instead of a tractor.

[5] In this case, the time taken to perform the outsourced task is not added to the total tractor use time. This is an important fact to bear in mind in that it increases the cost of depreciation of the tractor.

Table 1 - Assumed purchase prices and functional lifespan of the machinery.

Machinery	*Purchase price*	*Functional lifespan*	
		Years	*Hours*
Suspended spreader	500.00 €	30	1000
Trailer 4 x 4	1,000.00 €	50	3000
Small sprayer 4 x 4	1,250.00 €	20	1000
Self-fed branch chopper	10,500.00 €	20	1000
Herbicide bar	1,000.00 €	20	1000
Brushcutter	2,000.00 €	20	1600
Sprayer	15,000.00 €	20	1000
Cultivator	3,000.00 €	50	3000
Disc harrow	11,000.00 €	50	3000
Drag	5,000.00 €	50	3000
Roll	3,000.00 €	30	3000
Branch vibrator	1,500.00 €	10	2000
Trailer + boom	6,500.00 €	50	3000
Shaker	18,000.00 €	15	2000
Tractor	50,000.00 €	20	12000
Blower	500.00 €	10	1000
Chainsaw	450.00 €	10	1000

The opportunity cost of the fixed capital was set at 0.40% of the value of the fixed assets. This was the interest rate payable on 10-year Spanish government bonds at the time of writing this paper (December 2021).[6]

When calculating the costs, it is also necessary to include other costs that are independent from the time spent in the production tasks, such as financial costs (interest payable on loans for the purchase of machinery), the costs of insurance and storage of the machinery and the administrative costs. These costs have been set according to the percentages stipulated on the website of the Spanish Ministry for Agriculture, Fishing and Food (MAPA, 2008). All fixed costs are divided by the area of the farm in order to calculate the costs per unit of area (€/ha).

As regards the variable costs, we used the average input and energy costs for the 2020/2021 season. The fuel costs are quantified on the basis of consumption according to the demand for fuel required at each point in the task, distinguishing between low demand (e.g., when driving between places) and medium and high demand (e.g., when pulling the plough). The cost of maintenance is calculated as a function of fuel consumption as specified on the website of the Spanish Ministry for Agriculture, Fishing and Food (MAPA, 2008). The labour costs are calculated by multiplying the cost per hour (as set out in the collective agreement for agricultural workers in Jaén for the 2020/2021 season) by the FTi. Finally, the costs of production inputs (fertilizers and phytosanitary treatments) are included by multiplying the doses by the respective market prices. The doses have been taken from Barranco *et al.* (2017) and from the Specific Regulations on the Integrated Production

[6] It is important to stress that between October 2021 and September 2022, the interest rate on 10-year Spanish government bonds increased from 0.34% to 3.4%, with an average of 1.87%. This increase would significantly affect the opportunity cost of fixed capital.

Table 2. The different tasks (annual frequency) assumed under the different soil management systems.

Tasks	*No Tillage*	*Minimum Tillage*	*Tillage*	*Ground Cover*
Fertilizer	1	1	1	1
Pruning and shredding the debris	0.5	0.5	0.5	0.5
Shoot removal	1	1	1	1
Pre-emergent herbicide application	1	1	1	1
Post-emergent herbicide application	2	0	0	0
Trimming	0	0	0	3
Cultivator pass	0	2	1	0
Disc harrow pass	0	0	2	0
Drag pass	0	1	1	0
Roll pass	0	0	1	0
Phytosanitary treatments[a]	2/3/4	2/3/4	2/3/4	2/3/4

[a] *For phytosanitary treatments we assumed three treatments on rainfed land and four on irrigated land for olive groves with slopes of less than 20% and two treatments for groves with slopes of over 20%, also referred to as non-machine-workable traditional olive groves (NMTO).*

of Olives, published by the Regional Ministry of Agriculture and Fishing of the Regional Government of Andalusia, 2008 (CAP, 2008).

2.3. *Working hypothesis*

In order to calculate production costs and assess how they vary in different production strategies, we analysed a range of different production scenarios, varying the size of the farm, the size of the fields that make it up and the soil management technique.

Our calculations involved all the following tasks: fertilizing the soil, phytosanitary treatments, soil management, pruning and removing shoots, irrigation (where applicable), olive picking, transport of the olives to the press, cleaning and pressing. In order to find out the time required to perform each task, we surveyed 60 farmers in the province of Jaen and consulted various experts. Data were gathered by means of face- to-face interviews by specifically-trained professional interviewers.[7] In addition to the values of the variables needed for the estimation of the TT, IT, PT and FT, we asked farmers about the "dead" times in their work, such as the time spent in the queue at the olive mill for pressing the olives, the time needed to refill the barrel or spent dealing with administrative issues, amongst others. The province of Jaen was chosen as the study area because it is the most important olive oil-producing area in Spain, singlehandedly accounting for 37% and 21% of Spanish and global olive oil production, respectively (CAPDR, 2017a). It is also worth noting that the province of Jaen by itself produces more olive oil than the entire output of the world's second largest oil-producing country, Italy (MAPA, 2018; IOC, 2018).

As regards soil management, we considered all the methods used in the olive groves according to a survey conducted by the Spanish Ministry of Agriculture i.e., untilled, minimally tilled, tilled and ground cover (MAPA, 2019). Table 2 shows the assumed number of tasks performed each year for each soil management method. For instance, one such task is the application of fertilizer, for which we assumed one application a year for all the different soil management methods. By contrast, post-emergent herbicides are only assumed in the no tillage management system, in which we assumed they would be applied twice a year.

[7] We stratified the survey according to size (<5 ha; between 5-20 ha; larger than 20 ha), fragmentation (less than 4 plots, between 4 and 8 plots, more than 8 plots) and dispersion (none, less than 3 km, between 3 and 8 km, more than 8 km).

The estimation of production costs was carried out by means of various simulations using different farm structures in terms of the size of the farm, the size of the fields, the use of irrigation, the degree of mechanization and technology available and the type of management (soil management, outsourcing of farming tasks, self-employment). This enabled us to calculate how these factors influence the production costs of representative farms. We then compared the results with alternative cooperative approaches to production that would enable farmers to reduce the inefficiencies in production time and therefore costs. In the analyses described in this paper, due to the wide number of possibilities available, we assumed that the olives were rainfed and farmed with minimum tillage, the most frequently used soil management method in the study area (MAPA, 2019). We also assumed an average field size of 0.6 ha, as this is the most common in the province (Parras-Rosa *et al.*, 2020) with an average distance between fields of about 800 m (Perujo-Villanueva and Colombo, 2017). Average production is 3500 kg of olives per hectare with an industrial yield of 20%, so obtaining 700 kg of olive oil per hectare. We established three different farm types, which could be considered representative of the majority of the farms in the study area:

- Type A. Small farmer, with a farmed area of between 1 and 20 ha. Uses a 4x4 to pull the machinery when carrying out the different tasks on the farm. Has a small barrel with a capacity of 600 L for phytosanitary treatments and herbicides, a small 600 kg trailer for transporting the olives and a branch vibrator for knocking them down. The shredding of pruning debris, the two cultivator passes and the drag pass are all outsourced.

- Type B. Medium farmer, with a farmed area of between 5 and 40 ha. Uses a tractor to pull the machinery, and a sprayer with a capacity of 3000 L for the phytosanitary treatments, a 2000 L barrel with a herbicide bar for the herbicide treatments and a branch vibrator for knocking down the olives with a team of seven pickers. Outsources the shredding of pruning debris.

- Type C. Big farmer, with a farmed area of between 10 and 80 ha. Has the same technology as the Type B farmer except for using a trunk vibrator to shake down the olives, a shredder for pruning debris, an additional tractor for the collection and transport of the olives and a team of ten pickers.

- Cooperative model. Under this system, a group of farmers voluntarily pool their resources (skill, land, capital) to create a larger, better-organized and better-connected business. This cooperation is based on either formal (written contracts) or informal (trust-based relationships) agreement and commitment between the cooperating farmers. It is assumed that the farm is managed with the optimum pool of machinery, in other words with a Type A structure for farms of up to 11 ha, Type B for farms of up to 20 ha, and Type C from then on. Thanks to cooperation between adjacent plots, the farm is divided into 3 ha plots. The soil management method involves ground cover and machine mowing, a form of management which seems likely to expand quickly due to the new eco-schemes introduced by the forthcoming Common Agricultural Policy (CAP). Lastly, we analyse how the increase in efficiency and the improvement in technology resulting from a change from farm Types A, B and C to the Cooperative Model would affect the quantity and the type of labour employed (farmer's own work vs hired labour). To do this, we estimated the total working hours required on the four types of farm and estimated the contribution made by the owner of the farm as a percentage of the total working hours. Assuming that the owner is a full-time farmer, if we subtract the number of hours done by the farmer from the total, the remaining hours of work gives us some idea of the number of external staff required.

3. Results

The total time spent on each field task is the sum of the theoretical tillage times and all the downtimes. Table 3 shows the theoretical (TT), initial (IT), practical (PT) and final (FT) production times per ha for a set of field tasks for the four farm types described above. All times are expressed in h/ha.

Table 3 - Field task times.

Field task	*Task time*	*Harvest*	*Cultivator (dragger teeth-)*	*Spring (tooth harrow)*	*Herbicide treatment (Sprayer)*	*Weeds treatment (Sprayer)*	*Spreading of Fertilizers*
FARM A	TT	16.667	0.348	0.286	0.333	0.333	0.667
AF=5 ha	IT	16.867	0.948	0.686	1.580	1.971	1.192
	PT	21.403	1.275	1.013	1.832	2.206	1.530
	FT	24.133	1.789	1.505	2.378	2.788	2.076
	FT/TT	**1.45**	**5.14**	**5.27**	**7.13**	**8.36**	**3.11**
FARM B	TT	8.333	0.348	0.286	0.388	0.200	0.200
AF= 20 ha	IT	8.658	0.498	0.386	0.722	0.568	0.550
	PT	11.043	0.825	0.713	1.054	0.810	0.768
	FT	12.059	1.339	1.205	1.571	1.283	1.279
	FT/TT	**1.45**	**3.85**	**4.22**	**4.05**	**6.42**	**6.39**
FARM C	TT	2.083	0.348	0.286	0.388	0.200	0.200
AF=50 ha	IT	2.213	0.408	0.326	0.602	0.448	0.490
	PT	3.001	0.735	0.653	0.934	0.690	0.708
	FT	3.816	1.249	1.145	1.451	1.163	1.219
	FT/TT	**1.83**	**3.59**	**4.01**	**3.74**	**5.82**	**6.09**
Cooperative Model	TT	2.083	0.348	0.286	0.388	0.200	0.200
AF=50 ha	IT	2.213	0.408	0.326	0.602	0.448	0.490
	PT	2.571	0.552	0.467	0.740	0.545	0.579
	FT	2.956	0.664	0.590	0.883	0.676	0.715
	FT/TT	**1.42**	**1.91**	**2.07**	**2.28**	**3.38**	**3.58**

In the table, if we look for example at TT, a variable that depends solely on the plantation framework and the speed at which the task is performed, we can see that the TT are particularly high in Type A farms. This is due to the technology used which slows the speed at which this task is performed. This also happens when it comes to harvesting the olives, in which Type C farms are more efficient than Type B because they use trunk vibrators instead of branch vibrators. As regards IT, the times vary depending on aspects such as the type of machinery used and the size of the farm. Machines with sprinkler nozzles require the most initial time due to the particular cleaning and maintenance they need. Another important variable is farm size in that the larger the farm, the smaller the impact per hectare of the time required for maintenance, as can be observed in the largest type of farm, Type C. In addition, there are certain farm tasks, such as ploughing, for which only minimum maintenance of the machinery is required and there are no specific task times. In these cases, the IT are similar to the TT, except in small farms where the reduced farm area has a significant impact on IT per ha.

By comparing the task times, we can identify the main factors that produce inefficiency in the different types of farm. For example, the differences in the IT in the phytosanitary treatments between small farms (Type A) and the rest lies in the small size of the barrel used on Type A farms, which must be refilled more frequently, so producing the respective downtimes during each treatment associated with each refill. For this reason, it is important on the one hand to use a barrel with the highest possible capacity so as to increase the area that can be treated without refilling (Autonomy Area), and on the other to have nearby water refill points, so as to reduce refill times to a minimum.

As regards PT, considerable savings were observed in the Cooperative Model due to the increase in the size of the field, which leads to a drastic reduction in the TLEE and TLET. This model also reduces the time wasted due to having to travel between fields. As a result, in the Cooperative Model with 3 ha fields, the FT is on average 51% lower than in Type A farms with fields of 0.6 ha. In general, the FT are much

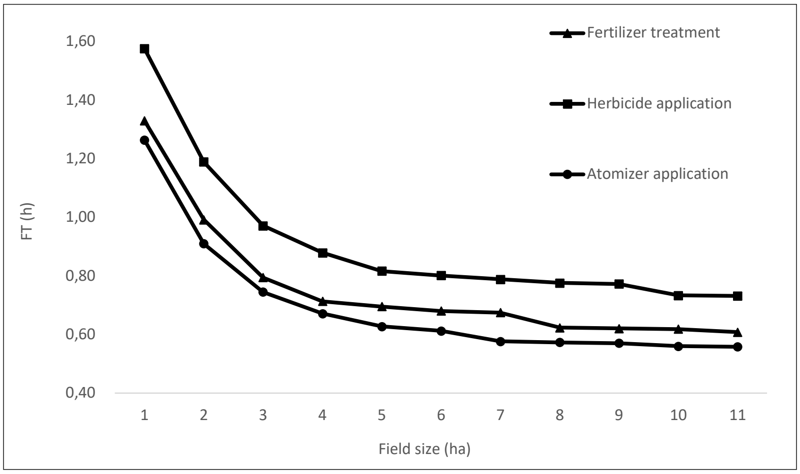


Figure 3 - Influence of field size on task times using a Type B farm of 20 ha.

higher than the TT, indicating that operational inefficiencies had a significant negative time impact on all the different farm tasks, so increasing the costs involved. It is also clear that to reduce task times, it will be necessary on the one hand to improve logistics in terms of access to the different production inputs (water, fertilizers, chemicals, etc.,) and on the other to reduce the fragmentation and dispersion of the fields.

Comparing the FTs allows us to analyse the marginal impact of different production structures and /or production inputs on production costs. Mediterranean olive groves are characterized by high levels of parcel fragmentation. Figure 3 shows the relationship between field size and final production time, using a Type B farm and three tasks (fertilizer treatment, leaf spraying and herbicide application) as an example.

Figure 3 shows that increasing the size of the plot always reduces task times, and in particular PT, due to the reduction in the time wasted by the field edge effect and the number of turns that have to be made due to the shape of the field. FT is also reduced by not having to move between small, scattered fields. Nonetheless, we can also see that the reduction in final task times is not linear and that fields of less than 3 ha are severely penalised. In particular, in terms of total operating time, on average it takes 0.36 h/ha (26%) less time to tend fields of 1 ha than it does to tend fields of 0.5 ha, while the difference between 1 and 2 ha fields is only 0.19 h/ha (19.0%) and between 2 and 3 ha it is 0.08 h/ha (10%). As field size increases up to 5 ha, time savings increase more slowly. The difference between 3 and 4 ha is 0.04 h/ha (6%) and between 4 and 5 is 0.02 h/ha (2%). Above 5 ha there is no significant reduction in average operational times. This suggests that small fields should be combined to increase their size, but at the same time there is little advantage to be gained from creating fields of over 5 ha. Furthermore, when calculating the ideal field size, other issues such as transaction, financial and fiscal costs also have to be considered, given that making larger fields requires several adjacent parcels to be joined together, either by acquisition or by joint management.

The increase in operating times caused by excessive fragmentation of fields has negative knock-on effects not only on the economy of the farm, but also on the environmental footprints due to increased fuel consumption and by extension CO_2 emissions into the atmosphere. Using a Type B rainfed farm as an example, a farm with fields with an average size of 3 ha rather than small fields of 0.6 ha, would consume 44.37 litre less diesel per hectare, so reducing CO_2 emissions by 123.79 kg/ha, assuming emissions of 2.79 kg of CO_2/litre according to data from Regional Government of Catalonia (Generalitat de Catalunya, 2011). In our study area, where olive groves stretch over 549,435 ha, this difference would enable savings of 68,016 tonnes of CO_2 per year. If the field size was 5 ha, the additional reduction in emissions compared to 3 ha fields would be 8,400 t of CO_2 per year.

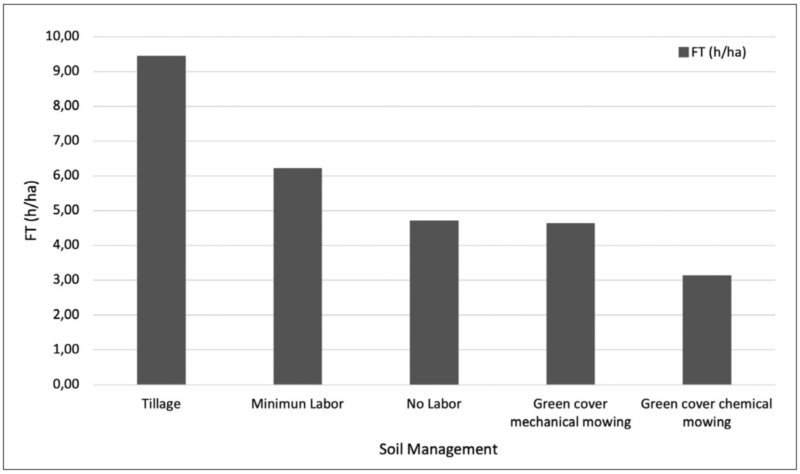


Figure 4 - Final Time as a function of soil management systems for a rainfed Type B farm of 20 ha.

In addition to the size of fields and farms, the soil management technique can also affect production times due to the different types and the number of tasks required (Table 2). In Figure 4, we compare the operating times for the main types of soil management for a rainfed Type B farm with 20 ha.

As can be seen, the operating times required for soil tillage are far greater than those for the other soil management techniques, of which the green cover technique requires the least operating time. This result is interesting given that green cover is not the most widely used form of soil management (MAPA, 2019), even though it is widely recommended in the bibliography (Barranco *et al.*, 2017). Furthermore, green cover management using mechanical means is associated with lower inputs and therefore cost savings. This is also the management system that provides most environmental benefits (Parras-Alcántara *et al.*, 2016; Gómez *et al.*, 2017).

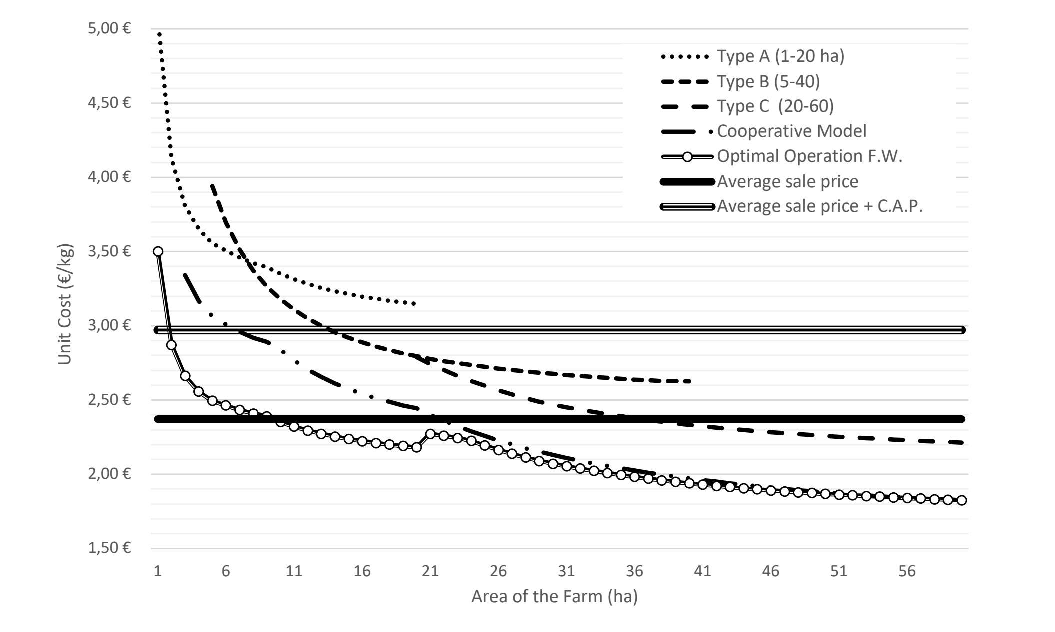
The influence of farm size on production costs can be seen in Figure 5, which shows the production costs for the 2020/2021 season, resulting from the three farm types described above and the Cooperative Model of farming. We also illustrate the production costs for the three farming models excluding the cost of family labour, due to its importance in the economy of olive farms. In this case, to simplify the representation on the graph, we use a single cost curve which indicates, for each surface area, the minimum production costs of the three types of farm being considered. In order to analyse the profitability of the crop, we used the average market price of olive oil in the area over the last 10 years, € 2.37 (POOLred, 2021) and the same price plus the contribution from the CAP subsidy.[8] The soil management system used is that of rainfed, minimum tillage, the most commonly used system in the study area.[9]

Various observations can be made. Firstly, the existence of economies of scale in production, such that production costs fall as farms become larger. For a given technology, production costs decrease as farms get bigger. Once a certain size is reached, it pays the farmer to invest in more sophisticated, more efficient machinery, that is better adapted to larger field sizes and reduces production costs even further. In this way Type A farms have the lowest costs up to 7 ha, Type B between 8 and 20 ha and type C from 21 ha onwards. This improvement in costs is achieved by increasing labour productivity and improving the

[8] The subsidy amount used is in this research was €0.60/kg oil. This value was calculated on the basis of payments made by the FEAGA (Spanish Agriculture Guarantee Fund) over the last year.

[9] In the case of irrigated land, the curves are very similar to those for rainfed land, albeit slightly lower due to the lower production costs per kg of oil produced. The graph for irrigated land, which was not included in this paper for reasons of space, is available on request from the authors.

Figure 5 - Costs of production of the different types of farms according to their size and soil management technique.



depreciation of the machinery. For example, if we compare Type A farms with Type C, there is a 52% increase in labour productivity, while the depreciation costs of a tractor in Type C farms are 47% lower than in Type B. Secondly, the importance of the CAP subsidy for maintaining the traditional olive groves. Without this subsidy only Type C farms of over 37 ha would make minimum profits, in that the production costs on smaller farms are higher than the average sale price of olive oil. Furthermore, the smallest farms (Type A) do not cover production costs even with the CAP subsidy. Thirdly, we observed that the reduction in fragmentation and the improvement in soil management techniques proposed in the Cooperative Model would enable farmers to reduce production costs in all farm sizes and would be profitable with a subsidy in farms of over 7 ha and without a subsidy in farms of over 22 ha. Fourthly, we noticed that cost savings decline sharply as farm size increases and are almost negligible when we go beyond 50 ha. In particular, when farm size is increased from 5 to 10 ha, the unit cost of production of 1 kg of olive oil is reduced by 0.076 €/kg of olive oil per additional hectare, and from 25 ha to 50 ha costs are reduced by 0.014 €/kg per additional hectare. This reduction gets progressively smaller until it becomes almost negligible in that if farm size were increased from 50 to 100 ha, the cost savings per additional hectare would be just 0.002 €/kg. Lastly, the importance of the farmers' own work in the profitability of their farms. When the salary costs saved by the farmer's own work are taken into account, production costs can be reduced significantly, enabling farmers to cover costs in small farms of over 2 ha if the CAP subsidy is included and over 10 ha if it is not. In this case, Type A farms have the lowest production costs up to 20 ha. This trend changes at 20 ha due to the change in technology, given that on farms of over 20 hectares it is impossible to continue producing with Type A technology because of the logistics required for harvesting the olives. Type B farms have lower costs up to 21 ha and from then on Type C farms have lower costs.

The increase in efficiency achieved with the increase in field size, farm size and improved technology reduces the FT of the operations and therefore the number of staff required. Table 4 shows the number of hours of work required on the different types of farm according to size (columns 2, 5, 8), separately displaying the hours

Table 4 - Total working hours as a function of farm size (FS), farm type and area.

FS	Type A			Type B			Type C			Coop.
	Total	Owner	% (Owner/ AWU)	Total	Owner	% (Owner/ AWU)	Total	Owner	% (Owner/ AWU)	Total
1	168	99	5%							
5	664	329	18%	525	184	10%				570
10	1,284	616	34%	1,023	341	19%				1,078
15	1,904	903	49%	1,521	497	27%				1,246
20	2,524	1,190	65%	2,018	654	36%	1,285	527	29%	1,652
25				2,516	811	44%	1,597	650	36%	1,180
30				3,014	968	53%	1,909	773	42%	1,408
35				3,511	1,125	62%	2,221	895	49%	1,636
40				4,009	1,282	70%	2,533	1,018	56%	1,865
45							2,844	1,141	62%	2,093
50							3,156	1,263	69%	2,321
55							3,468	1,386	76%	2,549
60							3,780	1,509	83%	2,778
65							4,092	1,631	89%	3,006
70							4,404	1,754	96%	3,234
75							4,716	1,877	103%	3,463
80							5,028	1,999	109%	3,691
85							5,340	2,122	116%	3,919
90							5,652	2,245	123%	4,147
95							5,964	2,367	130%	4,376
100							6,275	2,490	136%	4,604

worked by the owner of the farm (columns 3, 6 and 9) and these hours as a percentage of one Agricultural Work Unit (AWU).[10]

Changing the model of production leads to an improvement in labour productivity and therefore to a significant reduction in the amount of time the farmer will have to devote to farming (as a percentage of the AWU). 20 ha Type A farms require 20% more working hours than Type B farms and 35% more than Cooperatives. With one Agricultural Work Unit (AWU) a farmer can cultivate 14.4 ha in Type A farms, 18.5 ha in Type B, 28.7 in Type C and 39.1 in Cooperative farms. However, it is important to make clear that a single person cannot manage such large areas as there are certain tasks that require a team of workers. As a result, even if we assume that the owner of the farm is prepared to work full-time on the farm, he or she can only provide part of the necessary AWU and will also be able to do other work in addition to olive farming. In fact, the farm owner will only be fully employed on farms of over 72.7 ha. Moreover, assuming that on the different types of farms the same number of hours are spent in the field tasks (one AWU for instance), the percentage of the time worked by the farm manager will vary across the different types of farm, becoming smaller and smaller as the degree of mechanization - and thus the productivity of labour - increases. In Type A farms, the farm manager will devote 48% of his/her time, while in Type C he/she will devote just 39%. These results highlight the difference

[10] One AWU is equivalent to 1,826 hours, as worked over 228 8-hour days or 281 6.5-hour days (CAPDR, 2017a).

in the type of employment between large and small farms, with self-employment being most important on small farms and employed work on large ones. Olive growers with farms below the 72.7 ha threshold should be treated as part-time farmers and therefore only the time spent on olive production should be taken into account in the opportunity cost of their own labour. On the other hand, for those who consider themselves full-time farmers, the labour opportunity cost beyond the time actually spent on olive production should be considered zero. This last assumption could result in important changes in the interpretation of official statistics on olive production (for example, data from the Agricultural Accounts Data Network or the Agricultural Census).

4. Discussion and conclusions

Small traditional olive farms are vital for rural development and wellbeing in Mediterranean areas (European Parliament, 2014). However, the globalization of the olive oil market, the spread of low-cost, intensive plantation models associated with professional management systems and large capital investments threatens the survival of traditional olive-growing farms and thus the services provided by them. In this context, a more precise knowledge of the inefficiencies in production and how these vary across the different production systems can be a useful tool when it comes to analysing production costs. This in turn can help farmers identify possible sustainable alternatives that can help them survive. To this end, it is necessary to quantify how each inefficiency affects the production costs and how different production alternatives can reduce these costs.

In this paper, we develop a methodology with which to analyse the parameters affecting production costs in an independent way and quantify their economic impact on representative traditional olive farms, so improving farmers' decision-making capacity on the basis of more accurate information. At the same time, we propose alternative production systems that could enable small farms to become more competitive and sustainable.

The results highlight that inefficiencies in production due to downtimes, farm fragmentation and parcel dispersion have a highly significant impact on small olive farms, where real production times are far higher than theoretical production times. We also observed that these times can be reduced significantly with efficient management models, especially on small farms. These inefficiencies are linked to the preparation and maintenance of the machinery, and the time wasted in various tasks in small fields and in travelling between scattered fields.

We found that large farms are far more efficient than small farms due to their high labour productivity, achieved by using advanced technology and machinery. This improvement in productivity is the main trend driving the structural adjustment towards mechanization currently underway in the Mediterranean olive sector. To achieve this improvement, however, it is necessary to adapt the production system to the size of the farms and fields. When enlarging a farm, several important aspects must be considered. Firstly, the fact that field fragmentation and dispersion increase production costs. This suggests that the debate about farm size should focus on expanding both the total area of the farm and the size of each field. Secondly, the benefits achieved by increasing farm size and field size are most noticeable on smaller farms, while on farms of over 50 ha and fields of more than 3 ha, the increase in efficiency is almost negligible. The owners of olive farms should therefore take steps to expand their farms, while bearing in mind the diminishing returns above a certain size. Thirdly, farmers must incorporate the technology required for more efficient farming, given that each farm size requires a specific set of machinery to enable full depreciation during its life span. Improvements in technology enable improvements in productivity, significantly reducing the hours that must be worked on the farm. Fourthly, the improved economic performance of farms comes at a social cost. Results show that there is a trade-off between economic and social returns, as previously observed by Branca *et al.* (2016). In this case, increased economic profitability is achieved because less labour is required, although it must be stressed, as also found by Colombo *et al.* (2020), that this often leads to farmers reducing the number of hours worked by members of the family rather than cutting back on paid employees. The shift from family to paid work contributes to professionalize the sector, creating higher quality employment and increasing the overall competitiveness of traditional olive cultivation. In addition, the professional management of olive groves requires the use of new, more efficient technology and thus has the potential to create new indirect jobs in the agricultural service sector involving the sale and maintenance of the necessary machinery and equipment, such that the real total number of jobs lost is expected to be lower than might be forecasted. Finally, if the work is more mechanized, there is less need to recruit staff at the times of the year when demand for labour is highest (i.e. harvest time) and it is often difficult to find the necessary specialized staff.

The increase in efficiency and the use of better machinery with more advanced technology could increase the environmental sustainability of small farms by reducing CO^2 emissions, and via a more carefully controlled use of chemical products provided by more modern, more efficient application tools. The environmental footprint of olive groves can also be improved by adopting the "mechanical green cover" soil management system. Several research studies have shown that this system provides the best environmental outcomes in terms of the provision of ecosystem services (Parras-Alcántara *et al.*, 2016; Gómez *et al.*, 2017). It is also closely aligned with the requirements of the eco-schemes set out in the forthcoming CAP (European Commission, 2021). In this context, the joint management of adjacent fields can lead to improved environmental management of olive groves, due to the synergies arising from promoting the natural growth of green covers in adjacent plots. It also simplifies the switch to organic agriculture due to the reduction of the safe border limits that must be observed between fields with organic and conventional crops.

What does this mean for policies that seek to foster the competitiveness of traditional olive farms? Should governments subsidise investment in larger machinery, land acquisition, land consolidation or joint farming? Should farmers try to increase farm and field sizes? We acknowledge that there is no simple answer to these questions and that the response will vary according to the specific situation in each area, given that the possibility of increasing farm or field size will always be subject to a site-specific set of conditions.

The search for economies of scale and costs savings can be achieved by land acquisition, land consolidation or joint farming. If we start with land acquisition, the olive grove market is quite static and few sales take place. It is therefore unlikely that farmers can buy new land, especially adjacent to their farms where the benefits of economies of scale are maximized. Furthermore, by implementing policies that actively promote land acquisition (for instance by means of tax incentives), we run the risk of encouraging land grabs by large landowners (Van der Ploeg *et al.*, 2015). According to Aparicio *et al.* (2013), Andalusia is currently undergoing an acute phase of land concentration. In 2010, agricultural land concentration was 10 percentage points higher than in the mid-twentieth century, with 50% of the land in the hands of just 2% of farmers. This process is not so severe in the olive groves, although it is an important issue in that 23.14% of the land is owned by just 1.49% of farmers (Parras-Rosa *et al.*, 2020). Thus, policy makers should promote policies that incentivize the creation of larger farms while at the same time discouraging the concentration of land ownership and very large farms. The design of progressive tax regimes according to farm size could be an option worth evaluating. According to the results of this study, 50 ha could be used as a threshold for designing policies that aim to increase the profitability of traditional olive farms. Furthermore, the incentives should be designed to encourage the acquisition of adjacent parcels, so as to increase the sustainability of olive farming.

Land consolidation is another way of reducing parcel fragmentation and increasing the sustainability of the farms. This involves the reorganization of ownership so as to ensure a more efficient production structure. However, land consolidation is a complex, costly and sometimes controversial process, whose results must be carefully evaluated so as to avoid wasting public money. In the case of olive groves, previous attempts at land consolidation failed because farmers were not consulted before embarking on this initiative (Luo and Timothy, 2017). Furthermore, the olive groves in the study area are so heterogeneous that only a small percentage would be suitable for inclusion in land consolidation processes (Colombo and Perujo-Villanueva, 2019). Finally, land consolidation only enables a reduction in parcel fragmentation and does not increase farm size, so preventing the full benefits of economies of scale from being achieved.

Cooperative model joint farming is another alternative that can improve farm profitability by reducing land fragmentation and increasing farm size. The results of this paper clearly indicate that this is a win-win option that should be promoted by either public policies or private initiatives. One important benefit of joint farming is that farmers do not have to relinquish their rights to the land they own, thereby maintaining the link between farmers, the land, rural villages and the territory. The time savings provided by joint farming can also enable small farmers to consider other additional ways of supplementing their income from farming. This allows them to obtain an alternative source of income from other forms of economic activity. The fact that farms continue to be owned by large numbers of small owners, rather than being concentrated in just a few hands, enables the benefits to be spread further across rural society, so enhancing general rural welfare. Joint farming also promotes the sharing of ideas, encouraging innovation and the creation of social learning and social capital (Muhammad *et al.*, 2017), which enhance sustainable, resilient agriculture (Šūmane *et al.*, 2018). Despite the attractiveness of this farming system, there are several issues that must be considered in order for it to be implemented effectively. As Westerink *et al.* (2017) made clear: "The design of more effective collaborative governance arrangements requires spatial coordination across multiple farm holdings and collaboration among governmental and other actors, including, possibly, groups of farmers". Thus, efficient joint farming requires the fields to be connected, something that may be difficult to achieve due to the existing scattered property ownership system. Colombo and Perujo-Villanueva (2017b) showed that, in the case of traditional olive groves, it is likely that joining farms together would create a disconnected farm unless a large group of farmers take part. Second, transaction costs must be included in the production costs of group farming. Research has shown that transaction costs are an important factor discouraging farmers from participating in agri-environmental schemes (Mettepenningen *et al.*, 2009) and from joining cooperatives (Hernández-Espallardo *et al.*, 2013). Thirdly, efficient joint farming requires an investment in machinery and technology and acquisition of the skills required to use them (Jette-Nantel *et al.*, 2020). This means that, in order to yield optimum benefits, policies aimed at incentivising joint farming should be accompanied by measures that reduce the spatial dispersion of fields and the transaction costs arising from cooperation and incentivize farmers to use new technologies. Future studies should try to quantify the impact of these factors, which can impede farmers from grouping together, focusing above all on the institutional innovations required to put these initiatives into action.

In addition to these considerations on field and farm size, there are also various other factors that are important for reducing production costs and that farmers should bear in mind when trying to increase sustainability. These factors are related to the soil management techniques and the machinery/technology employed by farmers. As regards the soil management technique, the cheapest method is to use green covers that are controlled by mowing rather than by using chemical products. As regards technology, it is important that olive farmers have the right kind of machinery for the structure of their farm. Outsourcing of the different farm tasks should be preferred when the size of the farm does not enable sufficient use of the machinery for its efficient depreciation. For this reason, grants to encourage the purchase of machinery should be associated with their real use, so favouring those farmers or farmers' associations that can prove they have sufficient land.

This study has various limitations that must be borne in mind when interpreting the results. Firstly, it focuses on machine-workable traditional olive groves. The methodology we propose is valid for other forms of olive farming, although the times taken to carry out each task would need to be adjusted. In this case, it is expected that the olive groves that cannot be machine-worked would not achieve such significant cost savings as those observed in this paper, due to the limitations on the use of machinery that would increase productivity. In intensive olive groves, the methodology is transferable and future research should analyse the increase in profit margins and the sustainability offered by cooperative management systems. It is important to make clear that the methodology can also be applied in other crops and farming contexts. It is particularly applicable to other perennial crops, which tend to have a more rigid production structure than annual crops. Secondly, the calculation of the inefficiencies arising from fragmentation was performed by assuming that the different fields that form part of a farm have the same dimensions and are square in shape, this being the most favourable situation. In reality, however, fields have different shapes and sizes, a fact that adds more time inefficiencies. This means that the times and costs associated with fragmentation are slightly underestimated in this paper. Finally, it is important to remember that input prices and indeed financial costs may vary significantly over time. In this paper, we used input prices for the 2020/2021 season and the interest rate payable on 10-year Spanish government bonds at the end of 2021 because they were representative of the input prices and financial costs for the five years prior to writing this paper. Thus, the production costs obtained represent an average situation that may not be extrapolated to campaigns where either input prices or financial costs differ significantly from the average.

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