The socio-economic impacts of organic and conventional olive growing in Italy

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Abstract

Olive growing is the most important agricultural activity in Italy, representing, in 2010, 56% of Italian farms and 76% of land used for permanent crops. Producing high-quality products, such as healthy and socially responsible produces, while containing costs, is the current market challenge, and evaluation tools are of utmost importance to help farmers shaping management practices to obtain competitive products. This study applies Life Cycle Costing (LCC) and social Life Cycle Assessment (sLCA) as evaluation tools to compare the socio-economic impacts of organic and conventional farming systems of the Italian olive growing. Results showed a similar level of economic profitability in both scenarios, due to the public subsidies for organic farming, which balanced higher production costs. From a social point of view, some differences have been highlighted: organic farming would be suitable not only to increase incomes but also to improve the occupational health of the people involved.

Keywords: *Olive growing sustainability, Italy, Life Cycle Costing, Social Life Cycle Assessment, socio-economic evaluation.*

1. Introduction

The worldwide production of olive oil during the period 2017-2018 is estimated to be over 3 million tons.

In Mediterranean regions, olive growing is the principal responsible for the maintenance of rural economies: in 2010, it represented the 56% of Italian farms and the 76% of land used for permanent crops (ISTAT, 2012), as showed in Supplemental Material 1. However, many difficulties can affect the sector's socio-economic performance, which may depend on the planting system (traditional or intensive), the productivity, the level of mechanization, the investments, and the management costs (Bernardi *et al.*, 2016, 2018; Strano *et al.*, 2014; Mele *et al.*, 2018).

Moreover, modern markets are requesting more performing products, to satisfy conscious consumers and their growing demand for healthy, safe and quality products.

This rising wave of green and socially responsible consumerism offers a huge market opportunity for farmers and entrepreneurs to carry out sustainable business: olive growers should exploit these new markets by assuming socially responsible management practices and reducing the environmental impacts of their processes (Viswanathan and Varghese, 2018).

Balancing profitability while reducing envi-

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ronmental impacts and enhancing social performances is of utmost importance, and it requires suitable tools for farmers to organize and manage their business to reach these purposes (De Luca *et al.*, 2017).

Producing green and socially sustainable produces while maintaining the profitability is a challenging task for farmers: it entails catching consumers' needs, preserving the environment, paying attention to workers' wellbeing in the working environment, by adapting or modifying managerial and organizational features.

The aim of this study is to assess the socio-economic sustainability of the Italian olive growing sector, by comparing organic and conventional farming systems with the evaluation methodologies are Life Cycle Costing (LCC) and social Life Cycle Assessment (sLCA).

Results will provide information about the actual social sustainability (in terms of health risks) and profitability (in terms of costs) of organic and conventional oil olive growing systems and verify the suitability of life cycle methodologies to make managerial choices among farming systems. Environmental assessment is here excluded because the organic farming is generally less impactful than conventional one (Notarnicola *et al.*, 2004; Mohamad *et al.*, 2014; Salomone *et al.*, 2015; Romero-Gámez *et al.*, 2017), especially when impacts are measured per unit of land than per unit of output (Clark and Tilman, 2017; Meemken and Qaim, 2018).

The economic evaluation has been carried out through the application of Life Cycle Costing (LCC) method complemented with further economic indicators: this allowed to take into account all costs and revenues factors of investments incurred within the time boundaries considered. Social impacts have been assessed through a social Life Cycle Assessment (sLCA) in terms of social health, i.e. the possible impacts on those people that are directly involved in the life cycle, such as workers, farmers, experts, employees, laborers. Social impacts are caused both by the very nature of the productive process and by farms' responsibilities (organizational choices, managerial decisions, and internal policies) (De Luca *et al.*, 2015). Impacts here are assessed in terms of psychosocial risk factors (Silveri *et al.*, 2014; Iofrida *et al.*, 2019), i.e. the hours of potential exposure of workers to working conditions that can lead to health problems, measured in odds ratio (OR). Occupational diseases and injuries are considered one of the principal cause for working absences and compensation costs, representing, therefore, a real socio-economic issue for all actors involved (Chang *et al.*, 2016).

2. Theoretical background: Life Cycle Costing and social Life Cycle Assessment

Sustainability became the catchword of academic research in the last decades. This is mainly due to the growing interest of consumers, entrepreneurs, politicians and many other private and public actors in reduce human impacts on natural resources. Environmental sustainability is not the only concern: economic and social consequences of anthropic activities are felt as important to satisfy social necessities and human well-being.

Life Cycle Thinking (LCT) tools stand out for their ability to prevent burden shifts by considering all phases of the life cycle of a product, from planning to disposal or reuse (De Luca *et al.*, 2015). Organic production is widely recognized for being less impacting; therefore, this study implements a Life Cycle Costing (LCC) and a social Life Cycle Assessment (sLCA) to the case study. The first tool is aimed at the accounting of every cost generated all along the functioning of the life cycle, allowing a long-term evaluation of the cost-effectiveness (ISO, 2008; Stillitano *et al.*, 2016). The second one, is the most recent and controversial methodology among this family of evaluation tools; indeed, it is striving to reach consensus on many issues, such as the purposes of the assessment, the source of impacts to be considered, the impact assessment method and the epistemological bases underpinning the methodological choices (Iofrida *et al.*, 2018). The present study applies a Psychosocial Risk Factors (PRF) pathway (Gasnier, 2012; Silveri *et al.*, 2014; Iofrida *et al.*, 2019), that allows predicting damages on health on the workers directly involved in the life cycle of a product. Decent work, especially in agriculture, has been among the goals of international organizations (such as ILO, the International Labour Organization) and policies; indeed, many conditions can threaten the safety of workers, in terms of ergonomics, exposure to hazardous products, diseases and accidents, and psychosocial risks. Concerning these last, one of the most diffused definitions describes PRF as "those aspects of work planning and management – and their relative social and environmental contexts – that can potentially lead to physical or psychological damages" (Cox and Griffiths, 1995, p. 69).

Until now, few studies have focused on olive production systems applying LCC (De Gennaro *et al.*, 2012; Ramez *et al.*, 2014; Notarnicola *et al.*, 2004; Stillitano *et al.*, 2016, 2018) and only De Luca *et al.* (2018) integrated more life cycle tools to the olive growing sector, i.e. LCA and SLCA.

Based on the results of previous research (Stillitano *et al.*, 2016, 2018), this study represents a further development by assessing the social and economic impacts of Italian olive growing in the study area of the Plain of Lamezia Terme, in South Italy. Plains are commonly preferred for agricultural activities: in fact, in this kind of areas, it is concentrated the highest percentage of Calabrian olive orchards. In particular, the aim is to compare organic and conventional olive growing practices, to highlight differences in terms of long-term profitability and impacts on workers' health.

3. Italian olive growing

Statistical data about the characteristics of the olive growing sector, as well as planting densities, yields, market prices were retrieved from on-line agricultural database.[1]

According to the sixth Italian agricultural census (ISTAT, 2012), olive growing is the principal cultivation among permanent crops (47%), and the second most important cultivation in Italy, after cereals, with a surface of 1,12 million hectares (9% of Utilised Agricultural Area) and 902,075 farms producing olive oil and olives for fresh consumption. Concerning these latter, they represent only 1% of the total olive growing surface, confirming that olive oil is the principal produce.

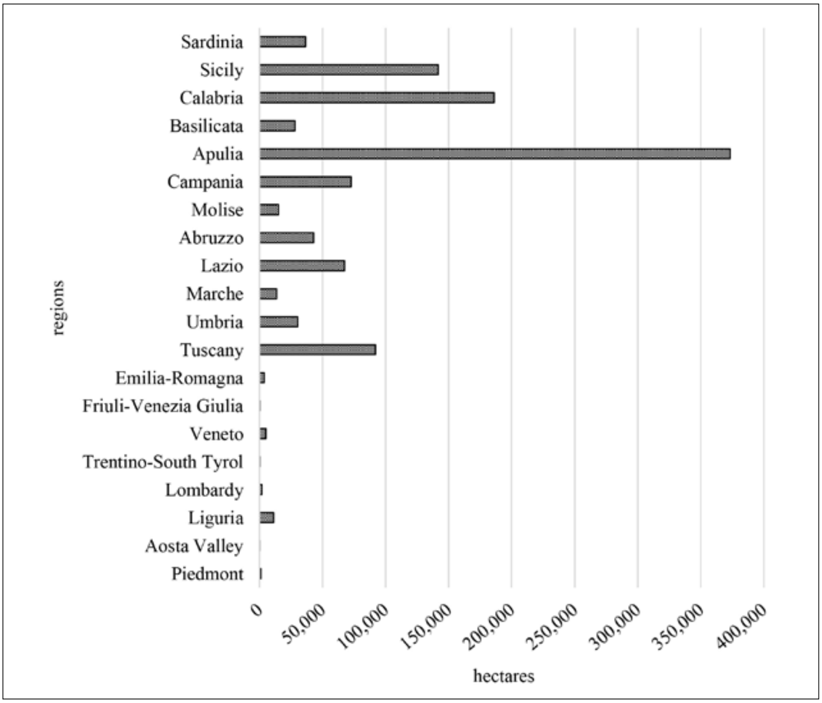
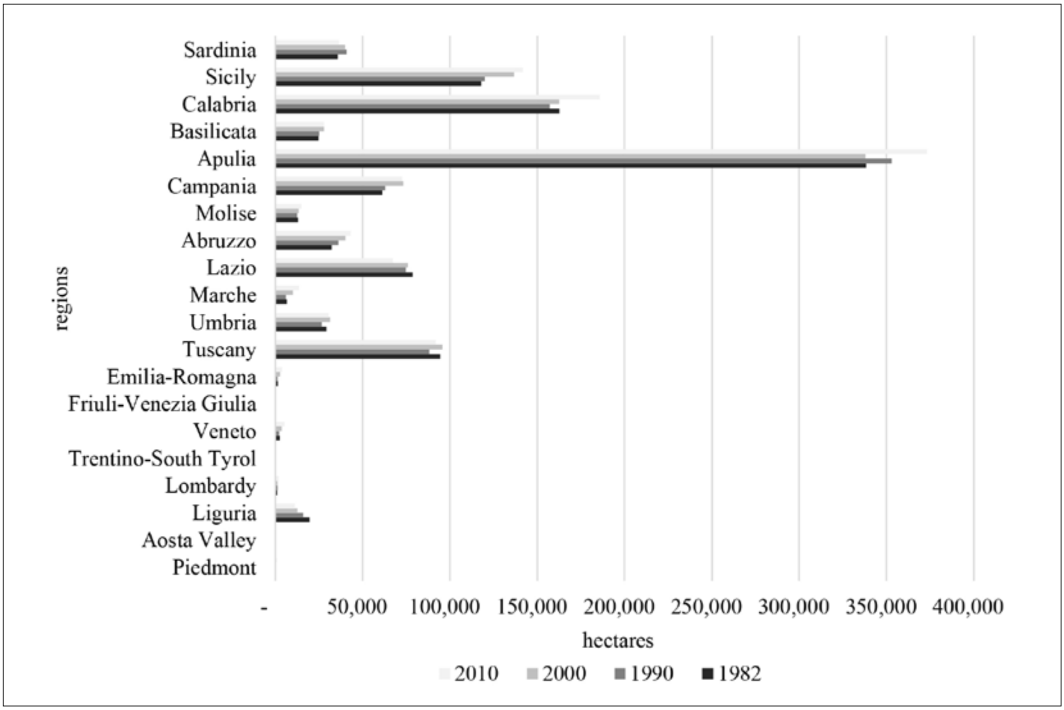


Figure 1 - Italian olive growing surfaces (ISTAT, 2012).

[1] http://dati-censimentoagricoltura.istat.it; http://www.sinab.it/content/bio-statistiche; http://www.ismea.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/9429.

Figure 2 - Olive groves trends, years 1982-2010, hectares (ISTAT, 2012).



As illustrated in Figures 1 and 2, the production is concentrated in the South: Apulia is the leading producer, both in terms of surfaces (33% of national production), followed by Calabria and number of farms, followed by Sicily.

In terms of topography, 61% of olive orchards are located in hilly areas, 29% in plains, and 11% in mountains (ISTAT, 2012); just in Apulia, this trend is different, where most of the orchards are located in plains, due to the orography of the region.

Concerning the trends of olive groves surfaces, in a 30-years period, i.e. from 1982 to 2010, olive growing farms decreased of 14%, while surfaces dedicated to olive orchards increased of 10% at national level, going against the overall Utilised Agricultural Area, that loosed almost 3 million of hectares in the same period (ISTAT, 2012). In absolute terms, Apulia, Calabria, and Sicily are the regions where the olive groves surfaces have grown the most, while Lazio, Liguria and Tuscany are the only regions that lost hectares of olive orchards (Figure 2).

Concerning the productivity, Table 1 shows the trends of oil olives harvested in the period 2006-2018: the overall production decreased at national level, except in the North and Central Italy, with Friuli-Venezia Giulia as the region with the higher increase of production.

According to the 6th Italian agricultural census (ISTAT, 2012), in 2010, organic farming represented 12% of the Italian olive growing surfaces, with the highest percentages in Calabria (24%), Basilicata (17%) and Umbria (14%). In absolute values, the surfaces of organic oil olive groves (Figure 3) were 234,762.02 hectares in 2017, with an increase of 112,913.19 hectares (i.e., +93%) compared to 2010 (Sinab, 2017). The increase of organic farming systems is due not only to new market trends but above all to the European subsidies, which have exactly the purpose of promoting and fostering the production of high quality produces.

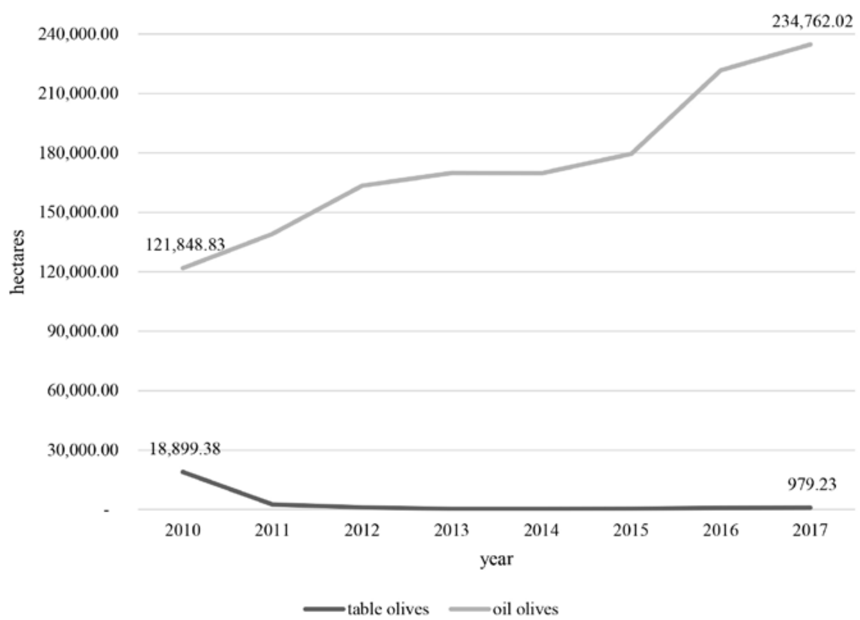
In the last decades, organic agriculture has gained a growing interest among consumers, concerned with healthier food consumption, and producers, attracted by new markets and positive demand trends. The consumption of organic products (all products) increased of +10,5% in 2018, maintaining a positive trend since dec-

Table 1 - Oil olives harvested in the period 2006-2018 (quintals).

Region	*2006*	*2010*	*2014*	*2018*	*2018/2006*
Piedmont	437.00	733.00	1,109	1,222	180%
Aosta Valley	0	0	0	0	0%
Lombardy	45,439	60,651	20,020	49,996	10%
Liguria	211,906	202,480	102,800	229,200	8%
Trentino-Alto Adige	10,899	16,333	16,825	28,000	157%
Veneto	86,833	73,012	127,540	243,705	181%
Friuli-Venezia Giulia	2,285	1,847	2,094	14,500	535%
Emilia-Romagna	56,907	56,567	32,553	72,112	27%
Tuscany	1,245,581	1,290,408	507,953	1,192.186	-4%
Umbria	877,718	624,117	223,442	374,888	-57%
Marche	256,736	291,170	112,765	169,597	-34%
Lazio	1,681,618	1,797,650	606,910	863,450	-49%
Abruzzo	1,406,773	1,255,100	682,423	1,215,400	-14%
Molise	458,550	402,000	365,728	570,600	24%
Campania	1,865,334	2,444,455	846,473	939,203	-50%
Apulia	11,988,125	10,053,610	7,844,600	5,616,560	-53%
Basilicata	359,506	368,000	326,877	295,573	-18%
Calabria	10,196,812	8,196,988	4,466,975	3,893,412	-62%
Sicily	2,320,732	2,939,569	1,898,965	1,993,438	-14%
Sardinia	469,362	406,720	350,586	303,400	-35%
ITALY	33,541,553	30,408,398	18,536,638	18,066,442	-46%

Source: our elaboration on http://agri.istat.it/

Figure 3 - Trend of organic olive groves in Italy in the period 2010-2017.



ades; among cultivations, organic olive groves increased by +23,7% in 2018 (Coldiretti, 2018).

Therefore, basing on official statistics, it is outlined that: (i) the conventional farming system is the most diffused among oil olive growers; (ii) the organic farming system is expanding at national level; (iii) oil olives are the most cultivated ones; (iv) the olive groves (farms and surfaces) are mainly concentrated in the South of Italy. Relying on these premises, the purpose of this study is to compare the socio-economic impacts of two of the most representative scenarios of Italian olive growing sector, i.e. organic and conventional farming systems.

4. Research design and scenarios

The aim of this research is to compare organic and conventional olive growing in Italy, in terms of economic and social impacts. To the purpose of this work, two average scenarios have been created, taking into account both statistical data above mentioned and primary data about farming operations (soil management, mechanization, yields, cultivars, pruning and harvesting, local price of olives), gathered by means of a web-questionnaire launched on social networks, to verify eventual differences and to design an average scenario.

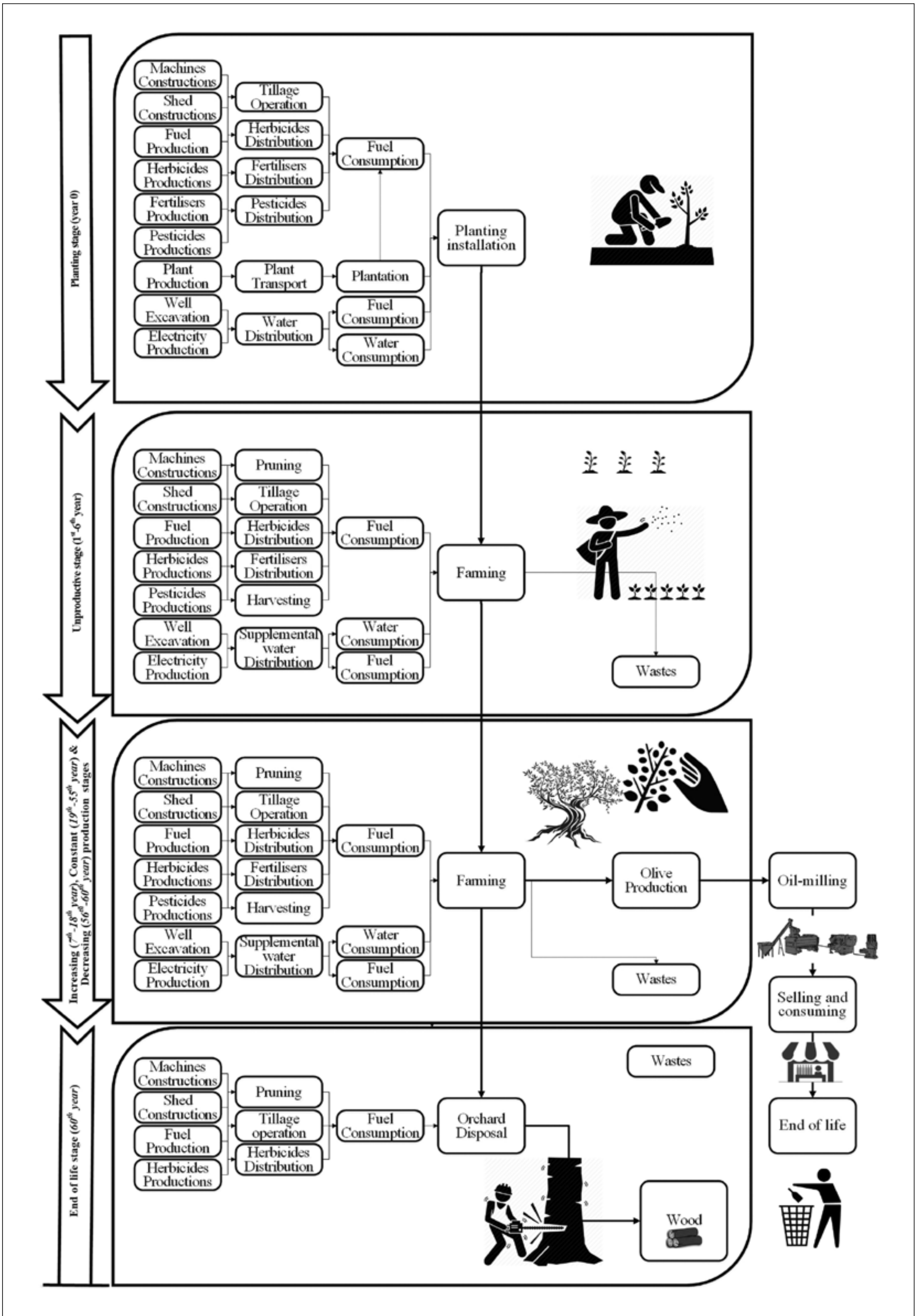
The first scenario is represented by conventional olive growing (COG), characterized by the use of chemical fertilizers, herbicides (glyphosate) and pesticides (especially organophosphates), and mechanized soil management. The second scenario is represented by organic olive growing (OOG), characterized by the use of organic fertilizers, mechanical weeding, low impact pesticides (according to EU recommendations), and mechanized soil management. Both scenarios are referred to a surface of one hectare: the national average is 1.25 ha (ISMEA, 2013) and, even if organic cultivations have usually a higher surface, to simplify the evaluation the functional unit has been approximated to 1 ha. Farming tasks have been referred to the most common operations due in hilly areas, where 61% of Italian olive growing is located. Concerning pruning and harvesting, time, volumes of wood and yields mostly depend on the cultivar and planting distances. Thanks to a wide biodiversity, Italy counts hundreds of cultivars with different characteristics; to the purpose of this paper, the cultivar 'Frantoio' has been taken as example to account farming tasks.

For both scenarios, a lifetime of 60 years was taken into account considering that olive trees reach maturity after 50 years, and the average age of Italian olive groves orchards is between 80-130 years, but intensive techniques usually reduce the lifespan of orchards (Fiorino, 2003). The system boundary is limited "from cradle to farm gate", therefore transport, olive-pressing, retail, and consumption are excluded (i.e. the agricultural phase of olive production is considered).

Being the assessment made by means of average scenarios, some assumptions have been necessary. Average technical data have been taken into account for farming operations (typologies and duration), considering data from literature, web surveys and questionnaires conducted for previous studies (Bernardi *et al*., 2018; Stillitano *et al*., 2018; De Luca *et al*., 2018; Guarino *et al*., 2019). Primary data were collected from the field through a semi-structured questionnaire using SurveyMonkey® submitted to a group of professional and amateur olive farmers on a social network, obtaining answers form all the Italian regions (61 filled questionnaires). The questionnaire consisted of both structured and open-ended questions on orchard structure (e.g. cultivar, planting density, and tree's age), farm inputs (typologies and quantities of agricultural inputs); machinery and human labour (frequency and hour of work), farm production (olive yield). Averaged data has been used to design the scenarios models to be compared and to build the inventory for the application of LCC and SLCA.

From an economic perspective, a Conventional LCC (Ciroth *et al*., 2016) based on cash flows model (ISO, 2008) was applied. For the purpose of this study, the olive orchard life cycle was divided into six main stages: (1) planting (year 0), (2) unproductive stage (from the 1st to the 6th years), (3) increasing production (from the 7th to the 18th years), (4) constant production (from the 19th to the 55th years), (5) decreasing production (from the 56th to the 60th years), (6) end of life (60th year). In the first step of the analysis, all costs and revenues throughout the

Figure 4 – Flowchart.



life cycle of each scenario were inventoried. All costs have been accounted, organized in initial investment costs, operating costs during the production stage and disposal costs were analysed. The total cost was accounted by its variable and fixed components. Within variable costs, fertilizers, pesticides, herbicides, fuel and lubricants consumption of machinery ownership, the rental cost of machinery for trenching, holes diggings and trees extirpation, human labour cost for field operations, outsourced cost items (e.g., expert consultancies) and interests on advance capital were accounted. Fixed costs comprised ownership costs of machinery and equipment (i.e. depreciation, insurance, repairs, and maintenance), rent for land use, interests on capital goods, taxes and administration overheads. Lastly, the total revenues were evaluated multiplying the olive yield by its market price, including EU direct subsidies. We collected the oil olive prices in the Italian market from the Italian Services Institute for the Agri-food Market (ISMEA), referred to the 2011-2012 harvesting season. Then an average price equal to 0.50 € kg^{-1} for COG scenario, and 0.60 € kg^{-1} for OOG scenario was assumed.

In the next step, all costs and revenues were discounted by using a discount rate equal to 1.8%, which was selected by opportunity cost approach in terms of alternative investments with similar risk and time. Cash flows assessment generated over the life cycle of the investment can provide useful information on its long-term viability; thus, Net Present Value (NPV) and Internal Rate of Return (IRR) were chosen as indicators of investment feasibility. In the final step, a sensitivity analysis was performed by assessing the NPV and IRR as a function of the olives selling price and by excluding public subsidies, in order to reflect the market price dynamics in a free market (Stillitano *et al.*, 2016).

Social impacts were assessed in terms of hours working conditions that can expose all typologies of workers to the possible risk of a psychophysical disease or illness. To this purpose, a PRF impact pathway was applied. The impact pathways are gaining more consensus in sLCA (Feschet *et al.*, 2013; Iofrida *et al*., 2018), even if until now have been little applied; they represent the implementation of a post-positivist epistemological posture in SLCA, i.e. dedicated to the search for quantification of cause-effect relationships and statistical validity, and therefore similar to environmental LCA (Iofrida *et al.*, 2018). The application of this methodology consisted of four steps. The first step coincided with the LCC inventory phase; in particular, data for the social impacts concerned the hours of work per each agricultural task and per each life cycle phase (quantitative data), qualifying also the typology of task, i.e. mechanization, open air, season (qualitative data). A spreadsheet was fulfilled with the details of each working task per each farming phase. The second step concerned the characterization of each task in terms of the typology of working condition, such as the exposure to a particular situation: pesticide (herbicides, insecticides, fungicides, fertilizers) exposure, noise, vibrations, temperature, work under pressure, etc. The third step consisted in collecting the odds ratios (ORs) data from scientific literature, i.e. those published studies that statistically quantified the associations between working conditions and psychosocial health risks. The literature review has been conducted by means of scientific databases such as Scopus and Web of Science, using keywords relating to the above-mentioned working conditions and the words "odds ratio". The OR is a statistical measure of the intensity of association between two variables, that is, in the case of this study, the ratio between odds of exposure in sick people and odds of exposure in healthy people. In other words, it represents the odds that a health trouble will occur given a particular exposure, compared to the odds of the same health trouble occurring in the absence of that exposure (Szumilas, 2010). Values >1 represent a positive association between the working condition and the disease/disorder; the higher the value, the stronger the association (Iofrida *et al.*, 2018). The odds ratios gathered have been classified (Table 2) according to the scale of intensity proposed by Bottarelli and Ostanello (2011). A PRF Matrix (Supplemental Material 2) has been constructed putting in relation every working condition accounted in the inventory phase with one or more psychosocial risk. Finally, the assessment and comparison of the two scenarios, highlighting the main differences or similarities, has been carried out.

Table 2 - Classification of odds ratio.

Negative Association	*No association*	*Weak*	*Moderate*	*Strong*	*Very strong*
0<OR<1	OR=1	1<OR<1,3	1,3<OR<1,7	1,7<OR<8	OR>8

Source: Bottarelli and Ostanello (2011).

5. Results and discussion

Results of the economic analysis showed that, in terms of cost per life cycle stage, the OOG scenario achieves the better performance compared to the COG scenario (Table 3). Focusing on constant production stage, among the agricultural practices, harvesting, and pruning operations had the highest share of operating costs with values ranging from 25% to 30% for both conventional and organic systems. These results were mainly due to the high human labour cost despite the medium-high level of farm mechanization, confirming the insights of De Gennaro *et al.* (2012) and Mohamad *et al.* (2014). According to Bernardi *et al.* (2016), a careful planning of machinery employment to accomplish the different agricultural practices could guarantee a greater production efficiency and lower costs.

Concerning the fertilization cost, the OOG scenario showed the best performances, with 17% of the total cost against 26% obtained in the COG scenario. This was affected by the exclusive use of farmyard manure in organic systems. However, the disease control cost in the organic system by 17.4% was more than conventional one by 8%, because of the greater treatment frequency (Pattara *et al.*, 2016) and input market price.

The findings of investment feasibility analysis by including public subsidies revealed that the OOG scenario was the most economically feasible alternative, with a NPV of 7,519.54 € ha^{-1} and an IRR of 2.40% (Table 4). This indicated that the profitability of the organic systems was positively affected by the higher olives market price, lower production costs, as well as the further subsidy to organic farms, confirming what observed by Sgroi *et al.* (2015).

Figures 5 and 6 highlight the results of the sensitivity analysis performed by assuming diverse

Table 3 - Average operating costs of conventional vs organic olive orchard per life cycle stages (€ ha^{-1} $year^{-1}$).

Life cycle stages	*COG*	*OOG*
Planting stage (*year 0*)	7,433.44	6,995.09
Unproductive stage (*1^{st}-6^{th} year*)	3,127.01	3,031.39
Increasing production stage (*7^{th}-18^{th} year*)	4,056.26	4,035.16
Constant production stage (*19^{th}-55^{th} year*)	4,342.26	4,280.43
Variable costs, of which:	*3,230,84*	*3,218,05*
- Tillage	336.57	309.14
- Fertilization	787.71	535.28
- Disease control	*243.64*	*533.29*
- Pruning	762.50	772.00
- Harvesting	925.50	920.50
- Other variable costs	174.92	147.84
Fixed costs	*1,111.42*	*1,062.38*
Decreasing production stage (*56^{th}-60^{th} year*)	3,918.43	4,050.99
End of life stage (*60^{th} year*)	7,235.76	7,235.76

Table 4 - Feasibility analysis of olive growing scenarios.

Items	*Unit*	*COG*	*OOG*
Yield (constant production stage)	Kg ha^{-1}	10,000	9,200
Olives sale price	€ kg^{-1}	0.50	0.60
Public subsidy	€ ha^{-1}	600	600
Subsidy to organic farms	€ ha^{-1}	-	700
NPV	€ ha^{-1}	-25,752.49	7,519.54
IRR	%	-0.25	2.40

olive sale prices, which range from 0.50 to 0.80 for the conventional scenario and 0.60 to 0.90 for organic one, and by excluding European subsidies. The simulations demonstrated that, at the current market prices, investments in olive production systems were not economically sustainable, endorsing also the results obtained by De Gennaro *et al.* (2012). To generate positive NPV and IRR values, the olive price must exceed 0.75 € kg^{-1} for COG scenario and 0.80 € kg^{-1} for OOG. Therefore, it can be affirmed that public subsidies strongly affect the economic sustainability of olive investments and, therefore, the final profitability of farms.

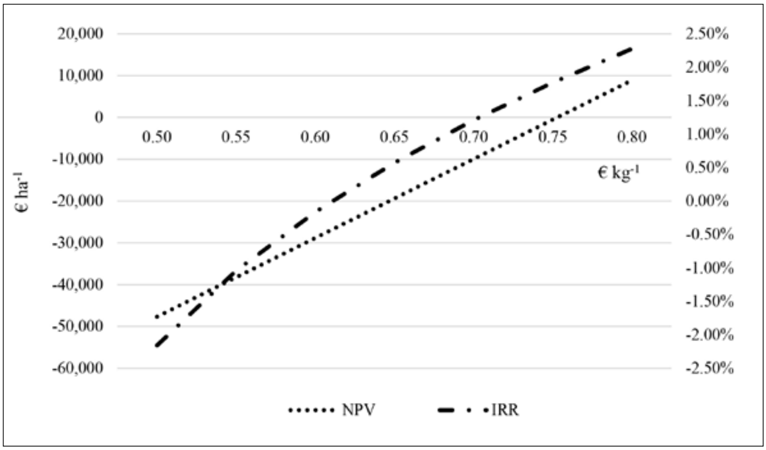


Figure 5 - Trend of NPV and IRR as a function of olives price and by excluding economic subsidies in the COG scenario.

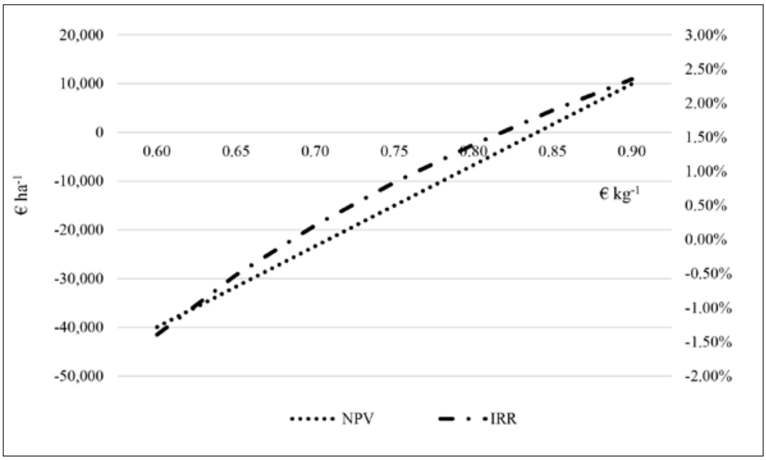


Figure 6 - Trend of NPV and IRR as a function of olives price and by excluding economic subsidies in the OOG scenario.

Concerning the social impacts, some assumptions have been necessary; results were not affected because the same assumptions were made for both scenarios. If a task concerned at the same time more psychosocial risks, the corresponding hours have been double counted, but crossed effects have not been taken into account because no references were found in the literature. Among synthetic chemical insecticides, the most applied in Italian conventional olive growing are organophosphates, followed by neonicotinoids and pyrethroids. The literature review found only studies about the associations of the former; therefore, this study considered that half of the phytosanitary treatments were applied with organophosphates (COG scenario). Obviously, synthetic chemical insecticides and fungicides were accounted only in the evaluation of the COG scenario (half of the treatments), while cupric products were considered for both scenarios (half of the phytosanitary treatments), because they are admitted in organic agriculture (EU Reg. n. 2018/1584). Some of the studies selected in the literature review analysed the impacts of "pesticides" in general, including in their evaluations synthetic herbicides, insecticides, fertilizers and fungicides, as it was the case of Kang *et al.* (2014) and Santibañez *et al.* (2012): in this case, impacts were accounted more times, one per each typology of pesticide application. Fertilization was accounted also as "pesticide exposure" in COG scenario, but not in OOG because synthetic fertilizers are forbidden in organic agriculture.

When more studies from the literature review had different odds ratio results for the same risk, the higher OR was taken into account, as it was the case of Hohenadel *et al*. (2011) and Fritschi *et al.* (2005), who found an association (OR) between herbicides and non-Hodgkin lymphoma of 1.24 and 3.28, respectively. Concerning the harvesting techniques, they can vary a lot according to local customs, plants age, tree-pruning shapes, topography and typology of oil to be obtained. For the purpose of this study, average data have been taken into account, referred to hilly areas (the more representative of Italian scenarios), with a mixed harvesting technique, i.e. vibration and mechanical beating with poles.

The results of the application of SLCA are reported in Figures 7 and 8.

Figure 7 - SLCA of Italian conventional olive growing.

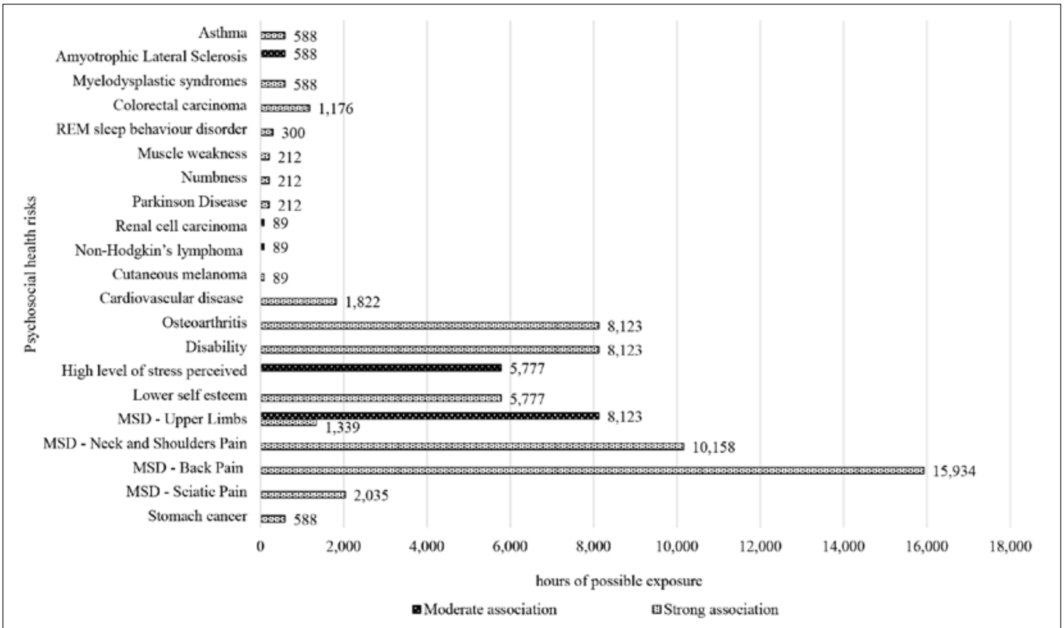
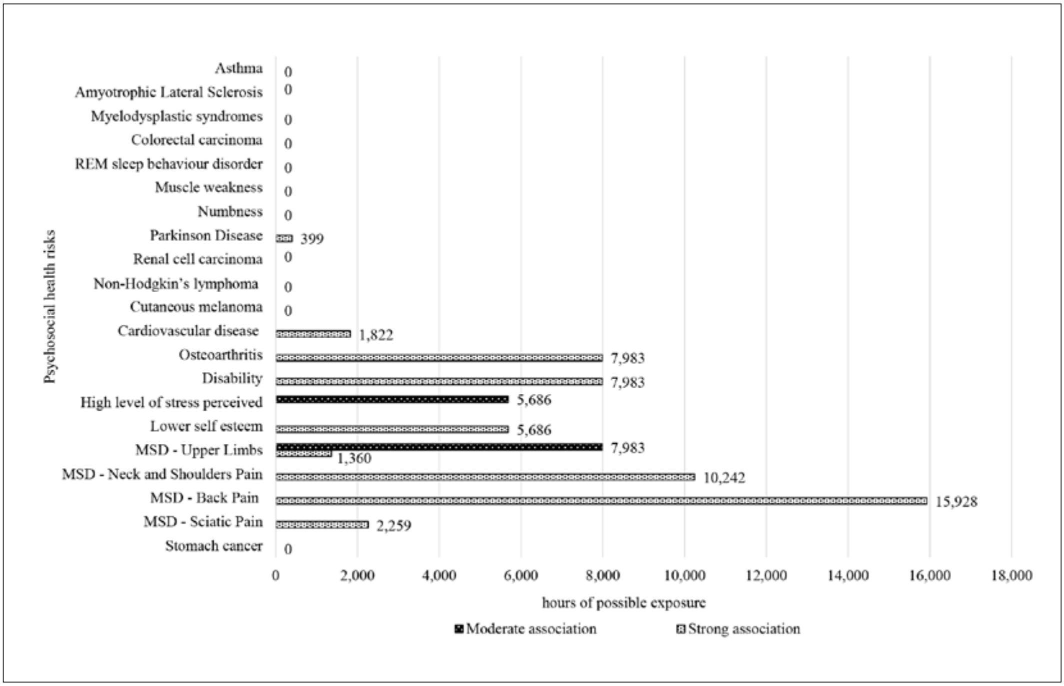


Figure 8 - PRF impact pathway of organic olive growing life cycle.



The OOG scenario showed to be better than the conventional one, especially in qualitative terms: indeed, even if the average working needs are very similar (more than 11,500 hours for the whole life cycle of both scenarios, with a little supplement of 75.5 hours in OOG scenario), the COG scenario expose workers to more serious health risks, such as diseases with possible mortal course.

More in details, both scenarios showed similar results for the highest values: the most important exposures for workers are the musculoskeletal disorders (± 16,000 hours of exposure to the risk of back pain, followed by ± 12,000 hours of neck and shoulder pain), with a strong association (1.7<OR<8) (Bovenzi and Betta, 1994; Domenighetti *et al.*, 2000; Stock *et al.*, 2006; Raeisi *et al.*, 2014).

Right after, osteoarthritis (Rossignol *et al.*, 2005) and disability (Lahelma, 2012) are the highest risks for workers (±8,000 hours of exposure with strong association), followed by musculoskeletal disorder of upper limbs with a moderate association (Stock *et al.*, 2006).

The exposure to synthetic phytoiatric products such as insecticides, herbicides, fungicides, and fertilizers is the reasons for the main difference between the two scenarios. Indeed, the COG scenario exposes workers, with a strong association, to the risks of colorectal carcinoma (1.176 hours), asthma (588 hours), myelodysplastic syndromes (588 hours), REM sleep behaviour disorder (300 hours), muscle weakness (212 hours), numbness (212 hours) and cutaneous melanoma (89 hours) (Salameh *et al.*, 2006; Lo *et al.*, 2010; Postuma *et al.*, 2012; Fortes *et al.*, 2016; Avgerinou *et al.*, 2017; Hongsibsong *et al.*, 2017). In addition, with a moderate association, the COG scenario exposes workers to the risks of amyotrophic lateral sclerosis (588 hours), renal cell carcinoma (89 hours) and non-Hodgkin lymphoma (89 hours) (Hu *et al.*, 2002; Fritschi *et al.*, 2005; Hohenadel *et al.*, 2011; Kang *et al.*, 2014).

The only impact category for which the OOG scenario is more negatively impacting is the Parkinson disease (399 hours in OOG against 212 hours in COG), due to the more frequent use of copper oxides in organic olive growing (Elbaz *et al.*, 2009).

6. Discussion and conclusion

Organic agriculture is already widely recognized as being less impacting on the environment. The main purpose of this study was to investigate and compare the economic impacts in terms of long-term feasibility and the social impacts in terms of working health in Italian conventional and organic olive groves and to highlight better management practices.

Results showed that the OOG scenario was the most economically feasible alternative, with a NPV of 7,519.54 € ha^{-1} and an IRR of 2.40%, because of the contribution of public subsidies and the competitive market prices for organic produces that balanced the higher production costs. However, at the current market conditions and by excluding public subsidies, investments in both scenarios were not economically sustainable.

Great differences have been highlighted also in terms of social impacts due not to the different farming operations, but mostly to the different products applied. The organic production showed the best results in terms of working conditions thanks to the typology of phytoiatric products applied.

Further research should be necessary to investigate the social impacts on other stakeholders' groups, such as supply chain actors and consumers. Likewise, impact categories should be weighted to assess scenarios in a manner coherent to the importance of each impact category.

Insights highlighted the main hotspots and concerns that need improvement, and which reengineering management and organizational strategies would be suitable to decrease agricultural practices costs and increase the production yield, but also to improve the occupational health of people involved. In details, a better mechanization of harvesting tasks would help reducing production costs, and the reduction of synthetic pesticides would be suitable to improve the socio-economic performance of the Italian olive-growing sector.

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