Life Cycle Assessment of olive cultivation in Italy: comparison of three management systems

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Introduction

The aim of this study is to evaluate the potential environmental life-cycle impacts of olives produced in three management systems of olive tree integrated with natural grassland.

In Italy, olive cultivation is one of the key crops. In fact, in terms of cultivation area, olives are in the second place, behind the wheat cultivation. In terms of production, olive trees take 6th place, just behind grapes, wheat, maize, tomatoes and apples. In terms of production, Italy is in the third place in the world, behind Spain and Greece. Their share in global production in 2016 amounted to 10.9% (2092175 tonnes). Olive's trees occupy an area of 1165562 ha (FAOSTAT 2016).

Olive trees can be cultivated in different farm systems: organic, traditional, silvopastoral and intensive. These systems differ in terms of both the costs incurred and the impact on the environment. Olive orchards integrated with cereals is the earliest agroforestry system in the Mediterranean area and characterize plantation crop and multipurpose tree systems, that improve nutrient cycling and erosion control (Ramachandran Nair, 1993).

Currently, organic farming is becoming more popular in agriculture. For instance, in Italy, more olive trees are grown in organic farming, a system spread in the recent years (Melelli and Fatichenti, 2010). Organic system is supposed to have better performance in reducing environmental influence in environmental burdens than conventional because of lower environmental impacts on resources depletion, highlighting higher efficiency in reducing fossil fuel consumption. However it is not at all times shown in the literature (Mohamend et al., 2014; Salomone and Ioppolo, 2012). This system uses less chemicals for plant protection and mineral fertilizers but productivity is typically lower. The results of most Life Cycle Assessment (LCA) studies show that mineral fertilization is the process contributing most to the environmental impacts (Mohamend et al., 2014; Romero-Gamez et all., 2017), but irrigation also contributes significantly to impacts (Notarnicola et all., 2015) in the production of olive oil. The Mediterranean basin is the largest area characterized by olive cultivation, where irrigation is necessary and widespread. Metzidakis et al., 2008 has shown that intensive cultivation results with higher yields but also higher labour cost and generate much more waste because of higher use of chemicals.

LCA is used to quantify different environmental impacts of the entire production system of the olive oil sector and also this method can specify the environmental hotspots in a production system (Avraamides and Fatta, 2008; Hanandeh and Gharaibeh, 2016; Notarnicola et al., 2015).

Material and Methods

The goal of this study was comparing the environmental impacts of different olive production system. The studied farms consist of three farms with olive trees in Orvieto, located in the Umbria region (Central Italy), each farm with a different management system: silvopastoral, organic and traditional. The functional unit is one kilogram of olives at the farmgate. Data were collected to implement life cycle inventories to each farm, from the establishment (several decades ago) to the time of the present study. Detailed questionnaires and interviews about the different management (cultivation, practices, etc.) were submitted to the farmers.

The agricultural practices were grouped in different categories (machinery use, fertilization and plant protection, irrigation and orchard establishment). LCA was done by applying SimaPro 8.4 software (Pré Consultants, 2006). To calculate the emissions of inputs production, Ecoinvent database 3.3 was used. Collected data were implemented to software and analysed. The following impacts were calculated using the CML method: global warming potential (GWP), acidification, eutrophication. The system boundary was cradle to olive farm gate (from the extraction of raw materials to the farm gate when the olives are harvested). FFigure 1 shows the general flow diagram for the three olive production systems considered. The environmental impact from excrement left on the field by sheep were assumed to be part of the life cycle of the sheep milk produced and thus not accounted in this study. The three farms were also compared with an olive production process in Italy used for the export market described in detail in the Ecoinvent database 3.3.

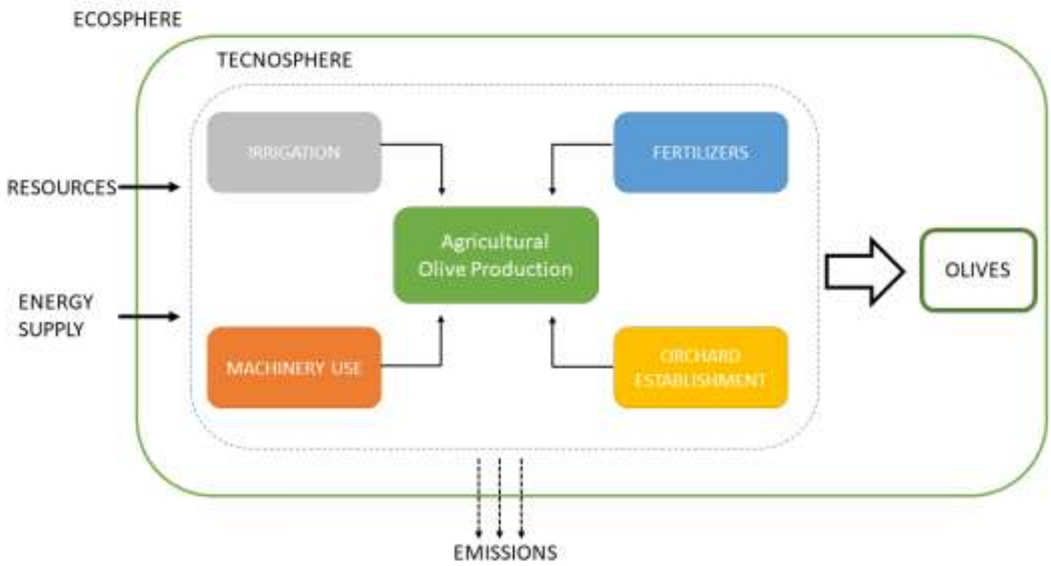

Figure 1. General flow diagram for the agricultural olive production systems

The main traits of the three farms involved in the study are shown below:

Silvopastoral management system **farm**. It is characterized by 135 trees per ha with a production of 3.6 t of olives per one hectare, surrounded by broadleaves wood area (agroforestry system). Sheep (177) are also kept in the farm, where they grazed nearby the olives trees for 150 days a year (producing 0.33 kg dung and 2.9 kg urine per day). The trees were planted around 1956, with sprouting after 1986. Also old/centennial trees are present, which lifespan was 60 years, at least. Fertilizers are not utilized, but biological copper (1.7 kg/ha) and fresh and dry sheep manure were applied.

Organic management system farm. Bagni farm is characterized by two areas. The first is about 40 years old, with a specialized olive plantation. The latter is more than 40 and characterized by traditional management. It produces 2.2 t of olives per hectare on a natural grass cover, with presence of wild asparagus at trees' base. Olive trees were planted on 4.5 hectares, with a density of 200 trees/ha. In general, 4 tons of cow manure per hectare and no plant protection were applied.

Traditional management system farm. It produces 7.05 t of olives per hectare. The olive trees were planted on 8.5 hectares, with a density of 529 trees/ha and a lifespan of 36 years. Olive trees were originally planted in 1982. The cultivation area is drip irrigated and fertilization was characterized by the utilization of pruning remains and olive pomace. Furthermore, glyphosate was utilized.

Table 1. Olives production at different farming management systems

Plant production	silvopastoral		organic		traditional		Average Italian farm
	area (ha)	yield (t)	area (ha)	yield (t)	area (ha)	yield (t)	yield (t)
Olives	1	3.64	4.5	2.2	8.5	7.05	4.3

Emission calculation

The emissions related to agricultural inputs mainly fertilisers and irrigations during cultivation of olives were calculated (Table 2). Dinitrogen monoxide (N_2O), ammonia (NH_3), nitric oxide (NO) were modelled based on methodology described in EEA/EMEP (2013). Carbon dioxide (CO_2) as well as irrigation were calculated based on Methodological Guidelines for the Life Cycle Inventory of Agricultural Product (2014). The emissions related to pesticide use were not included due to the fact that they have low influence on calculated environmental impacts.

Table 2. Estimated on field emissions caused by fertilization and irrigation.

Agricultural practice	On field emissions	methodology	Unit/ha/yr	silvopastoral	organic	traditional
Fertilization	Dinitrogen monoxideN_2O	EEA/EMEP (2013)	kg	0	0.0005	0.00031
	Carbon dioxide CO_2	WFLDB-Guidelines	kg	0	0	0.03118
	Ammonia NH_3	EEA/EMEP (2013)	kg	0.00892	0	0.00103
	Nitric oxide	EEA/EMEP (2013)	kg	0.01235	0.0342	0.00024
Irrigation	water	WFLDB-Guidelines	m^3	0	0	0.14

Results and discussion

In the presented work, three main impacts categories were studied - global worming potential, acidification, eutrophication. The comparison of results of others authors is very difficult as the farming systems and system boundaries varies in between publication (Avraamides, Fatta, 2007; Hanandeh, Gharaibeh 2015; Romero –Gamez et al., 2017). The highest GWP was calculated for traditional farming system while the lowest for organic system. It is clear from fFigure 2 that fertilisation has the higher impact on GWP second important impact was coursed by irrigation. Romero –Gamez et al., (2017) relates it with CO_2 and NO_2 emissions to air caused by the manufacture and application of fertilisers to the cropping systems. In our research CO_2 and N_2O (Table 4) from fertiliser and machinery use were effecting the cropping system. The highest acidification was calculated for silvopastoral and organic farm more than twice in compare to average Italian farm (Figure 3). Fertilisation and machinery use related to NH_3 and NO had the highest impact on acidification (Table 4). Romero – Gamez et al., (2017) have found that in his case acidification was dominated by

NH_3 emissions to the air and those emissions were allocated to fertiliser production. Eutrophication was also highest for silvopastoral and organic farm system 20% higher compared to average Italian farm (Table 3), caused by machinery and fertiliser use (Figure 4). In the study of Romero – Gamez et al., (2017) eutrophication was caused mostly by P fertilisation, in our case NH3 was influencing the most in traditional and organic farming while P was second elementary flow (Table 4Table 4).

Table 3. Environmental impacts of different olive cultivation systems

Impact category	Unit	silvopastoral	organic	traditional	average Italian system
Global warming (GWP100a)	kg CO_2 eq	0.1664	0.2658	0.6546	0.3882
Acidification	kg SO_2 eq	0.0215	0.0178	0.0070	0.0076
Eutrophication	kg PO_4 eq	0.0050	0.0048	0.0023	0.0041

Table 4. Most relevant elementary flows

Impact category	Elementary flows	Compartment	Main LC stage	Farming system
Global warming (GWP100a)	Carbon dioxide, fossil	Air	Machinery use	silvopastoral
Global warming (GWP100a)	Dinitrogen monoxide	Air	Fertiliser	organic
Global warming (GWP100a)	Carbon dioxide, fossil	Air	Fertiliser	traditional
Acidification	Ammonia	Air	Machinery use	silvopastoral
Acidification	Nitrogen oxides	Air	Machinery use	organic
Acidification	Ammonia	Air	Fertiliser	traditional
Eutrophication	Ammonia	Air	Machinery use	silvopastoral
Eutrophication	Nitrogen oxides	Air	Machinery	organic
Eutrophication	Ammonia	Air	Fertiliser	traditional

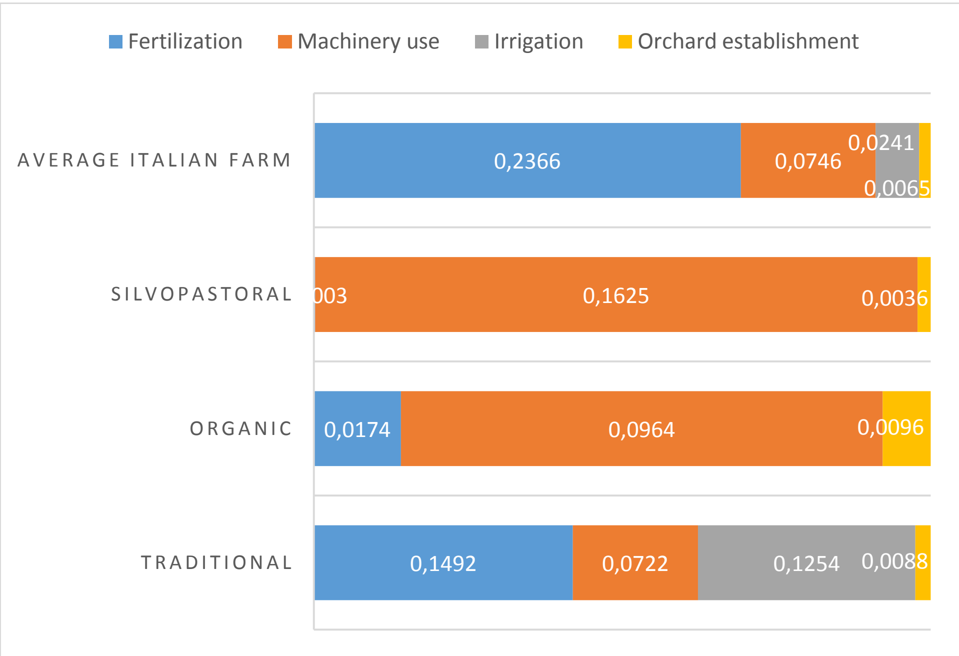

Figure 2. Impact of agricultural practices on GWP (kg CO_2 eq)

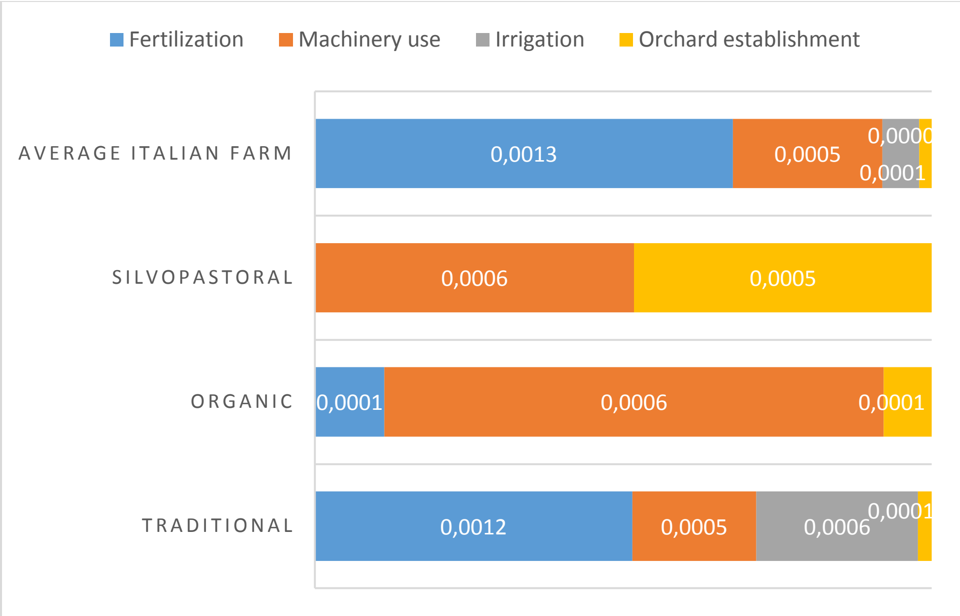

Figure 3. Impact of agricultural practices on acidification (kg SO2 eq)

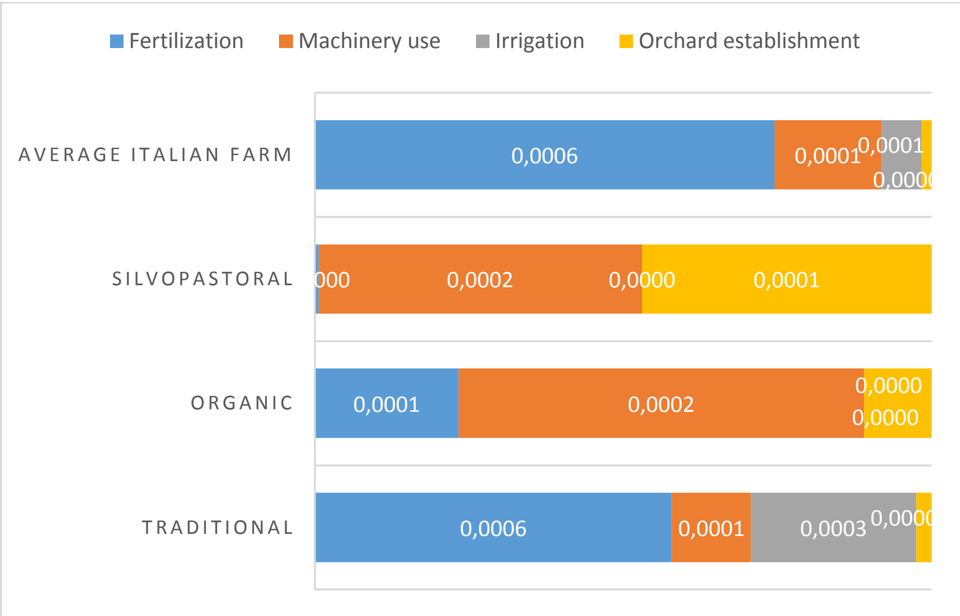

Figure 4. Impact of agricultural practices on eutrophication (kg PO4- eq).

Conclusion

This study compare tree small farms using different farming systems (silvopastoral, organic and traditional) with an average Italian farm using life cycle assessment methodology. The most related to agriculture impact categories were assessed: Global Worming potential, acidification and eutrophication. All farms were are using small amount of fertilisers, low use of chemicals, and non-pesticides. However among all agricultural practises, fertilization has the highest environmental impact followed by machinery use. In this case organic farming system is looking as the most promising one due to low organic fertiliser application.

Literature:

Avraamides M., Fatta D., 2008. Resource consumption and emissions from olive oil production: a life cycle inventory case study in Cyprus. Journal of Cleaner Production 16, 809-821.

FAOSTAT 2016

Hanandeha A.E., Gharaibeh M.A., 2016 Environmental efficiency of olive oil production by small and micro-scale farmers in northern Jordan: Life cycle assessment. Agricultural Systems Volume 148, October 2016, Pages 169-177

Meleli A., Fatichenti F. Qualità e multifunzionalità dell´agricoltura in Umbria: elementi per un bilancio. Rivista Geografica Italiana 117(1), 127-156.

Metzidakis I., Martinez-Vilela A., Castro Nieto G., Basso B., 2008. Intensive olive orchards on sloping land: Good water and pest management are essential. Journal of Environmental Management 89, 120-128.

Mohamed R. S., Verrastro V., Cardone G., Bteich M. R., Favia M., Moretti M., Roma R., 2014. Optimization of organic and conventional olive agricultural practices from a Life Cycle Assessment and Life Cycle Costing perspectives. Journal of Cleaner Production 70, 78-89.

Notarnicola B., Salomone R., Petti L., Renzulli P. A., Roma R., Cerutti A. K. (Eds.) 2015. Life Cycle Assessment in the Agri-food Sector Case Studies, Methodological Issues and Best Practices. XXI, 390 p., Hardcover, www.springer.com/978-3-319-11939-7.

Pré Consultants, 2006. SimaPro version 7. Pré Consultants, Amersfoort, Netherlands

Ramachandran Nair P.K. (Eds.) 1993. An Introduction to Agroforestry. Kluwer Academic Publishers, Dordrecht, Netherlands, p. 499.

Romero-Gamez M., Castro-Rodriguez J., Suarez-Rey E. M., 2017. Optimization of olive growing practices in Spain from a life cycle assessment perspective. Journal of Cleaner Production 149, 25-37.

Salomone R., Ioppolo G., 2012. Environmental impact of olive oil production: a Life Cycle Assesssment case study in the province of Messina (Sicily). Journal of Cleaner Production 28, 88-100.