

# Opportunities for olive oil value chain enhancement through the by-products valorisation: A life cycle assessment in the Andalusian region (Spain)



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## Abstract

This work presents a Life Cycle Assessment (LCA) of the production of virgin olive oil in the most representative region of Spain (Jaen). The total cultivation area of Jaen is around 620,000 ha, where 580,000 ha are dedicated to olive grove.

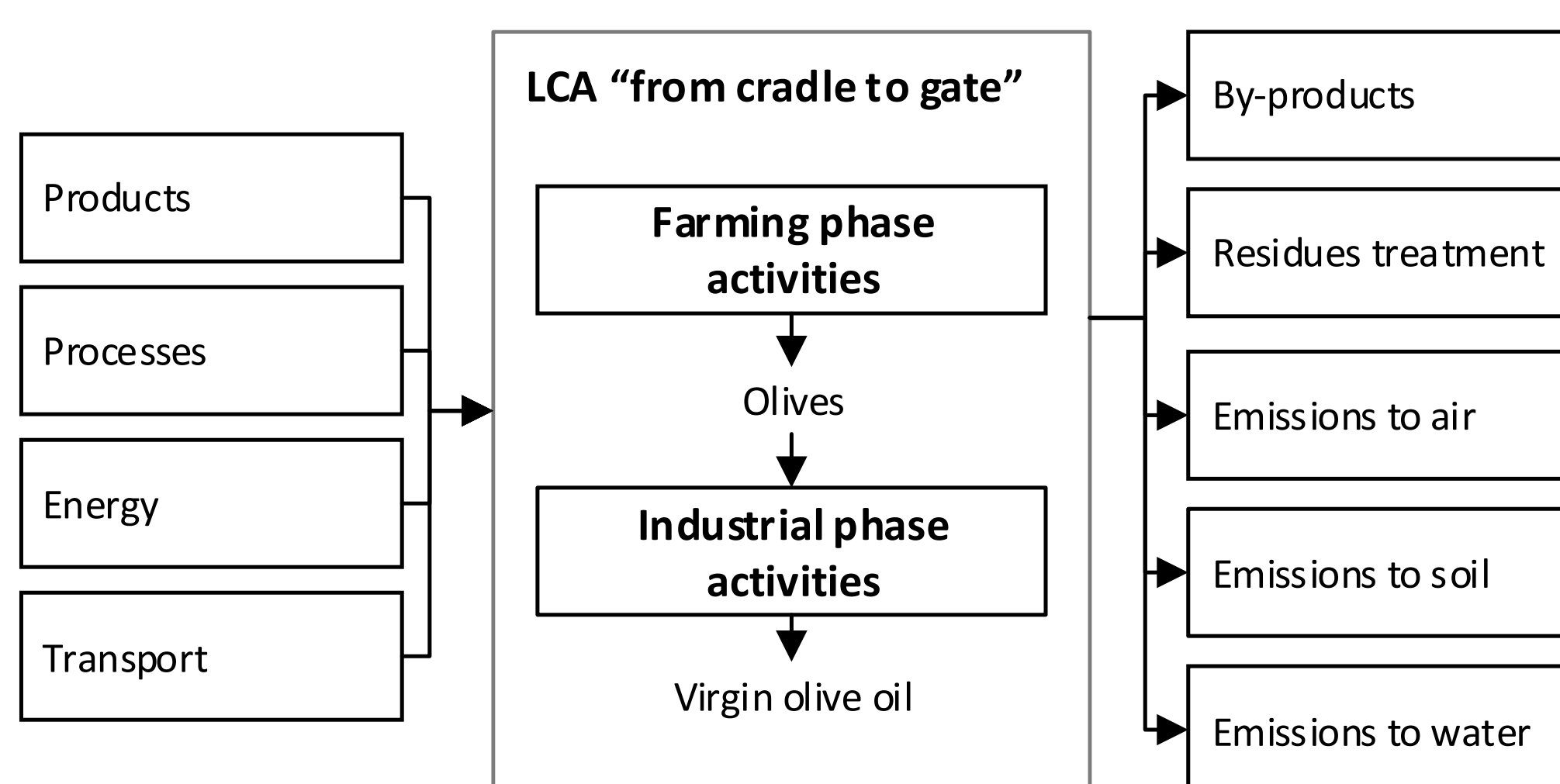


Figure 1. Scope of the LCA

The scope is "from cradle to gate" in a study period of 5 harvests (2015-2020). The results obtained show a value for GHG emissions from 1.93 to 3.00 kg of CO<sub>2</sub> equivalent, with a weighted average of 2.39 kg of CO<sub>2</sub> equivalent per functional unit (1 kg of virgin olive oil).

## Introduction

Spanish olive oil production represents around 45% worldwide [1], where approximately 80% is produced in the Andalusian region. Jaen is the most representative region with 45% of the Andalusian production. Traditional cultivation (non-organic) is the most representative type of crop (47.51%). Relevant farming data in this region can be seen in the next table [2].

	Weighted average for the harvests 2015-2020	Source
Irrigated area (%)	43.20	Government of Spain
Olive yield (kg/ha)	4,086.00	
VOOs yield (kg/ha)	874.35	
Annual precipitation (l/mm2)	417.70	

Table 1. Main data of virgin olive oil production in the province of Jaen.

The main characteristics of olive oil for the harvests 2015-2020 can be expressed as follows:

- Type of crop: 43.20% irrigated – 56.80% dryland, conventional (non-organic), with a medium-low slope and extensive (100-150 trees per ha).
- The industrial phase takes place in an olive oil mill with a 2-phase extraction process and olive pomace valorization.
- The residues generated in the farming phase (pruning) are chopped up and leave on the field.

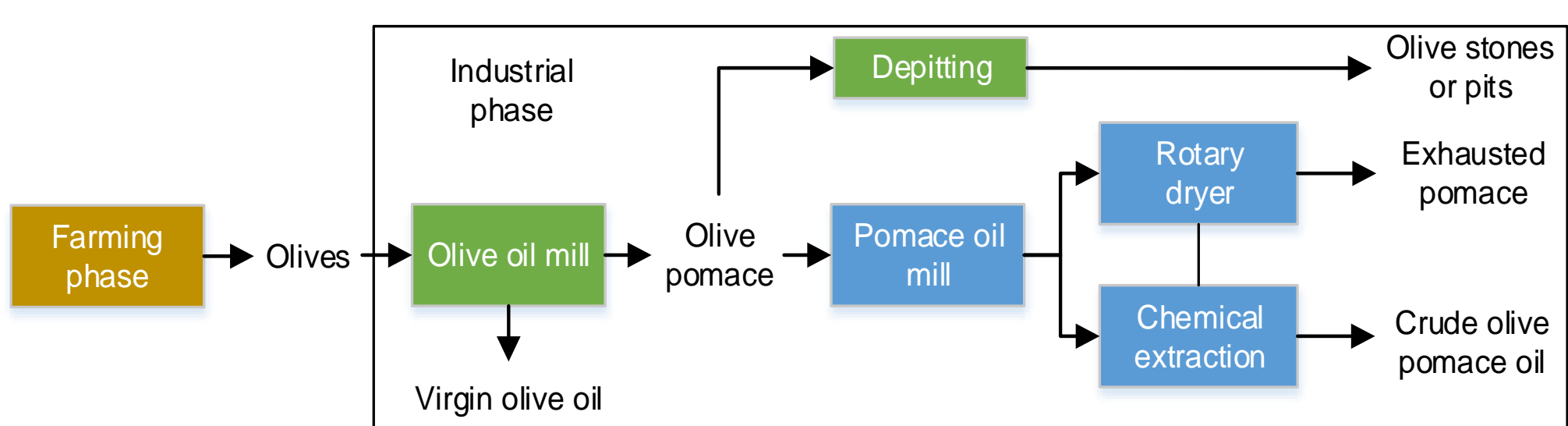


Figure 2. Flow diagram of the virgin olive oils production in Spain

## Methodology

- Table 2 and 3 show an environmental inventory has been developed in the way of surveys for the olive oil stakeholders (farmers, mill owners and extractors).
- The area covered by the surveys represents 3,920 ha of olive groves, and the average annual production of virgin olive oils for the period studied is 7,269 tons.
- Data from surveys and applying the Product Environmental Footprint Category Rules (PEFCR) for Olive Oil [3], an LCA has been carried out using the software SimaPro 9.0 [4]. The functional unit chosen is 1 kg of unpacked virgin olive oils at the point of production.

Activity	Process / Product	Unit	Quantity	
Harvesting	Petrol	kg	12.936	
	Transport with tractor and trailer	tkm	30.185	
Cutting	Petrol	kg	1.636	
	Electricity	kwh	298.536	
Irrigating	Water	m3	303.438	
	Application of PPP	ha	2.272	
PPP & Herbicides	Water	m3	2.272	
	Glyphosate	kg	1.625	
	Copper oxide	kg	1.916	
	Phenylurea herbicides	kg	2.317	
	Other PPP & Herbicides	kg	0.501	
	Transport with lorry 7.5-16 ton	tkm	26.066	
	Soil Management	Harrowing	ha	1.000
		Ploughing	ha	1.000
Tillage		ha	1.000	
Transport with lorry 7.5-16 ton		tkm	0.081	
Pruning	Transport with tractor and trailer	tkm	0.131	
	Agricultural machinery	kg	0.070	
Fertilizing	Fertilizing by broadcaster	ha	0.040	
	Nitrogen fertilizer	kg	69.505	
	Potassium fertilizer	kg	10.828	
	Phosphate fertilizer	kg	10.828	
	Ammonium sulfate	kg	31.370	
	Potassium nitrate	kg	7.664	
	Urea	kg	12.972	
	Other fertilizers	kg	11,865	
	Transport with lorry 7.5-16 ton	tkm	48.154	

Table 2. Farming phase inventory data (per ha).

Activity	Process / Product	Unit	Quantity	
Olive oil extraction	Olives	kg	4,850.872	
	Electricity	kwh	157.250	
	Water	m3	1.828	
	Cellulose fibre	kg	1.127	
	Olive stones	kg	62.328	
	Transport with tractor and trailer	tkm	83.545	
	Petrol	kg	0.016	
	Lubricating oil	kg	0.006	
	Cleaning products	kg	0.298	
	Dedicated portion of facilities (average)	u	5.70E-06	
	Crude pomace olive oil extraction	Exhausted pomace	kg	658.120
		Electricity	Kwh	77.039
		Water	kg	196.387
Transport with lorry 16-32 ton		tkm	78.555	
Hexane		kg	6.131	
	Dedicated portion of facilities (average)	u	8.43E-07	
By-products generation (outputs)	Olive stones	kg	415.522	
	Crude pomace	kg	157.409	
	Exhausted pomace	kg	1,887.692	

Table 3. Industrial phase inventory data (per 1.000 kg of virgin olive oil).

## Results

The LCA results in different environmental impact categories are shown in table 4 as a weighted average of the 5 harvests considered (2015-2020).

Impact Category	Unit	Value
Climate change	kg CO2 eq	2.39E+00
Ozone depletion	kg CFC-11 eq	1.78E-07
Human toxicity, non-cancer effects	CTUh	1.06E-06
Human toxicity, cancer effects	CTUh	1.02E-07
Particulate matter	kg PM2.5 eq	1.65E-03
Ionizing radiation HH	kBq U235 eq	2.48E-01
Ionizing radiation E (interim)	CTUe	1.05E-06
Photochemical ozone formation	kg NMVOC eq	1.55E-02
Acidification	molc H+ eq	1.36E-02
Terrestrial eutrophication	molc N eq	5.15E-02
Freshwater eutrophication	kg P eq	5.74E-04
Marine eutrophication	kg N eq	3.71E-03
Freshwater ecotoxicity	CTUe	3.28E+01
Land use	kg C deficit	4.86E+01
Water resource depletion	m3 water eq	5.29E-02
Mineral, fossil & ren resource depletion	kg Sb eq	2.43E-04

Table 4. Weighted average of the environmental impact for the period 2015-2020.

The farming phase is the main responsible of the environmental impact in all categories (from 59 to 100%). The following graph shows the impact that each farming activity has on each category.

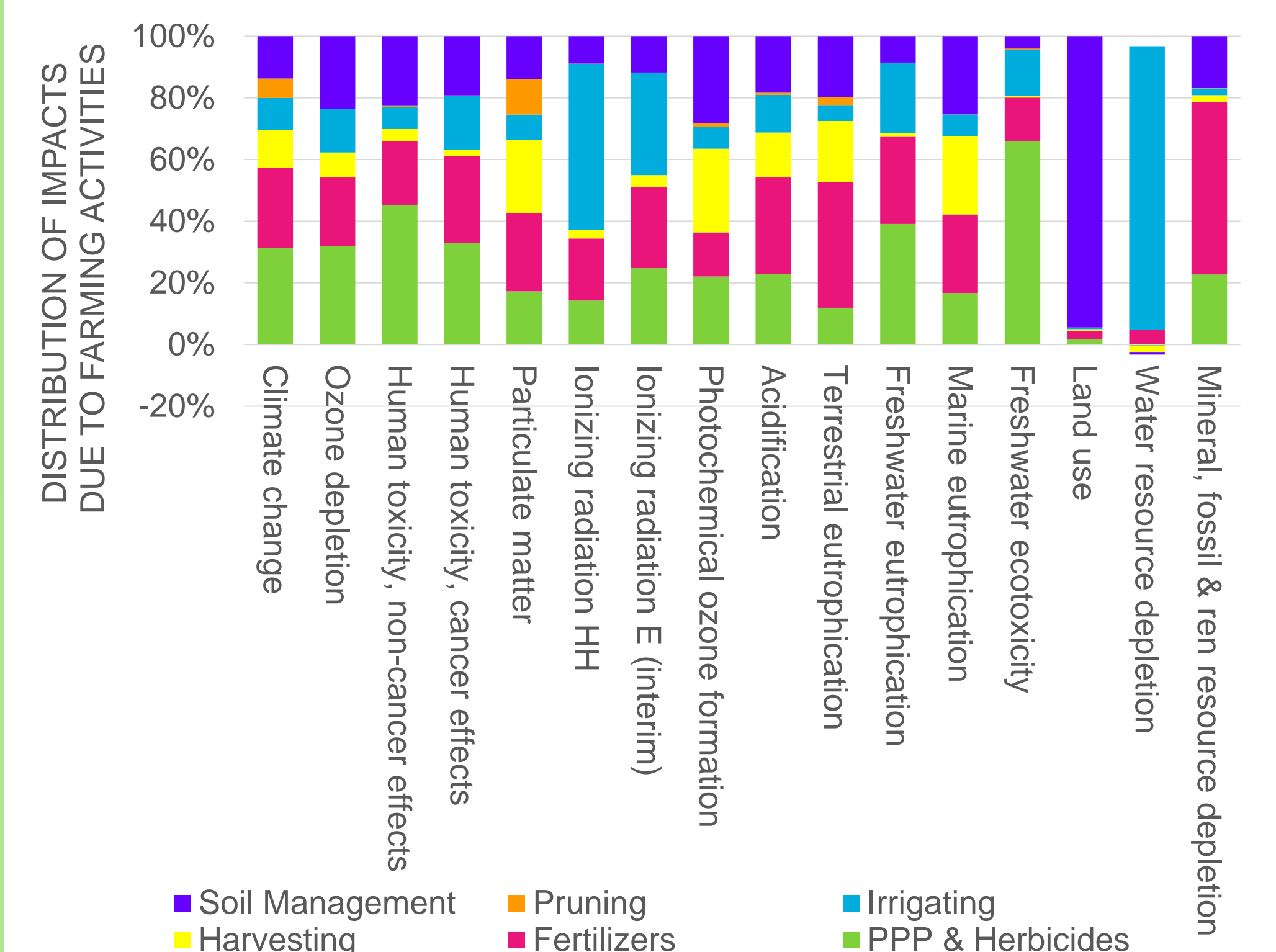


Figure 3. Distribution of environmental impact in the farming phase.

Generally, Plant Protection Products (PPP) & herbicides and fertilizers are the hotspots of the farming phase, reaching values between 35% and 65% for the most categories. The following figure shows the different distribution between phases due to the olive yield of each harvest.

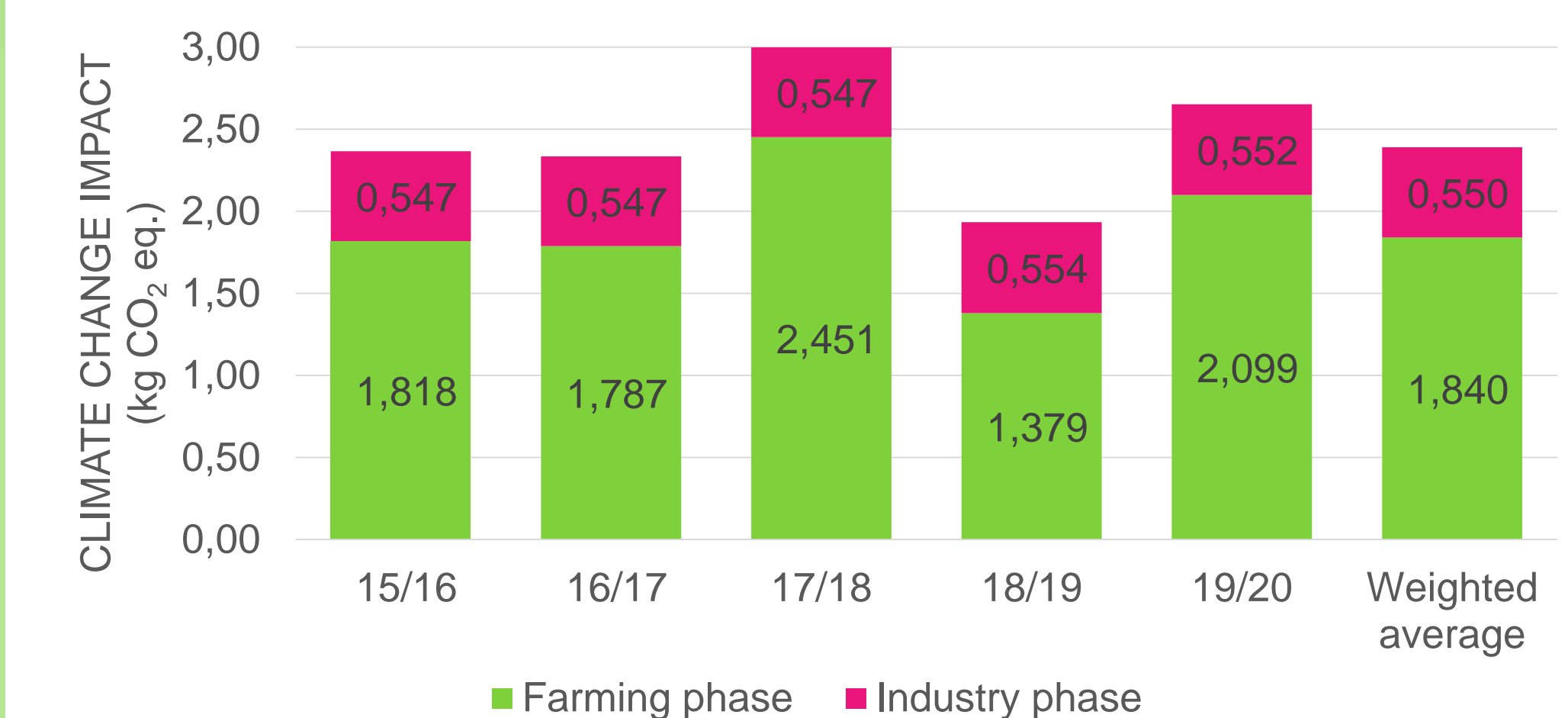


Figure 4. Climate change impact by phases and harvests.

## Conclusion

- This study presents a LCA "from cradle to gate" of the olive oil production for the most representative region of Spain (Jaen).
- This work was carried out following the PEFCR, including type of cultivation, olive oil extraction (2-phases) and wastes valorization (pomace and pits).
- For Climate Change category, the production of 1kg of virgin olive oil produces an overall impact between 1.93 (in the harvest 2017/18) and 3.00 kg CO<sub>2</sub> eq. (2018/19) with an average impact of 2.39 kg CO<sub>2</sub> eq.
- The hotspots in the farming phase are the using of plant protection products and herbicides (24.11 % of the average whole value) and fertilizers (20.01 %). In the industrial phase, 80,57 % of the impact is caused by pomace treatment, representing an average whole value of 18.56 %.

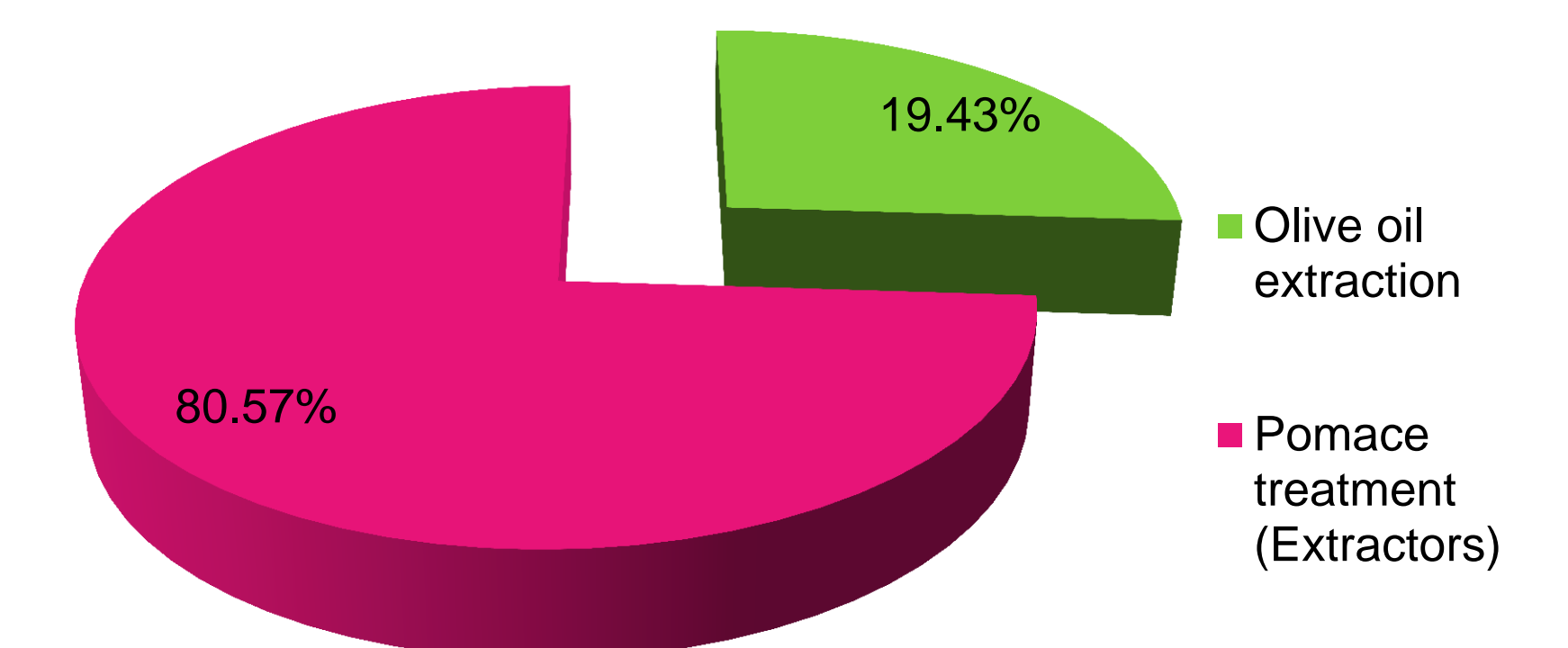


Figure 5. Distribution of climate change impact in the industrial phase.

Therefore, as future lines of research, it would be reasonable to apply alternative technologies to the current value chain of products and by-products to reduce the environmental impacts.

## References:

- [1] International Olive Oil Council. <http://www.internationaloliveoil.org>
- [2] Ministry of Agriculture, Fisheries and Food, 2015-2020. Areas and annual crop production. <https://www.mapa.gob.es>
- [3] Schau, E.M., Palomino, J.A.P., Michalopoulos, G., Russo, C., 2016. Product Environmental Footprint Category Rules for Olive Oil. Draft for 3rd public consultation phase.
- [4] Simapro (Version 9.0). LCA software for fact-based sustainability. [www.simapro.com/](http://www.simapro.com/)

## Acknowledgements

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