Life Cycle Assessment of Extra Virgin Olive Oil produced by three groups of farmers in south Greece

11.04.2011

George Michalopoulos Lito Christodoulopoulou RodaxAgro Ltd Kottou 48, Metamorphosis Athens 14452	Georgia Giakoumaki Chrysoula Manolaraki Peza Union Kalloni, Pediados Heraklion, Crete	Stella Malliaraki Katerina Aggelaki Mirabello Union Neapoli, Lasithi Crete	Efi Zontanou NILEAS group of farmers Hora Messinias, 24600 Peloponnese

SUMMARY

A comprehensive LCA (Life Cycle Assessment) was carried out on olive oil of extra virgin quality, produced from 487 olive groves by three groups of 68 olive growers in south Greece. The study refers to the crop period February 2010 - mid January 2011.

GOAL AND SCOPE

The first goal of the study is to assess the environmental performance of olive oil in order to use it for an Environmental Product Declaration (EPD) according to PCR 21537 of ENVIRONDEC.

A second, equally significant goal is to use the LCA as a starting point for the continuous improvement procedure with regard to the environment, by identifying the areas with the most significant impacts, and by taking measures for their control.

The functional unit of the study is 0.75 litre extra virgin olive oil, packed in a glass bottle to be sold in Sweden.

The Extra Virgin Olive Oil (EVOO) under study is produced by farmers organized in three farmers' groups in three different areas of south Greece, as it is shown in the table below. All three groups implement an environmental management system based on ISO 14001, since more than 5 years. Not every member of each farmer group is a participant in the scope of the present study, as participation has been voluntary. However, the extra virgin olive oil that is subject to the study is produced exclusively by farmers and olive groves that participate in the study and is separated from the olive oil of non registered farms and of not registered farmers of the rest of each group. From the environmental point of view it is noted that the olive groves under study in each area are surrounded by other olive groves belonging to farmers not participating in the present study.

TABLE 1

Farmers' group	Location	Farmers	Sites	Area (ha)	Trees	Olive oil mills
Peza	Central- Crete	37	406	72.360	13.731	2 (+10)
Mirabello	NE Crete	22	53	25,946	3,644	5 (+1)
Nileas	SW Peloponnese	9	28	27,140	5,082	1 (2)
TOTAL		68	487	131,160	23,479	8 (19)

Note: Number of oil mills in brackets show olive oil mills that have not provided usable data for the LCA.

The LCA covers the cradle to grave perspective from extraction of the raw materials used for the production of olive fruit, pressing the fruit to extract olive oil, packing, delivering to the market and end of life by disposal / recycling of the packing material. Use phase is not included, as the product is considered to be consumed as raw in salads, while the use in cooking is limited and linked to high uncertainties. According to PCR 21537 the environmental impact categories examined are: global warming, stratospheric ozone depletion, acidification, photochemical oxidant formation, eutrophication, depletion of abiotic resources, ecotoxicity, human toxicity and land use. One more category has been added, that of air emissions, since it is recommended as a core indicator by the Eco Management ad Audit Scheme – EMAS.

(Reg. 1221/2009). Biogenic flows of CO_2 (carbon dioxide) are approached in two ways this study. According to the PCR 21537 they are excluded from the calculations. They are examined as a separate issue though, as significant room for improvement of the overall environmental performance seems to exist. Further work is under way in order to find how to increase the gap between carbon sequestration potential of the olive trees and CO_2 emissions. Both can be altered by improving farm practices.

In addition to impact categories, results on the use of water and of material resources and energy resources (renewable and non-renewable) are presented in the inventory. Also, indicators are reported on material subject for recycling, on waste generation (in Kg) including hazardous / environmentally active waste (wet pomace) as well as on net consumption of electricity. No data are presented on toxic emissions as such emissions have not been identified.

Only primary data have been used for all the site-specific processes, including local transportation and other machinery operation. This has been considered necessary in line with the two goals of the study i.e. a) EPD and b) environmental performance improvement.
With regard to the EPD the use of site specific data is required by PCR 21537. This requirement is reasonable considering that the product can use EPD elements in order to be marked with an 'environmental label' which must reflect exactly the performance described by the EPD i.e. that is traceable to the participating olive groves and farmers records.

SIMAPRO 7.2.4 program has been used for the design of LCA model, for calculations and for impact assessments. Ecoinvent and ELCD databases data have been used for international and national transport as well as for the production of the inputs used. System expansion has been used wherever possible in order to avoid allocation.

An earlier LCA study "Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the ecoproduction of olive oil" (ECOIL Project) was used as a reference several times, since it is based on an identical scope (Cyprus, Crete and Spain).

ABBREVIATIONS:

Ha:	Hectares (10 000 square meters
t:	metric tonne
fu:	Functional unit
kg:	kilogram

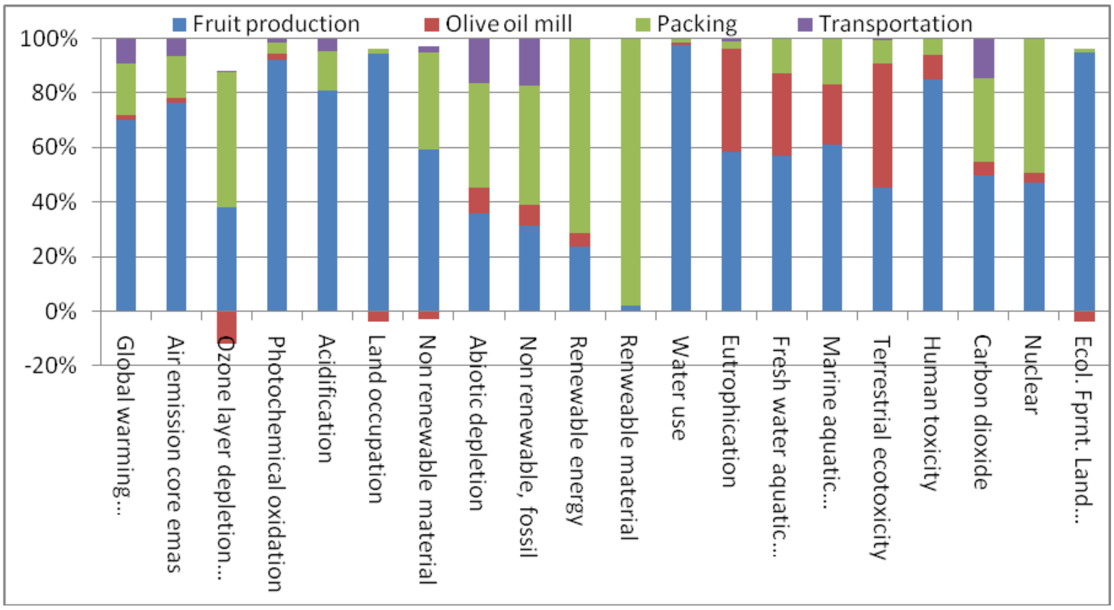
Results

The characterization results according to EPD (2008) method show that the field stage is responsible for most of the environmental impacts and for most of the impact categories as shown in the summary table below and in Chart 1 in next page.

ENVIRONMENTAL PERFORMANCE			**Upstream**	**Core**		**Downstream**
POTENTIAL ENVIRONMENTAL IMPACT		Total	Field	Extraction	Packing	Transportation
1. Global warming (GWP100)	kg CO_2 eq.	**2.506**	1.757	0.043	0.480	0.226
2. Emissions to air	kg	**0.030**	0.023	0.001	0.005	0.002
3. Ozone layer depletion (ODP)	kg CFC-11 eq	**0.000**	0.000	0.000	0.000	0.000
4. Photochemical oxidation	kg C2H4 eq	**0.008**	0.007	0.000	0.000	0.000
5. Acidification gases	kg SO_2 eq.	**0.023**	0.019	0.000	0.003	0.001
6.1 Materials to recycle/other use	kg	**0.354**	0.106	0.248	0	0
6.2 Waste for renewable energy	Kg	**1.716**	0.576	1.140	0	0
6.3 Other waste	Kg	**3.719**	0	3.719	0	0
6.4 Hazardous/Active material	Kg	**0**	0	0	0	0
6.5 Toxic emissions	kg	**0**	0	0	0	0
7. Land occupation	m2a	**9.723**	9.945	-0.400	0.178	0.000
8. Non renewable material	kg	**0.387**	0.244	-0.012	0.146	0.009
9. Non renewable (fossil) energy	MJ eq.	**18.579**	5.838	1.414	8.145	3.183
9.1 Abiotic resources	(kg Sb eq.)	**(0.010)**	(0.003)	(0.001)	(0.004)	(0.002)
10. Renewable material	Kg	**0.046**	0.001	0.000	0.045	0.000
11. Renewable energy	MJ eq.	**1.518**	0.357	0.077	1.079	0.004
12. Water use	m^3	**0.277**	0.271	0.002	0.004	0.000
13. Electricity use	MJ	**8.315**	4.048	0.60	3.666	0.000
14. Eutrophication	kg PO_4 eq.	**0.026**	0.015	0.010	0.001	0.000
15.1 Ecotoxicity – fresh water	kg 1,4-DB eq.	**0.837**	0.478	0.252	0.107	0.000
15.1 Ecotoxicity – marine	kg 1,4-DB eq.	**1 691**	1 031	0 374	0 284	0 003
15.1 Ecotoxicity – terrestrial	kg 1,4-DB eq.	**0.011**	0.005	0.005	0.001	0.000
16. Human toxicity	kg 1,4-DB eq.	**5.402**	4.586	0.479	0.329	0.007
17 Ecological footprint	Global m2a	**25.409**	23.928	-0.67	1.619	0.586

[1] Lubricants, pomace ash, leaves, not burnt wood
[2] Olive fruit wash water and OMWW
[3] Dry pomace and pruned wood, as fuel

CHART 1



A comprehensive sample of characterization results is presented below, with reference to the most important of the impact categories. All the results are presented for the entity «EPD Extra Virgin Olive Oil» i.e. no comparisons are made between the three farmers groups or between the two geographical areas (Peloponnese and Crete). All results are presented on a functional unit basis as a base case. However, whenever the results are analyzed per field activity the expression is on a per hectare basis.

1. Global warming – emissions of greenhouse gases (GHG) –

The 'Carbon Footprint' of the 2010-2011 EPD Extra Virgin Olive oil is described with the following statement:

Climate information: For every bottle of the present extra virgin olive oil that has been produced, packed and transported to the markets of northern Europe **2.51 Kg CO_2 eq.** of fossil origin CO_2 eq. have been emitted to the atmosphere.

The dominant player for the fossil GHG emissions is the field stage and much less packaging and transportation. The main responsible factor in the field is fertilizers use and to a lesser extent irrigation as shown in Charts 2 and 3 in next page.

CHART 2

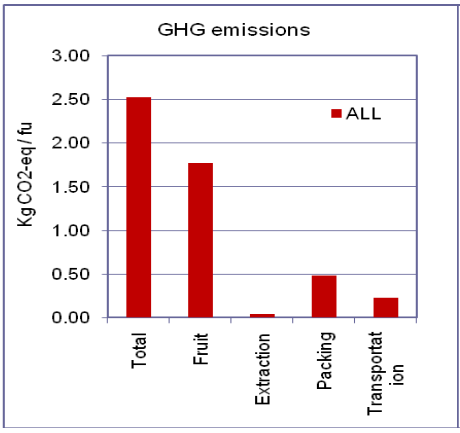
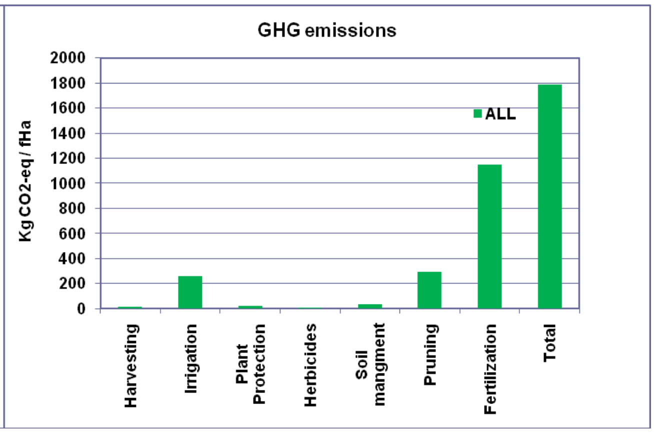
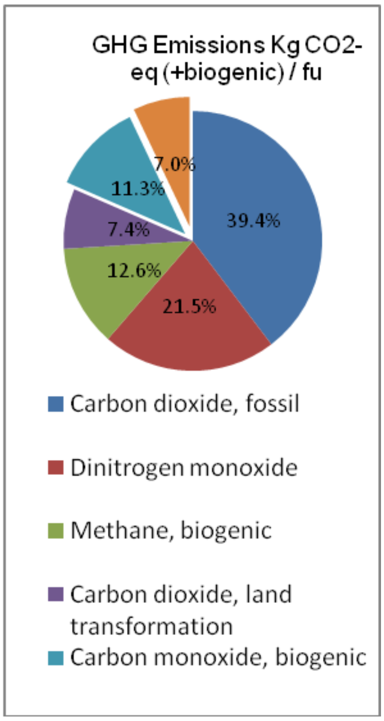


CHART 3



In this assessment the biogenic CO_2 emissions are not taken account of although their contribution is not insignificant, exceeding 18% as shown in Pie-Chart 4 below. Most of the biogenic emissions are due to CO produced by incomplete burning of pruned wood.

CHART 4



Biogenic CO_2 emissions

Biogenic carbon oxides from burning pruned wood are part of the balance of carbon in the olive groves, which seems possible to be managed by farmers and achieve a significant environmental benefit. The other players within the boundaries of the present LCA to be taken account of are the following:

Fixation of CO_2 in leaves of olive trees by photosynthesis

Fixation of CO_2 in leaves of weeds by photosynthesis

Emissions of CO_2 and N_2O by soil organic matter decay

Emissions of GHG by olive crop management

Emissions of CO_2 and other GHG by burning wood

Emissions of GHG by core and downstream processes

Removal of CO_2 contained in olive oil and sludge out of boundary

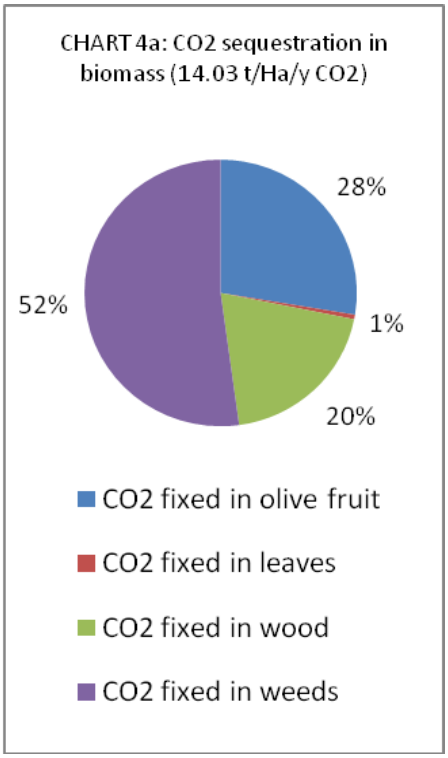
The net effect of Extra Virgin Olive Oil with regard to greenhouse related emissions is considered after all the above have been calculated. The result -with a reservation for the uncertainty linked to some of the contributions- is that olive oil production under the regime that applies to the scope of the present LCA leads to less CO_2 eq. been emitted then CO_2 sequestered. A difference of 2% of the total quantity of CO_2 (14.03 t/ha/y) is stored in the soil, as shown in Charts 4a and 4b in next page. The difference corresponds to 0.370 tonnes per Hectare or 0.370 Kg per functional unit. So, the statement on a Carbon +biogenic

Footprint below (top, next page) could be supported, since a worst case scenario has been used in the model used (see Appendix 1).

<u>Climate information</u>: For any bottle of the present extra virgin olive oil that has been produced, packed and transported to the markets of northern Europe and taking account of CO_2 fixed by photosynthesis and green house gas emissions at least 370 g of CO_2 per year may be removed from the atmosphere and stored in the soil of greek olive groves.

This benefit can be broadened by proper farmers' practices and be maintained for a long number of years in the form of enhanced content of soil in organic matter. Actually, there are reports from Italy, for a much larger quantity of CO_2 in oliveculture soil under relatively similar conditions (Xiloyannis at al 2009, in: Le acque reflue urbane trattate: risorsa da valorizzare nella olivicoltura meridionale. In Acta Italus Hortus 1 - 2009: 37-41).
This procedure of CO_2 storage in soil organic matter is accompanied by a number of other environmental benefits, like moisture retention, erosion control, increased soil fertility and less dependence on chemical fertilizers, facilitating thus the spreading of organic olive culture for the success of which nitrogen availability in soil is the limiting factor.

The overall picture of carbon cycle in an olive grove is attempted in the next page. It is stressed again that there is considerable uncertainty with regard to some of the values especially the ones related to the emissions of CO_2 and N_2O. Work is still pending in order to answer if permanent no till under the conditions that prevail in Greek olive groves would have a positive, neutral or negative effect on the mineralization of carbon and nitrogen.



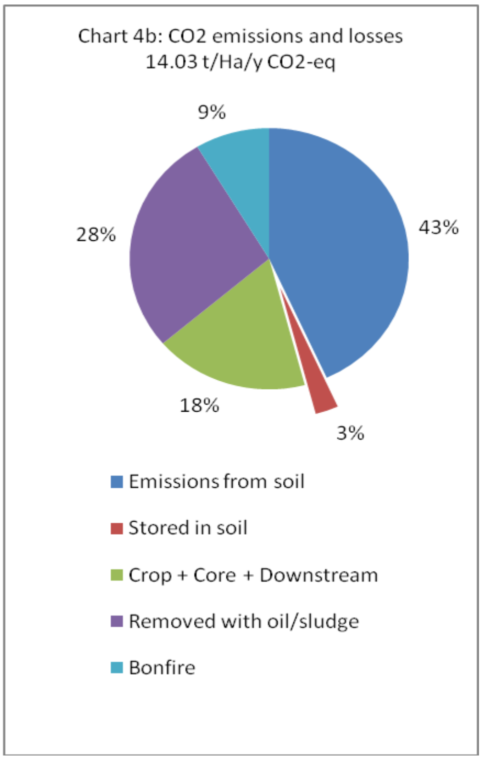


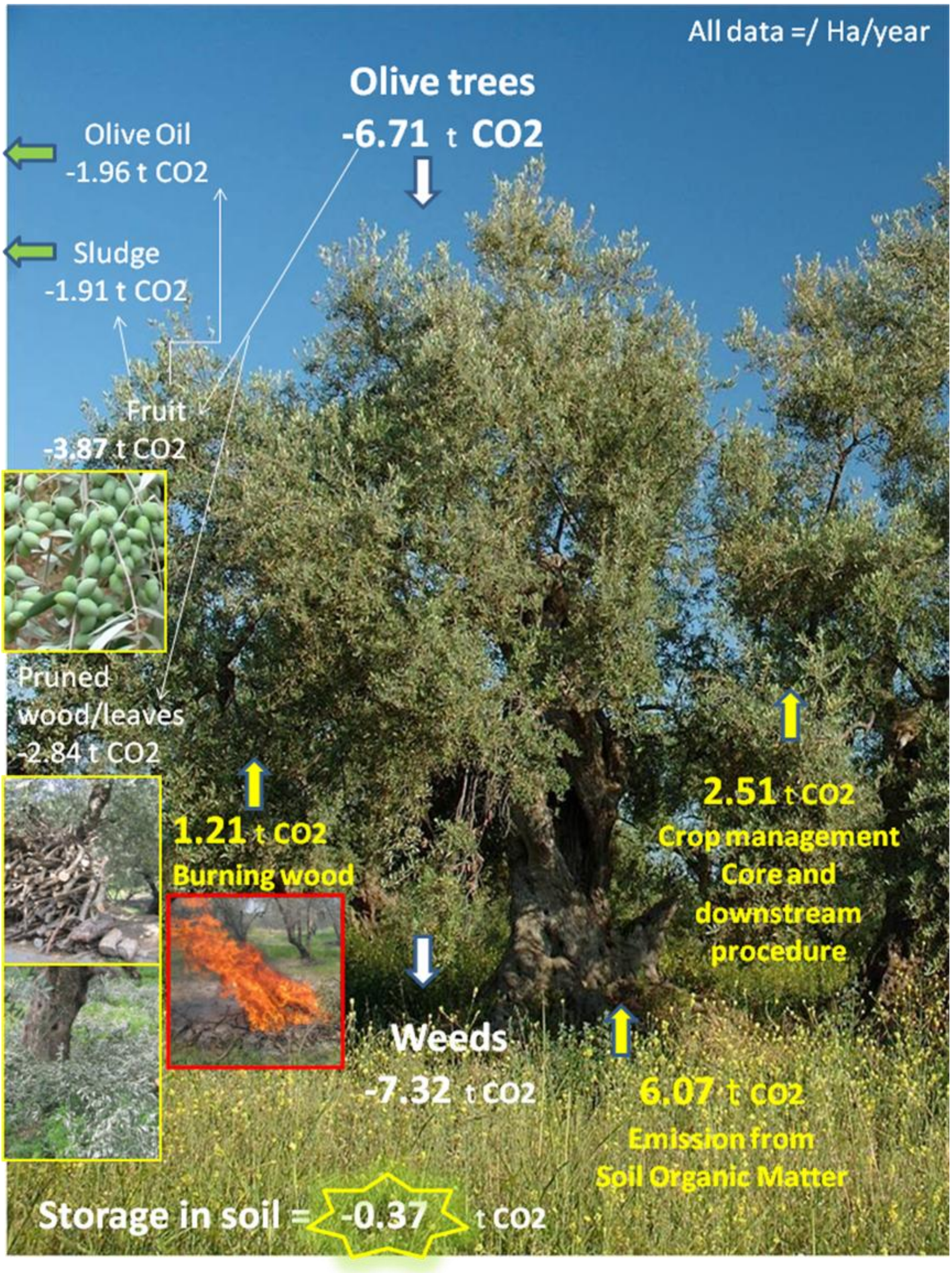
Figure 1: Carbon balance in an olive grove

Based on:

Yield of 0.7 tonnes of olive fruit/ha,

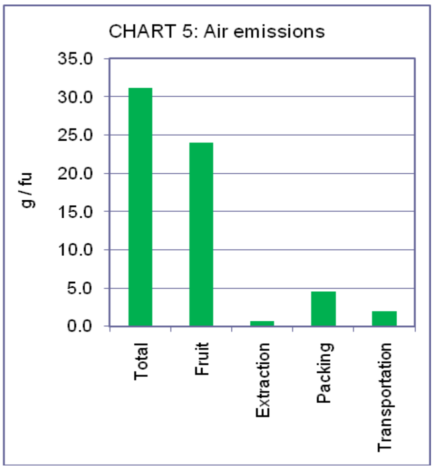
Soil Organic Matter = 2.5% and

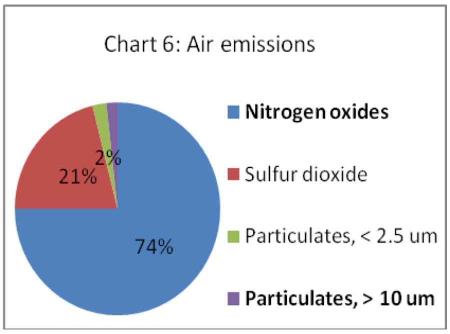
Weed biomass = 0.4 tonnes of dry weight/ha/year.



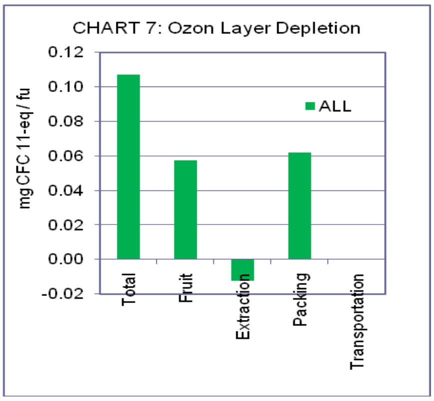
2. Emissions to air

Beyond green house gases (GHG) the following have been found to be emitted to air, mainly from the field phase as shown in Chart 5. More specifically, they are linked to the N_2O emissions of inorganic fertilizers as shown in Chart 6. Sulphur dioxide is linked to glass production. Particulates are linked to lignite burning for electricity production.



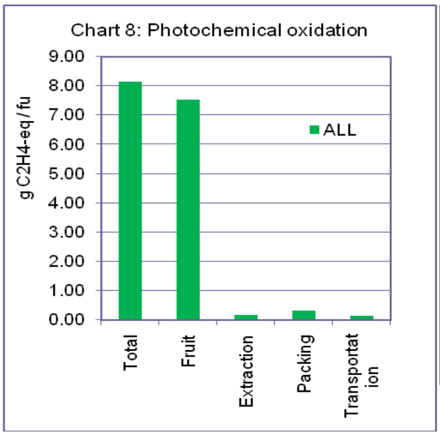


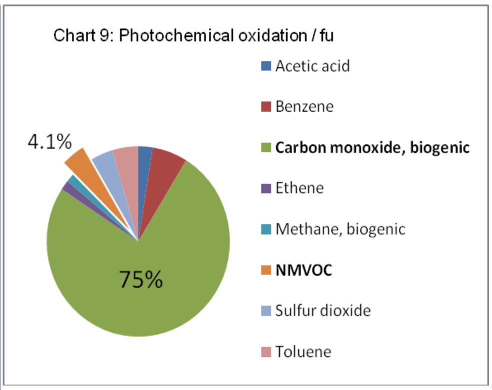
3. Emissions related to Ozon Layer Depletion (ODP)



The emission related to packing prevail in this impact category, followed by field phase with fertilizers again being primarily responsible. Some relief is offered by the use of leaves -separated from olive fruit in olive oil mills- as fertilizers substitute. The same occurs with the use of pruned wood as fuel replacement, since fuel production is also linked to production of ODP gases.

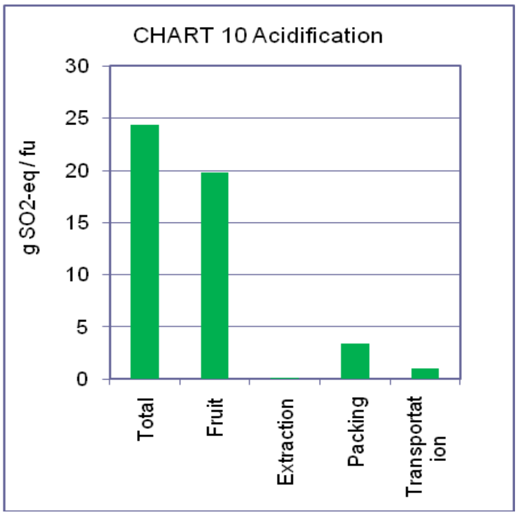
4. Photochemical oxidation





This is almost exclusively due to the field phase, namely to burning of wood from pruning. Some of the gases produced during this incomplete burning (carbon monoxide, benzene, NMVOC) are important for human health as well as for the deterioration of olive oil quality if burning takes place at the same time with harvesting and milling of the fruit. And, of course, wood burning deprives the soil of valuable organic matter.

5. Acidification



Mostly due to the field phase and secondarily to packing, emissions consist of nitrogen oxides (47%) ammonia (25%) and sulphur dioxide (27%). About 80% of the two first gases are emitted locally after applications of nitrogen fertilizers, while the remaining 20% as well as all the sulphur dioxide are emitted at the fertilizer production phase. Practically no ammonia is emitted in the core phase. Some nitrogen oxides are also emitted during packaging due to glass production for the bottles.

6. Waste

This water and wood ashes from dry pomace burnt as fuel in olive mills furnaces are local waste emissions. Also local is the empty packages of plant protection products and empty fertilizer bags.

6.1 Waste for recycling or other use

No recycling of waste –except for lubricants- has been considered in Greece, but only in the country of destination, i.e. Sweden for packing material. However, a number of items is used for other purposes such as ash from pomace used as fuel in oil mills and leaves separated from olive fruit in the oil mills are used as replacement for fertilizers. Also a part of pruned wood is used for fences, tool making etc.

6.2 Waste used as renewable energy source

Pomace from 3-phase oil mills is used as fuel in oil mills, in greenhouses for growing vegetables etc, as fuel replacement. The same is true for large pieces of pruned wood which is used in farmers' houses in stoves and fireplaces also as fuel replacement.

6.3 Other waste – Final waste flows

This includes water from olive fruit-washing process and Oil-Mill-Waste-Water for which emissions have been included in the overall pattern. Also, the empty packages of plant protection products and of empty fertilizer bags.

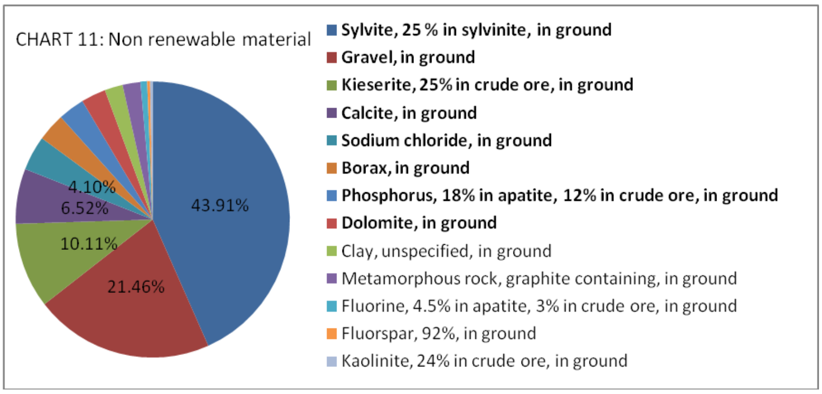
6.4 & 6.5 No hazardous or any toxic waste is emitted.

7. Land occupation

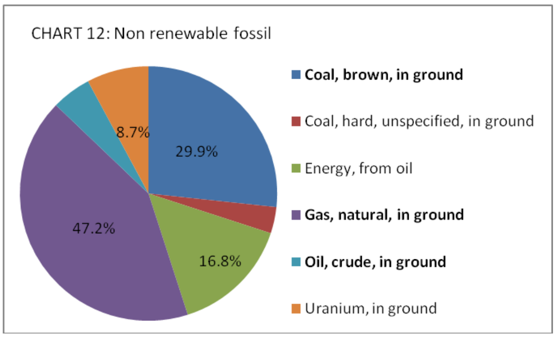
This can be attributed almost exclusively to olive groves, which have not undergone land use change during the last centuries in order to accomodate olive culture. Almost 10 m2 (9.99 m2) of olive grove are required for the production of one functional unit.

8. Use of non renewable material

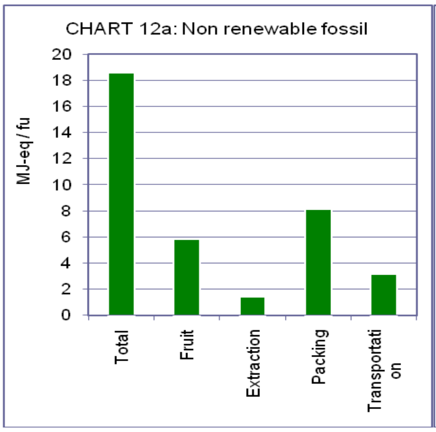
An amount equal to 0.39 Kg is required in total per functional unit. As shown in Chart 11 it is used mainly for fertilizers (Sylvite is required for K) production, while also glass manufacturing requires gravel from the ground.

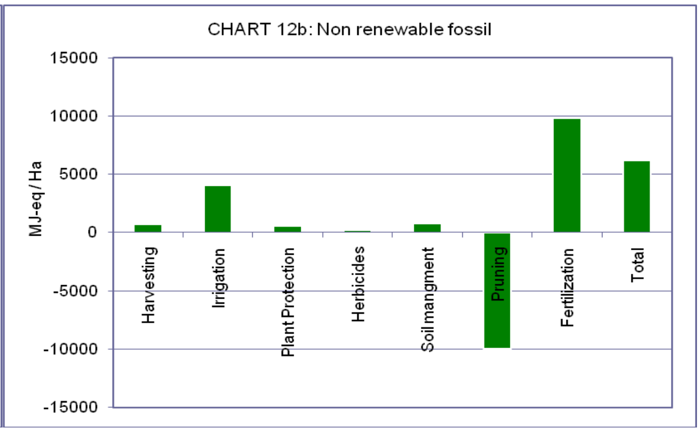


9. Consumption of non renewable fossils.



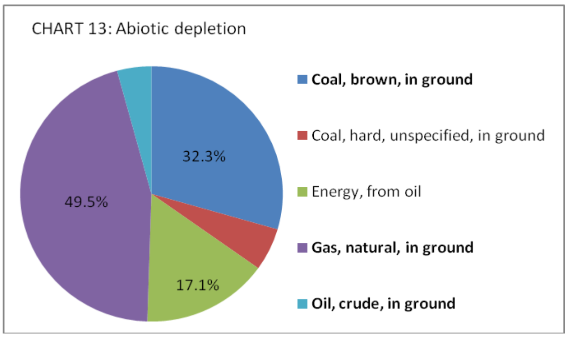
Resources used for energy production as shown in Charts 12 & 12a are used up for all the phases in the life cycle of olive oil summing up to 18.579 MJ/functional unit. In the field phase though (Chart 12b) the net effect is negative due to the replacement of fuel oil by pruned wood.





9.1 Abiotic resources depletion

From another angle, a pattern similar to non renewable fossil fuels resources above is found (pie-chart 13) for abiotic resources, equivalent to about 10 g of Sb per functional unit, according to CML baseline 2000 method.



10. Renewable material.

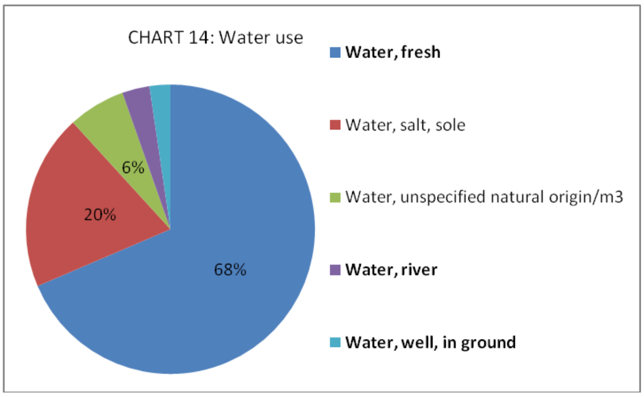
Almost exclusively renewable material (wood) is used for corrugated paper production

11. Renewable energy

There is only a small use for fertilizers production and for electricity production in Greece.

12. Water use

Irrigation is by far the main use of water, so local extraction is the issue. Also local comsumption is related to water used for oil extraction in olive oil mills which represents the 2% of all water usage (Water, well in ground as shown in the pie chart below). In a life cycle perspective, a significant use of water is indirect, i.e. for insecticides and fungicides manufacturing (Water salt, sole equal to 20% of total water use) and for irrigation of the juta plants from which the harvesting sacks are made (water, river).



13 Electricity

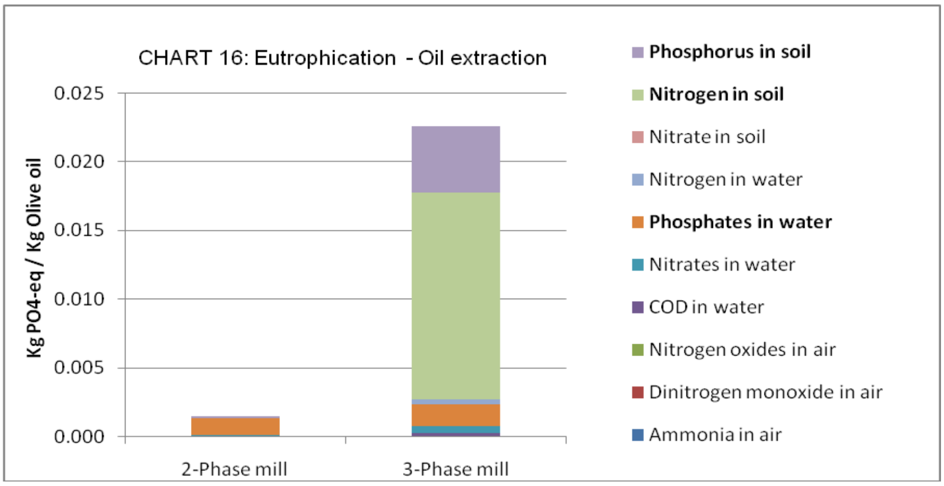
Its use is shared between field and packing phases as shown below.

USE OF ELECTRICITY	Unit	Total	Field	Extraction	Packing	Transportation
	MJ	**8.315**	4.048	0.60	3.666	0.000

14. Eutrophication

As shown in the chart on the left, two are the main sources of emissions related to eutrophication, fruit production and olive oil extraction. For fruit production stage it is obvious that fertilization and to some extent irrigation are the principal sources of emissions.

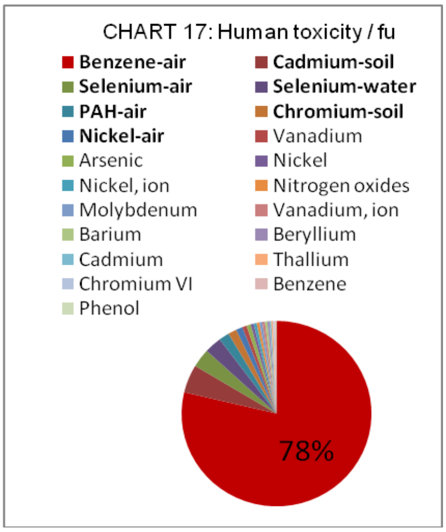
The extraction phase is marked by the difference between 2 phase mills and three phase mills, as shown in the graph below.



15. Ecotoxicity

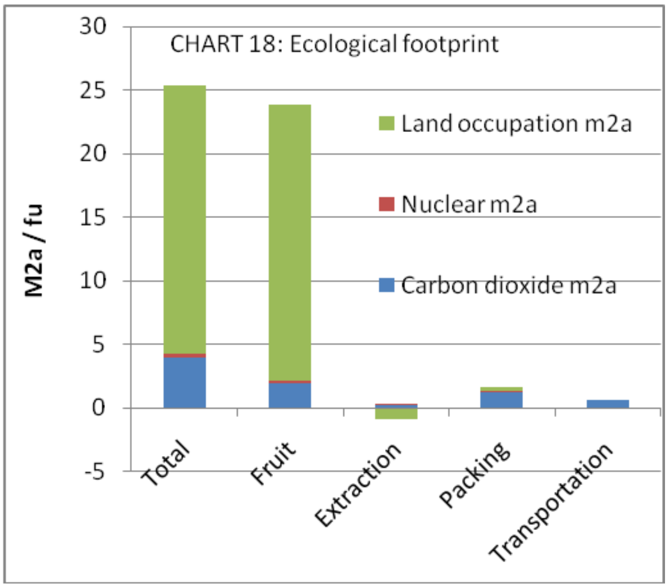
Both, fresh water and marine ecotoxicity are influenced by heavy metals emitted from lignite burning electricity production units. In addition to them for terrestrial ecotoxicity insecticides also play a small role.

16. Human toxicity is related almost exclusively to wood burning after pruning, as one of the products, benzene predominates as an emission, as shown in the graph.



17. Ecological footprint.

It is calculated to be 25.43 m2a, which is quite high but not so important since it almost all due to the field phase i.e. the olive grove area as shown in chart 18 below.

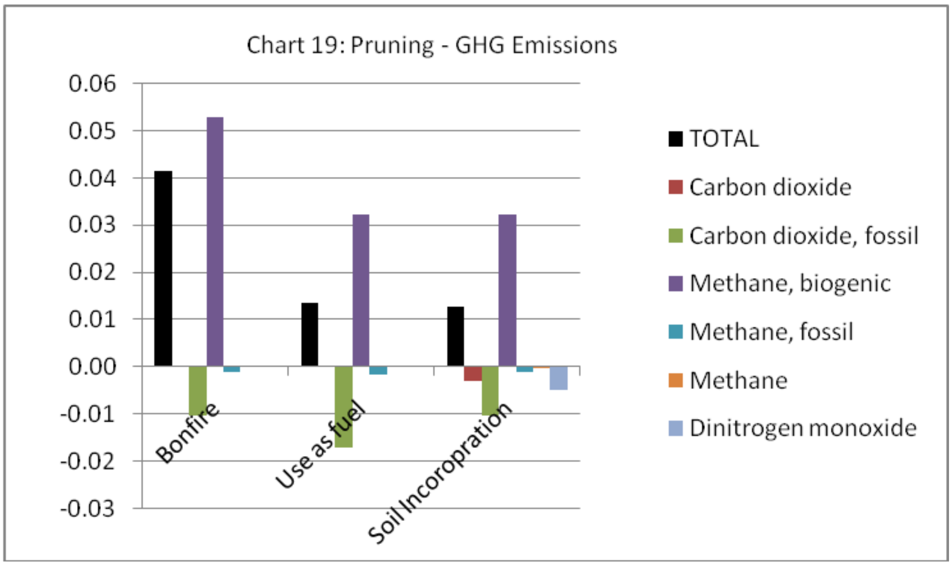


The significance of land occupation for olive fruit production is highlighted by the fact that it is an extensive, relatively low input olive-culture as it is practiced in all three areas of interest is nothing else but a natural, millennium old olive forest.

INTERPRETATION

The study included 4 sensitivity analyses, two of which showed significant findings so they are presented here.

- As seen in Chart 16 in previous page, oil mill technology is very important for eutrophication which is a local threat given the proximity of the three areas to the sea. Fortunately the shift from 3 phase oil mills to 2-phase oil mills is taking place in a rapid pace already.
- The fate of pruned wood is also very important for a number of impacts like GHG emissions, as shown in graph 19 below.



So, the overall focus of the Environmental Product Declarataion is on performance with regard to GHG and climate change, where it seems that the biogenic part of the emissions contributes in a way that does not justify for its exclusion. On the contrary, it should be taken in account as an objective for the second goal of the study, this of environmental improvement. In this sense reduction of atmospheric CO_2 seems feasible by storing it in the soil sink, until soil organic matter is increased to such an extent that a steady state between inputs and outputs is reached. The time that will be required for that is quite long and will depend on the efficiency of the farming practices e.g. no tillage, no burning of wood etc. that will ensure that CO_2 will remain sequestered in the soil as much as possible.

CONCLUSIONS, LIMITATIONS AND RECOMMENDATIONS

The fate of pruned wood and plant debris like dead weeds and leaves from the oil mill i.e. incorporation in the soil (after composting, maybe, but without soil disturbance) relates to a number of significant impacts and seems to be the single point of improvement, over the current practice of burning. Exploitation of this plant material would reduce the need for inorganic fertilizers which are responsible as a serious contributor to a number of impacts. In addition, soil incorporation of dead wood could enhance soil fertility and at the same time the storage of CO_2 in the ground. Work is still needed in order to ensure via suitable farmers practices that the highest possible fraction of soil incorporated plant material stays there being transformed to humus, and that the release of CO_2 and other GHGs from its decomposition delays and diminishes.

From the data on the 487 olive groves it is manifested that «no two farms are alike» as uncertainty is immense at that level, as shown by the large figures of standard deviation in the LCI values. Uncertainty diminishes as one moves from the field to the olive oil mill, the packing house and transportation. This finding leads to the conclusion that the present LCA should not be used as a representative study for olive culture and olive oil production, but only as an indication of opportunities for improvement of environmental performance. A robust management system has to assure that only producers who provide credible primary data i.e. accurate and timely recordings are accepted as EPD users. This is a prerequisite in order that improvement can be credibly documented.