"Life Cycle Assessment (LCA) as a Decision Support Tool (DST) for the ecoproduction of olive oil"

TASK 4.1

Life Cycle Impact Assessment (LCIA) and Identification of Key Points in Ribera Baja (Navarra, Spain)

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Córdoba, España, 2006

Financial support from the EC financial instrument for the environment

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DEMONSTRATION PROJECTS

Index

1 Life Cycle Impact Assessment

Life Cycle Impact Assessment (LCIA) is the phase in which the set of results of the Inventory analysis – mainly the inventory table – is further processed and interpreted in terms of environmental impacts and societal preferences. To this end, a list of impact categories is defined, and models for relating the environmental interventions to suitable category indicators for these impact categories are selected. The actual modelling results are calculated in the characterisation step, and an optional normalisation serves to indicate the share of the modelled results in a worldwide or regional total. Finally, the category indicator results can be grouped and weighted to include societal preferences of the various impact categories. (Guineé *et al*, 2001)

ISO 14.042 determines structure of this stage distinguish between obligatory –impact categories selection, category indicators and models; classification and characterisation -and optional steps.

For this study we will just perform obligatory analysis using SIMAPRO v 7.0 that allows us to classify inventory and characterize –calculate category indicators- easily.

After entering results from inventory, steps for further calculations are performed semi-automatically and results are shown in form of tables and graphics for an easier interpretation.

As stated in previous project tasks, we will follow two methodologies: Ecoindicator 99 and CML 2 Baseline 2000.

In the next sections, results for each phase will be presented, focusing in detail in Agricultural Phase (the one which has more environmental impact following Ecoindicator 99 and CML 2 Baseline 2000 impact assessment methodologies) and for the whole Life Cycle of Extra Virgin Olive Oil production.

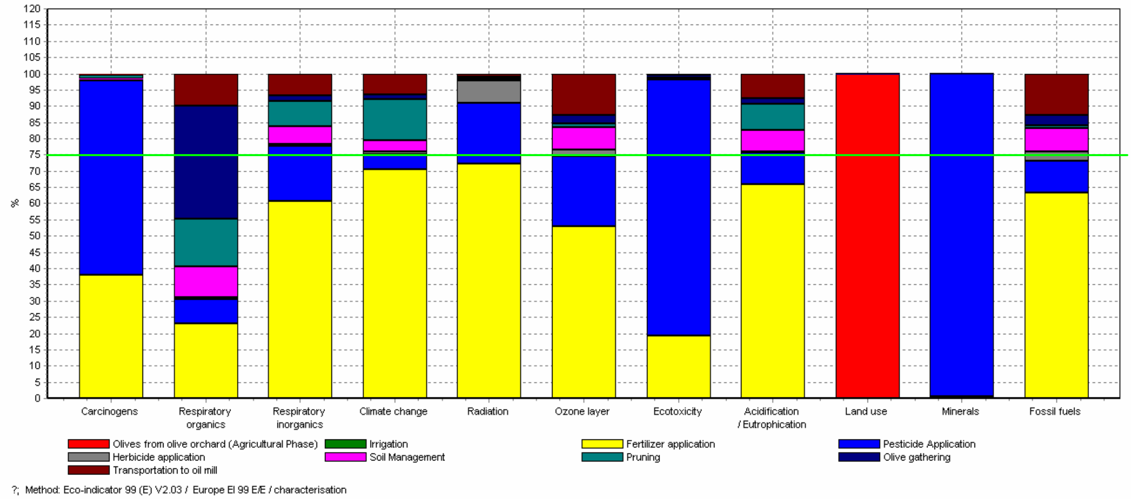
When presenting phases in details, only Ecoindicator 99 methodology has been follow, as far as most LCA studies follow this methodology. As it will be clearly seen, CML 2 Baseline 2000 results are very close to those shown in Ecoindicator 99.

For a better understanding of LCIA results, the easiest and more comprehensive way to achieve this is present them in form of graphs, moving from an overall picture to specific results for each impact category.

1.1 Agricultural Phase

1.1.1 Ecoindicator 99

1.1.1.1 Resume



From a first impression, it can be checked how fertilizer application and pesticide application has an impressive environmental impact through all impact categories except for land use.

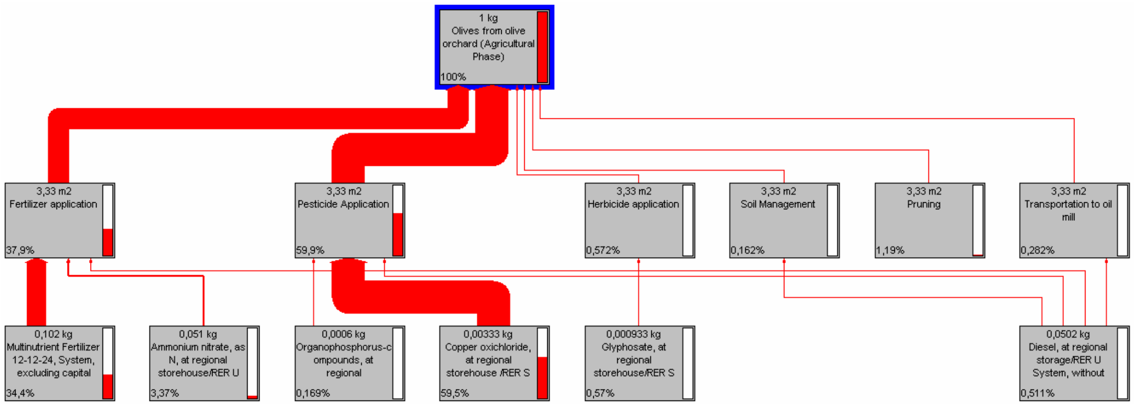
The line over the graph mark the 75% of environmental impact in olive tree cultivation, and except for the categories respiratory inorganics, land use and fossil fuels, fertilizer application and pesticide application surpass that line. In case of fossil fuels, summing impacts of fertilizer application, pesticide application and herbicide application go beyond 75% of overall environmental impacts.

In the impact categories carcinogens, radiation, ecotoxicity and minerals, fertilizer application and pesticide application sum more than 90% of environmental impact.

1.1.1.2 Detailed results

1.1.1.2.1 Carcinogens

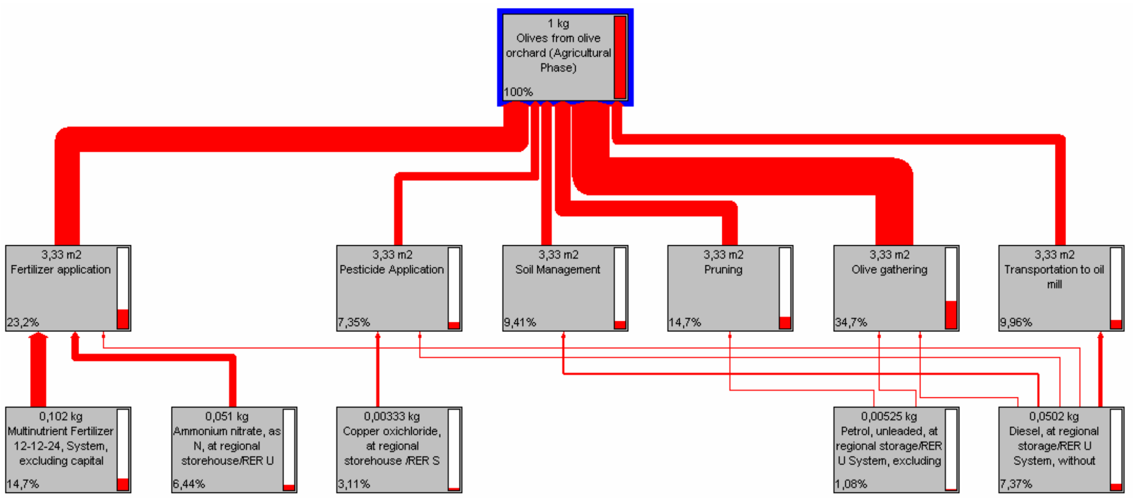
When representing processes contributing more than 0,1 %, production of copper oxychloride and Multinutrient fertilizer 12-12-24 reach about 95% of contribution to this category.



1.1.1.2.2 Respiratory organics

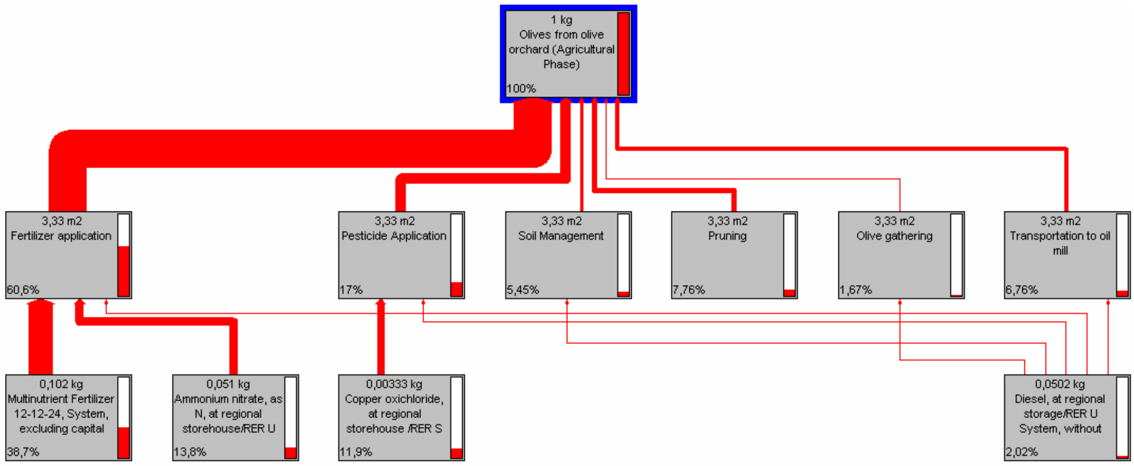
Processes contributing more than 1% are shown in next figure, where it can be appreciated that most contributing stage is olive gathering followed by fertilizer application (production of 12-12-24 fertilizer more than on field task) and pruning.

Entry of data has been checked in order to understand this “anomaly” when comparing with the rest of impact categories. All data were correct, so it will be assume that emission of gasoline gases (only in olive gathering by limb vibrator and pruning by chainsaw) is the main contributor. For further analysis, gasoline emissions should be checked with more detail.



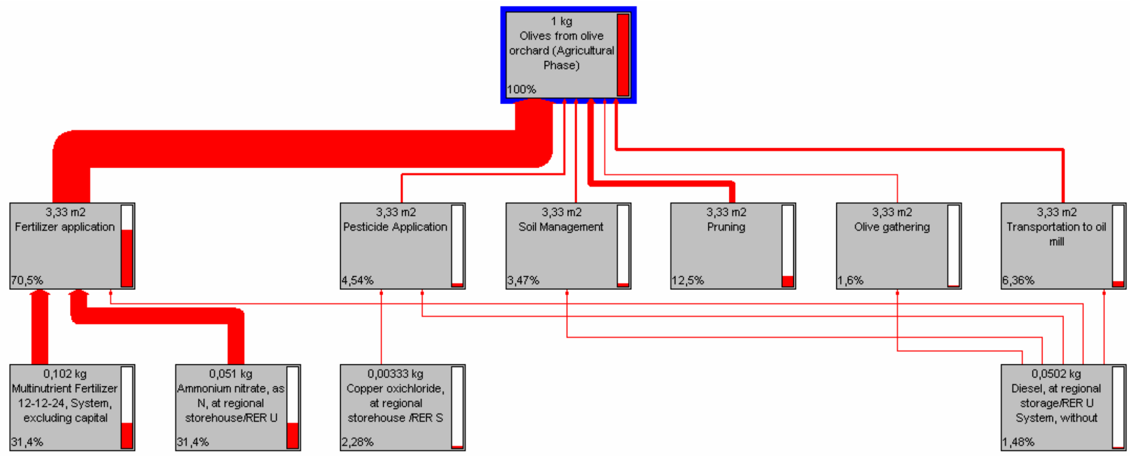
1.1.1.2.3 Respiratory Inorganics

If we represent processes contributing more than 1%, fertilizer production has a predominant position. Also, production of copper is significant in this impact category.



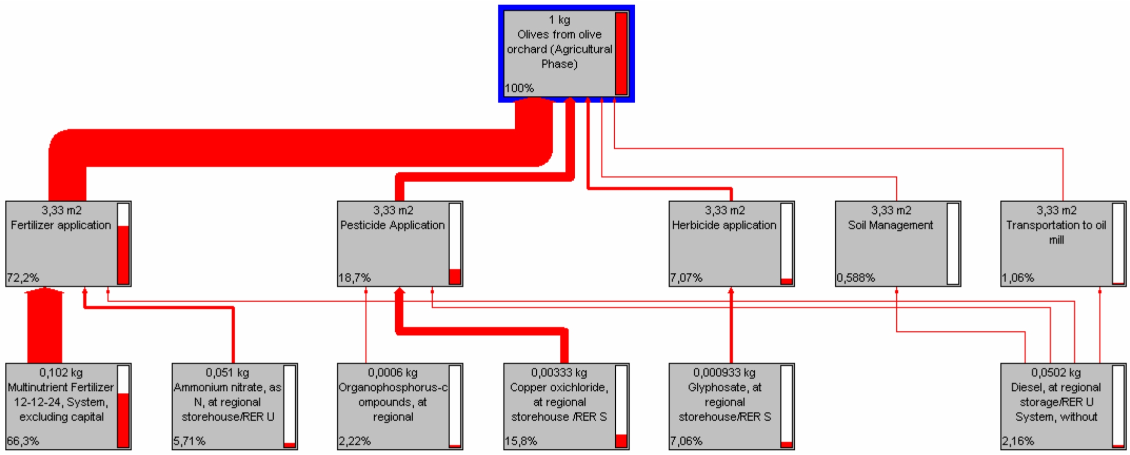
1.1.1.2.4 Climate change

Processes contributing more than 1% are mainly production of fertilizers (both 12-12-24 and ammonium nitrate) and pruning (mainly burning pruning residues). However, as it has been explained in Task 3.3, differentiation between biogenic and fossil carbon dioxide in processes can lead to differences in other Life Cycle Impact Assessment.



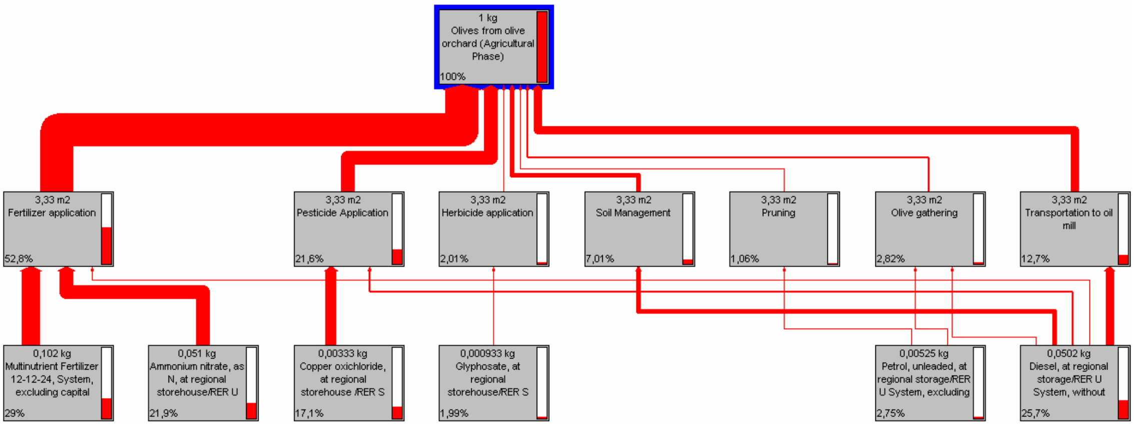
1.1.1.2.5 Radiation

Production of fertilizers (especially 12-12-24) and copper oxychloride have an impressive total impact in this category (90%) when representing processes contributing more than the 0,5 %.



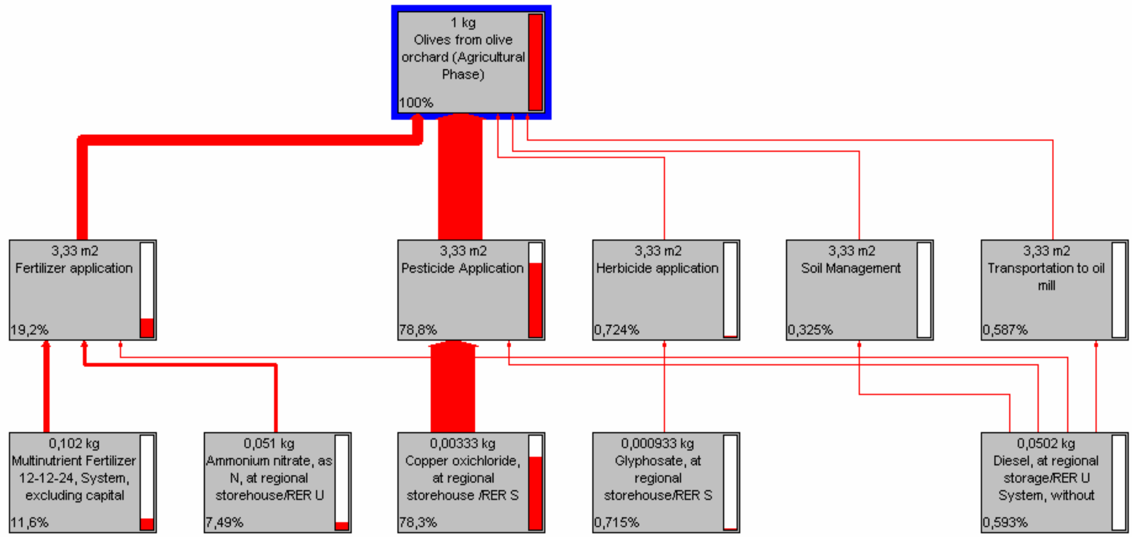
1.1.1.2.6 Ozone layer

Once again, production of chemical agroinputs (fertilizers and copper fungicide) have a relevant position. Also, in this case, diesel production and distribution has about a 25% of the overall contribution. (In the graph, processes contributing more than 1%).



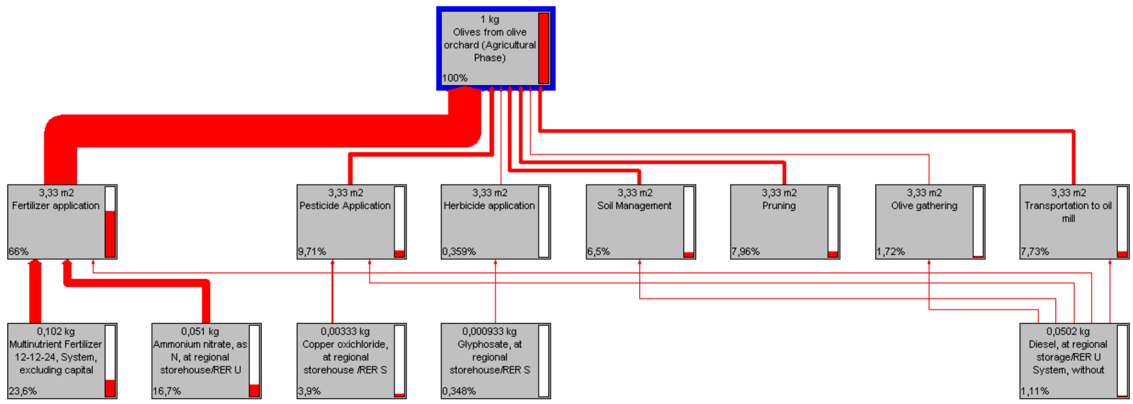
1.1.1.2.7 Ecotoxicity

For ecotoxicity, if we present processes contributing more than 0,25 %, it can be clearly appreciated how production of copper oxychloride and production of fertilizers reach up to 98%). On field fertilizer and pesticide applications do have a very low impact in this category, which is not usual in another environmental impact studies.



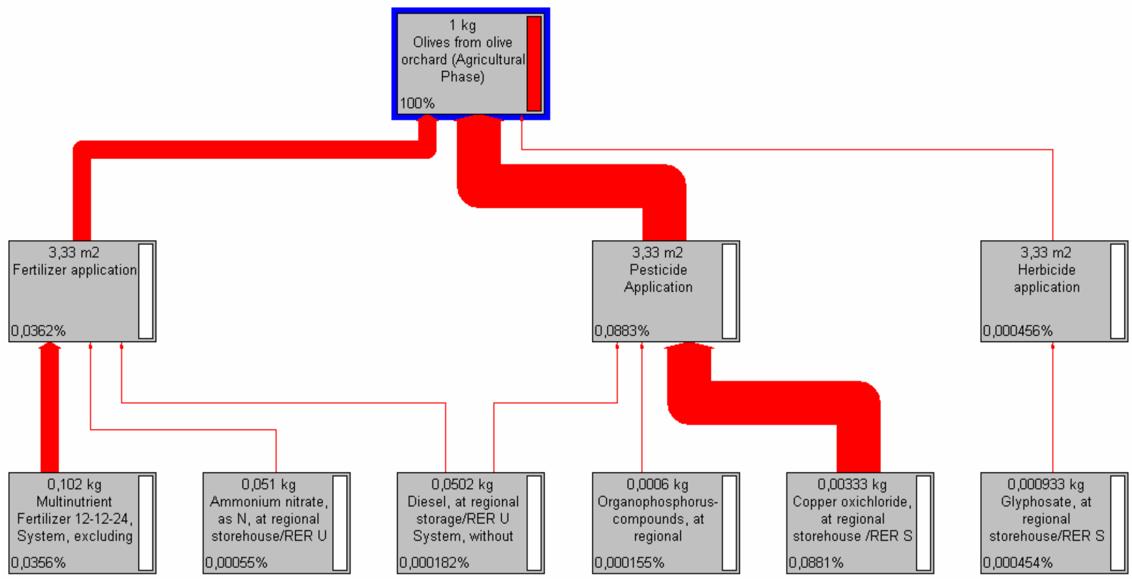
1.1.1.2.8 *Acidification/Eutrophization*

Processes contributing more than 0,25 % are represented below, where can be appreciated that overall impact is caused by fertilizer application, mainly by on field tasks (fuel emissions, nitrogen emissions and others) -25,7%- and production of fertilizers (12-12-24, 23,6% and ammonium nitrate, 16,7%). Other on field activities and transport relaying on tractor use have a lower –but significant- environmental impact.



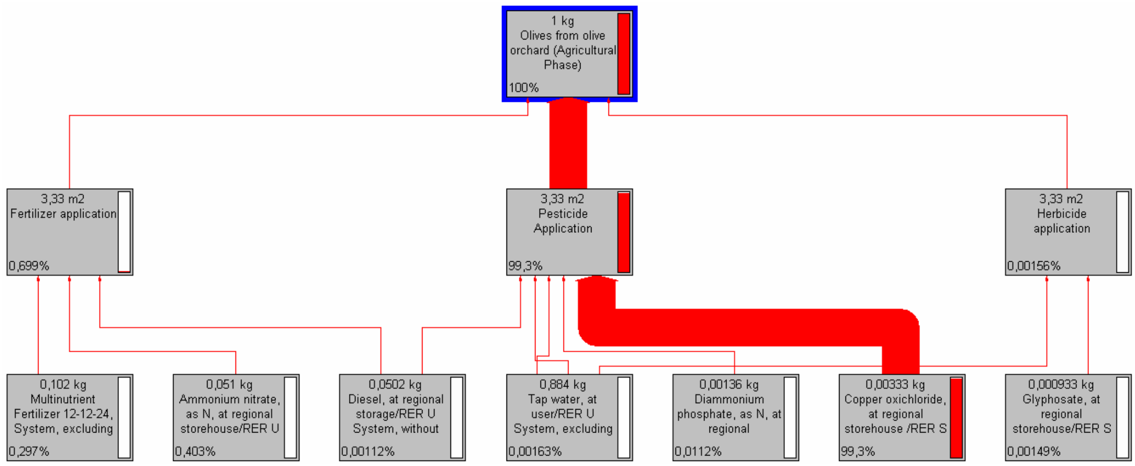
1.1.1.2.9 *Land use*

In this case, land occupation is almost 100% produced by the olive grove occupation. Other process has a negligible impact. (In the graphs, processes contributing more than 0.0001%. Please note 100% of olives from olive orchard)



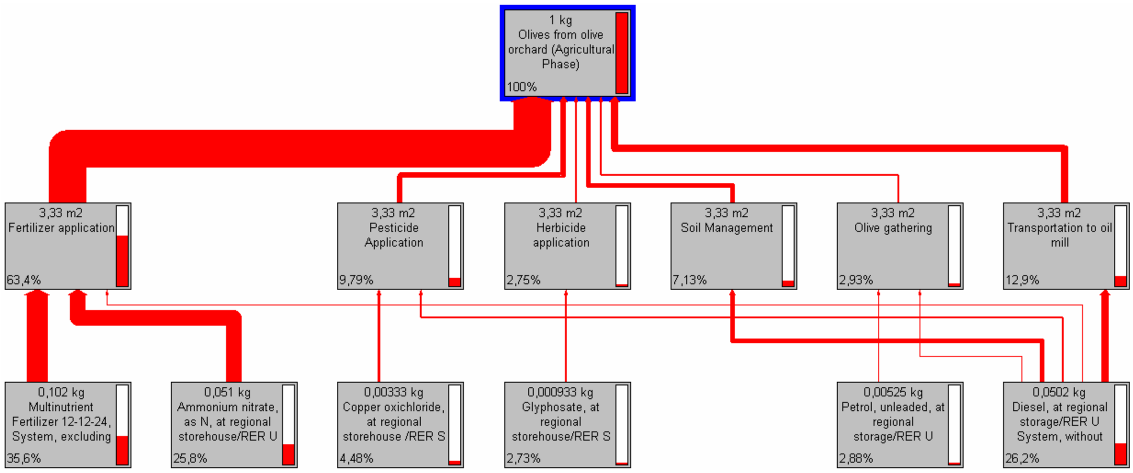
1.1.1.2.10 Minerals

Main impact to this category comes from the production -and distribution- of copper oxychloride (In the graph, processes contributing more than 0.001%)



1.1.1.2.11 Fossil Fuels

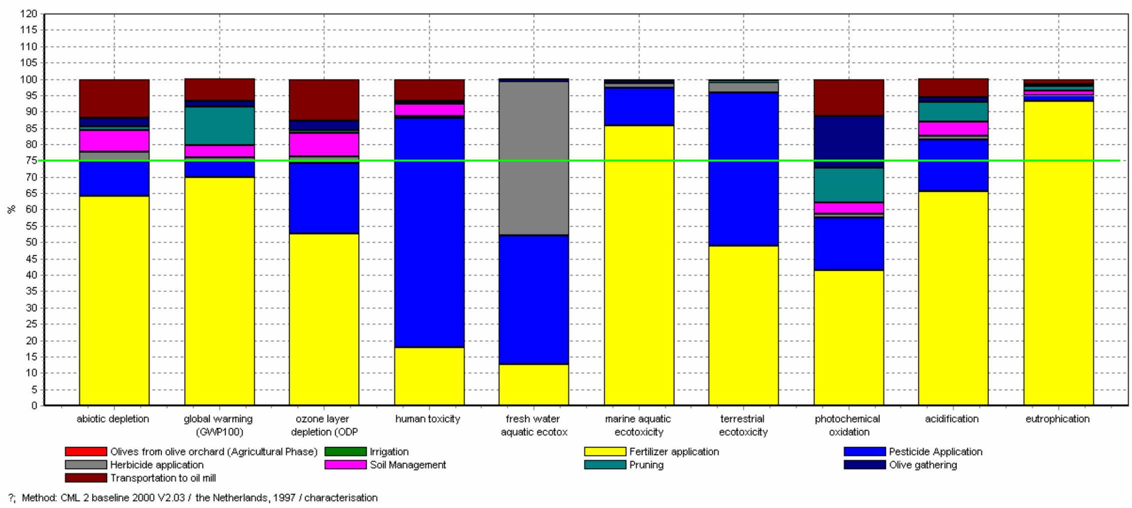
Production of 12-12-24 fertilizer, ammonium nitrate and production and distribution of diesel has almost 90% of contribution to this impact category. (In the graph, processes contributing more than 1,5%)



1.1.2 CML Baseline 2

Results from this impact methodology, show, as well that in Ecoindicator 99, that fertilizing and pesticide application have a predominant environmental impact. In 8 of 10 impact categories, the sum of both processes reach up to/more than 75% of impact category.

The other two impact categories, fresh water aquatic ecotoxicity and photochemical oxidation also shows important contribution of chemical agroinputs. For the first one, fertilizer application, pesticide application and herbicide application sum almost 100% of contribution in this category. For the second one, the three mentioned tasks reach a value of about 57%.



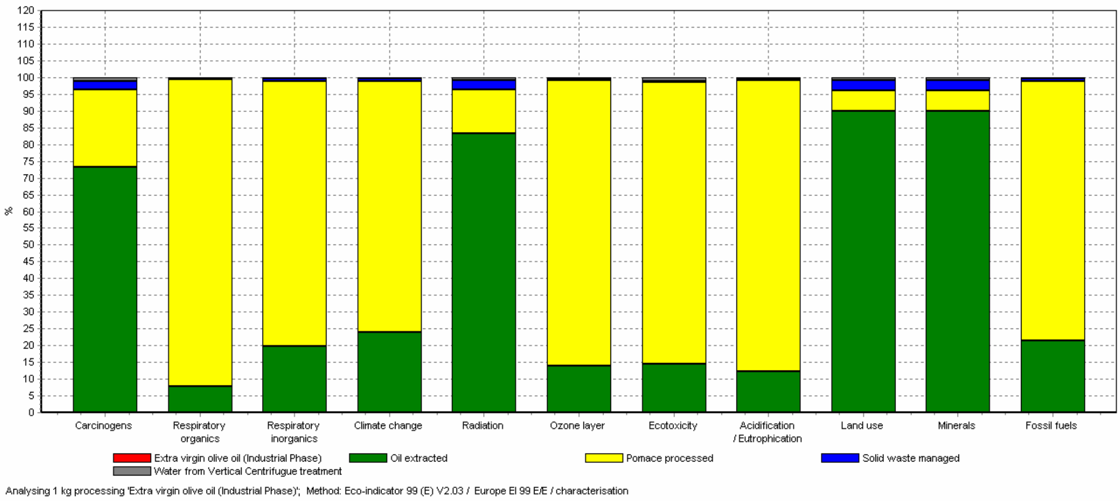
1.2 Industrial Phase

Many times when thinking about industrial processes, we expect them to have a significant environmental impact in the whole process chain. For the case of production of bulk extra virgin olive oil, the LCA has shown that this is not absolutely true. Comparison of agricultural phase vs. industrial one will be made in section 1.3.

However, pomace (watery pomace, in case of 2 phase oil mills), does have a significant environmental impact. In the following sections, a resume for selected impact methodologies are presented.

1.2.1 Ecoindicator 99

For all impact categories, extraction of oil and pomace transport (processing) do have a very significant contribution to the process (check figure below). Treatment of water from vertical centrifuge and management of solid waste (leaves and browse) have a very low impact in this phase.



Comparison of environmental impacts of these two main processes can be checked in

Table 1. Comparison of Impact categories reaching more than 75% in Olive oil extraction and Pomace Processing

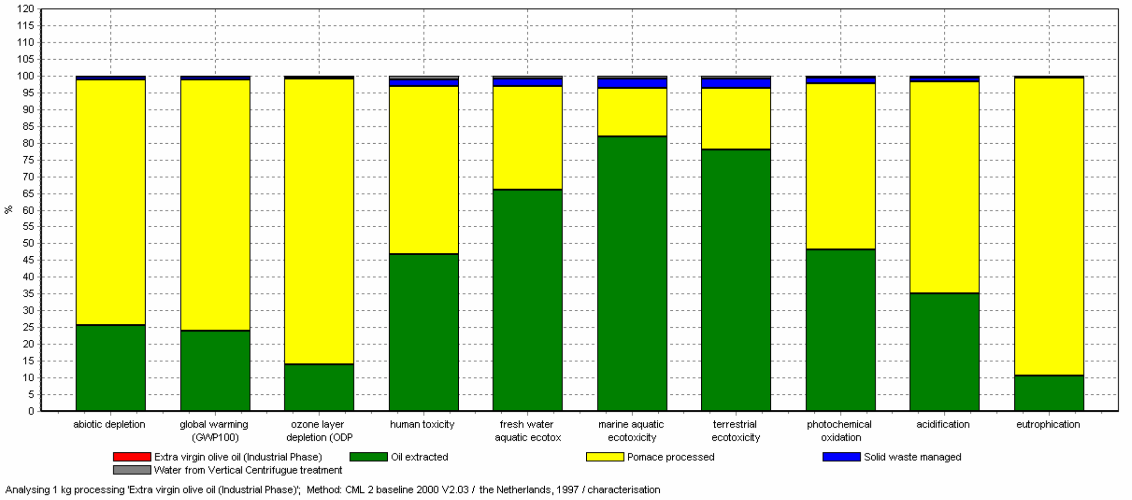
Olive oil extraction	% (app.)	*Pomace processing*	% (app.)
Land use	90	Respiratory Inorganics	90
Minerals	90	Acidification/Eutrophication	90
Radiation	80	Ozone layer	85
Carcinogens	75	Ecotoxicity	85
		Respiratory Inorganics	80
		Fossil fuels	80
		Climate Change	75

1.2.2 CML 2 Baseline 2000

Results from this methodology are similar from those presented for Ecoindicator 99.

However, there are some changes when referring to different toxicities, especially because CML 2 Baseline 2000 present them in a detailed way. Pomace processing (transport) do have a very important contribution in fresh water, marine and terrestrial toxicity, whereas human toxicity is almost similar to both processes.

"Abiotic depletion" is more detailed in Ecoindicator –minerals and fossils fuels- and thus, the overall sum of them –among others- gives us a 75% of impact for pomace processing in abiotic depletion (CML 2 Baseline 2000.). This is a direct consequence of huge consumption of fuel when transporting pomace to further oil extraction.

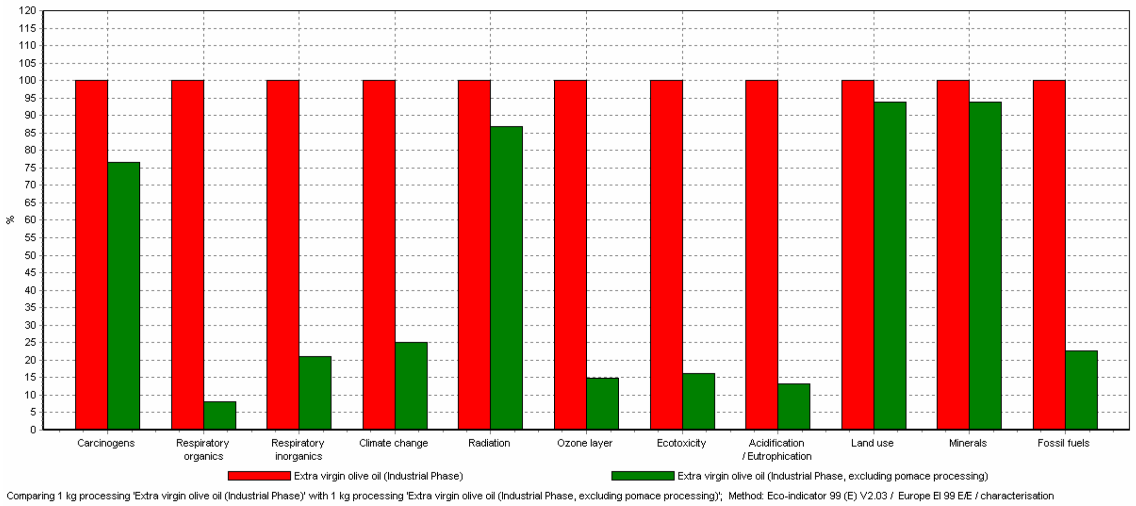


1.2.3 Excluding pomace from analysis

Previous results conclude that pomace processing is the most pollutant activity where producing olive oil, and thus, a further analysis.

In the above graph, a comparison of industrial phase including pomace processing vs. industrial phase excluding pomace processing has been carried.

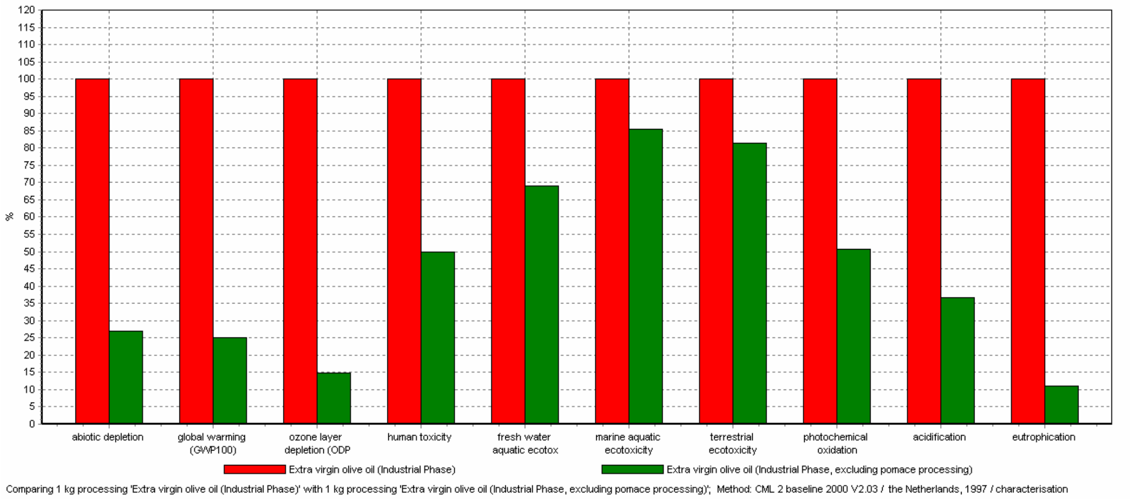
Ecoindicator 99



Environmental impacts of production of extra virgin olive oil fall below 25% in many cases (8 of 11), except for carcinogens, radiation, land use and minerals, where it is maintained among 75 and 95%.

CML 2 Baseline 2000

Results in this methodology does not represent exactly from those founded with Ecoindicator, but it must be mentioned than in 7 of 10 impact categories, effects go below 50% of its environmental impact when including pomace.



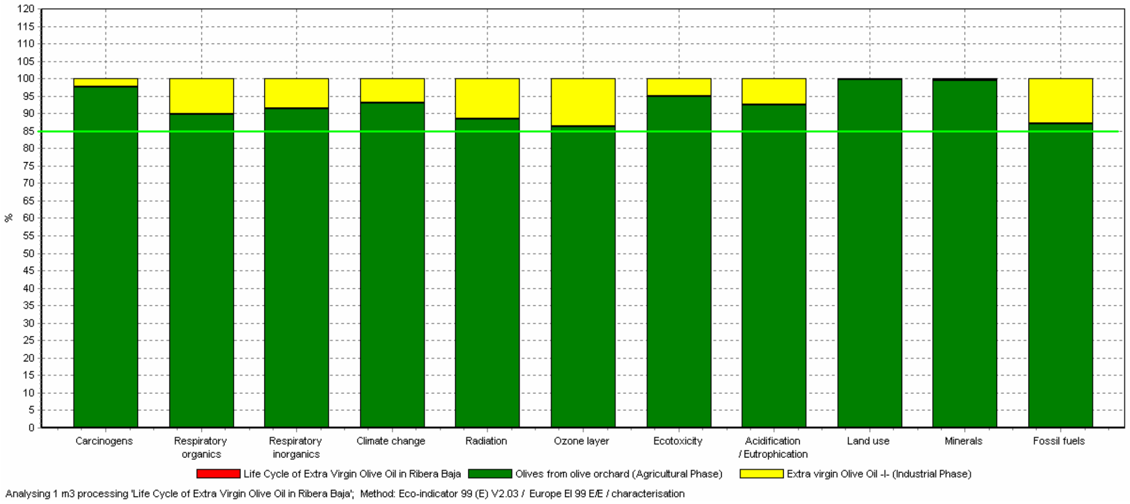
1.3 Life Cycle of Olive Oil production

After analysis, results in the two stages, the overall impact of olive oil production can be assesed.

1.3.1 Ecoindicator 99

From the general graph represented in the resume, it can be easily appreciated how industrial phase do not have more than 15% of contribution for all environmental processes.

1.3.1.1 Resume



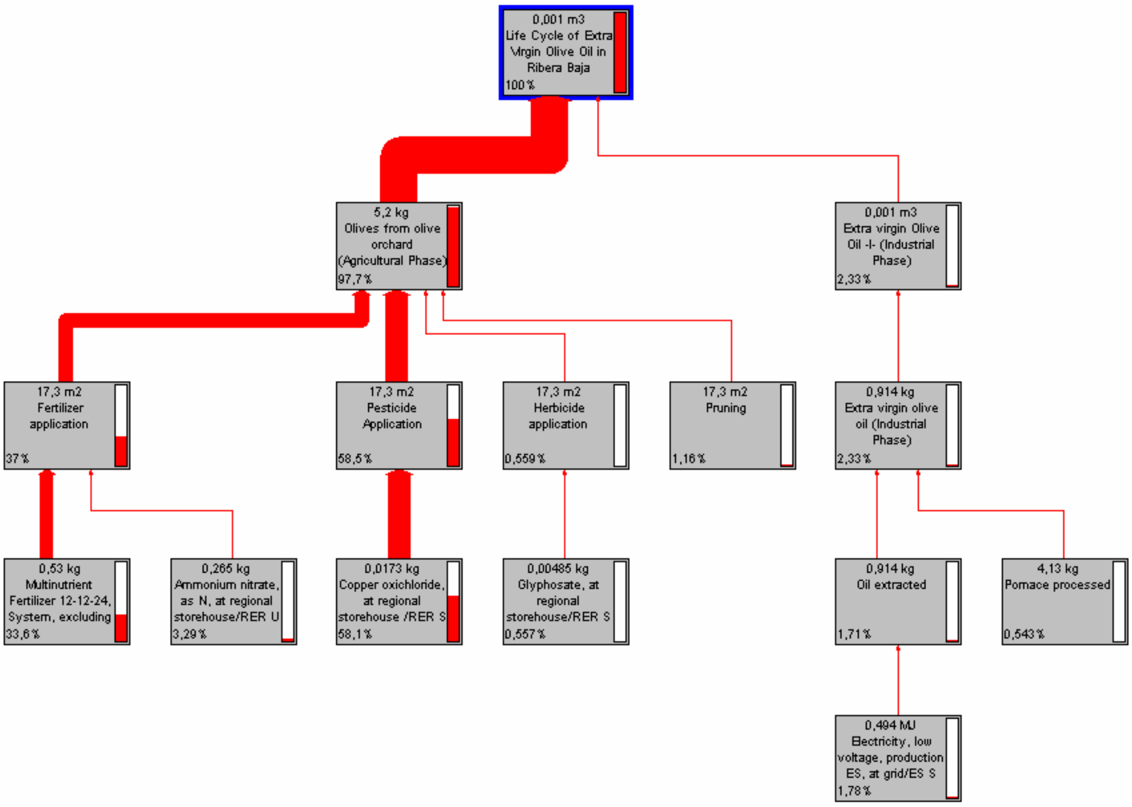
In Table 2, a resume of the whole environmental impacts following Ecoindicator 99 through phases is shown.

1.3.1.2 Detailed results

Detailed results are displayed in the next pages, but results do not differ so much from those previously commented in section 1.1.1.2. and repetition of data have no sense when results can be checked at one glance.

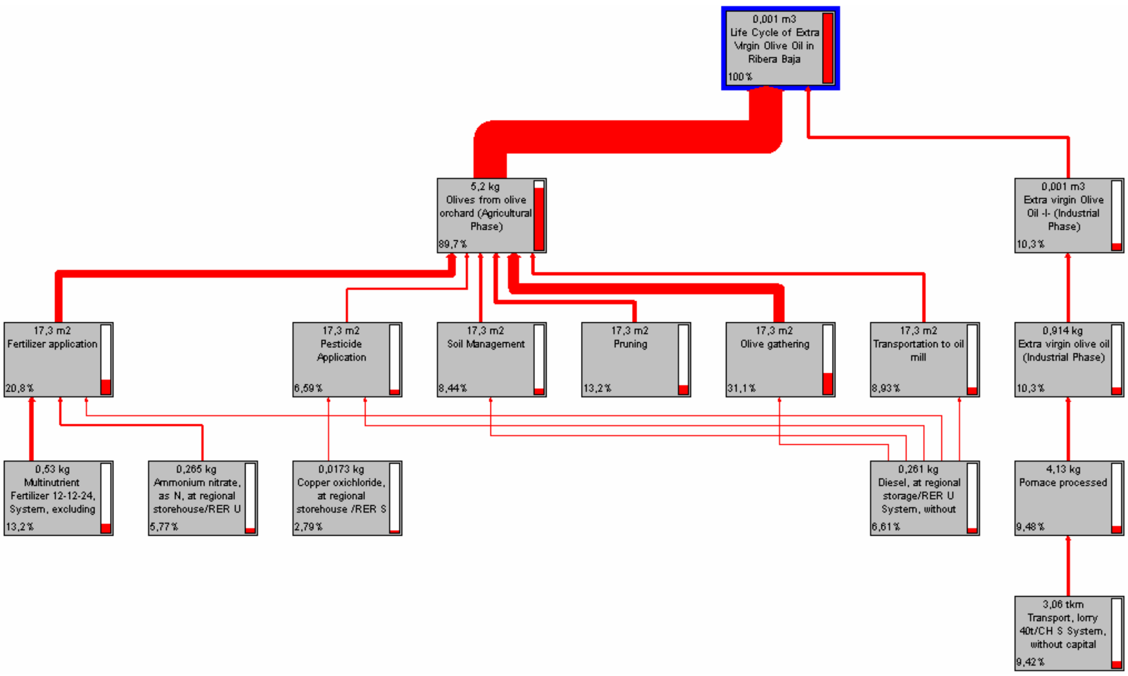
1.3.1.2.1 Carcinogens

Processes contributing more than 0.5 %



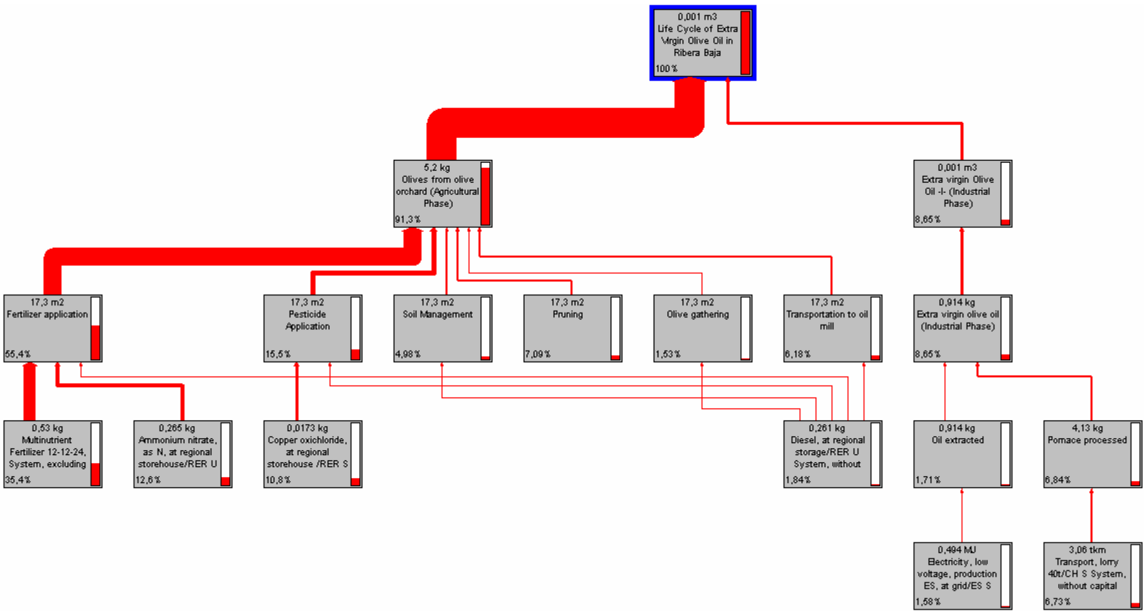
1.3.1.2.2 Respiratory Organics

Processes contributing more than 1%



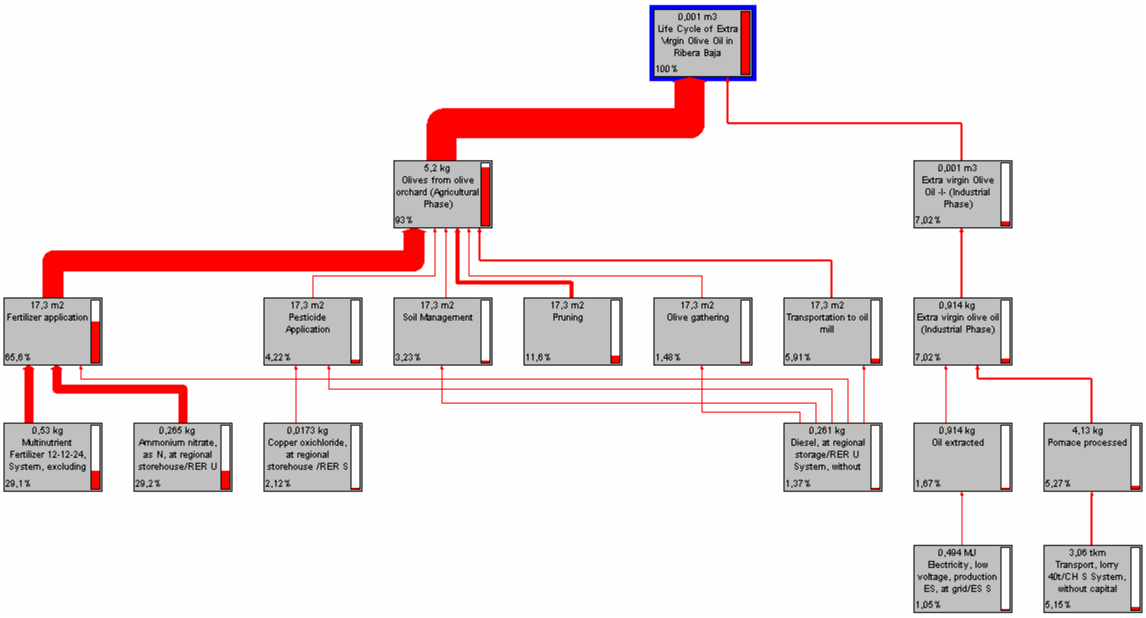
1.3.1.2.3 Respiratory Inorganics

Processes contributing more than 1%



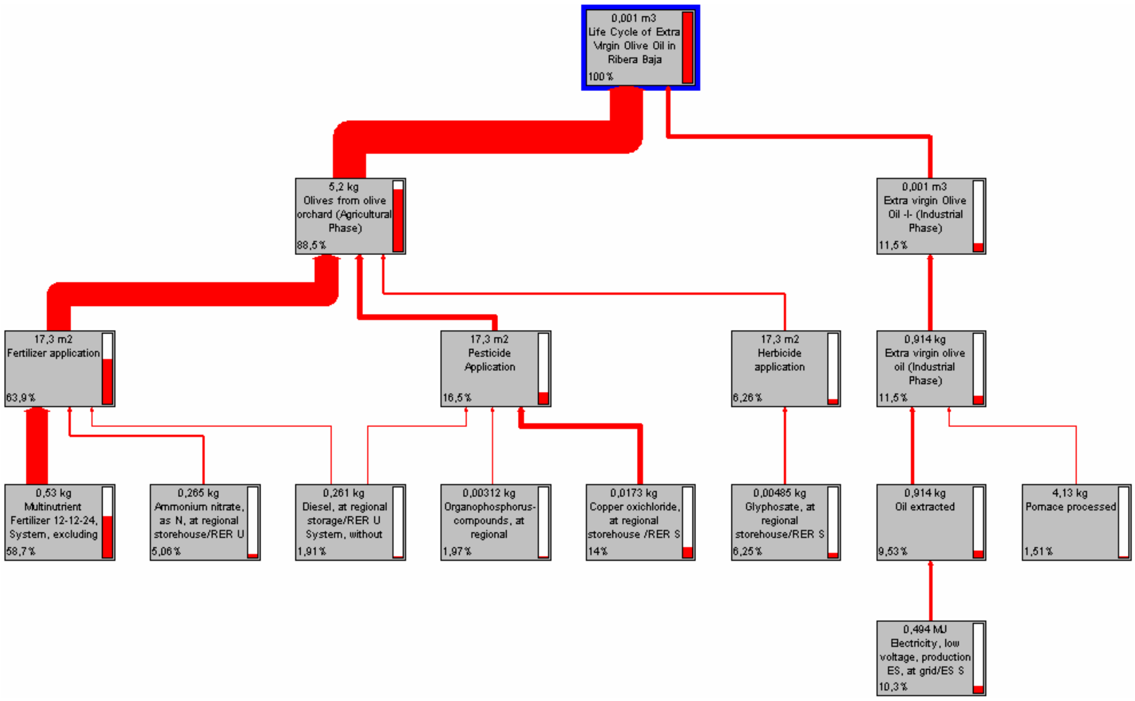
1.3.1.2.4 Climate Change

Processes contributing more than 1%



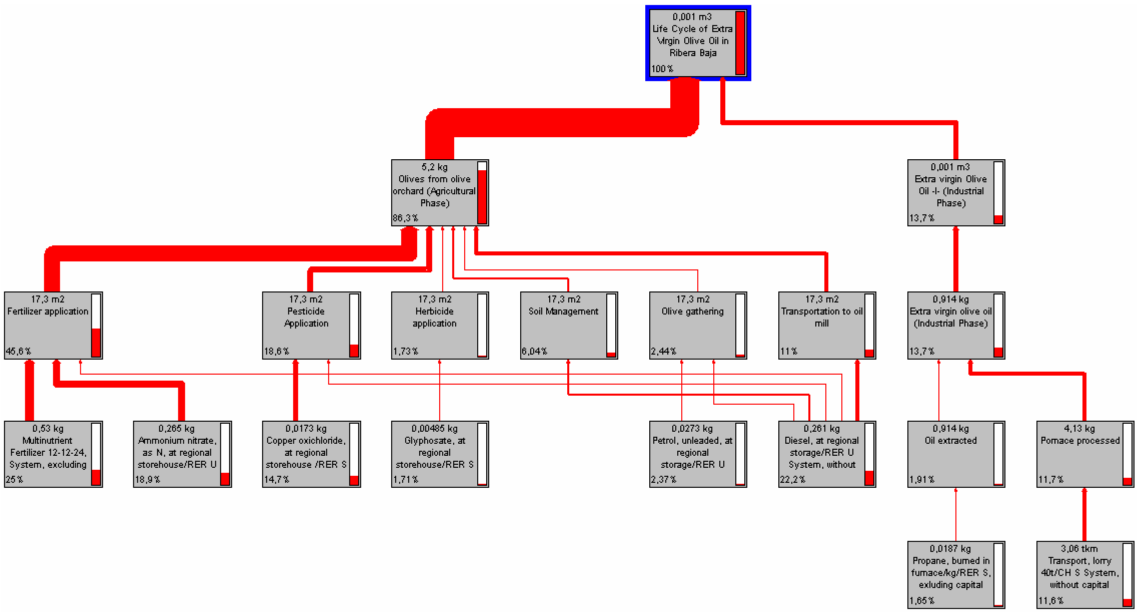
1.3.1.2.5 Radiation

Processes contributing more than 1%



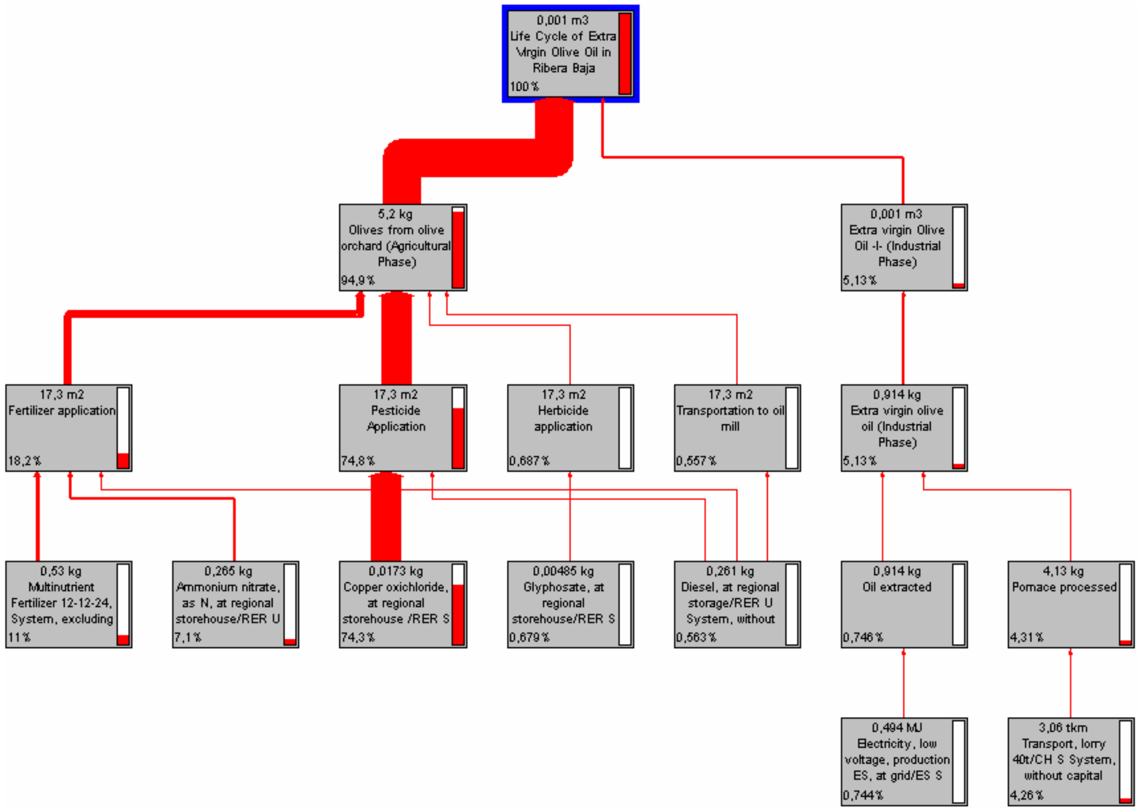
1.3.1.2.6 Ozone Layer

Processes contributing more than 1%



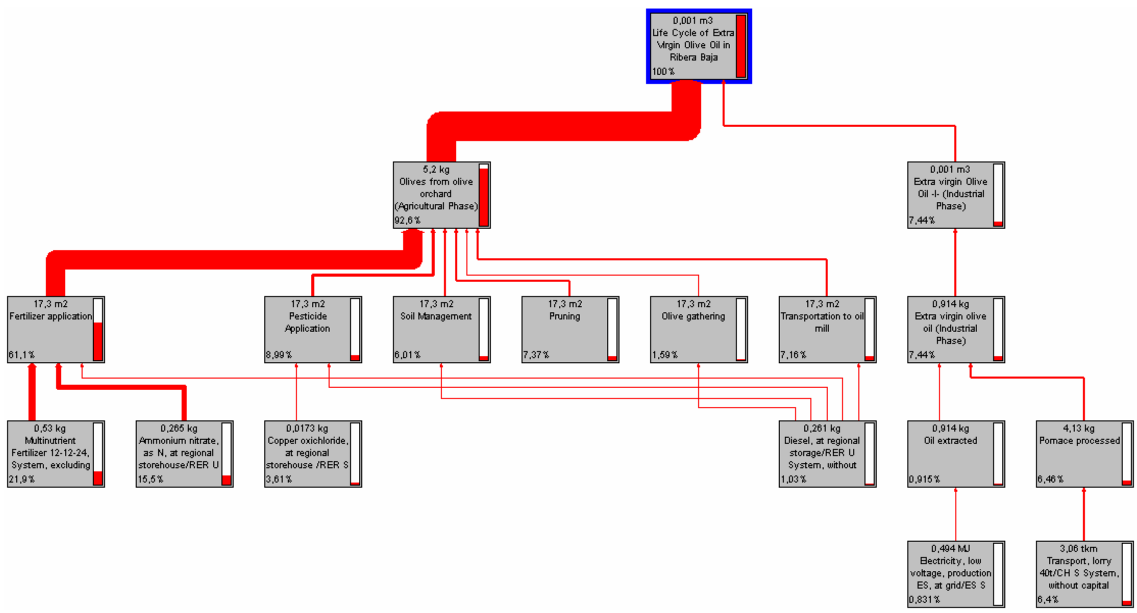
1.3.1.2.7 Ecotoxicity

Processes contributing more than 0.5%



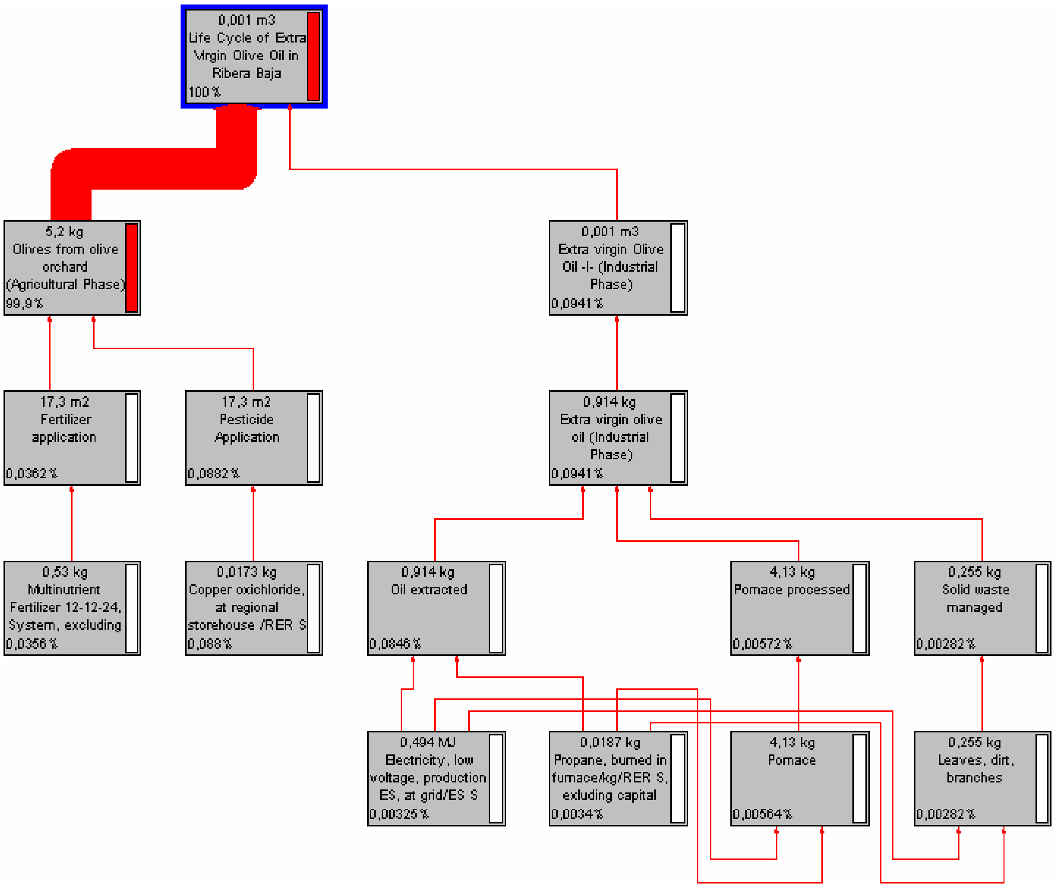
1.3.1.2.8 Acidification/Eutrophication

Processes contributing more than 0.5 %



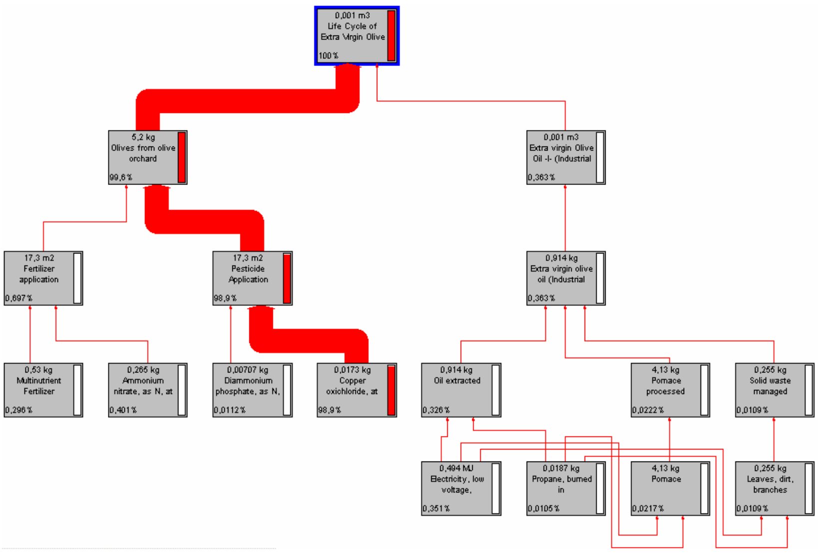
1.3.1.2.9 Land use

Processes contributing more than 0.001



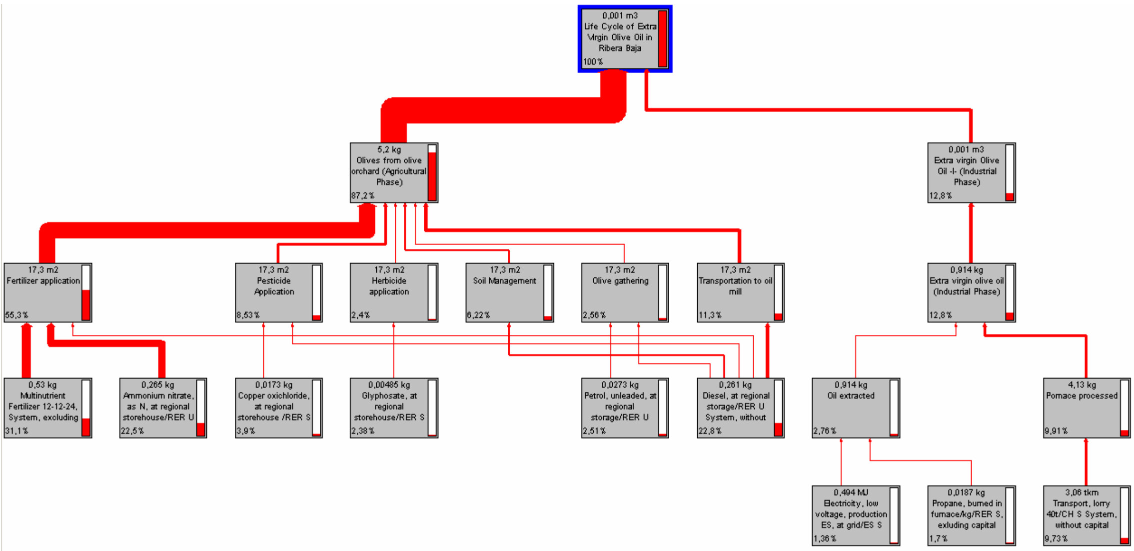
1.3.1.2.10 Minerals

Processes contributing more than 0.01%



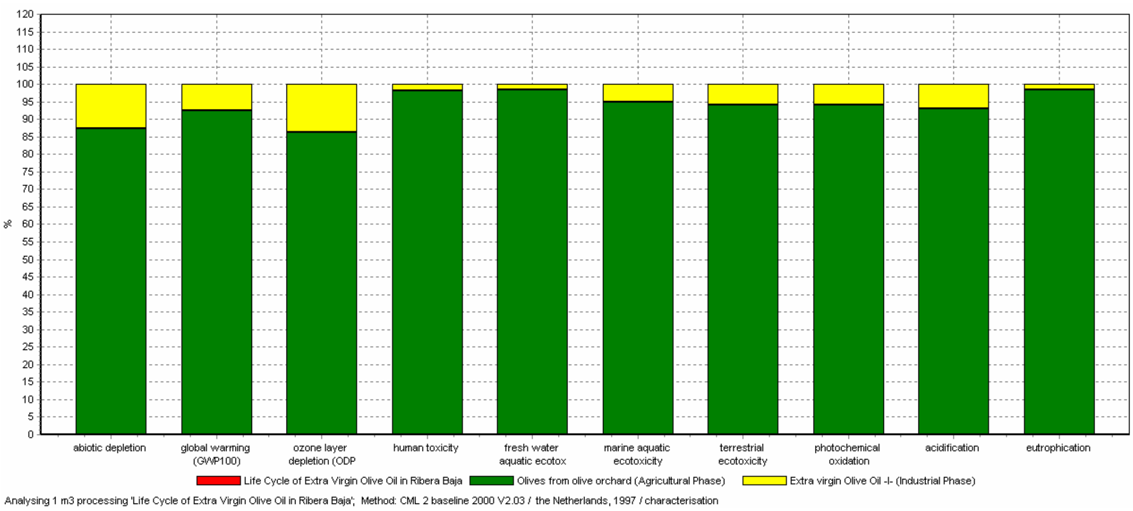
1.3.1.2.11 Fossils Fuels

Processes contributing more than 1%



1.3.2 CML 2 Baseline 2000

Results from this methodology are close to those founded with Ecoindicator 99: the industrial phase (milling processes) do not represent more than 15% in whole impact categories



2 Life Cycle Interpretation: Identification of hot-spots

Life cycle Interpretation is the last step in LCA, consisting mainly in Identification of Key points, Evaluation and extraction of conclusions and recommendations. For practical reasons, Interpretation has been divided in three documents: Identification of Key Points (Task 4.1), Evaluation (Task 4.2) and Conclusions and Recommendations (Task 4.3)

Determining Key Points can be a complex process, that is why it is recommended to follow these analysis (US EPA, 2001):

- Contribution Analysis: different stage of life cycle or process are compared
- Dominancy Analysis: With statistics tools or other methodologies (qualitative analysis) significant contributions are checked.
- Anomaly Analysis: Based on previous experience and abnormal deviations or surprising of those expected results or calified as normal

Contribution and Dominance Analysis (in qualitative terms) have been performed throughout the whole text and are comments to results for each category impact in Ecoindicator 99 and CML 2 Baseline 2000.

Anomaly Analysis has consisted in checking unexpected results (i.e., carcinogens impact category due to gathering) in this document and a comparison of LCIA results and Hot Spots with other LCA (Task 4.2).

3 Key Points

1. The agricultural phase is the main pollutant stage when producing olive oil
2. In the agricultural phase, main environmental impacts come from production and transportation of agricultural inputs: fertilizers, pesticides (mainly copper oxychloride) and herbicides. On field application has a smaller environmental impact when using LCA:
3. In the industrial phase, pomace processing (transport) has a high environmental impact. It must be taken into account an environmental allocation of 7% when interpreting results.
4. In the overall life cycle, it has been shown that environmental impact comes from “occult” or non-visible processes that cannot be uncover without using Life Cycle Assessment.

Table 2. Resume of environmental impacts (Ecoindicator 99)

	Carcinogens	Respiratory organics	Respiratory Inorganics	Climate change	Radiation	Ozone Layer	Ecotoxicity	Acidification/ Eutrophication	Land use	Minerals	Fossil fuels
Threshold	0,50%	1,00%	1,00%	1,00%	1,00%	1,00%	0,50%	0,50%	0,001%	0,01%	1,00%
Agricultural Phase	97,7	69,7	91,3	93	93,5	86,3	94,9	92,6	99,9	99,6	87,2
Irrigation											
Fertilizer Application	37	20,8	55,4	65,6	63,9	45,6	18,2	61,6	0,0362	0,697	55,3
Field tasks	0,11	1,83	6,4	7,3	0,14	1,7	0,1	24,2		0	1,7
12/12/2024	33,6	13,2	36,4	29,1	58,7	25	11	21,9	0,0356	0,296	31,1
Ammonium Nitrate	3,29	5,77	12,6	29,2	5,06	18,9	7,1	15,5	0,00055	0,401	22,5
Pesticide Application	58,5	6,59	15,5	4,22	16,5	18,6	74,8	8	0,0082	98,9	8,53
Field tasks	0,4	3,8	4,7	2,1	0,53	3,9	0,5	4,39			4,63
Dimethoate					1,97						
Piriproxyfen											
Bottles											
Diammonium Phosphate										0,0112	
Copper oxychloride	58,1	2,79	10,8	2,12	14	14,7	74,3	3,61	0,088	98,9	3,9
Herbicide Application	0,559				6,26	1,73	0,697		0,000456		2,4
Field tasks	0,5033	0	0	0	0,01	0,02	0,018				0,02
Glyiphosate	0,0557				6,25	1,71	0,679		0,000454		2,38
Soil Managemet		9,44	4,98	3,23		6,04		6,01			6,22
Pruning ((include burning)	1,16	13,2	7,09	11,5				7,37			
Olive gathering		31,1	1,53	1,48		2,44		1,59			2,56

	Carcinogens	Respiratory organics	Respiratory Inorganics	Climate change	Radiation	Ozone Layer	Ecotoxicity	Acidification/ Eutrophication	Land use	Minerals	Fossil fuels
Threshold	0,50%	1,00%	1,00%	1,00%	1,00%	1,00%	0,50%	0,50%	0,001%	0,01%	1,00%
Transportation to oil mill		8,93	6,18	5,91		11	0,557	7,16			11,3
Industrial Phase	2,33	1,03	8,65	7,02	11,5	13,7	5,13	7,44	0,0941		12,9
Oil extracted	1,71		1,71	1,67	9,53	1,91	0,746	0,915	0,0846	0,326	2,76
Pomace processed	0,543	9,48	6,84	5,27	1,51	11,7	4,31	6,46	0,00572	0,0222	9,91
Soil waste managed											
Water from vertical centrifuqe											
Transport by van											
Tap water											
Petrol						2,37					2,51
Diesel		6,61	1,94	1,37	1,91	22,2	0,563	1,03			22,8
Electricity	1,78	1,58		1,05	10,3		0,744	0,831	0,00325	0,351	1,36
Propane						1,65			0,0034	0,105	1,7
Transport by lorry		9,42	6,73	5,15		11,6	4,26	6,4			9,73

Colours represent environmental impacts in percentage

<5 %	5-15 %	15-25 %	>25 %