



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

TASK 3.1

Implementation of Life Cycle Inventory in Voukolies /
Polemarchi region of Crete

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1 Case Study - Voukolies

For thousand years olive tree cultivation has been the most known process in Greece. Tradition mentions that olive oil tree was first planted in Acropolis by Athena goddess. Olive tree branch was the official logo for the Olympic Games 2004 that took place in Athens. The olive oil tree coverage in 1835 was 61.700 acres and reached 642.500 acres in 1900. Nowadays the total coverage reaches 1.000.000 acres (Source: Ministry of Agriculture).

Depending on the olive oil fruit weight, there are many varieties which are classified in three basic categories, (a) those with small fruit, (b) those with a medium fruit and (c) those with the heaviest fruit.

Crete is the largest island of Greece (fifth in place of the largest Mediterranean Islands) located in the southern region of the country. Its population is approximately 600.000 residents living on 8.331 Km². It consists of four prefectures, (a) prefecture of Chania, (b) prefecture of Rethimno, (c) prefecture of Heraklion and (d) prefecture of Lasithion. The case study for this project took place at the area of Voukolies which is located at the northwestern part of the Chania Prefecture, The area covers approximately 75.000 Km² (Municipality of Chania,



2001) at an altitude of 110m above the sea level and inhabited by 3.296 people (mostly farmers). Figure 1 shows a satellite image of this region. The climate is temperate with north winds during winter and autumn and weak winds during summer. The minimum temperature during winter time is 12°C and 27°C the maximum during summer. The region, apart from olive tree cultivation, is also rich in cultivation of citrus, vines and vegetables.

Crete is among the largest olive cultivation areas and olive oil producers in Greece. Olive trees in Crete are more than 35 million covering almost 25% of the area of Crete. The average olive oil production is rather high, approximately 150.000 tons per year and is presenting an increasing trend, almost 3% yearly. Until ten years ago, the yearly olive oil production presented big differentiations from one year to the other, but nowadays these deviations have been minimized and the oil production has been stabilized. This can be mainly attributed to the fact that application of irrigation practices has been introduced to the 30-35% of the olive cultivation areas of the island.



Figure 1: Aerial photograph of Voukolies region (Europa technologies, NASA 2006)

2 Identification of the characteristic cycle in Voukolies

Task 2 report mentions that Life Cycle Assessment (LCA) is a technique that models the production chain of a product. It is necessary to make simplifications and assumptions in order to model and analyse the olive oil production.

In order to identify the characteristics of the life cycle of olive oil in Voukolies accurate data on olive oil agriculture and olive oil production must be collected as a first step. Data were collected by local farmers with the questionnaire method (Appendix A). These questionnaires were apportioned to the farmers that are registered in the local olive oil farmer co-operation of Polemarchi.

The questionnaire covers every process during the cycle of the production such as soil management, tree management (fertilisers, irrigation, etc) but also covers the use of every alternative process as well as quantitative data on the main material flows. The results of these collected data are described in the next chapters.

26 farmers were interviewed having at their possession a total number of 15.010 olive trees covering 725,5 km² of land. Analysis shows that the majority of farmers own more than 600 trees so it can be assumed that there are “large” farmers (few farmers with many trees). According to this fact, it was decided not to exclude any of these farmers. It is important to notice for the analysis following that each questionnaire was given “weight” proportional to the number of olive trees it represents.

2.1 Characteristic olive agriculture processes

2.1.1 Planting the olive trees

In order to achieve financial sustainability followed by the minimum use of chemicals and dangerous for the environment practices new olive groves first need to be carefully examined. This can be done by the proper land selection, the variety of olive oil that will be planted as long as the planting practice. Some practical regulations for these are mentioned below.

The first thing that a farmer should take into account is that the soil pitch must not exceed 25%. Soil with ice and lack of satisfactory run-off must be avoided as long as saliferous lands. At cold regions it's suggested the South - Southwestern orientation of the field. Some regions have major soil corrosion issues and a way to confront it, is the alternation of cultivated and non cultivated soil. Whereas there is a high risk of *Bactrocera oleae* infection, cultivation of mixed olive types should be avoided. Also, every region's climate can accept certain type of olive trees and a certain density of tree grid. The maximum affordable density is 300 trees per hectare in order to avoid non acceptable cultivation and production practices.



Planting usually takes place in November and December by digging holes of dimensions 60cmx40cm with a mattock and a spade. The depth of the holes is such that the root of the new tree is at the same depth as was in the nursery bucket. During planting of the young olive trees special care is taken so that the walls of the hole are not compacted. After the hole is filled with soil the tree is irrigated. The water quantity used when planted is, according to the olive growers, approximately two litres of water per tree. The empty buckets are reused.

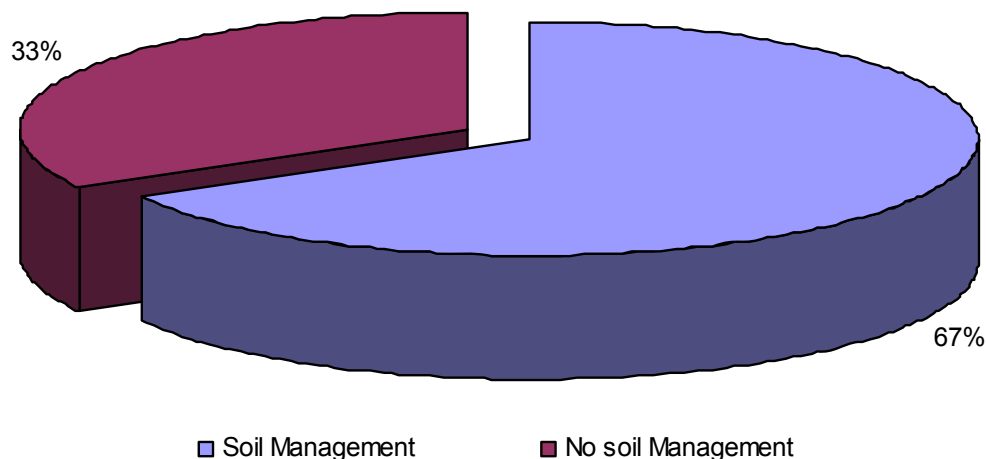
2.1.2 Soil Management

The soil management of olive cultivation areas is of particular importance and needs to be made in the appropriate manner and on time. The aim of soil management is to protect the area from the pests and insects that 'steal' from the trees the valuable humidity and nutrients. The most common soil management practice is plough. In the past years, farmers used manual equipment and animals so soil management was a time consuming practice. Nowadays plough is fully mechanized and used by the 100% of "farmer" community. For the best available practice on the soil number of plough tools developing every day such as rippers, chisel and disc ploughs, harrows. Figure 2 shows one of the latest tools that a farmer can find on the market.



Figure 2: Chisel Plough (Agrobon Bonja, 2006)

Questionnaires from this case study show that plough take place only once a year covering averagely the 50% of orchards. No plough procedure takes place according to 38% (72% of trees) of the farmers (see Appendix B).

Diagram 1: Soil Management

2.1.3 Field Water Supply and irrigation

Olive oil tree has a very strong defense mechanism to dry spell and for that reason its cultivation is possible to dry spell conditions that no other fructiferous tree can grow. Then again, this strong defense mechanism is against its growth and productivity. Many studies have shown that olive trees increase their productivity linear to irrigation increase. Irrigation should take place in any of the following cases:

- When rainfall at this region is inadequate,
- when rainfall is located at specific season (e.g. winter),
- If the soil is sandy or gravelly with no water retention

Irrigation is also important for the production of “heavy” fruit olives (also called “table olives”), in places with high density olive tree grids and when this practice combines with pruning and fertilization.

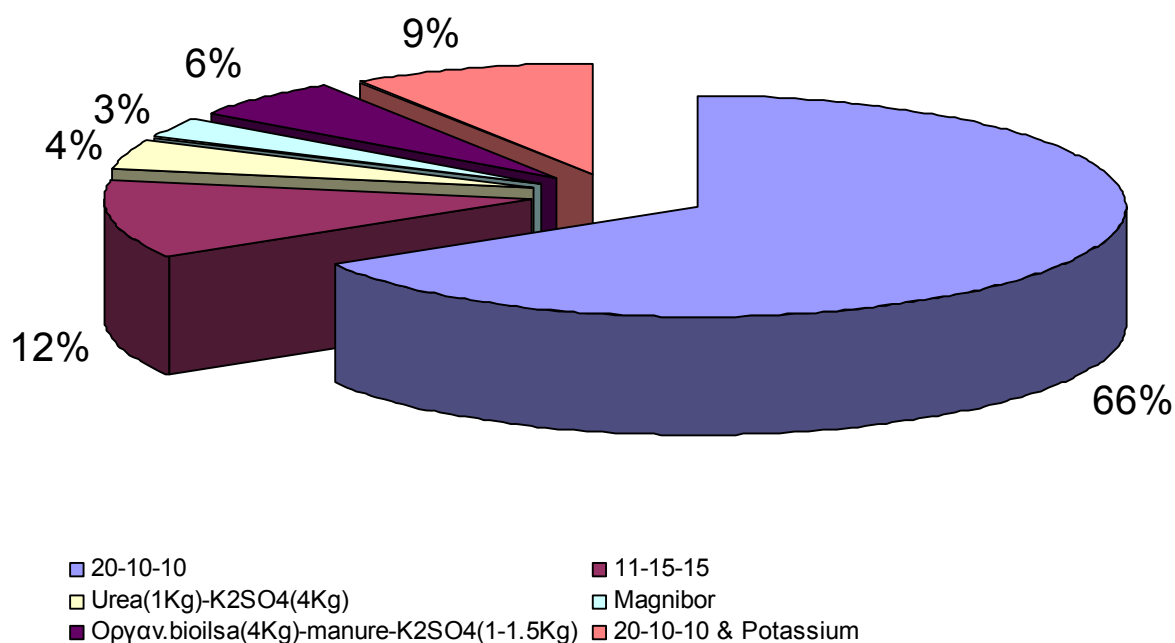
The method used for irrigation in Voukolies region olive orchards is spray type sprinklers. In other regions farmers use and flooding technique (Cyprus case study- Lythrodontas). Water is pumped from the local water supply system by electric pumps with an average frequency 3 times per year and average field coverage 81% (Appendix B). The average distance from water source is 100m. The average water use is $0,4385\text{m}^3$ of water per tree.

2.1.4 Fertiliser Application – Production - Transportation

The installation of a new olive grove requires soil analysis in order to make the proper decision about the type and quantity of fertiliser application. This same analysis shows also soil calcium levels. Olive grove where no analysis took place since its installation, special measures are indicated such as the use of 0-20-0 and 0-0-50 fertiliser types (These numbers represent the composition of Nitrogen-Phosphate - Potassium in its ingredients). Thus, olive grove has the proper amount of phosphorous and potassium for the next 5 to 8 years.

Data obtained from the survey analysis (Appendix B) shows that the majority of the farmers uses fertilisers labeled 20-10-10. The following diagram shows the application of various types of fertilisers.

Diagram 2: Fertiliser Type Application



Considering the data above, the fertiliser application that should be included in the model is the NPK 20-10-10. This application takes place one time per year with the dispersion method.

The production of the characteristic fertiliser used was traced via the Cooperative in Polemarchi. It is a dense granual compound comprising of ammonium nitrate, ammonium sulphate, monoammonium phosphate, diammonium phosphate and 100% water-soluble potassium sulphate.

According to Kallis (2006), the NPK 20-10-10 fertiliser used in Voukolies olive orchards, is produced in Nea Karvali, Kavala, Greece, packaged in plastic 50kg

polypropylene (PP) mesh bags. The production site is operating their own port, thus this fertiliser is transported by freight-ship from Kavala to Souda (524 km). The fertiliser is then transported from the port in Souda to the Cooperative in Polemarchi (the main supplier for olive farmers in Voukolies). It is assumed that transportation takes place by 3-axle, 16-tonne Lorries, which travel a distance of approximately 30 km. Finally, the fertilisers are purchased by olive farmers and transported to the olive orchards in Voukolies at a distance of approximately 10 km using their own private pickup vans, i.e. vehicles of gross weight less than 3.5 tones.

2.1.5 Pruning methods and residue management

The most significant procedure related to olive oil fructification is pruning. According to TDC-Olive (2005) the main objectives are:

- Vegetation – fructification balance
- Minimization of the non productive period
- Avoid early ageing of the tree
- Delay senescence
- Save soil water, a critical factor in non irrigated orchards

There are tree types of pruning especially for olive oil trees: (a) pruning formation at young trees (helps olive fruit collection procedure), (b) pruning for production

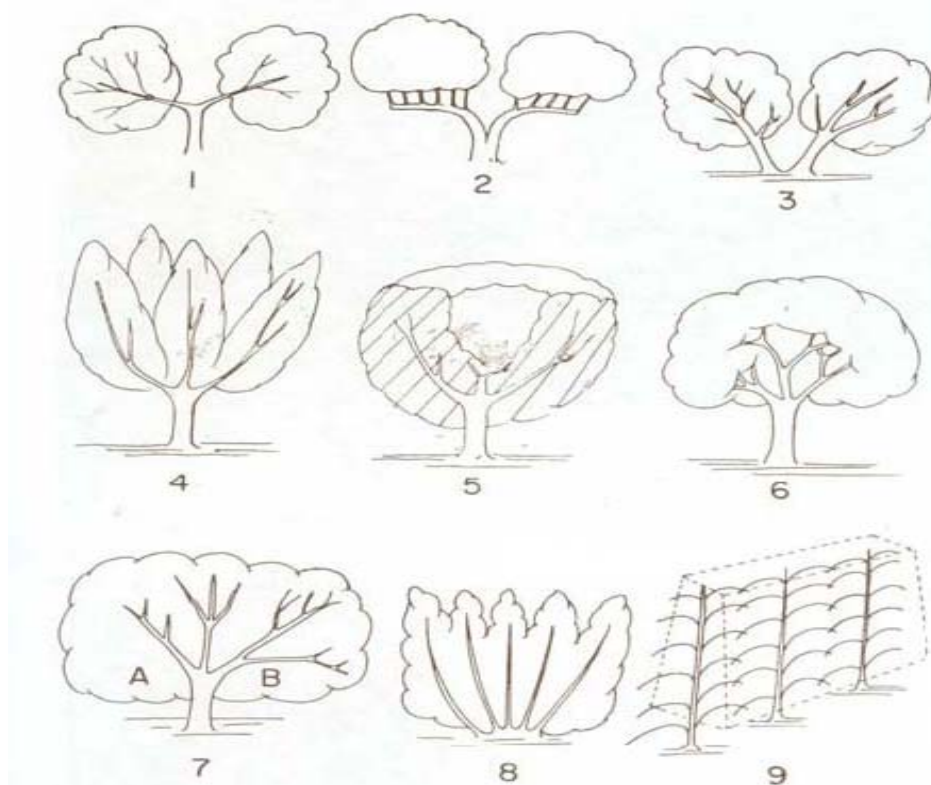


Figure 3: Different types of pruning (TDC Olive, 2005)

improvement), (c) refreshment pruning especially at older trees. Figure 3 shows the basic types of pruning.

The frequency of pruning depends on several parameters such as the level of rainfall, the yield of the previous year, the vegetative condition of the tree, the end – product and the planting density.

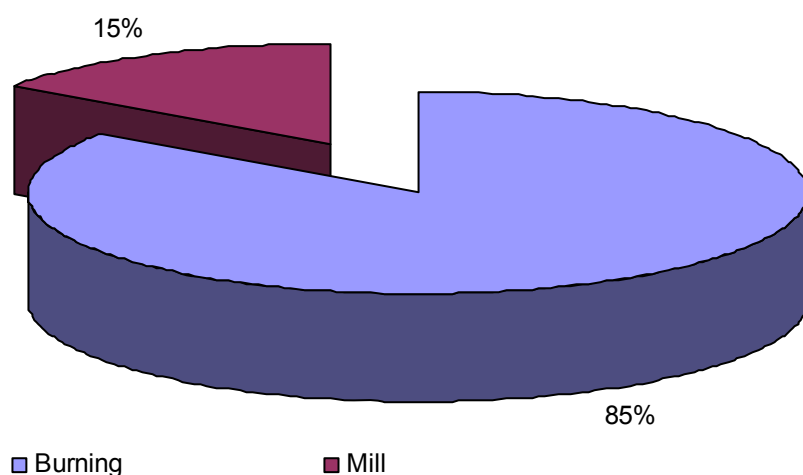
Olive farmers in Voukolies use only one method/equipment for pruning. This method uses hand-held petrol chainsaw.



Figure 4: Pruning by petrol ran chainsaw

The average frequency per olive tree is one time per year. In regards to the subsequent treatment of the pruning residue, all growers responded that pruned branches are burned in controlled open fires in vegetation free areas adjacent to the orchards. The residual ash is disposed to the agricultural land by manual methods. The diagram below shows that only 15% of the farmers use machines to mill the pruning residue. Considering the results from this analysis, pruning by petrol chainsaw as long as burning of the residue and the disposal of the ash to the agricultural land will be used in the LCA model.

Diagram 3: Pruning residue Method



2.1.6 Pesticide application – production – transportation

There are 2-4 significant pests associated with olive plantations plus a further 10 or so of secondary or localized importance (including fungi and other problems). The main pests cited by Cirio (1997) are: *Bactrocera oleae* (olive fly), *prays oleae*, *Saissetia oleae* and *Capnodium elaeophilum*. The presence and seriousness of these pests, fungi, etc., depends partly on prevailing environmental conditions (temperature, humidity), but also on practices such as cultivation, pruning and irrigation (Cirio, 1997).

Olive fly is the most important pest. It is much more problematic in more humid, frost-free areas, where it can decimate the olive crop leading to greatly reduced oil quality. However, in dry, high-altitude areas, the presence of olive fly tends to be much less and control measures may not be necessary on a regular basis.

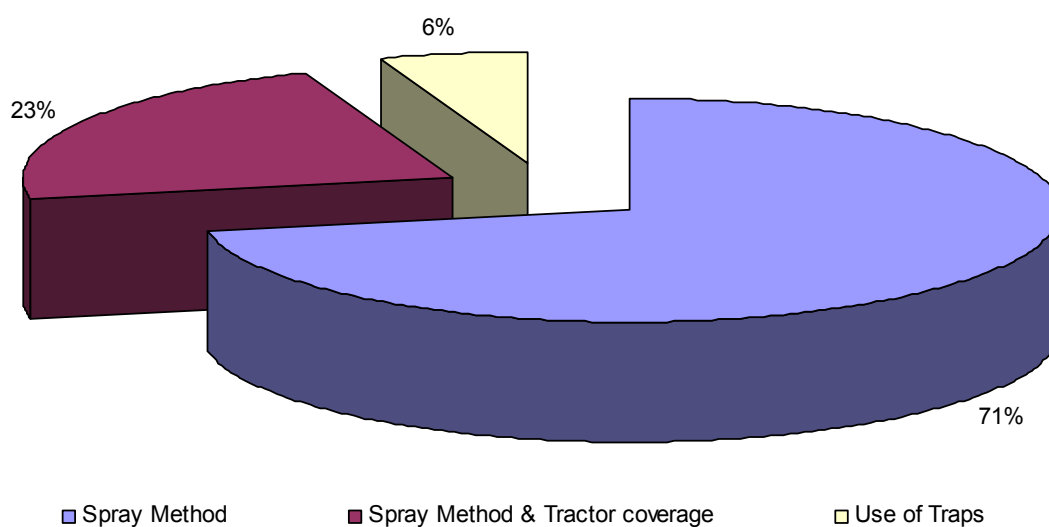
Olive fly is normally treated with Dimethoate sprays, either by the farmer or through large scale aerial spraying. Typical quantities applied are 1.5 liters of 40% Dimethoate per hectare for terrestrial application or 0.5 liters per hectare for aerial application according to Guerrero (1997). Alternative control systems are being developed, such as mass-trapping using baits, but these are more expensive and labor-intensive (TDC-Olive 2005). In some areas, chemical control measures against olive fly only started to be taken relatively recently while in some areas no measures are taken; as a result, olive oil may be of inferior quality, especially in years when this pest is widespread.



Figure 4: Pesticide application methods

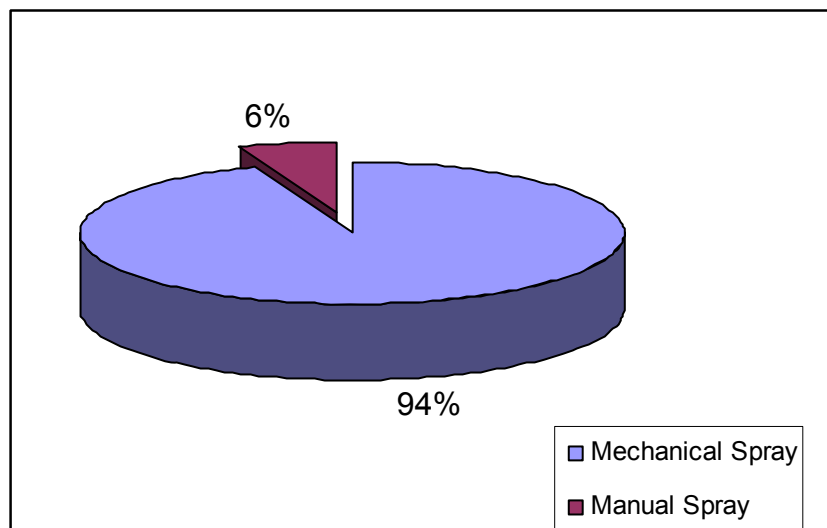
Interviews with the farmers show that the most common pesticide application is spraying method with an average frequency 3 times per year. The main pest that causes problems to these trees is *Bactrocera oleae* (olive fly). The next diagram proves that spraying method is the common practice for this case study which will be included in the LCA model for Voukolies region.

Diagram 4: Pesticide Application Method



Considering spray technique, there are two main types of application equipment, spray by truck or spray by hand (manual spray). Diagram 5 shows that 94% of the farmers use their trucks to spray. In particular they connect sprayers to tractors via air hose.

Diagram 5: Pesticide spraying application equipment



The source of the particular pesticide product used in the region was traced in order to determine all associated production and transportation processes. It was found that the active ingredient (dimethoate) is produced in Denmark, where it is mixed at a 40% concentration with inactive ingredients to form the final product. The inactive substances comprise of xylene (CAS number 1330-20-7) at 20% concentration, cyclohexanol (108-94-1) at 25% concentration and emulsifiers at 5% concentration (K&N Efthymiadis, 2004).

2.1.7 Herbicide application

Olive oil trees can survive at “poor” land with almost the need of no water. On the other hand, many weeds are adjusted at the same conditions mentioned above making them grow faster by “stealing” water and nutrients from the soil.

According to TDC Olive 2005 the application of herbicides depends in many parameters such as the climate, soil characteristics, irrigation methods, topology and farmers decisions. There are two methods for controlling weeds either by mechanical techniques such as ploughing neither by chemicals such as spray methods. There is a variety of weed control methods except these mentioned above such as physical soil coverage, irrigation under the soil level. The most common practice is the combination of these techniques.

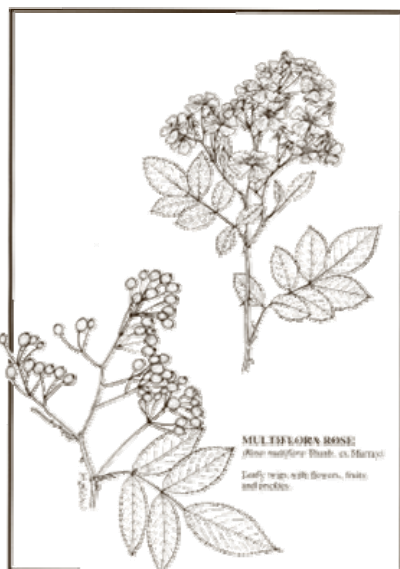
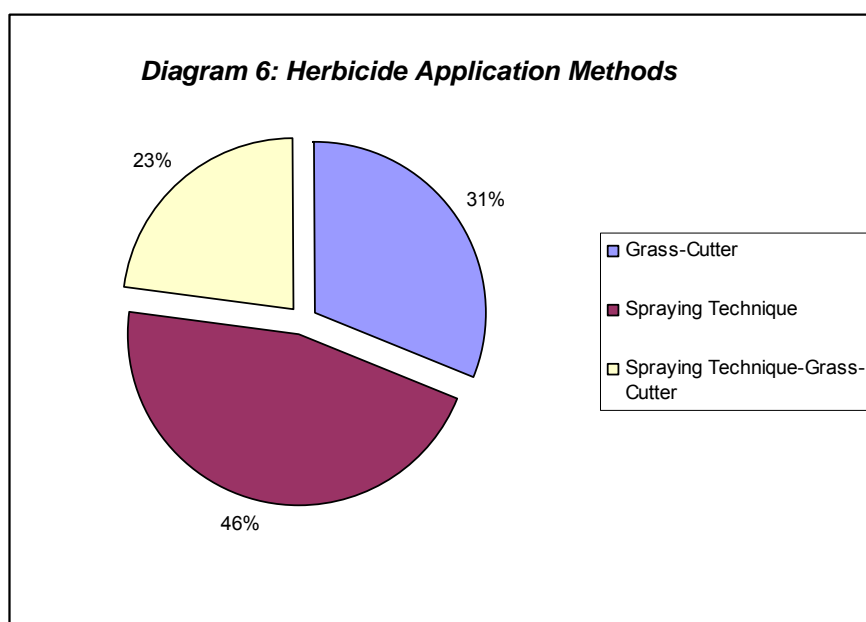


Figure 5: Common Olive Herbicides

Diagram 5 shows the results from the questionnaires about the weed control technique. The most common technique is the round-up method. After thoughtful consideration it was decided to use Spraying techniques by tractor in the characteristic cycle of olive oil production in Voukolies.



2.1.8 Collection of olives

The harvest period ranges from September to February, depending on climatic conditions, variety of olive tree, whether the olives are for table use or oil, etc. There is a tendency in many areas to harvest earlier now than in the past, in the pursuit of improved oil quality.

In most plantations the olive harvest is manual, either by hand, with combs or by beating the branches with sticks to shake the olives off. Nets are usually extended under the tree to catch the olives. Many olives fall on the ground before the harvest, especially when attacked by olive fly. These olives are collected with rakes

or new machines (rollers with spikes, vacuums, etc.). For quality oil, it is important to separate these olives from those taken directly from the tree.

Mechanised harvesting is becoming increasingly widespread, both in modern intensive plantations and in intensified traditional plantations (see typology below). Various models of vibrators (tractor-mounted, self-propelled, and hand-held) are used to shake the trunk or individual branches of the tree. New “bush” type plantations are designed for harvesting with a vineyard harvester.

Manual harvesting requires a large labour input which can amount to between 1/3 and 2/3 of a plantation’s direct costs during the year. Mechanical harvesting requires much less labour. The latest machines with “umbrellas” (a built-in automated net) can be operated by one person. Labour is thus greatly reduced compared with manual harvesting.

According to Tombesi *HW_ DO* (1996), one person using various different mechanical harvesting machines can harvest: 17kg, 40kg, 90kg or as much as 200-400kg in one hour, depending on the type of machine. This compares with a maximum under manual harvesting of 15-20kg per person per hour. In other words, to harvest one “average” hectare of 2,500kg manually requires 167 man hours, compared with 6 man hours using the most efficient mechanised systems.

Mechanised harvesting is difficult to introduce in plantations with old, awkwardly shaped trees or if the ground is water-logged, although some machinery is available which is suitable (e.g. hand-held “vibrating poles”).

Indirectly, the harvesting method has important implications for the environment, in particular the question of whether olives are collected from the ground or only from the tree. The collection of olives from the ground requires completely bare and flat soil, which is achieved through intensive use of herbicides and/or mechanical methods. Preparing the ground in this way exposes the soil to erosion in winter rains as well as removing an element (the grass layer) in the biodiversity of the plantation.

On the other hand, if olives which have fallen on the ground are not collected, then it is beneficial to have a grass layer under the trees, as this facilitates the handling of the nets and avoids excessively muddy conditions in wet years, in addition to the environmental benefits of soil protection and biodiversity.

The comb operators “rake” the moving combs through the foliage to remove the fruit, which is collected in underlying nets, as shown in Figure 6.

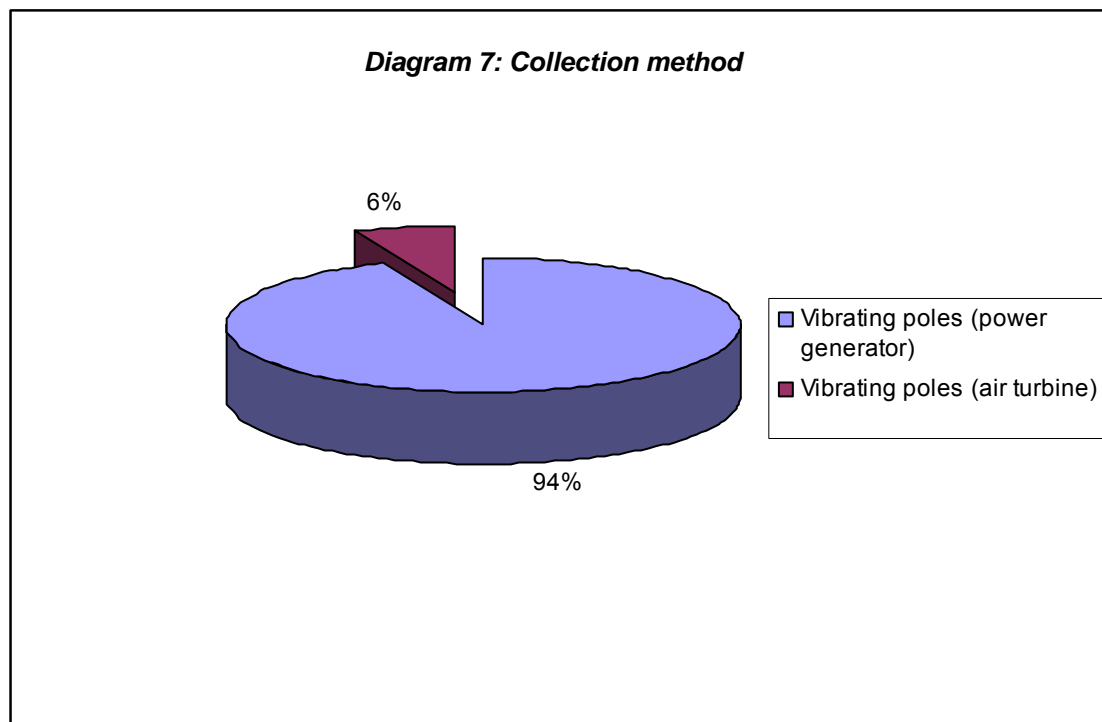




Figure 6: Olive collection to nets

Interviews with farmers have shown that the most common practice for olive oil collection is the use of “vibrating” poles powered by electric generators (diagram 6).

Olives are collected from the underlying nets by hand and are put in plastic boxes or mesh bags, in which they are later transported to the processing plant. On the basis of these conclusions, in regards to olive collection, the use of “vibrating” poles powered by electric generators and the hand collection from the underlying nets were accounted in the model.



2.1.9 Olive transportation to processing unit

Typically, the processing of olives from Voukolies region into olive oil takes place locally. A modern olive oil processing unit is situated in the outskirts of Polemarchy village.

Interviews have shown that olives from the 100% of the tress in the region are processed in the Polemarchy unit exclusively.

The Polemarchy processing unit is located at the outskirts of the Polemarchy residential area, and the average distance of the olive orchards to the plant has been estimated to approximately 10 km.

All farmers responded that for transportation of olives for processing, they use their private pickup vans (gross weight < 3.5 tonnes), which was included in the analysis model.



3 Data Collection

The most effort-consuming step of the implementation of LCA studies is the collection and collation of data in order to build the life cycle inventory. For each unit process, within the system boundary defined, qualitative and quantified data on inputs and outputs were collected based on the data collection plan established during Task 2 of this project .

The flow types for which data was required for each unit process within the system boundaries are: output to technosphere (product), inputs from technosphere (manufactured or processed materials, fuel, energy etc.), inputs from the environment (raw materials) and outputs to the environment (emissions). The latter two are also described as elementary flows. In SimaPro 7, these are recorded by the flow name (e.g. carbon dioxide fossil), the category, the subcategory and the unit. Categories describe the different environmental compartments air, water, soil and resource uses. The categories “air”, “water” and “soil” describe the receiving compartment and are used for (direct) pollutant emissions whereas the category “resource” is used for all kinds of resource consumption. Subcategories further distinguish sub-compartments within these compartments which may be relevant for the subsequent impact assessment step. For instance, water consumption is recorded as an input in the category/subcategory “resource/in water”. Land transformation and occupation is recorded as an input as well, namely in the category/subcategory “resource/land”.

During the development of the LCA framework for this study, a number of data sources were identified and a data collection plan was established. As prescribed in this framework for the majority of data for background processes, secondary data sources would be used to collect, obtain and calculate the datasets from published sources such as industry data reports, validated life cycle inventory databases, laboratory test results, government documents and reports, reference books, previous life cycle inventory studies, equipment and process specifications.

SimaPro 7 contains several validated databases, from which suitable background data could be selected. Such databases are: ETH-ESU 96, BUWAL 250, IDEMAT 2001, Franklin USA 98, LCA food and Ecoinvent 1.2.

ETH-ESU 96 database is focused on electricity generation and related processes like transport, processing and waste treatment. It includes 1200 unit processes and 1200 system processes. BUWAL 250 focuses on packaging materials (plastic, carton, paper, glass, tin plated steel, aluminium), energy, transport and waste treatments. IDEMAT 2001 mainly covers engineering materials (metals, alloys, plastics, wood), energy and transport. Franklin USA 98 database includes north American inventory data for energy, transport, steel, plastics, processing, whereas



LCA food database, which was recently added to SimaPro software provides datasets on basic food products (does not include olive oil) produced and consumed in Denmark and covers processes from primary sectors such as agriculture and fishery through industrial food processing to retail and cooking.

A major source of background data was the Ecoinvent database version 1.2 (Swiss Centre for Life Cycle Inventories, 2005). The Ecoinvent 2000 project was undertaken by the Swiss Centre for Life Cycle Inventories aiming at providing a set of unified and generic LCI data of high quality. The database developed contains more than 2500 datasets of products and services from the energy, transport, building materials, chemicals, pulp and paper, waste treatment and agricultural sector. Each dataset describes a life cycle inventory on a unit process level and they are classified into categories and subcategories. This classification serves an informative purpose only and can be used to search for certain processes. The datasets are available in two versions: the unit process and the system process. The unit process describes a single operation and is linked to other processes. The equivalent system process aggregates all elementary flows of all other unit processes with which a unit process is linked as if it is one process. The advantage of a unit process is that the origin of elementary flows can be traced and it gives a better insight into what is included. However, using processes leads to extremely large and unmanageable networks. For this purpose, in this study, unit processes were used to review what the process includes (and to exclude capital infrastructure as discussed below), but selected unit processes were converted into system processes in order to keep the model network manageable and for more practical interpretation of the analysis results.

According to Frischknecht *et al.* (2004a), the products and services analysed in the Ecoinvent database mainly cover the market (and consumption) situation in Switzerland in the year 2000. Because Switzerland's economy is closely linked to the surrounding countries, a lot of processes are also described for the situation in Europe. In some cases data from outside Europe have been used, e.g. extraction of mineral and energy resources. For all these the reference year 2000 was applied but due to reduced data availability older data has been used in exceptional cases.

Nevertheless, for some regions, data availability is poor. This is mainly the case for south European countries including Cyprus, Greece and Spain. Therefore, background data obtained from databases are not country-specific. Nevertheless, in most situations production conditions are rather similar.

According to the boundary definition, capital infrastructure is not excluded in the system. However, most Ecoinvent processes do include capital infrastructure. In order to exclude them, the unit process version of each selected dataset was calculated, without the capital infrastructure (this function is only available in



version 7 of SimaPro) and its inventory was saved as a new system process, which therefore excluded the capital infrastructure.

In regards to cut-off rules, according to ISO 14041 (1998) several criteria are used to decide which inputs to be studied, including mass, energy, and environmental relevance. However, the Ecoinvent database does not follow a strict quantitative cut-off rule. According to Frischknecht *et al.* (2004a), “environmental knowledge of the people involved in compiling LCI data is used to judge whether or not to include the production of a certain input or whether or not to include the release of a certain pollutant”.

The same cut-off approach was applied for the foreground data collected. The main sources of data were the olive growers in the region, as discussed earlier, processors, agricultural and environmental experts and olive oil farming associations. The data collection methods included the circulation of questionnaires, telephone and personal interviews, on-site measurements and laboratory analyses. For the compilation of data from various sources and their adjustment to a reference flow extensive calculations were undertaken. The underlying principles of the calculations as well as the assumptions considered are clearly documented.

The majority of data on the main flows at the agricultural stage were obtained through the questionnaire in Appendix A. The responds to the questionnaires were treated as values weighted in accordance with the number of trees cultivated.

The quality of individual datasets is related to the data quality goals defined during the goal and scope definition of this study, through the pedigree matrix of data quality indicators suggested by Weidema and Wesnaes (1996), provided in Table 1.



Table 1: Pedigree matrix of data quality indicators

Indicator score	1	2	3	4	5
Reliability	Verified ¹ data based on measurements ²	Verified data partly based on assumptions or non-verified data based on measurements	Non-verified data partly based on assumptions	Qualified estimate	Non-qualified estimate
Completeness	Representative data from a sufficient sample of sites over an adequate period to even out normal fluctuations	Representative data from a smaller number of sites but for adequate periods	Representative data from an adequate number of sites but from shorter periods	Representative data but from a smaller number of sites and shorter periods or incomplete data from an adequate number of sites and periods	Representativeness unknown or incomplete data from a smaller number of sites and/or from shorter periods
Temporal correlation	Less than three years of difference to year of study	Less than six years difference	Less than 10 years difference	Less than 15 years difference	Age of data unknown or more than 15 years of difference
Geographical correlation	Data from area under study	Average data from larger area in which the area under study is included	Data from area with similar production conditions	Data from area with slightly similar production conditions	Data from unknown area or area with very different production conditions
Further technological correlation	Data from enterprises, processes and materials under study	Data from processes and materials under study but from different enterprises	Data from processes and materials under study but from different technology	Data on related processes or materials but same technology	Data on related processes or materials but different technology

In the following sections, data for each unit process included in the model, the sources used to obtain the data, the collection, calculation and measurement methods, the associated assumptions as well as their data quality indicators are reported.



3.1 Fuel Production

3.1.1 Diesel

The process of diesel production starts at the extraction of fossil fuels and ends at the distribution of the fuel for regional storage. The output to technosphere of this process is the production and distribution of 1kg of diesel.

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Diesel I” (process identifier IDEMAT0106626600018) and is classified under the Material/Fuels/Oil/Diesel subcategory. The data has been collected by the University of Technology Delft and represents the production of 1 kg diesel with 15% North Sea oil. Geographically the dataset represents the situation in Western Europe and although the data is rather old (1994) it covers average technology and excludes capital infrastructure.

The data quality index for this dataset, with reference to Table 1, is (1, 1, 5, 3, 2).

3.1.2 Petrol

Similarly, the process of petrol production starts at the extraction of fossil fuels and ends at the distribution of petrol for regional storage. The output to technosphere of this process is the production and distribution of 1kg of petrol.

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Petrol I” (process identifier IDEMAT0106626600033) and is classified under the Material/Fuels/Oil/Petrol subcategory. The data has been collected by the University of Technology Delft. Geographically the dataset represents the situation in Western Europe and although the data is rather old (1994) it is considered as representative as it covers average technology and excludes capital infrastructure.

The data quality index for this dataset, with reference to Table 1, is (1, 1, 5, 3, 2).

5.1.3 Crude oil

The process of oil production starts at the extraction of fossil fuels and ends at the distribution of the fuel for regional storage. The output to technosphere of this process is the production and distribution of 1kg of crude oil.

Data in regards to the resources and energy consumed and emissions associated with the production of diesel was obtained from IDEMAT 2001 database. The name of the process selected is “Crude Oil I” (process identifier IDEMAT0106626600019) and is classified under the Material/Fuels/Oil/Crude oil subcategory. The data has been collected by the University of Technology Delft and represents the production



of 1 kg crude oil from Africa 36%, Eastern Europe 12%, Middle East 44% and the remaining 7% includes production and transportation in Europe. Geographically the dataset represents the situation in Western Europe. Data was collected between 1990 and 1994, represents the average from all suppliers and covers average technology.

The dataset excludes capital infrastructure in line with our system boundaries. The data quality index for this dataset, with reference to Table 1, is (1, 1, 5, 3, 2).

3.2 Electricity production

Electricity is a main input of many processes in the olive oil processing stage, as well as in the agricultural stage. Electricity production is a significant polluting activity, thus it was included within the system boundary. Two types of electricity production are encountered in the system: production of grid electricity and production of field electricity. The following sections report on the data collected for these two processes.

3.2.1 Grid electricity production

The process of grid electricity production starts at the extraction of fossil fuels required and ends when electricity is supplied to the grid. The production and maintenance of capital infrastructure, such as the power plant and the distribution network is excluded. The output to technosphere (product) of this process is the production and supply of 1kWh of electricity. Data on the environmental exchanges of this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “electricity,oil, at power plant/GR” (process identifier EIN_UNIT06567701461) and is classified under the “energy/electricity by fuel/oil” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes all energy use, use of chemicals, emissions to air and water including treatment of flue gasses and effluents. In regards to geographical correlation, the data is specific estimation for Greece. Technology represented from the dataset is average.

The data quality index for this dataset, with reference to Table 1, is (2, 1, 1, 3, 2).

3.2.2 Field electricity production

The process of field electricity production starts at the extraction of fossil fuels with which a typical on-site diesel electricity generator is fed and ends when electricity is produced on site. The production and maintenance of capital infrastructure, such as the generator is excluded. The output to technosphere (product) of this process is the production of 1kWh of electricity in the orchards of Polemarchi.



Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “diesel, burned in diesel-electric generating set” (process identifier EIN_UNIT06567701389) and is classified under the “energy/electricity by fuel/mechanical” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The inventory includes diesel consumption and emissions for the use of diesel in electric generating sets. Transport to site is not included. Geographically the dataset is representative of the situation in Norway and the United States; however the technology is typical of that used in Crete.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 3, 4, 2).

3.3 Production of agricultural chemicals

The production of chemicals used as inputs at the agricultural stage of olive oil production is also a significant activity in environmental terms. The collection of data for the production of the characteristic fertilisers and pesticides is reported below.

3.3.1 Fertiliser production

The process of fertiliser production starts at the extraction of raw materials required for the product and ends when 1kg of the identified 20-10-10 compound fertiliser (NPK) is produced and stored at the manufacturing plant. The transformation that takes place in this process is of chemical nature. The production and maintenance of capital infrastructure, such as manufacturing plant buildings and equipment are excluded. The output to technosphere (product) of this process is the production of 1kg of the characteristic fertiliser.

According to EFMA (2000) NPK fertilisers can be produced by two main methods, via the mixed acid route and by the nitrophosphate route. According to Kentepozidis (2006) the characteristic fertiliser used in Polemarchi is produced through the mixed acid route. This production method allows the creation of a large variety of multinutrient fertilisers by combining phosphoric, sulphuric and nitric acid as well as ammonium nitrate solution in some cases. The manufacture of these products begins with the production of phosphoric acid, a step which creates a large quantity of gypsum. The mixing of the acids, with ammonium nitrate in some cases, is followed by a neutralization step in which gaseous ammonia is added. Other materials may be added at the end of or during this production step (in this system potassium sulphate) in order to enlarge the variety of the final products. The last step consists in the granulation of the final product.

According to PFI (1998) the characteristic fertiliser comprises of ammonium nitrate, ammonium sulphate, monoammonium phosphate, diammonium phosphate and



potassium sulphate. The packaging of the product states that ammonium nitrate is at 36% w/w concentration. The concentration of each of the other ingredients is unknown, however this was estimated through a trial and error calculation procedure, based: [1] on the known weight of ammonium nitrate in 1kg of the fertiliser, [2] on the known weight percentage of each nutrient in each ingredient obtained from Zublena *et al.* (1991) and [3] on the known total weight of each nutrient in 1kg of a 20-10-10 fertiliser product, as shown in Table 2.

Table 2: Composition of the characteristic Polemarchi fertiliser

Material	Weight (kg)	N		P ₂ O ₅		K ₂ O	
		%	Wt (kg)	%	Wt (kg)	%	Wt (kg)
Ammonium nitrate	0.36 ⁽¹⁾	30 ⁽²⁾	0.11 ⁽⁵⁾	-	-	-	-
Ammonium sulphate	0.25 ⁽⁴⁾	21 ⁽²⁾	0.05 ⁽⁵⁾	-	-	-	-
Monoammonium phosphate	0.07 ⁽⁴⁾	11 ⁽²⁾	0.01 ⁽⁵⁾	48 ⁽²⁾	0.04 ⁽⁵⁾	-	-
Diammonium phosphate	0.13 ⁽⁴⁾	18 ⁽²⁾	0.02 ⁽⁵⁾	46 ⁽²⁾	0.06 ⁽⁵⁾	-	-
Potassium sulphate	0.2 ⁽⁴⁾	-	-	-	-	50 ⁽²⁾	0.1 ⁽⁵⁾
Total	1.0	20% ⁽³⁾	0.2 ⁽³⁾	10% ⁽³⁾	0.1 ⁽³⁾	10% ⁽³⁾	0.1 ⁽³⁾

(1) Manufacturers data (PFI,1998)

(2) Zublena *et al.* (1991)

(3) For a 20-10-10 compound fertiliser

(4) Trial and error value

(5) Calculated value

The inventory for the production of the characteristic fertiliser was compiled from the production of each ingredient and more specifically: 0.11kg of ammonium nitrate as N, 0.05kg of ammonium sulphate as N, 0.01kg of monoammonium phosphate as N, 0.04kg of monoammonium phosphate as P₂O₅, 0.02kg of diammonium phosphate as N, 0.06kg of diammonium phosphate as P₂O₅ and 0.1kg of potassium sulphate as K.



Data for the production of ammonium nitrate as N was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Ammonium nitrate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700044) and is classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the production of ammonium nitrate from ammonia and nitric acid. Transports of the intermediate products to the fertiliser plant as well as the transport of the fertiliser product from the factory to the regional storehouse are included. Production and waste treatment of catalysts were not included.

Data for the production of ammonium sulphate as N was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Ammonium sulphate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700045) and is classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the use of energy resources cited in Kongshaug (1998), needed for the production of ammonium sulphate as by-product during the manufacture of nylon. According to the database documentation, these values must be considered as uncertain, because the system boundaries were not clearly defined by Kongshaug.

Data for the production of monoammonium phosphate as N and as P_2O_5 was obtained from Ecoinvent database, version 1.2. The multi-output-process 'monoammonium phosphate, at regional storehouse' delivers the co-products 'monoammonium phosphate, as N, at regional storehouse' and 'monoammonium phosphate, as P_2O_5 , at regional storehouse'. Allocation was based on the energy requirements of the respective nutrients for the production processes: 45% for 'monoammonium phosphate, as N, at regional storehouse' and 55% for 'monoammonium phosphate, as P_2O_5 , at regional storehouse'. Therefore, the allocated inventories are both included in the process (0.01kg of MAP as N and 0.04kg of MAP as P_2O_5). The names of the processes selected are “Monoammonium phosphate, as N, at regional storehouse/RER” (process identifier EIN_UNIT06567700052) and “Monoammonium phosphate, as P_2O_5 , at regional storehouse/RER” (process identifier EIN_UNIT06567700053) and are classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the processes were analysed as unit process by excluding capital goods and their inventories were saved as a new system process. The inventories take into account the production of monoammonium phosphate from ammonia and phosphoric acid. Transports of



raw materials and intermediate products to the fertiliser plant were included. Production and waste treatment of catalysts were not included.

Data for the production of potassium sulphate as K_2O was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Potassium sulphate, as K_2O , at regional storehouse/RER” (process identifier EIN_UNIT06567700057) and is classified under the “material/chemicals/fertilisers (inorganic)” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process. The unit process inventory takes into account the production of potassium sulphate from potassium chloride and sulphuric acid. Transports of raw materials and intermediate products to the fertiliser plant were included. Production and waste treatment of catalysts were not included.

According to the inventory database documentation used for these inventories, the European average is derived from mean values of several fertiliser plants within Europe. The production of raw materials and/or intermediates outside Europe was taken into account by considering the production technology in the respective country and the relative import shares, whereas production inventory was derived from detailed literature studies and specifications from the manufacturer, relevant for the European production. The data quality index for this dataset, with reference to Table 1, is (2, 1, 1, 2, 2).

3.3.2 Pesticide production

The process of pesticide production starts at the extraction of raw materials required for the product and ends when 1kg of the identified pesticide is produced and stored at the manufacturing plant. The production and maintenance of capital infrastructure, such as manufacturing plant buildings and equipment are excluded. The output to technosphere (product) of this process is 1kg of the characteristic pesticide produced.

Most modern synthetic pesticides are manufactured entirely from intermediates derived from fossil fuels. Primary pesticide production conventionally entails several process steps involving a variety of unit operations such as heating, stirring, distilling, filtering, drying and similar processes to build up a biologically active chemical entity from raw materials and/or specific chemical intermediates (Bhat et al., 1994). Secondary processing involves the formulation of the pesticide in a marketable form, such as wettable powders, dusts, emulsifiable concentrates, granules etc. This normally involves purely physical operations such as vessel charging, mixing, milling, warming, cooling, product transfer, granulation, drying, sieving and packaging. No chemical reactions take place during secondary processing. Nevertheless, both the production and the formulation processes require direct energy inputs for processing, in addition to the intrinsic energy inputs



needed (Nemecek, 2004). The production of the characteristic pesticide for Voukolies involves the production of the active substance dimethoate and the product formulation into emulsifiable concentrate with 40% concentration of the active ingredient.

According to Nemecek (2004) it is very difficult to obtain current, accurate and specific data on pesticide production and the reason for this is twofold. Firstly, detailed information on the production processes is not easily available to public since a company often does not share information on its patent-protected pesticides. Secondly, the unavailability of data is attributed to the very large number of chemical compounds used as pesticides – over 6,000 worldwide, whereas the active substances belong to very different chemical categories and are synthesised by various, sometimes highly complex chemical pathways.

Data for the production of deltamethrin based pesticide was obtained from Ecoinvent database, version 1.2. Since deltamethrin is not one of the substances covered by Green (1987) and inventoried by Ecoinvent, the process selected is “Pesticide, unspecified, at regional storehouse/RER” (process identifier EIN_UNIT06567700120) and is classified under the “material/chemicals/pesticides” subcategory. Values represent the average of the inventories of all active ingredients (totally 41) included in Green (1987), who approximated energy inputs required for the manufacture of selected pesticides. Apart from energy inputs other inputs are not included. The World Bank (1998) gives the quantity of solid waste produced as 200kg per tonne of active ingredient and this was included in the inventories. According to the same data source the emissions of active ingredients to the environment during manufacture, amounted to only 0.03-14mg per kg of active substance. These emissions are negligible compared to emissions from pesticide application, thus they were not included in the Ecoinvent datasheets (Nemecek, 2004). In the other hand, waste heat production stemming from the use of electricity was quantified as emission into the air.

In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The values used for this inventory primarily apply to US American conditions. It is assumed that these figures can be applied to the manufacturing process in the European Union. Values given represent approximated values which are based on hypothetical material flow sheets and line diagrams from which the energy input of manufacturing process was derived. The manufacturing process was modelled on information given about the method of manufacture in the patents or, in case of



pesticides which are no longer subject to patent protection, on detailed literature on the production process.

The data quality index for this dataset, with reference to Table 1, is (2, 2, 4, 3, 2).

3.4 Transportation

The investigation of the means, with which agricultural inputs and outputs are transported, revealed that three main transportation modes are used: freight ship, 3-axle 16 tonne lorry and pickup van. In the following sections environmental exchanges for transportation of goods through each of these are reported. The transportation processes with these modes are combined in order to simulate the transportation practice for the various inputs and outputs.

3.4.1 Transportation by freight ship

The process of transportation by freight ship starts when loading the goods in the freight ship at the origin port and ends when the goods are unloaded at the destination port. The nature of the transformation that takes place is physical. The production and maintenance of capital infrastructure, such as the vessel and the port is excluded. The output to technosphere (product) of this process is the transportation of a 1-tonne load over 1km by a typical freight ship.

Data for the unit process of transporting goods by freight ship was obtained from Ecoinvent database, version 1.2. The name of the process selected is “operation, transoceanic freight ship/RER” (process identifier EIN_UNIT06567701792) and is classified under the transport/water/operations subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes the supply of fuel, direct airborne emissions of gaseous substances, particulate matters, dioxins, PAHs, halogens and heavy metals. Also, the disposal of bilge oil and emissions of tributyltin compounds are included. The spill of oil due to accidents is not included.

Individual hydrocarbons are estimated based on the share of diesel engines of road vehicles. Heavy metals are estimated from trace elements in fuel. A distinction between distilled (28%) and residual fuel (72%) is applied. Amount of disposed bilge oil is estimated as 0.6% of the consumed fuel.

In regards to geographic scope, the data is global, whereas in regards to technology, average data for steam turbine (5%) and diesel engine (95%) propulsion is used. The fuel used is Heavy Fuel Oil (HFO) and is representative for slow speed engine types (speed: 14 knots per hour). The data represents solid



bulk transport (about 40,000 dwt). Literature studies and own estimates have been used during sampling procedure for compilation of this process in the Ecoinvent database.

The data quality index for this dataset, with reference to Table 1, is (4, 5, 1, 2, 2).

3.4.2 Transportation by 16-tonne lorry

The process of transportation by a 3-axle, 16-tonne lorry starts when loading the goods in the lorry at the origin location and ends when unloading the goods at the destination location. Thus the nature of the transformation that takes place is also physical. The production and maintenance of capital infrastructure, such as the vehicle and the roads is excluded. The output to technosphere (product) of this process is the transportation of 1 tonne of goods by a 16-tonne lorry over a distance of 1km.

Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “transport, lorry 16t/RER” (process identifier EIN_UNIT06567701774) and is classified under the transport/road subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes diesel and petrol supply as well as direct airborne emissions of gaseous substances, particulate matters and heavy metals. Also heavy metal emissions to soil and water are included. Emissions due to losses of air condition systems are estimated. The original Ecoinvent unit process also included the construction, renewal and disposal of roads but these have been excluded from the process, in accordance with the system boundaries.

In regards, to geographic scope, data refers to average transport conditions in Europe, however Crete is not included. Nevertheless, as transport conditions in Crete are similar to the rest of Europe, the data is considered as geographically representative. The sampling sources used include: European statistics, literature studies and official publications of the European Environmental Agency.

In regards to the technology represented, the data is based on diesel engine concepts, which is representative of the situation in regards to such vehicles in Greece and Crete, where transportation takes places for the life cycle of olive oil modelled.

The data quality index for this dataset, with reference to Table 1, is (3, 1, 1, 3, 2).



3.4.3 Transportation by pickup van

The process of transportation by pickup vans starts when loading the goods in the van at the origin location and ends when unloading the goods at the destination location. The production and maintenance of capital infrastructure is also excluded. The output to technosphere (product) of this process is the transportation of 1 tonne of goods by a van with gross weight less than 3.5 tonnes over a distance of 1km.

Data for this unit process was obtained from Ecoinvent database, version 1.2. The name of the process selected is “transport, van<3.5t/RER” (process identifier EIN_UNIT06567701780) and is classified under the transport/road subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and its inventory was saved as a new system process.

The inventory includes diesel and petrol supply, as well as direct airborne emissions of gaseous substances, particulate matters and heavy metals. Furthermore the inventory includes heavy metal emissions to soil. For petrol vans in particular, platinum emissions are accounted for. The original Ecoinvent unit process also the construction, renewal and disposal of roads but these have been excluded from the process, in accordance with the system boundaries.

The data is for the operation of an average European van and geographically the data refers to average transport conditions in Europe. Although Crete is not included, transport conditions in Crete are similar to the rest of Europe, therefore the data is considered as geographically representative. The sampling sources used include: European statistics, literature studies and official publications of the European Environmental Agency (EEA).

In regards to the technology represented, the data is based on both diesel and petrol engine concepts, which is representative of the situation in regards to such vehicles in Crete, with diesel engines dominating.

The data quality index for this dataset, with reference to Table 1, is (3, 1, 1, 3, 2).

3.4.4 Transportation of fertilisers

The process of fertiliser transportation starts when loading 1kg of the fertiliser at the production site, i.e. in Kavala, and ends when unloading 1kg of the fertiliser at the point of application, i.e. Polemarchi. The production and maintenance of capital infrastructure, such as vessels, vehicles, roads and ports is excluded. The process combines all intermediate transportation that takes place by the all modes used. The output to technosphere (product) of this process is the transportation of 1kg of the characteristic fertiliser used in Polemarchi, as determined in Chapter 3, from its production site in Kavala to the Polemarchi olive orchards.



Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. Transportation routes and distances were identified and measured from geographical maps. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular routes.

In the process inventory, for 1kg of the output to technosphere, the inputs from technosphere are: 1kg*524km, i.e. 0.524 tonnes*km of transportation by freight ship (documented in section 5.4.1), 1kg*30km, i.e. 0.03 tonnes*km of transportation by 16-tonne lorry (documented in section 5.4.2) and 1kg*10km, i.e. 0.01 tonnes*km of transportation by pickup vans (documented in section 5.4.3).

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 1, 1, 1).

3.4.5 Transportation of pesticides

The process of pesticide transportation starts when loading 1kg of the pesticide at the production site in France and ends when unloading 1kg of the pesticide product at the point of application, i.e. the olive orchards in Polemarchi. The production and maintenance of capital infrastructure, is excluded. The process includes all intermediate transportation that takes place by the all modes used, including transportation in Greece for packaging. The output to technosphere (product) of this process is the transportation of 1kg of the characteristic pesticide used in Polemarchi, from its production site in France to the Polemarchi olive orchards.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. Transportation paths and distances were identified and measured from maps. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular routes.

In the process inventory, for 1kg of the output to technosphere, the inputs from technosphere are: 1kg*2127km (total from Genoa-Piraeus and Piraeus-Souda), i.e. 2.127 tonnes*km of transportation by freight ship, 1kg*454km of total transportation by 16-tonne lorry, i.e. 0.454 tonnes*km and 1kg*10km of transportation by pickup vans (documented in section 5.4.3), i.e. 0.01 tonnes*km.

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 1, 1, 1).



3.4.6 Transportation of herbicides

The process of herbicide (Roundup) transportation starts when loading 1kg of the herbicide at the production site in Belgium and ends when unloading 1kg of the herbicide product at the point of application, i.e. the olive orchards in Voukolies. The production and maintenance of capital infrastructure, is excluded. The process includes all intermediate transportation that takes place by the all modes used, including transportation in Greece for packaging. The output to technosphere (product) of this process is the transportation of 1kg of the characteristic herbicide used in Voukolies, from its production site in Belgium to the Voukolies olive orchards.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. Transportation paths and distances were identified and measured from maps. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in regards to transportation modes is average technology used for the particular routes.

In the process inventory, for 1kg of the output to technosphere, the inputs from technosphere are: 1kg*5670km (total from Antwerp-Piraeus and Piraeus-Souda), i.e. 5.67 tonnes*km of transportation by freight ship, 1kg*35km (Athens to Piraeus 5Km and Souda to Voukolies 30 Km) of total transportation by 16-tonne lorry, i.e. 0,035 tonnes*km and 1kg*10km of transportation by pickup vans, i.e. 0.01 tonnes*km.

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 1, 1, 1).

3.4.7 Transportation of olives

The process of transportation of olives starts when 1kg of olives are loaded at the collection point, i.e. the olive orchards of Polemarchi and ends when they are delivered at the olive oil processing unit. The production and maintenance of capital infrastructure, such as vehicles and roads is excluded. The output to technosphere (product) of this process is the transportation of 1kg of olives, from Polemarchi orchards to the processing unit.

Data for this process was collected during the characteristic cycle identification through personal and telephone interviews. The data is therefore specific for this case study and collected within the last year (2006). The technology considered in



regards to transportation modes is average technology used for the particular route.

In the process inventory, for 1kg of the output to technosphere, the only input from technosphere is $1\text{kg} \cdot 10\text{km}$, i.e. $0,01 \text{ tonnes} \cdot \text{km}$ of transportation by pickup vans.

No other direct flows from and to technosphere or from and to the environment have been identified.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 1, 1, 1).

3.5 Agricultural processes

Processes, which take place within the olive orchards, including the supply of water needed for irrigation and other uses within the orchard, the planting of new trees, irrigation and the management of the agricultural soil etc, are processes of primary importance to the system. Collection of data on the environmental exchanges of each of these processes was based on information obtained from the actual olive growers where possible and also on the application of the results of research undertaken in the past, as found in the relevant literature.

3.5.1 Field water supply

The process starts from the central water supply system (called ΟΑΔΥΚ) from two separate regions as identified in Chapter 3 and ends when water is supplied to the sprinkler irrigation system at the appropriate operational pressure. The production and maintenance of capital infrastructure e.g. turbine pumps and pipes are excluded in line with the definition of the system boundary. The output to technosphere (product) of this process is 1 lt (kg) of water supplied for irrigation.

A water main is a valuable resource and its consumption within a technosphere system shall be considered as an environmental input in an LCA. Thus, for the supply of 1kg of water for irrigation, 1 litre (kg) of water from water main in ground is recorded as an input from nature. However, for easier interpretation in the water consumption pattern within the system, water resource from wells, from rivers and from lakes are all recorded as water from unspecified natural origin.

The main input from technosphere in this process is electrical energy consumed by the electric turbine pumps to extract the water from the central water main. This is done by two ways described below.

A 100 HP, i.e. $74.6\text{kW} \approx 75\text{kW}$ turbine pump is used. The supply of 1kg of water at a flow rate of 90tonnes/hour corresponds to 1.11×10^{-5} hours of operation of the



turbine pump, thus 8.32×10^{-4} kWh of electricity produced is consumed from the process, thus included in the inventory as input from the technosphere.

Two turbine pumps, a 60HP, i.e. 45kW and a 75HP, i.e. 56kW are used. These pumps work simultaneously only when the demand of irrigated water is very high at the areas that they serve. An average and representative value about the power of these two pumps during the year that can be accepted is 100HP, i.e. 75kW. The flow rate is about 110tonnes/hour. So, the supply of 1kg of water at a flow rate of 110tonnes/hour corresponds to 9.09×10^{-6} hours of operation of the turbine pump, thus 6.82×10^{-4} kWh of electricity produced is consumed from the process, thus included in the inventory as input from the technosphere.

According to the latter, the cumulative amount of power (electricity produced) from both sites, that is consumed from the process is 1.51×10^{-3} kWh of field electricity produced.

No other flows to and from the environment and the technosphere have been identified in this process.

The data quality index for this dataset, with reference to Table 1, is (3, 3, 1, 1, 1).

3.5.2 Olive tree planting

The process of olive tree planting starts when new trees in plastic buckets are transported from the tree nursery to the field. It ends when a new Crete olive tree is being planted in the Polemarchi orchards. The process does not include any exchanges occurring as a result of processes taking place in the tree nursery, such as the treatment of cuttings with rooting media. The production of plastic buckets, which contain the new tree prior to planting, is also excluded. As identified in Chapter 3, the buckets are reusable, thus no disposal of buckets is considered.

Furthermore the production and maintenance of capital infrastructure such as the tools used are excluded in line with the system boundary definition. The output to technosphere (product) of the process is one olive tree of the Crete variety planted in the Polemarchi orchards.

No mechanical equipment is involved, since only manual tools are used (mattocks and spades), therefore neither energy or fuel consumption, nor emissions to the environment are recorded. The only material flow identified during the process is the use of water, which is surplus to the regular irrigation of the trees. Thus 2 litres of water, as estimated by the growers, from the “field water supply” process, are recorded as an input from technosphere to the tree planting process. Furthermore, trees for planting are transported from the public tree nursery in Platanias (10km) by private pickup vans.



Considering that the weight of a young olive tree planted in a plastic bucket weighs an estimated 4kg, 0.040tonnes*km of “transportation by private pickup van”, documented in section 5.4.3 is also included in the process as an input from technosphere.

No other flows to and from the environment and the technosphere have been identified in this process.

The data quality index for this dataset, with reference to Table 1, is (2, 1, 1, 1, 1).

3.5.3 Irrigation

The process of irrigation starts when water is supplied at the appropriate pressure to the characteristic spray type irrigation system and ends when water is applied to the root of the olive trees. The production and maintenance of the sprinkler irrigation system (capital infrastructure) is excluded. The output to technosphere (product) of this process is the application of 1 kg of water to the root of the olive trees.



Figure 7: Irrigation of Olive trees

The only input to technosphere in this process is water supplied for irrigation. Provided that water is supplied at the appropriate pressure for the sprinkler system to operate, as assumed in the inventory of irrigation water supplied, no other energy or material inputs are required for irrigation. However loss of water during its application needs to be accounted. Irrigation water losses include air losses, which for this particular system can be large, ground evaporation, runoff and deep percolation. Assuming ground evaporation, runoff and deep percolation are negligible, the efficiency of water application through a solid set sprinkler irrigation system, according to Rogers (1997) varies between 70% and 85%, i.e. an average of 77.5%. Therefore it is assumed that 1.29kg of supplied water is required from the technosphere in order to apply 1kg of water to the olive tree root.

The 0.29kg of water lost are accounted as emissions (vapour) to air. No other flows to and from the environment have been identified in this process.

The data quality index for this dataset, with reference to Table 1, is (3, 1, 1, 1, 1).

3.5.4 Soil Management

The process of soil management includes all material and energy flows associated with soil ploughing operations carried out in Polemarchi olive orchards, as identified in Chapter 3. The production and maintenance of tractors and ploughing implements (capital infrastructure) is excluded. The output to technosphere (product) of this process is 10000m² (1 hectare) of ploughed agricultural land. As identified in Chapter 3, according to the grower survey the prevailing ploughing technique is by means of a chisel plough attached to a 45-horsepower tractor.



Figure 8: Soil Management by tractor

Data in regards to emissions from the operation of tractor during soil management was obtained from the Ecoinvent database, version 1.2. The name of the process selected is “Tillage, ploughing/ CH” (process identifier EIN_UNIT06567700189) and is classified under the “processing/agricultural subcategory”. The inventory takes into account the diesel fuel consumption and the amount of agricultural machinery and of the shed, which has to be attributed to the ploughing. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The following activities were considered part of the work process: preliminary work at the farm, like attaching the adequate machine to the tractor; transfer to field (with an assumed distance of 1 km); field work (for a parcel of land of 1 ha surface); transfer to farm and concluding work, like uncoupling the machine. Not included are dust other than from combustion and noise. The inventories are based on measurements made by the FAT, in Switzerland (Nemecek, 2004). Emissions and fuel consumption are those of the newest models of tractors set into operation

during the period from 1999 to 2001 and measurements were made in the period 1999-2001.

However two adjustments were made to this dataset prior to its use in the system. Firstly, the production of capital infrastructure included in the process above (tractor, agricultural machinery and shed) was excluded from the process by analysis the unit process without the capital infrastructure and saving it as a system process.

Secondarily, the tractor consumption for soil management is 16,8 lt per hectare or 14,2 Kg per hectare on average terms. Thus about 14,2 kg of diesel, the production consumed per 10000m² (as shown in table 3) of land ploughed through the particular method and this is included as an input from technosphere to the process.

Table 3: Average energy consumption of some tillage operations: reproduced from (Nalewaja, 2001)

Operations	Diesel consumption (litres/hectare)	Energy consumption (kcal/ha)
Mouldboard plough	16.81	256,669
Cultivator	5.61	52,285
Disk harrow	6.55	61,046
"Chisel" plough	8.89	82,855
Harrow	3.37	30,476
Pass with no tillage	0.94	8,761

No other flows to and from the environment have been identified in this process.

The data quality index for this dataset, with reference to Table 1, is (3, 1, 1, 3, 1).

3.5.5 Pruning

The process of olive tree pruning includes the material and energy flows required in order to undertake regular pruning in Polemarchi. The production and maintenance



of the petrol chainsaw (capital good) is excluded. The output to technosphere (product) of this process is the pruning of one olive tree.

Figure 9: Olive tree Pruning



The characteristic pruning equipment in Polemarchi is the petrol chainsaw. Giametta *et al.* (1997) report that pruning duration ranges from 2,4 minutes per tree for pruning with specialised machines to 76,8 minutes per tree for pruning with traditional saws. The interviews of olive growers in Polemarchi have shown that typically a 45cc chainsaw would be used for 15 minutes in order to prune a tree of average age and size. Therefore the use of the chainsaw for 15 minutes, i.e. 0.25 hours is an input from technosphere to the process of pruning.

The exchanges associated with the actual use of the chainsaw include the consumption of fuel and lubricants and the emissions from combustion. These data were obtained from IDEMAT 2001 database. The name of the process selected is “industrial chain saw” (process identifier IDEMAT0106626600501) and is classified under the “processing/wood subcategory”. The process is a second order process i.e. it includes material and energy flows including operations but excludes the production and maintenance of capital infrastructure, in line with our system boundaries. The source of data is the statistical yearbook (1993) of the Delft University of Technology. The inventory includes the input of petrol and oil and the emission of carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen oxides, hydrocarbons and soot to air. No emissions to soil which may occur from potential oil leakage are accounted. The data represents average technology; however its geographic origin is mixed.

Pruning residue is subsequently burned. Thus 17.8kg of “burning of pruning residue” was included in the pruning process inventory as “waste to treatment”.

The data quality index for this dataset, with reference to Table 1, is (3, 1, 1, 3, 1).

3.5.6 Burning of pruning residues and disposal of ash

The process of pruning residue burning in open fires starts when pruned primary and secondary branches are collected and ends when the leftover ash is sprayed to the agricultural land. The production and maintenance of any capital infrastructure, is excluded. The process is a waste treatment process, thus no outputs to technosphere (products of value) are produced.

The inventory of this unit process is based on the assumption that no significant transportation takes place, since the olive growers' survey indicated that incineration takes place very near to the orchards and also no fuel is used for initial ignition of the residue.

The typical composition of wood is 50,5% carbon, 6% hydrogen, 42,4% oxygen, 0,2% nitrogen, 0,05% sulphur and 1% other non-combustibles (Cheremisinoff, 1992). The emissions to the environment due to its incineration comprise of the emissions to air due to combustion, i.e. smoke and the emissions to soil due to the subsequent spreading of the ash at the land.

Smoke is composed primarily of carbon dioxide, water vapour, carbon monoxide, particulate matter, hydrocarbons and other organic chemicals, nitrogen oxides, trace minerals and several thousand other compounds. The actual composition of smoke depends on the fuel type, the temperature of the fire, and the wind conditions. Different types of wood and vegetation are composed of varying amounts of cellulose, lignin, tannins and other polyphenolics, oils, fats, resins, waxes and starches (Shafizadeh, 1981), which produce different compounds when burned. The inventory of this process included a typical chemical composition of wood smoke, obtained from EPA (1993), as shown in Table 4. It is highlighted that average values were used in the inventory when ranges were given whereas some species, which are not considered by standard environmental impact assessment methods were excluded.



Table 4: Chemical composition of wood smoke, EPA 1993

Substance/ parameter	Probable range (g/kg wood) ¹	Inventory value (g/kg wood)	Substance/ parameter	Probable range (g/kg wood) ¹	Inventory value (g/kg wood)
Water vapour	70	70	Benzofluorant henes	6×10^{-4} - 5×10^{-3}	2.8×10^{-3}
Carbon dioxide	120	120	Benzo(a)pyre ne	3×10^{-4} - 5×10^{-3}	2.65×10^{-3}
Carbon monoxide	80-370	225	Benz(ghi)pery lene	3×10^{-5} - 1.1×10^{-2}	5.52×10^{-3}
Methane	14-25	19.5	Dibenzo(a,h) pyrene	3×10^{-4} - 1×10^{-3}	6.5×10^{-4}
VOCs (C ₂ -C ₇)	7-27	17	Dibenz(a,h)a nthrane	2×10^{-5} - 2×10^{-3}	1.01×10^{-3}
Aldehydes	0.6-5.4	3	Sodium	3×10^{-3} - 1.8×10^{-2}	0.01
Substituted furans	0.15-1.7	0.93	Magnesium	2×10^{-4} - 3×10^{-3}	1.6×10^{-3}
Benzene	0.6-4.0	2.3	Aluminium	1×10^{-4} - 2.4×10^{-2}	0.01
Toluene	0.15-1.0	0.58	Silicon	3×10^{-4} - 3.1×10^{-2}	0.02
Acetic acid	1.8-2.4	2.1	Chlorine	7×10^{-4} - 2.1×10^{-1}	0.11
Formic acid	0.06-0.08	0.07	Potassium	3×10^{-3} - 8.6×10^{-2}	0.04
Nitrogen oxides	0.2-0.9	0.55	Calcium	9×10^{-4} - 1.8×10^{-2}	9.45×10^{-3}
Sulphur dioxide	0.16-0.24	0.2	Titanium	4×10^{-5} - 3×10^{-3}	1.52×10^{-3}
Napthalene	0.24-1.6	0.92	Vanadium	2×10^{-5} - 4×10^{-3}	2.01×10^{-3}
Phenol (and derivatives)	0.2-0.8	0.5	Chromium	2×10^{-5} - 3×10^{-3}	1.51×10^{-3}
Catechol (and derivatives)	0.2-0.8	0.5	Manganese	7×10^{-5} - 4×10^{-3}	2.04×10^{-3}
Fluorene	4×10^{-5} - 1.7×10^{-2}	8.5×10^{-3}	Iron	3×10^{-4} - 5×10^{-3}	2.65×10^{-3}
Phenanthrene	2×10^{-5} - 3.4×10^{-2}	0.02	Nickel	1×10^{-6} - 1×10^{-3}	5×10^{-4}
Anthracene	5×10^{-5} - 2.1×10^{-2}	0.01	Copper	2×10^{-4} - 8×10^{-3}	4.1×10^{-3}

The mass of the leftover ash is assumed to be 0.45% of the mass of the wood (Shafizadeh, 1981 and Misra, 1993), thus for every 1kg of pruning residue burned 4.5g of ash is disposed to land.

From the questionnaires it's calculated that for every tree the burning of pruning residues is 45,8 Kg on average terms and it is described in the inventory as waste to treatment.

It is worth mention that there is no disposal of ash takes place in Voukolies thus this procedure is calculated as final waste flow under the subcategory wood ash.

The data quality index for the whole "burning of pruning residues and disposal of ash" dataset, with reference to Table 1, is (3, 3, 4, 4, 3).

3.5.7 Fertiliser application

The process of fertiliser application includes all materials and energy flows associated with the hand application of the 20-10-10 NPK characteristic fertiliser in Polemarchi orchards. The treatment of fertiliser packaging is excluded from the process inventory. The output to technosphere (product) of this process is the application of 4.07 kg of the 20-10-10 NPK fertiliser to the Voukolies olive orchards. This quantity refers to the average calculated quantity of fertiliser applied per olive tree in Voukolies.

The main inputs from technosphere for this process are the production and transportation of 4.07 kg of the characteristic fertiliser as previously documented, assuming no material losses during production and transportation.

No mechanical equipment is used in Voukolies and the fertiliser is simply left to the root of the trees by hand. Therefore neither fuel consumption nor emissions from the operation of mechanical equipment are included in the inventory. The only additional material flow within the process of fertiliser application is the quantity of water used immediately after the fertiliser is left to the root.

Furthermore, the inventory for this process covers the emissions to air, water and soil directly attributed to the application of the characteristic fertiliser in Voukolies orchards. Since actual measurements of emissions are neither practical nor appropriate for LCA purposes, estimates of emission factors and estimation techniques from literature were obtained. However, it must be highlighted that emissions are strongly influenced by soil type and climatic conditions (Brentrup and Kusters, 2000) and although every effort was taken in order to use emission rates and techniques developed under similar to Voukolies conditions, the emissions included in the inventory contain a significant degree of uncertainty.



According to the definition of the system boundary, “fertilisers, pesticides, herbicides and possibly other chemical inputs on agricultural soils should not be counted as emissions into nature as a whole, but only those substances and quantities that leach into deeper soil and water or evaporate in the atmosphere. Thus the main emission flows covered by the inventory of this process are: ammonia volatilisation (air), emissions of dinitrogen monoxide (air), emissions of nitrogen oxides (air), nitrate leaching (groundwater) and emissions of phosphorus (groundwater), identified by several authors (Brentrup and Kusters, 2000, Webb *et al.*, 2000, Canals, 2003, Nemecek *et al.*, 2004). Another potential environmental emission of this process is heavy metals entering the soil, which are only partly taken up by the trees, and thus become part of the technosphere (Canals, 2003). Audsley *et al.* (1997) suggest that the entire fraction not leaving the system with the crop may be considered as an emission to soil. However, in line with the definition of the system boundary in this study and in the absence of evidence that heavy metals enter deeper strata of soil or surface and ground waters, they are not included in the process inventory.

Emissions of dinitrogen monoxide (N_2O), which is one of the greenhouse gases, are the result of mainly two microbial processes, denitrification and nitrification and are influenced by many complex interactions between soil and climate factors (Brentrup and Kusters, 2000). Although the complexity of the interactions between the various parameters is up to now not well enough understood (Enquete-Kommission “Schutz der Erdatmosphäre”, 1994), Bouwan (1995), based on field experiments, proposed an emission factor for N_2O -N emissions from mineral and organic fertilisers equal to 0.0125 of the N input, corrected for ammonia emissions, as these predominantly occur earlier than N_2O emissions (Kroeze, 1994).

During denitrification processes in soils, NO_x may also be produced. Grub (1996) cited in Nemecek (2004) suggests that these emissions can be estimated as 21% of the emissions of N_2O . Since this process is not a conversion from N_2O to NO_x but a parallel process, no correction of N_2O emissions is required. The estimated NO_x emissions using the Grub (1996) factor are 4.2×10^{-3} kg. NO_x are usually measured as NO_2 . For the same emissions, Audsley *et al.* (1997) proposes a factor of 10% of N_2O -N emissions for NO_x - N emissions. Based on this approach the estimated NO_x -N emissions are 1.29×10^{-3} kg, thus NO_x emissions, measured as NO_2 are approximately 4.24×10^{-3} kg.

Nitrates’ leaching to groundwater is a direct result of the imbalance between net nitrogen-uptake by the trees (Canals, 2003), nitrogen produced by microorganisms in the soil via mineralization of organic matter and the total nitrogen that is returned to it in the form of fertilisers. As nitrate is easily dissolved in the water, in periods of heavy rainfall, when precipitation exceeds soil evaporation and transpiration of the plants and following initial saturation of soil with water, nitrates percolate to the



groundwater (Nemecek *et al.*, 2004). This balance is affected by the facts that: precipitation and subsequently nitrate leaching is highest in autumn and winter, and also, in late summer, nitrogen-uptake by the trees is low (Stauffer *et al.*, 2001). Therefore, the most important parameters determining the nitrate leaching are: soil related (field capacity of the effective root zone), climate related (drainage water rate) and agriculture related (nitrogen balance) (Brentrup and Kusters, 2000)

Nitrates' leaching to groundwater was calculated using the method suggested by (Brentrup and Kusters, 2000). The field capacity in the effective root zone FC_{RZe} was calculated by multiplying the available field capacity FCa by the effective root zone RZe . Both of these parameters depend on the soil texture. Based on the fact that upper strata in Polemarchi orchards mainly consist of silty clay, the average field capacity is $16\text{mm}\cdot\text{dm}^{-1}$ and the effective rooting zone is 10dm (DBG, 1992), thus the field capacity in the effective root zone FC_{RZe} is 160mm.

The rate of drainage water (W_{drain}) is the difference of the precipitation rate (W_{precip}) and the evapotranspiration rate (W_{et}). Thus, based on the average precipitation rate, which in Polemarchi is 621,5 mm/year (Greek Meteorological Service, 2006) and on an average evapotranspiration rate is 391,545 mm/year the rate of drainage water W_{drain} is equal to 229,995 mm/year.

A measure for the quantity of water that percolates through the soil profile into the groundwater is the exchange frequency of the drainage water, which can be calculated from the ratio of W_{drain} to FC_{RZe} and is equal to 1.417/year.

Therefore, based on the calculated nitrogen balance (available for leaching) and the calculated exchange frequency, the nitrate emission into groundwater via leaching attributed to the application of 86,371 kg of the characteristic fertiliser in Polemarchi is 6,547 kg $\text{NO}_3\text{-N}$.

In regards to phosphorus, Nemecek *et al.* (2004) distinguish three different kinds of phosphorus emissions to water: [1] leaching of soluble phosphate to ground water, [2] run-off of soluble phosphate to surface water and [3] erosion of soil particles containing phosphorus, by surface water. Since there are no significant surface waters around the Polemarchi orchards (no olive cultivations are adjacent to the two small dams in the region and the Koutsos water stream) only the first mechanism is considered.

The quantity of phosphate leaching to groundwater was calculated based on a factor of 0.06 of the P input applied, suggested by Nemecek *et al.* (2004). Thus for 4,07kg of the 20-10-10 NPK fertiliser applied in Polemarchi, of which P input is 0.41kg, the quantity of P leaching into groundwater is 0.025kg. It is highlighted that no correction factor is applied since no fertilisation by slurry takes place.



The data quality index for the inventory of this process, with reference to Table 1, is (2, 2, 3, 3, 2).

3.5.8 Pesticide application

The process of pesticide application includes all material and energy flows associated with the spraying of the characteristic pesticide used in the region (40% dimethoate) through compressed air hand-held sprayers connected to agricultural tractors. The production and maintenance of capital infrastructure, such as the tractor and the sprayer is excluded. The treatment of pesticide packaging is also excluded from the process inventory. The output to technosphere (product) of this process is the application of 1kg of the characteristic pesticide product to the Polemarchi olive orchards.

In regards to material and energy flows occurring from the operation of the tractor for spraying the pesticides, data were obtained from the Ecoinvent database, version 1.2. The name of the process selected is “Application of plant protection products, by field sprayer/CH” (process identifier EIN_UNIT06567700156) and is classified under the “processing/agricultural” subcategory. The productions of capital infrastructure included in the process above (tractor, agricultural machinery and shed) were excluded from the process, in line with the requirements of our system and the process was saved as a system process. The inventory takes into account the diesel fuel consumption, which is attributed to the application of the pesticide. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The emissions and fuel consumption refer to the newest models of tractors set into operation during the period from 1999 to 2001. Since the inputs and outputs in the database process are recorded per m² of application area and not per kg of pesticide, based on the survey analysis on land use (see analysis in appendix B) the 1kg is converted to 875,5m² of the Ecoinvent process and was included in the “pesticide application” process as input from technosphere.

The data quality index for the inventory of this process, with reference to Table 1, is (2, 2, 3, 3, 2).

3.5.9 Herbicide application

The process of herbicide application includes all material and energy flows associated with the spraying of the characteristic herbicide used in the region (2.5%w/v deltamethrine) through compressed air hand-held sprayers connected to agricultural tractors. The production and maintenance of capital infrastructure, such as the tractor and the sprayer is excluded. The treatment of herbicide packaging is



also excluded from the process inventory. The output to technosphere (product) of this process is the application of 1kg of the characteristic herbicide product to the Polemarchi olive orchards.

In regards to material and energy flows occurring from the operation of the tractor for spraying the herbicides, data were obtained from the Ecoinvent database, version 1.2. The name of the process selected is “Application of plant protection products, by field sprayer/CH” (process identifier EIN_UNIT06567700156) and is classified under the “processing/agricultural” subcategory. The production of capital infrastructure included in the process above (tractor, agricultural machinery and shed) was excluded from the process, in line with the requirements of our system and the process was saved as a system process. The inventory takes into account the diesel fuel consumption, which is attributed to the application of the herbicide. Also taken into consideration is the amount of emissions to the air from combustion and the emission to the soil from tyre abrasion during the work process. The emissions and fuel consumption refer to the newest models of tractors set into operation during the period from 1999 to 2001. Since the inputs and outputs in the database process are recorded per m² of application area and not per kg of herbicide, based on the survey analysis on land use the 1kg is converted to 3810m² of the Ecoinvent process and was included in the “herbicide application” process as input from technosphere.

For 1Kg of pesticide used it is calculated that 50% emits to the air (0,50Kg), 0,11% emits to water (0,0011Kg) and 49,89% to soil (0,4989Kg).

One of the most drastic compounds of herbicide roundup used is glyphosate with 41.5% concentration. Thus, above the previous mentioned emissions there are and 0.415Kg of this compound.

3.5.10 Collection of olives

The process of olive collection includes all material and energy flows associated with the collection of olives and their temporary storing into plastic boxes or reusable mesh bags, as shown in Figure 7, in the Polemarchi olive orchards. As identified in Chapter 3, according to the olive agriculture survey, the prevailing collection technique is through the use of hand-held pneumatic combs connected to a motorised air compressor and reusable underlying nets. The production and maintenance of capital infrastructure, such as the air compressor and the combs is excluded. The production of the reusable nets and plastic storage boxes or mesh bags is also excluded. The output to technosphere (product) of this process is the collection of 1kg of olives. It is highlighted that the 1 kilogram of olives is as measured in the orchards and includes a small mass percentage of leaves, dust



and other foreign matter, which will be accounted in the inventory of the olive purification process later in this report.

Figure 10: Reusable mesh bags



This type of comps, typically work with electricity which comes from white gasoline electric generators. A typical generator has a 3kW power and a gas tank of 4 lt. According to region's farmers the whole tank can work for about 2 hours continuously. Usually farmers connect two comps over the generator. Thus for the collection of 1Kg olives it is required $1,43 \times 10^{-2}$ hr of work. At this time the electric generator consumes 0,043KWh (input to technosphere) or 0,019 lt of burning fuel.

No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 1, is (3, 1, 1, 1, 1).

3.5.11 Olive agriculture

The envelope unit process of olive agriculture starts with the plantation of the trees and ends when olives in the Polemarchi orchards are collected. The process includes all agricultural sub-processes as previously documented. The production and maintenance of capital infrastructure is excluded in line with the boundary definition (Avraamides *et al.*, 2005). The output to technosphere (product) of this process is 4.29kg of unprocessed collected olives of the Crete variety, which include some impurities such as leaves, dust etc. This quantity is based on the statistical analysis of the responses obtained from the questionnaire as well as on the measurements undertaken in the processing unit, and it is the average quantity of unprocessed Crete variety olives required to produce the system reference flow,

i.e. one litre of extra virgin olive oil. Thus all inputs and outputs in the inventory of this process refer to the output quantity.

The first input from technosphere in this process is the planting of the olive trees. Based on the statistical analysis of the results obtained from the survey (Appendix B) and based on the average yield production of olive trees during their life, the calculated input of tree planting was 0.0043 trees per 4.29kg of olives.

Another input from technosphere is olive tree irrigation. Based on the analysis of the results obtained from the interviews, considering the average annual yield production of olive trees and the annual consumption of water for irrigation purposes through a sprinkler system, the calculated input quantity was 185 kg (or 0.185 cubic metres).

According to the analysis of the data collected, based on the area of the orchards, the ploughing frequency and the annual olive yield in Polemarchi, an average of 4.1256m^2 of agricultural land are ploughed for every 4.29kg of olives produced. Thus, 4.1256m^2 of soil management are included as input from technosphere.

In regards to fertiliser application, the analysis has shown that the mean quantity of the 20-10-10 NPK fertiliser applied in Polemarchi is 0.7207Kg per 4.29kg olives produced. This quantity is based on the frequency of application, the applied quantity and the annual yield production of the olive orchards in the region. Therefore 0.7207kg of fertiliser application is another input from technosphere.

Similarly, for pesticides, the mean quantity of the 2.9% deltamethrin pesticide product applied in Polemarchi is 0.0006kg per 4.29kg olives.

Similarly, for herbicides, the mean quantity of the 36% glyphosate herbicide product applied in Polemarchi is 0.0012kg per 4.29kg olives.

Another input in the process, is tree pruning. Considering the pruning frequency and the average yield production of olive trees 0.1753 trees are pruned for every 4.29kg of olives produced.

Finally, assuming no material losses during collection, 4.29kg of olive collection through the characteristic technique is another input from technosphere to the process.

For methodological purposes, almost all inputs from the environment, as well as the emissions to the environment for the olive agriculture stage have been included in the appropriate sub-processes for ease of interpretation of the results. However, two inputs from the environment apply, which apply agricultural stage as a whole, are inventoried in this process. These are the land occupation and the absorption of carbon dioxide from the trees. It is highlighted that, since according to the definition of the system boundary the agricultural system is considered as part of the production system (technosphere), both the occupation of the land and the



absorption of carbon dioxide are environmental inputs to the system and must be accounted.

In regards to land occupation, based on the survey analysis of Appendix B, for every 4.29kg of olives of the Crete variety produced in the region, a mean area of 8.43m² of land is being occupied for one year. This resource was categorised as "Occupation, permanent crop, fruit", and will be taken into account later in the impact assessment stage in the Eco-indicator 99 method (Goedkoop and Spriensma, 2000).

Carbon dioxide absorption of olive trees has been studied by Sofo *et al.* (2005). The calculated carbon dioxide sequestration is 3.16kg per 4.29kg olives.

No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 1, is (1, 1, 1, 1, 1). It is noted that the index refers to the flows recorded under this inventory and not to the whole inventory of the agricultural system.

3.6 Municipal water treatment and water supply

Although water is a renewable resource its treatment and supply are processes entailing environmental exchanges (consumption of resources and energy and emissions) which must be accounted in an LCA study. This requirement for a deeper insight is more important when stages of the product system under study, are theoretically considered as significant consumers of potable water. The three phase centrifuge technology applied in Polemarchi olive oil processing, is a very good example of this necessity as it is considered a relatively important water consuming activity.

3.6.1 Water treatment

The process of water treatment starts when 1kg of raw water is supplied at the water treatment facilities in Voukolies and ends when treated potable water exits the treatment works. In this unit process, a combination of physical, chemical and biological transformations take place. The production and maintenance of capital infrastructure, e.g. the civil works and electromechanical installations have been excluded in line with the boundary definition. The output to technosphere (product) of this process is 1kg of treated water at the Voukolies water works.

Data on material and energy flows for this process was collected by personal and telephone interviews of officials from the Municipality of Voukolies and employees of the Voukolies Water Treatment Facilities.

The input from nature is 1 kg of water from the natural spring in Laxiana. As discussed earlier, for easier interpretation in the water consumption pattern within



the system, water resource from lakes, springs, rivers and wells are all recorded as water from unspecified natural origin.

For the treatment of water, chlorine (during pre and post chlorination), is used. This is therefore included in the unit process inventory as input from technosphere. It is highlighted that the production and disposal of packaging for this material input is not included due to their small quantities in relation to the reference flow of the system, which are therefore not expected to contribute any significant environmental load.

According to Bobolakis (2006) (Mayor of Voukolies), chlorine liquid is added at a dosage of 4kg per 80m³ of water, therefore an average of 5×10^{-5} kg of chlorine is used in the process per 1kg of treated water. Data for the process of chlorine production was obtained from Ecoinvent database, version 1.2. The name of the process selected is “Chlorine, liquid, production mix, at plant/RER” (process identifier EIN_UNIT06567700273) and is classified under the “material/chemicals/gases” subcategory. In order to exclude production and maintenance of capital infrastructure, the process was analysed as unit process by excluding capital goods and the inventory was saved as a new system process. The unit process establishes an average European chlorine production from the three different electrolysis cell technologies (mercury, diaphragm, membrane) and additionally includes the energy consumption for the liquefaction step from gaseous to liquid chlorine.

In regards to electricity consumption, the average electric energy required for the operation of the treatment plant is 0.0654kWh/m³. Thus 6.54×10^{-5} kWh of electric power is consumed in the plant for the treatment of every kg of water.

3.6.2 Water Supply

The process of water supply starts when 1kg of raw water is extracted from Laxiana spring and ends when 1kg of potable water is supplied to the olive oil processing unit in Polemarchi. It includes all water transportation processes but excludes all water treatment processes which have been included in the “water treatment process”. The production and maintenance of capital infrastructure, such as pipes, civil works and electromechanical installations of pump stations are excluded. The output to technosphere (product) of this process is 1kg of potable water supplied to the processing unit in Polemarchi.

Voukolies have their own water distribution and production network. The oil mill is also supplied by this same network. Lahania spring has a high altitude so the water reaches the village with physical flow. In addition to this network, there exists and a well with water pump at Syrili region. There are 4 large storage tanks where chlorination the water takes place. According to latter, there is a small amount of



energy consumed. Thus, in the LCA model there is no energy consumption for the water supply procedure.

3.7 Olive mill processes

The quantity of unprocessed olives (of the characteristic variety) required to produce 0.92kg of olive oil, i.e. 1 litre (reference flow) was determined as 4.29 kg. Approximately 4.29 litres of water are required in total in the olive mill for processing of the 4.29kg of raw olives.

3.7.1 Olive purification

The process of olive purification starts when 4.24 kg of raw olives transported to the olive oil processing unit in Polemarchi are placed in the input crate and ends when purified olives pass through electronic weighing system. The transformation that takes place in this process is of physical nature and involves the transfer of olives by conveyor belts, application of suction for removal of foreign materials, spraying with recycled water and electronic weighing. The production and maintenance of capital infrastructure, such as the electromechanical equipment and the building are excluded. The output to technosphere (product) of this process is 4.24kg of purified olives. For this process farmers use 0,86lt (0,86Kg) of water which is the 20% of raw olives transported to olive processing unit.

To calculate the energy consumption in the process, the operation time of each piece of electrical equipment associated with the processing of 100kg olives input was recorded and this was multiplied with the equipment's power as specified in the manufacturer's brochures.

In regards to olive purification, electricity is consumed for the operation of the conveyor belt and of the purification machine. A total of 0,011kWh of grid electricity is consumed is included as an input from technosphere to the olive purification process.

Furthermore during the process, 0.05kg of impurities (mainly leaves, dust and other materials) are produced. These are stored on site and due to the small quantity involved their biodegradation and associated emissions are not considered, thus the flow is recorded as a final waste flow.

No other direct flows from and to technosphere or from and to the environment have been identified. The data quality index for the inventory of this process, with reference to Table 1, is (1, 2, 1, 1, 1).



5.7.2 Olive grinding

The process of olive grinding starts when the 4.24 kg of purified olives produced from the olive purification process (input from technosphere) enter the olive crusher and ends when olive paste leaves the mixing vat. The process block involves the transfer of purified olives by conveyor belts and the operation of the olive crusher and the mixing vat. The production and maintenance of capital infrastructure (electromechanical equipment and the building) are excluded. The output to technosphere (product) of this process is 4.24kg of olive paste.

In regards to energy consumption during olive grinding, the consumption of electricity is associated with the operation of the conveyor belt, the crusher and the mixing vat. A total of 0.21kWh of electric energy produced is included as an input from technosphere in the olive grinding process.

In Voukolies case study there is no water presence at the milling process.

No other direct flows from and to technosphere or from and to the environment have been identified. The data quality index for the inventory of this process, with reference to Table 1, is (1, 2, 1, 1, 1).

3.7.2 Olive oil extraction

The process of olive grinding starts when 4.24kg of olive paste produced from the olive grinding process (input from technosphere) is pumped to the centrifuge decanted and ends when olive oil is flowing out of the olive oil separator. The transformation that takes place in this process is of physical nature and involves the transfer of olive paste with the aid of an electric pump to the centrifuge decanter, the operation of the decanter and the olive oil separator as well as the extraction of the waste streams (liquid and solid) from the process. The production and maintenance of capital infrastructure (electromechanical equipment and the building) are excluded. The output to technosphere (product) of this process is 1 litre of olive oil. In the same process a by-product is also produced, pomace. Pomace is normally considered as a solid waste from the virgin olive oil extraction process, however, it is further utilised for heat production, it is considered as a by-product. Nevertheless, in order to allocate environmental load of the process, pomace is allocated a 0% allocation factor, based on its economic value compared to olive oil.

In the decanter and in order to facilitate the transfer of olive paste from the mixing vat to the decanter 2.72kg of water are added in total, while a further 0.71kg of water are added after centrifugation, prior to oil separation. It is highlighted that the quantities are normalised for 1 litre of olive oil output, based on data provided by Mouzouris (2006). Thus a total of 3.43kg of supplied water is included in the process inventory as input from technosphere.



In regards to energy consumption during olive oil extraction, the consumption of electricity is associated with the operation of the electric pump used for transferring the olive paste to the decanter, the decanter, the oil separator as well as the two electric pumps which transfer liquid and solid waste out of the unit. A total of 0.22kWh of electric energy produced is included as an input from technosphere in the olive oil extraction process.

In regards to materials flowing out of the process, apart from the main product (olive oil) two streams are encountered: 2.12kg of pomace by-product extracted from the centrifuge decanter (on-site mass measurements normalised to 1 litre olive oil output) and extracted during oil separation, i.e. a total of 4.63kg. Solid waste, as discussed earlier is considered as a by-product with 0% allocation, whereas the latter is considered as an output waste to treatment.

The data quality index for the inventory of this process, with reference to Table 1, is (1, 2, 1, 1, 1).

3.7.3 Disposal of liquid waste

The process starts just after 1 litre of liquid waste from the oil extraction process is pumped outside of the olive processing building to an evaporation pond about 500m away from the processing unit and ends when the liquid waste evaporates completely over the summer months, when the processing unit is idle. The production and maintenance of capital infrastructure e.g. the piping has been excluded. Since this is a waste treatment operation (disposal) there is no product output resulting from the process.

Liquid wastes from olive oil processing units are considered a highly polluting effluent due to their high organic load (Balice and Cera, 1984), the presence of phenolic substances, which resist biological degradation (Abid. and Sayadi, 2005; Sayadi *et al.*, 2000; Ramos-Cormenzana *et al.*, 1995; Saez *et al.*, 1992; Paredes *et al.*, 1986; Wang *et al.*, 1967), as well as their acidity and high concentration of potassium, magnesium and phosphate salts (Arienzo and Capasso, 2000). Thus, its uncontrolled disposal may lead to significant environmental pollution problems (Paredes *et al.*, 2002).

The composition of the liquid waste from olive oil processing units is variable, both qualitatively and quantitatively, affected by the cultivation soil, harvesting time, degree of ripening, olive variety, climatic conditions, use of pesticides and fertilisers, duration of aging and employed olive oil extraction process (Niaounakis and Halvadakis, 2004). Thus, it is only possible to obtain an idea of the range of values for each parameter.



Many different processes have been proposed to treat the effluent (Vitolo *et al.*, 1999); however, the disposal into evaporation ponds has been the most economic option, especially for small rural areas like Polemarchi.

According to Niaounakis and Halvadakis (2004), in such a lagoon, the sun's energy is used to speed up the process of evaporation and drying of the olive mill liquid waste. Moreover, the waste is partially degraded by a natural biological route, over very long time periods. In practice treatment period spans for about 9 months, from late February or early March to beginning of November, when the olive mill is idle, as discussed earlier. According to Mouzouris (2006), liquid waste evaporates completely over this period.

The main concerns of this disposal process are: the odours released by volatile substances and the risk of leakage through the soil into groundwater. In regards to odours, methane and other pungent gases (hydrogen sulphide, etc.) emanate due to anaerobic fermentation of the waste water (Stolting and Bolle, 2000; Niaounakis and Halvadakis, 2004). However, research on quantification of emissions from evaporation ponds is extremely limited, especially for three-phase centrifuge effluent.

COD removals of up to 80% in 4 months have been reported by Niaounakis and Halvadakis (2004) and Rozzi and Malpei (1996). Borja *et al.* (2006) in their experiment recorded a production of methane of approximately 22 litres, for an effective volume of 460 litres of liquid waste from two phase centrifuge olive mill extraction process (168g/l COD). In the absence of more specific information, and based on the fact that ambient temperature variation in Andalusia, where the experiment was carried out, is similar to that of Polemarchi, methane production in Polemarchi evaporation pond was calculated by assuming that methane production in the evaporation pond is linearly proportional to the initial volume and the chemical oxygen demand. Thus, 1 litre of liquid waste from the three-phase processing in polemarchi generates 0.033 litres of methane.

Rana *et al.* (2003) in a study on the possible volatilisation of substances contained in olive mill wastewater when sprayed on the soil found that when olive mill waste was spread on soil, phenols were released into the atmosphere. Thus it is assumed that the 3.1g of volatile phenols will be emitted to the atmosphere.

In regards to groundwater contamination, there is no evidence of the efficiency or the satisfactory condition of the clay layer at the bottom and sides of the pond as no monitoring has ever been undertaken. Additionally leakage from transfer pipes in several locations was observed. In the absence of any information in literature in regards to the magnitude of groundwater contamination from poorly managed evaporation ponds for liquid waste from olive mills, an inventory of the polluting load in groundwater and soil was calculated based on an assumption that 2.5% of



the polluting load leaches into groundwater, whereas the residual load after evaporation and leaching is treated as emissions to soil.

The data quality index for the inventory of this process, with reference to Table 1, is (5, 4, 3, 4, 5).

3.7.4 Bulk storage of olive oil

The process of olive oil storage starts when olive oil is placed into the plastic containers and ends when it exits the olive oil processing unit, when sold. The output to technosphere (product) of this process is 1 hour of storage of olive oil. Olive oil storage takes place at room temperature, thus no energy, material flows and emissions have been recorded. The sample used for the acidity test is small, therefore the materials used for titration and wastes are not included in the inventory for the olive oil storage process.

3.7.5 Olive oil processing

The envelope unit process of olive oil processing starts with the transportation of olives from the orchards to the plant location and ends when the system product, i.e. 1 litre of extra virgin olive oil exits the olive oil processing unit (gate). The process includes all processing sub-processes as previously documented. The production and maintenance of capital infrastructure is excluded in line with the boundary definition (Avraamides *et al.*, 2005). The output to technosphere (product) of this process is 1 litre of extra virgin olive oil (reference flow) and all inputs in the inventory of this process refer to the output quantity.

The first input from technosphere in this process is the transportation of 4.29kg olives of the characteristic variety from the orchards. The second input is 1 litre of olive oil extracted from the oil extraction processes. Finally, storage input is another input from technosphere to this process. The average storage period is 4320 hours (6 months). No other material or energy flows have been identified in this process. The data quality index for the inventory of this process, with reference to Table 1, is (1, 1, 1, 1, 1). It is noted that the index refers to the flows recorded under this inventory and not to the whole inventory of the olive oil processing system.



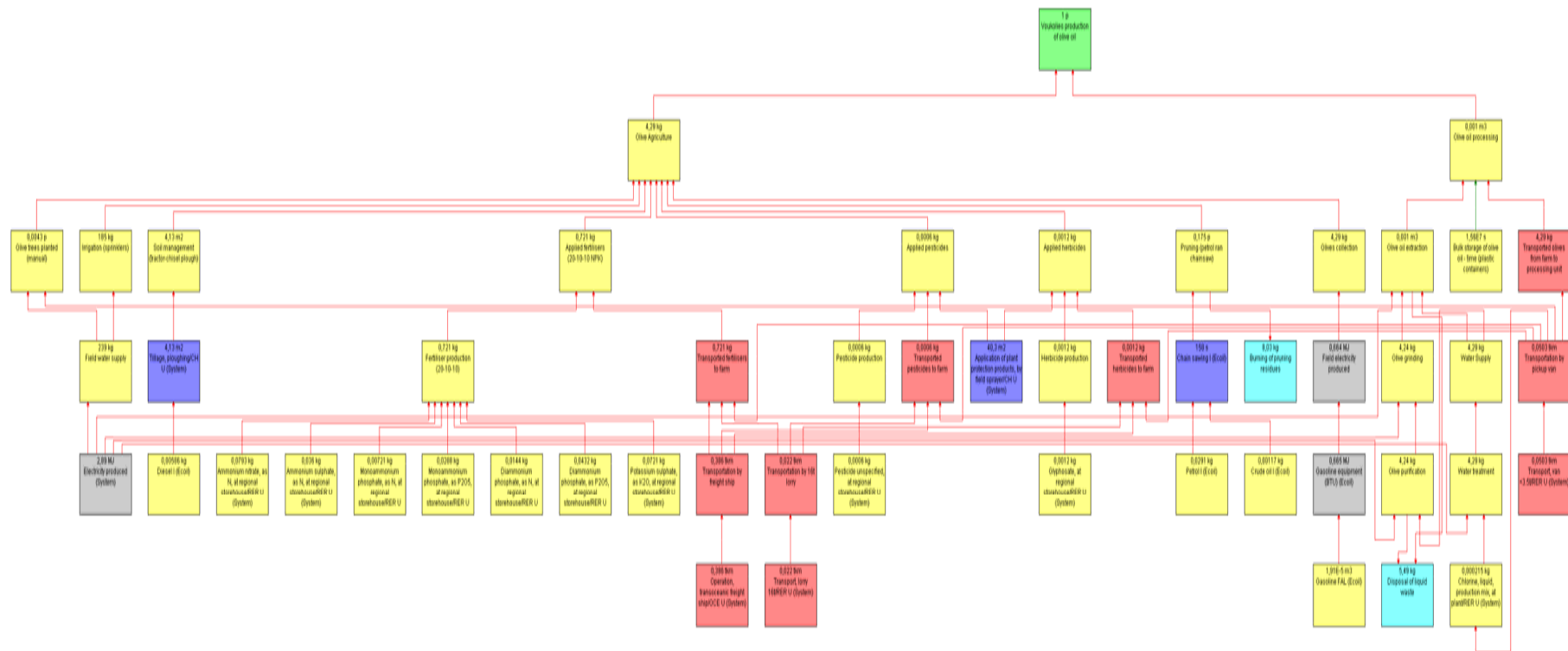
4 Life Cycle Inventory Analysis

The data reported in Chapter 3 were imported into the customised model of Figure 11. The final analysis model network including all process inputs from databases, is provided in Appendix C. The model was analysed in SimaPro 7.0.

In the following sections, indicative parameters of the inventory are investigated and the contribution of individual processes is discussed. A summary of the results is provided in section 4.5, whereas an extended inventory of the product system with the total amounts of raw materials consumed and of substances emitted to air, water and soil, as well as the contribution of the agricultural and processing stages, is provided in Appendix D.



Figure 11: Customised LCA model for Polemarchi



4.1 Consumption of environmental resources

4.1.1 Crude oil

Crude oil is a valuable non-renewable resource, mainly used for producing fuel oil and petrol, both important “primary energy” sources. It is also the raw material for many chemical products, including solvents, fertilisers and pesticides.

The analysis has shown that the system consumes 0,204 Kg of crude oil for the production of 1 litre of olive oil, of which 0,162 Kg (79,5%) are consumed in the agriculture related processes of the system and the rest in the olive oil processing stage, as shown in Figures 12,13.



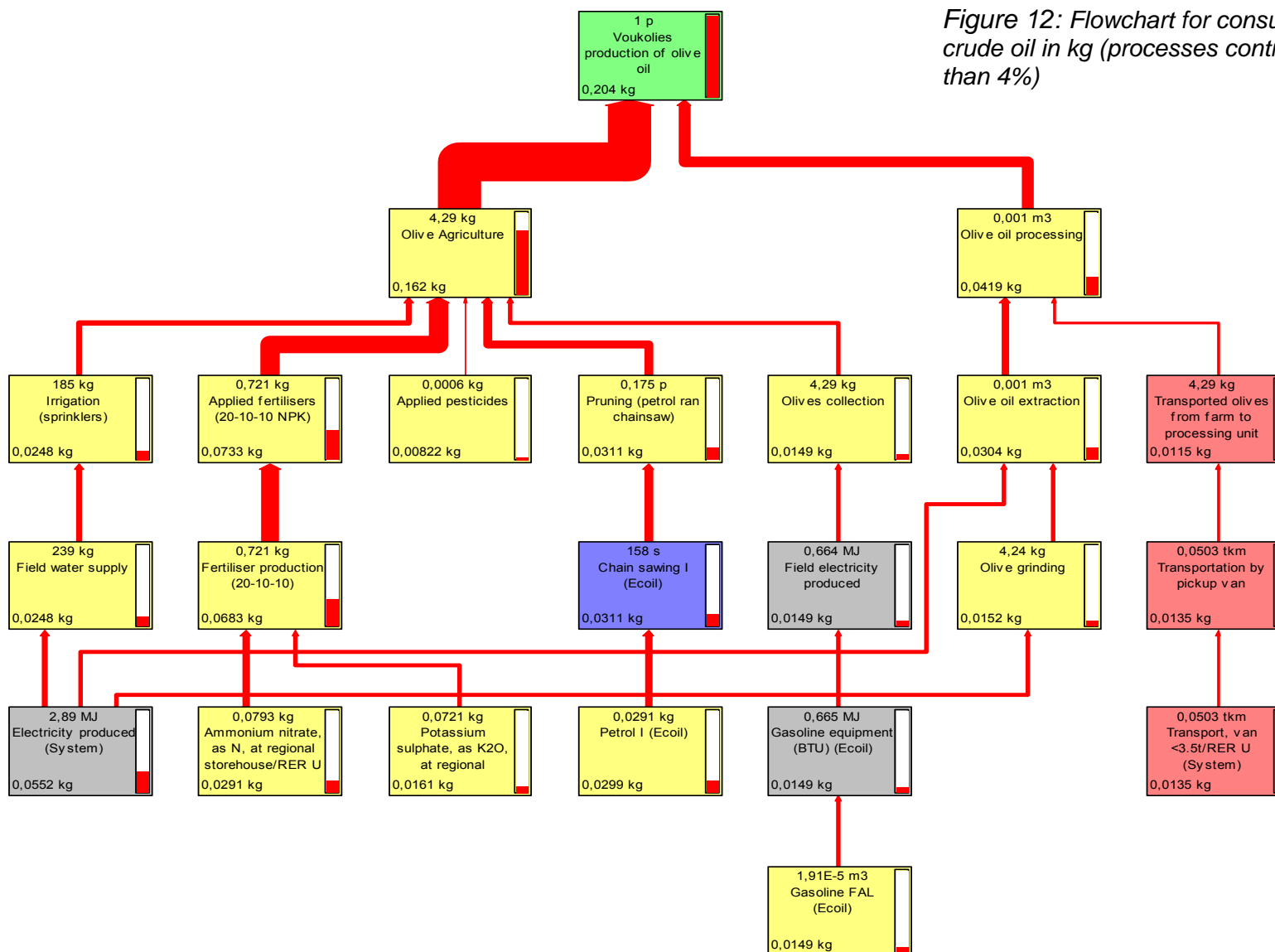


Figure 13: Flowchart for consumption of crude oil in % (processes contributing more than 4%)

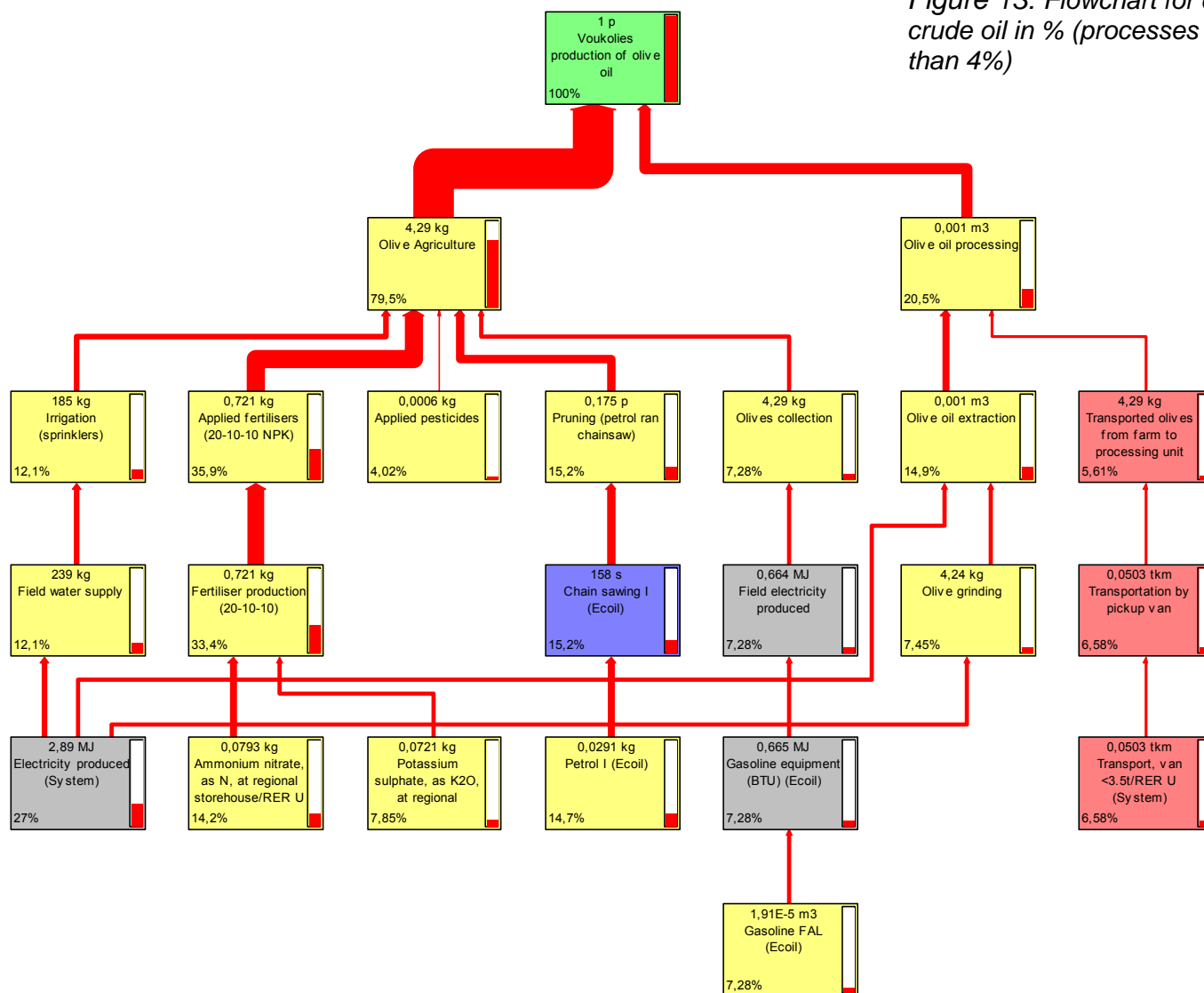
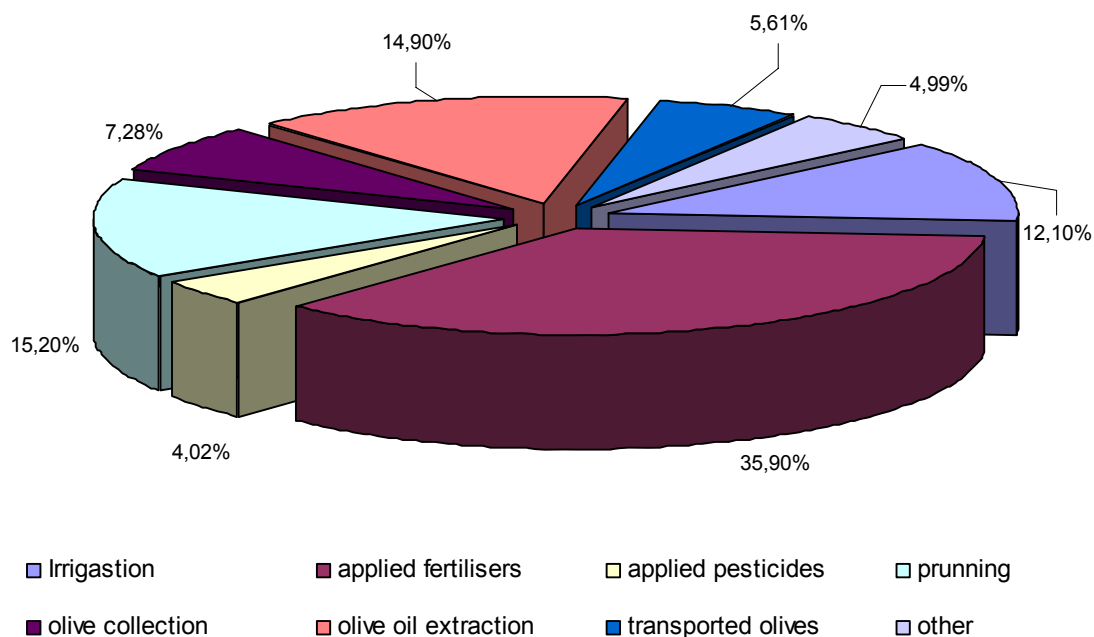


Diagram 9: Crude oil consumption in % process contribution to overall load



Within the system, crude oil is consumed in almost all processes, from the production of agricultural inputs to transportation, electricity generation etc. Figures 12.13 illustrates crude oil consumption flow from processes consuming more than 4% of the overall 0,204Kg load.

The activities which most heavily consume crude oil are fertiliser application, pruning and olive oil extraction. Diagram 9 shows the percentage contribution of every significant process.

4.1.2 Consumption of fresh water

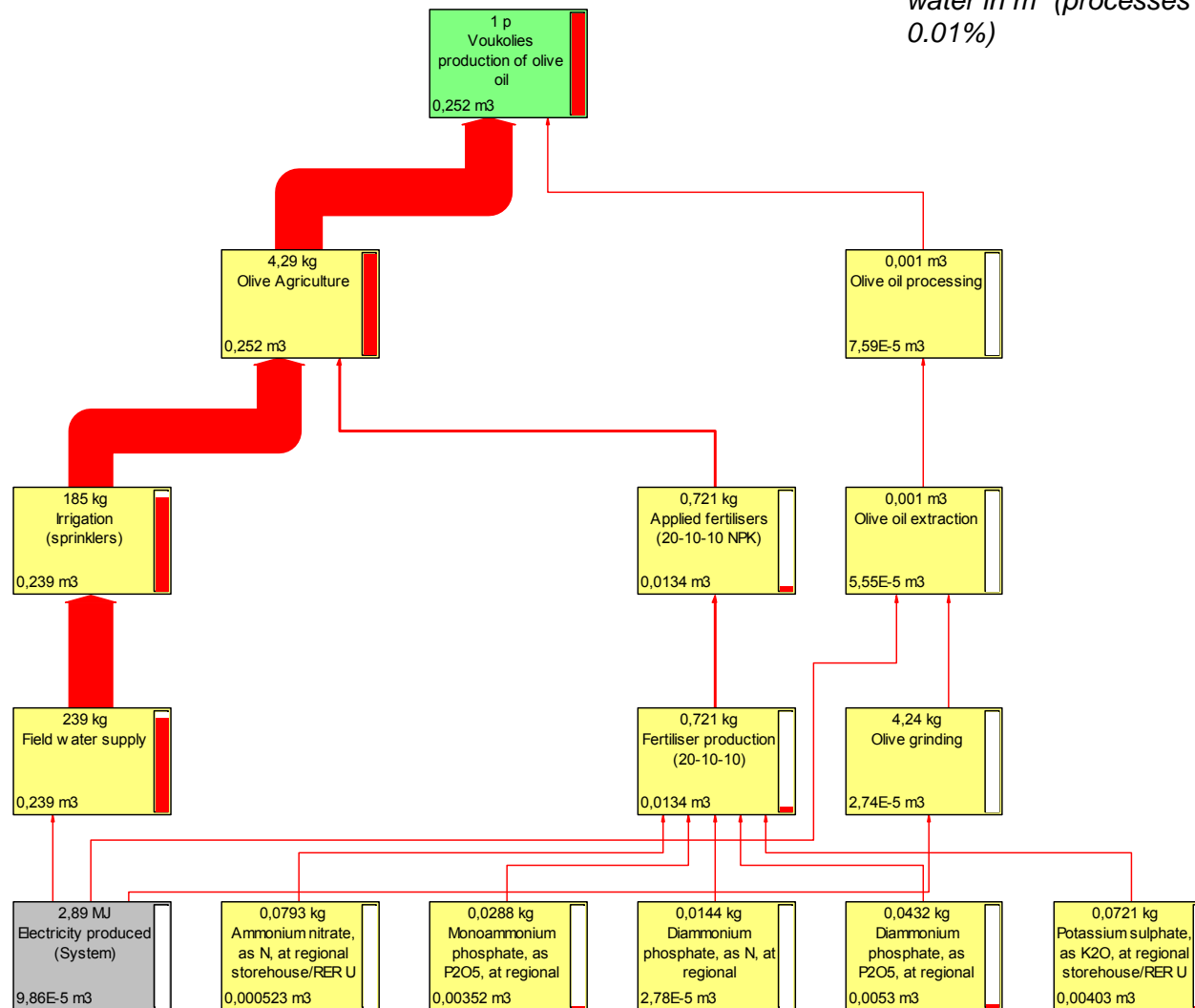
Although renewable, water is a valuable resource, especially in a dry ecosystem like Crete. The olive oil system consumes a total of 255 litres of fresh water for the production of 1 litre of olive oil. Despite the perceived importance of the olive oil processing stage, especially with the three phase centrifuge technology used in Polemarchi, the analysis has shown that it only consumes 21 litres of water (0.824% of overall consumption).

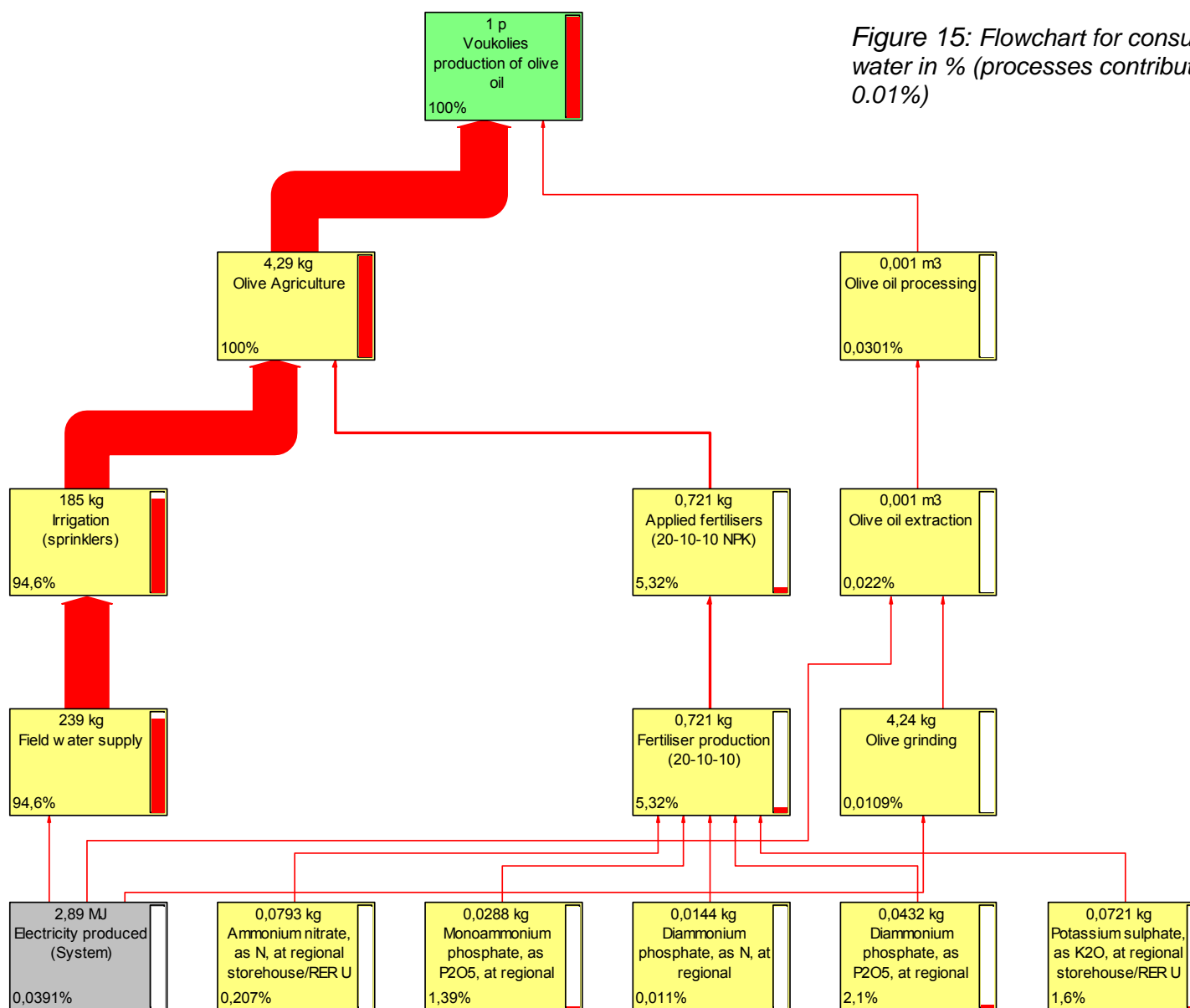
In the other hand, the agricultural stage is responsible for an enormous consumption of 253 liters from 255 lt total used. However, it must be highlighted that much of the water use is consumed in background processes, such as the production of fertilisers. This consumption takes place in countries where water scarcity is possibly not of concern.

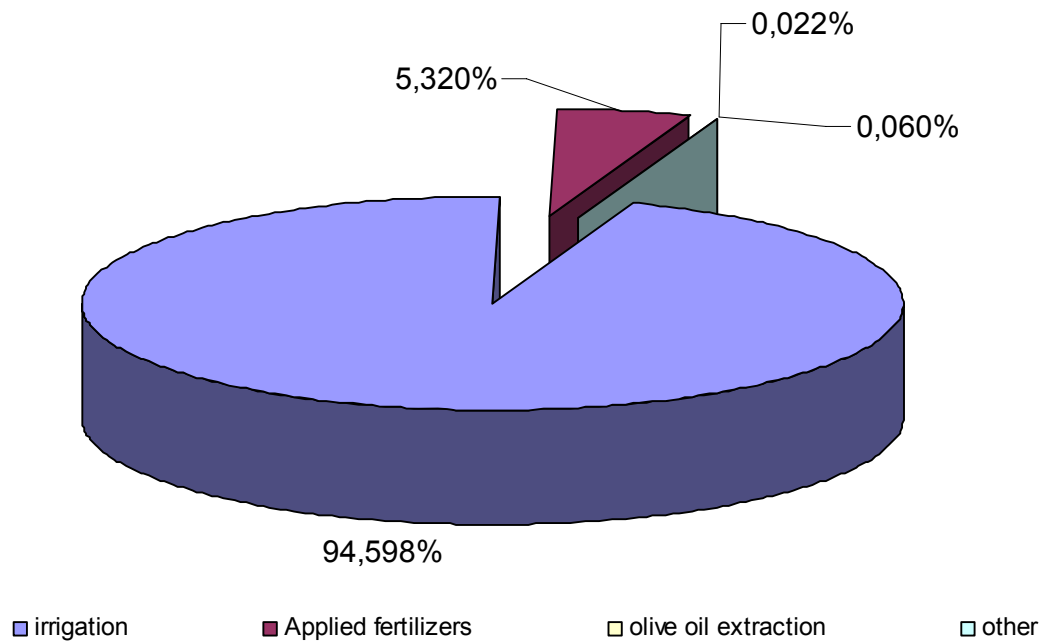
Irrigation is, naturally, the highest water using process, as it consumes 239 litres of water (93,7%) per litre of olive oil produced, followed by fertilisation. Again it is highlighted that each process in Figures 14, 15 envelops all lower level associated sub-processes, e.g. production (with associated power generation), transportation, and application.



Figure 14: Flowchart for consumption of fresh water in m³ (processes contributing more than 0.01%)







4.2 Emissions to air

4.2.1 Carbon dioxide, fossil

Carbon dioxide is an important greenhouse gas, which derives from multiple natural sources such as fermentation and cellular respiration of various microorganisms (biogenic carbon dioxide) and man-made sources like combustion of fossil fuels for power generation and transport and burning of forests (fossil carbon dioxide). In this section the latter sources of carbon dioxide emissions are discussed, whereas carbon dioxide from biogenic sources is separately included in the inventory (Appendix D).

Figure 16: Flowchart for consumption of fossil CO₂ in Kgr (processes contributing more than 1.5%)

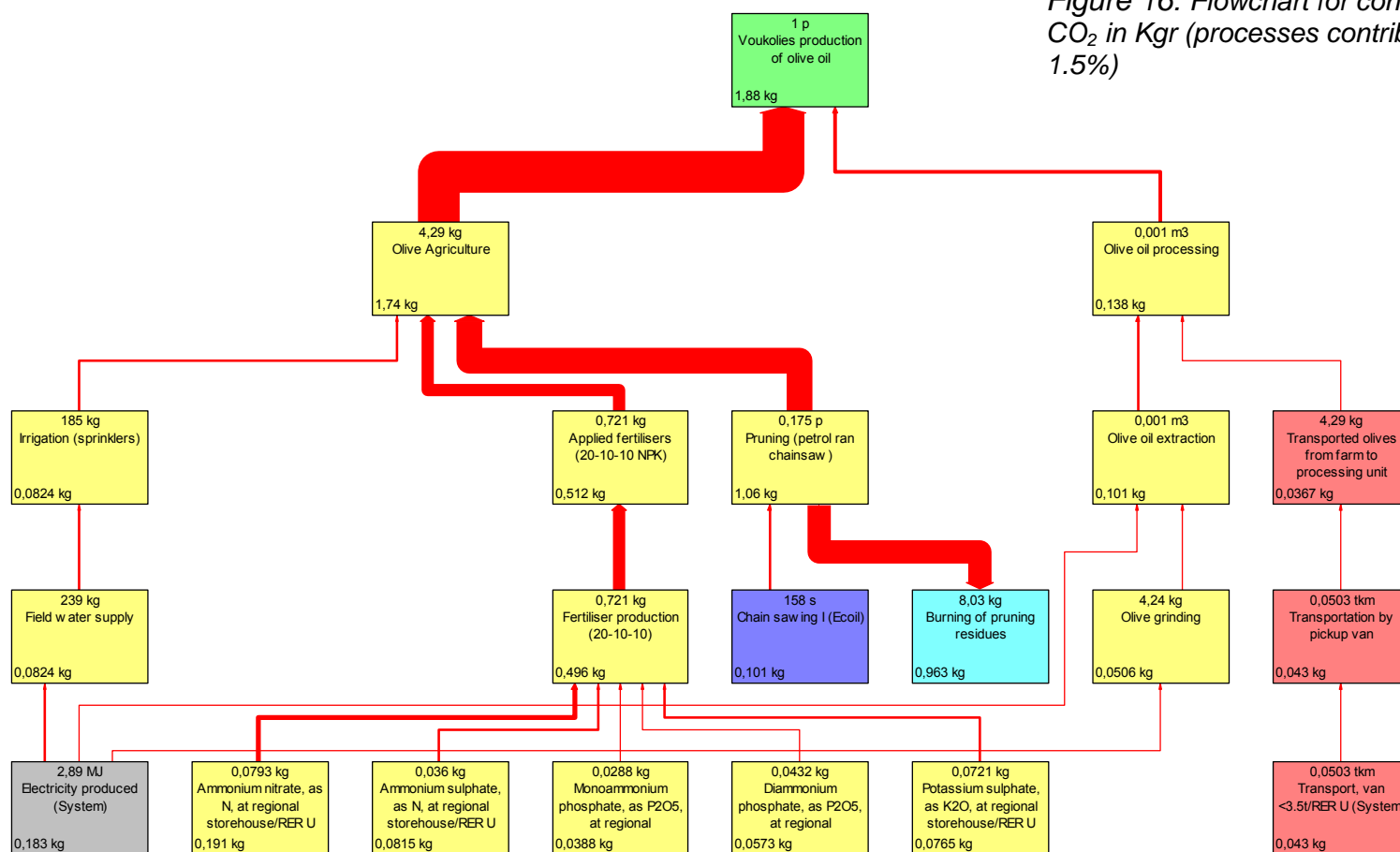
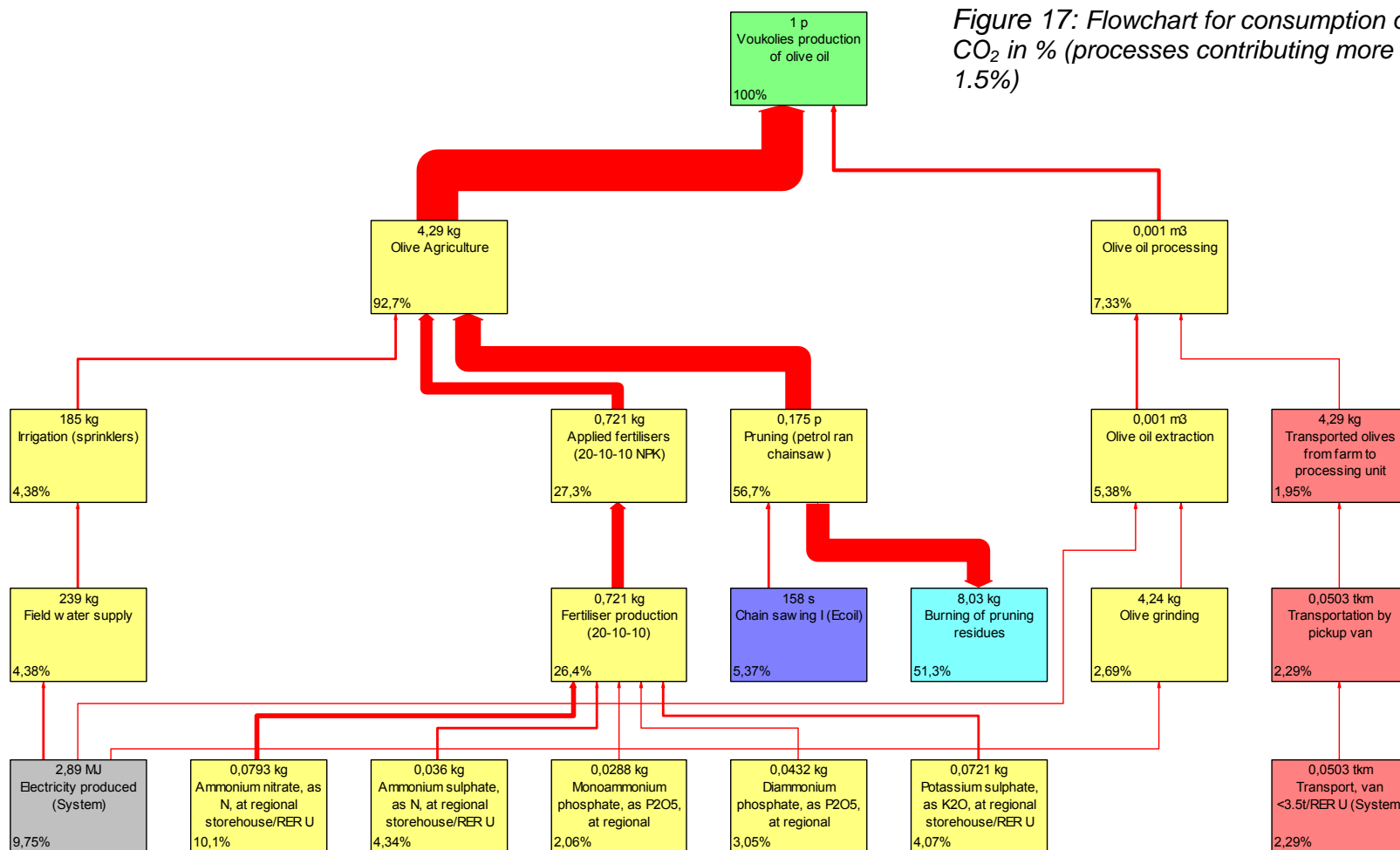


Figure 17: Flowchart for consumption of fossil CO₂ in % (processes contributing more than 1.5%)

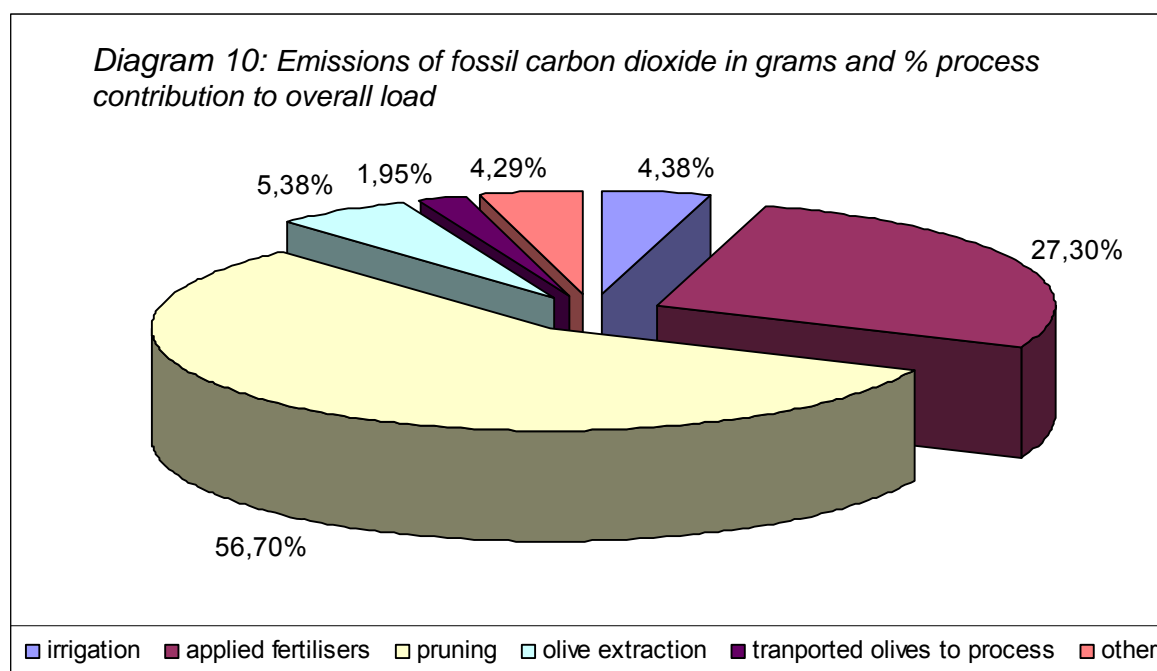


The overall system releases 1,88 Kg of fossil carbon dioxide per litre of olive oil produced, from which 1,74kg (92,7%), as shown in Figures 16, 17 are released from processes related to the olive agriculture.

Within the agricultural phase, emissions of fossil carbon dioxide are relatively evenly distributed between fertilisation, pruning, whereas transportation of fertilisers and burning of pruning residues emit significantly less amounts of the gas. The contribution of planting and collection is again negligible relatively to the overall load.

Pruning is the most significant activity in regards to CO₂ as it releases 1,06 Kg (56.7% of overall CO₂ emissions) from which 693gr are released when pruning residues are burned.

The contribution of envelope processes in the overall carbon dioxide load is shown in Diagram 10. Fertilisation is accountable for the release of 0.512 Kg (27.3%) of carbon dioxide per litre olive oil produced, the source of which is traced mainly at the industrial production processes of its constituents.



4.2.2 Nitrogen oxides

Nitrogen oxides (NO_x) refer to the total concentration of NO plus NO₂, expressed as NO₂. During daylight NO and NO₂ are in equilibrium with the ratio NO/NO₂ determined by the intensity of sunshine (which converts NO₂ to NO) and ozone (which reacts with NO to give back NO₂).

The system overall produces 34,5g of nitrogen oxides per litre of olive oil produced, from which 34,3% are released from processes related to the agricultural phase of

the product. Application of fertilisers and pesticides, pruning, transportation of olives to processing units are the main NO_x polluters within the system, as shown in Figures 18,19.

Figure 18: Flowchart for consumption of NO_x in Kgr (processes contributing more than 0.7%)

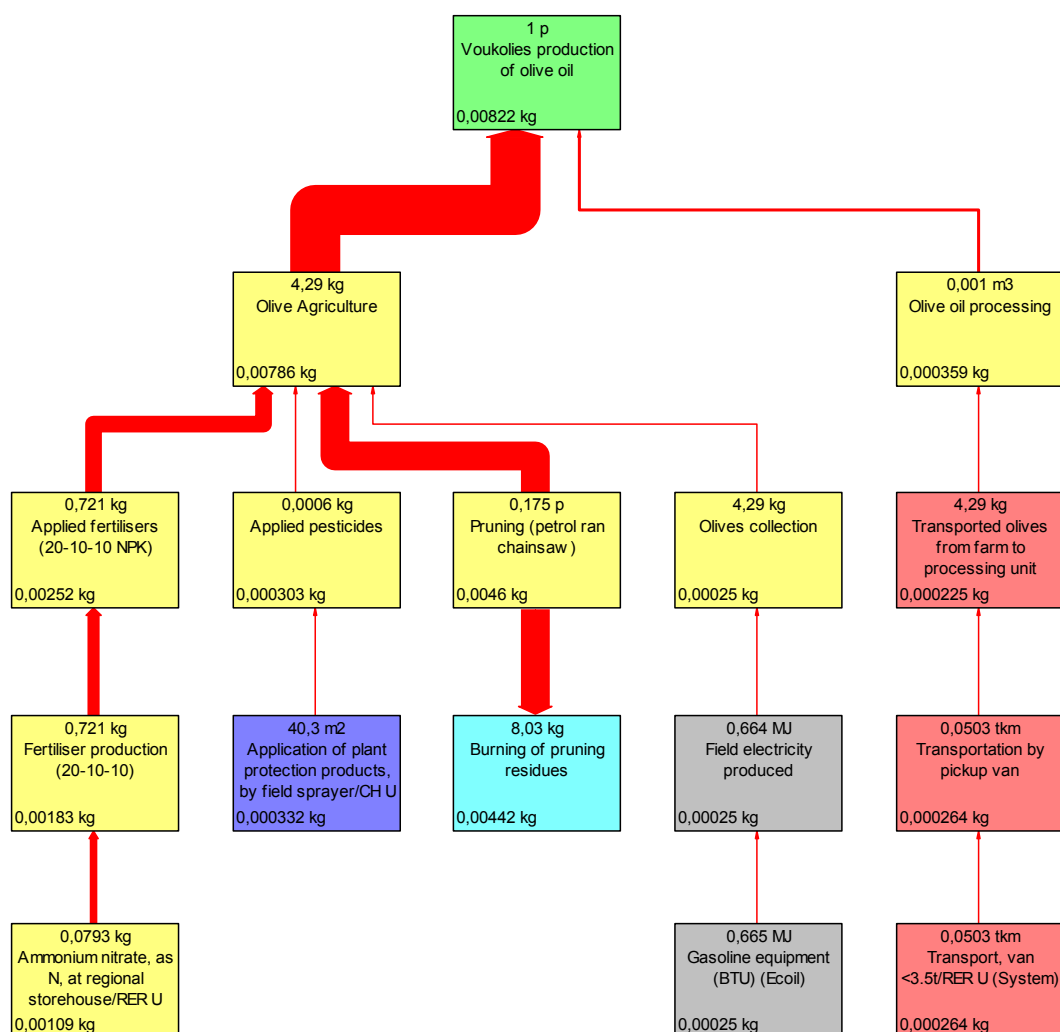
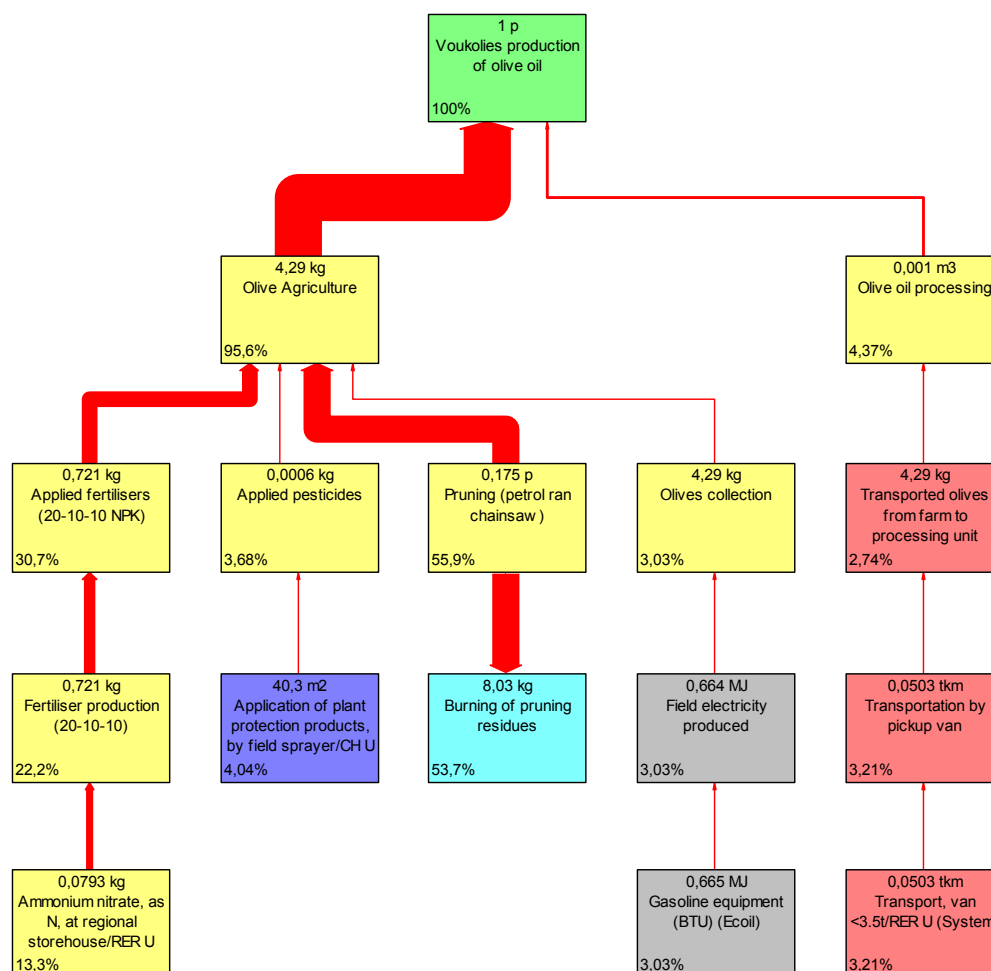
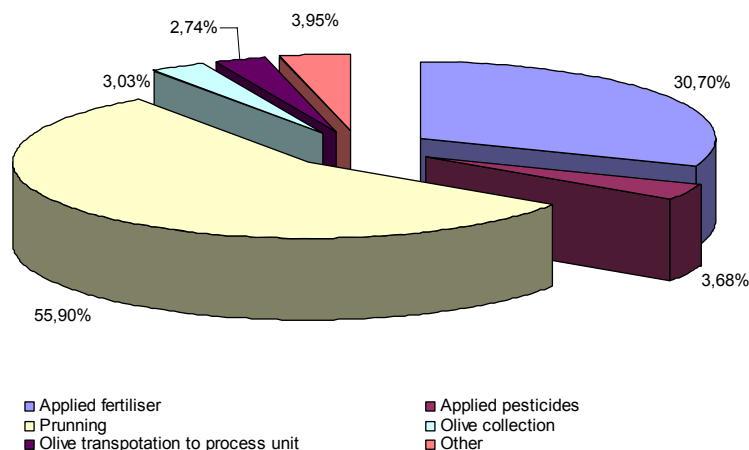


Figure 19: Flowchart for consumption of NO_x in % (processes contributing more than 0.7%)



The emission of nitrogen oxides from applied fertilisers (30.7%) as long as pruning (55.9%) are the main contributors to the overall load. The overall olive agriculture process contributes by 95,6% to overall emissions of NO_x (Diagram 11).

Similarly, the emissions of nitrogen oxides from transportation to processing unit contribute by 2.74% of the total NO_x emissions. The next diagram shows the contribution of these processes to NO_x emissions.



*Diagram 11:
Emissions of
nitrogen oxides in
grams and %
process contribution
to overall load*

4.2.3 Sulphur dioxide

Sulphur dioxide (SO_2) in general, is emitted by various industrial processes including electricity generation. Its presence in air can cause adverse health effects, mainly breathing problems. Furthermore, SO_2 , along with nitrogen oxides, are the main precursors of acid rain.

The olive oil production system produces 7,69gr of SO_2 per litre of olive oil, from which 5,83gr (88,8%) are released from processes related to the agricultural phase of the product, as shown in Figures 20,21 and 8,61gr (11,2%) of SO_2 emissions are released during olive oil processing.

The use of fertilisers is by far the primary contributor of sulphur dioxide emissions as they contribute a total of 4,39gr per liter of olive oil produced which corresponds to 57.1% of the total SO_2 load of the product system. From these, 4,32g are emitted during the production of the 0,07gr (per liter of olive oil) 20-10-10 fertiliser used in Voukolies.

Other significant sources of SO_2 emissions from the olive oil system include pruning. The contribution of each of this process is 1.65g, which corresponds to 21.5% of the overall load of the system, as shown in Diagram 12.

Figure 20: Flowchart for consumption of NO_x in % (processes contributing more than 2%)

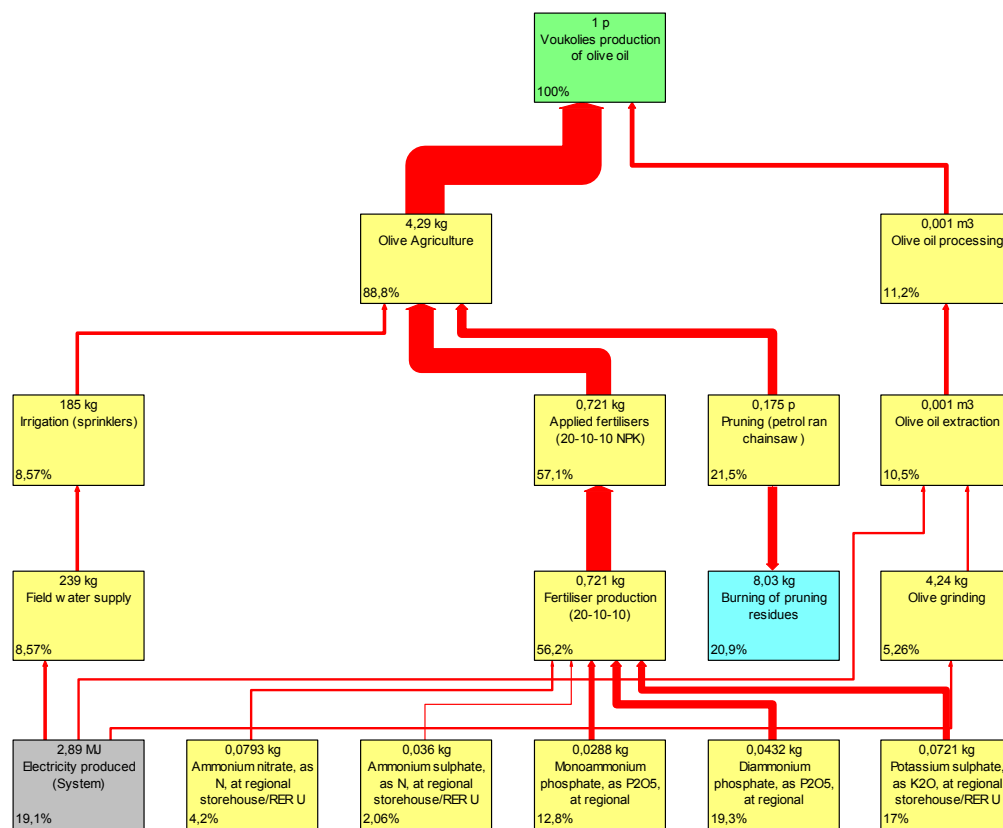


Figure 21: Flowchart for consumption of NO_x in Kgr (processes contributing more than 2%)

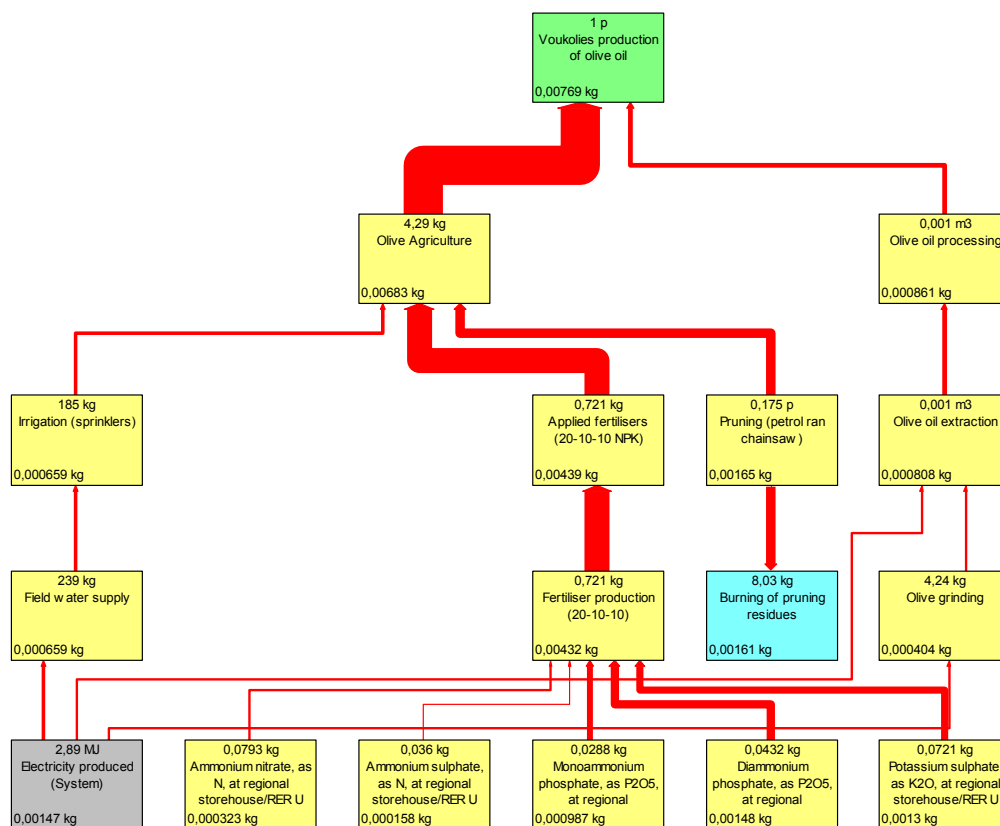
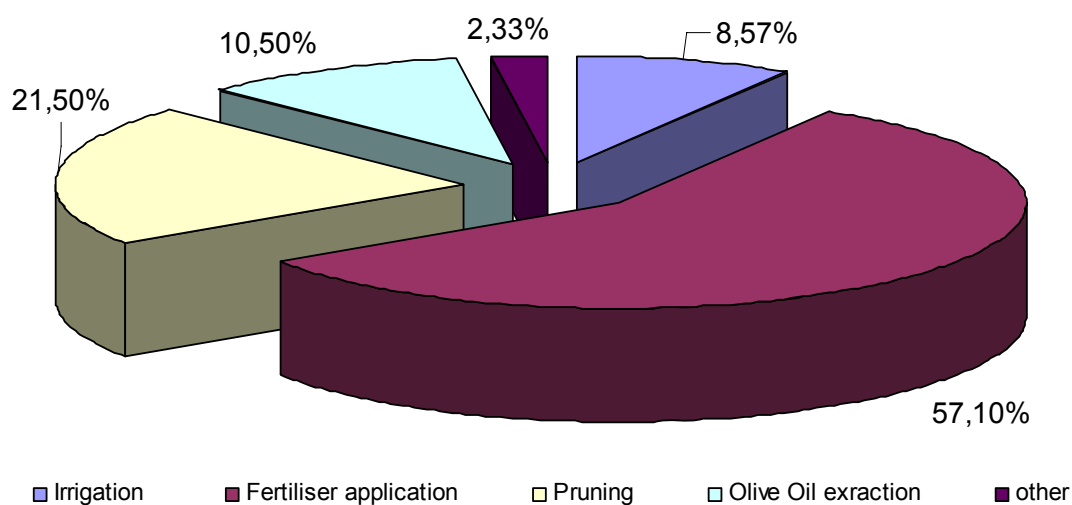


Diagram 12: Emissions of sulphur dioxide in grams and % process contribution to overall load



4.3 Emissions to water

4.3.1 Chemical Oxygen Demand (COD)

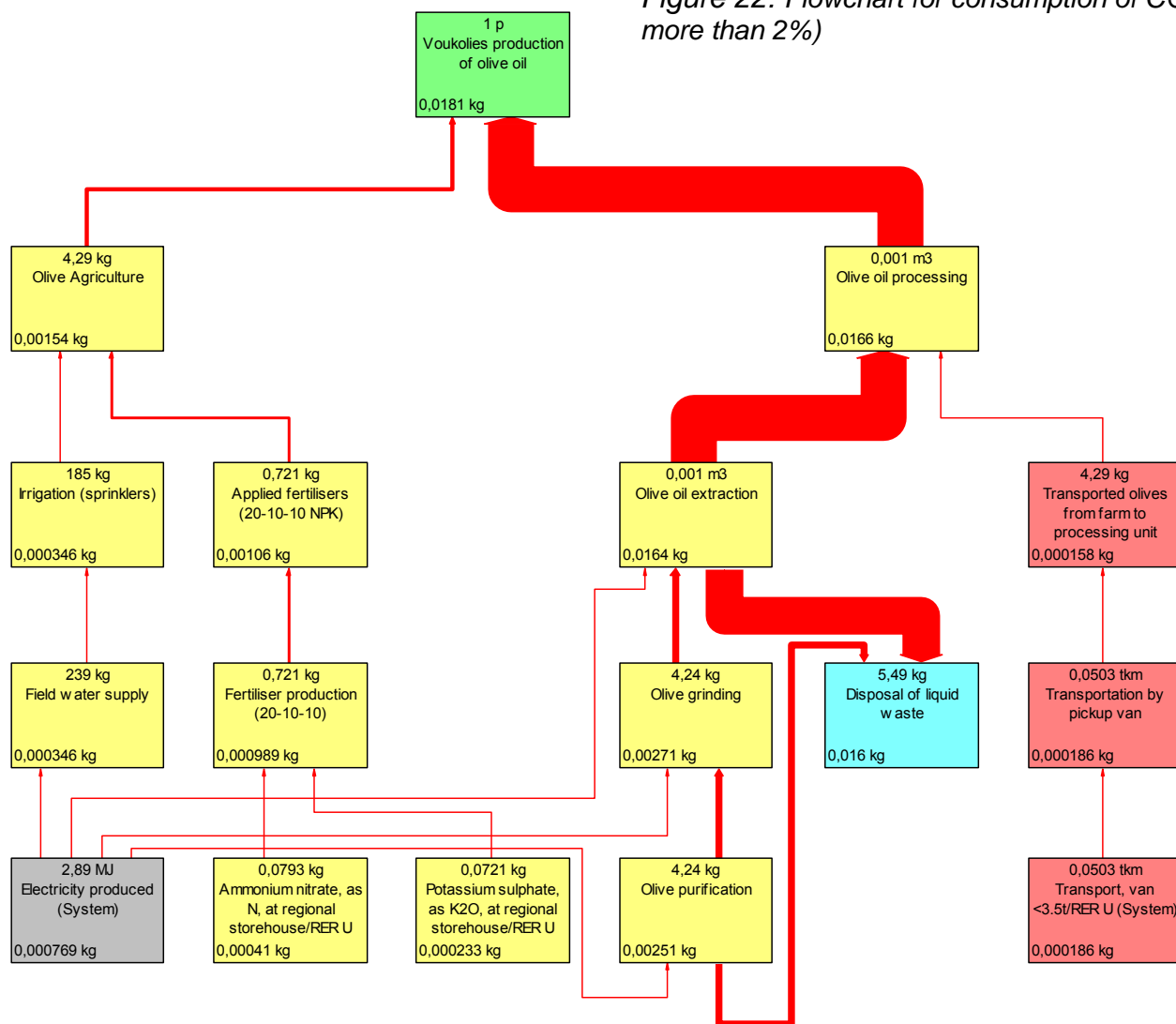
Chemical Oxygen Demand (COD) is the test commonly used to indirectly measure the amount of organic compounds in water. Usually COD is expressed in milligrams per litre (mg/l), which indicates the mass of oxygen required to chemically oxidise organic and inorganic compounds present in 1 litre of water.

Nevertheless, dealing with COD (and BOD) emissions in a life cycle system raises two concerns. Firstly, both COD and BOD are not specific substances but indicators of the presence of various substances. As a result the inclusion in a process inventory may result to double counting (Heijungs *et al.*, 2002). For this reason these are not included in most standard life cycle impact assessment methods. Moreover, the nature of the LCA technique dictates that environmental inputs (resources) and outputs (emissions) should be normalised to the product reference flow. For this reason both COD and BOD emissions are expressed as masses per reference flow, i.e. kg COD per litre of olive oil produced, and not as concentrations. As a result the analysis, for these indicators in particular, does not give a very useful representation of the problem occurring. For example, 1kg of total COD emitted in several large rivers would not be an issue of environmental importance whereas 1kg of COD emitted in a small stream could be.

Bearing the above concerns in mind, the olive oil production system produces 18.1gr of COD per litre of olive oil produced, from which 16.6gr (90.6%) are released in the olive oil processing stage, as shown in Figure 22 and Diagram 13, and 1,54gr are released from agriculture related processes.



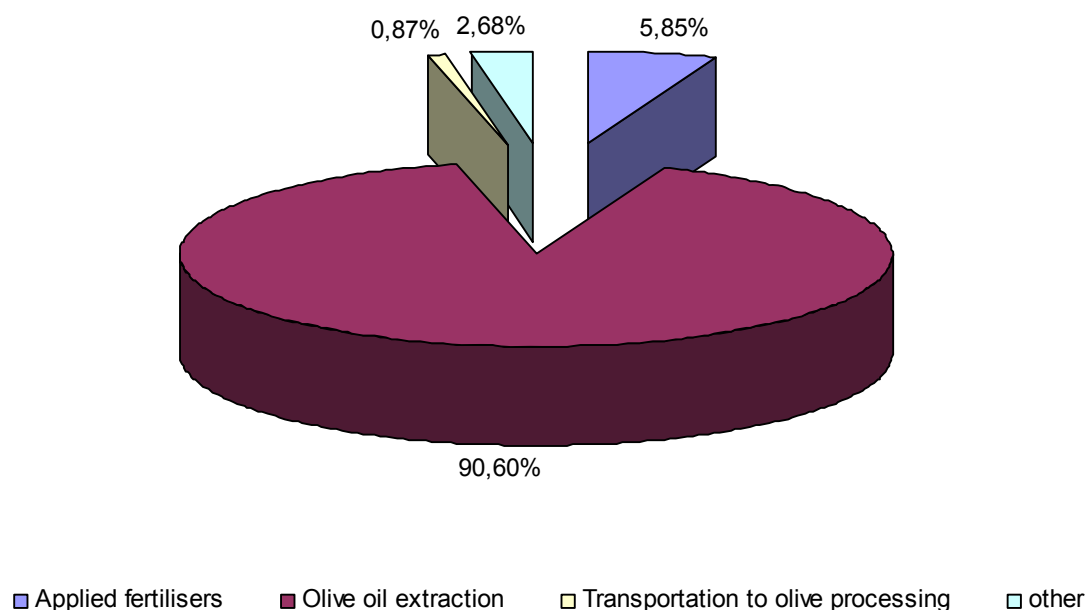
Figure 22: Flowchart for consumption of COD in Kgr (processes contributing more than 2%)



More than 88% of the total load is released in the environment when liquid wastes from the olive mill are transferred to evaporation lagoons, mainly due to groundwater contamination from leaks in transfer pipes and potentially poor performance of the impermeable layer with which evaporation ponds are supplied.

Within the agricultural stage, fertilisation is the main sources of COD as it is accountable for the release of 5.85% of total COD. The next diagram shows the contribution of every significant process to COD emissions.

Diagram 13: Emissions of (g) COD for the production of 1 litre of olive oil from production processes



6.3.2 Biological Oxygen Demand (BOD)

Biological oxygen demand (BOD) is an indicator of the concentration of biodegradable organic matter present in water. The main difference with COD is that BOD indicates organic compounds which can be biologically degraded, whereas in the COD test non-biodegradable compounds can also be oxidised.

According to the analysis of the system, the production of 1 litre of olive oil releases 8.62gr of BOD in waters in total. From these, 7.11gr (82.5%) are released in the processing stage, which 6.53gr (75.8%) refers to liquid disposal. This is mainly attributed to the large concentrations of phenolic substances in liquid wastes from olive mills which induce a smaller ratio of biodegradable to non-biodegradable organic matter when compared to wastewaters of several industrial processes.

Figure 23: Flowchart for consumption of BOD in Kgr (processes contributing more than 1%)

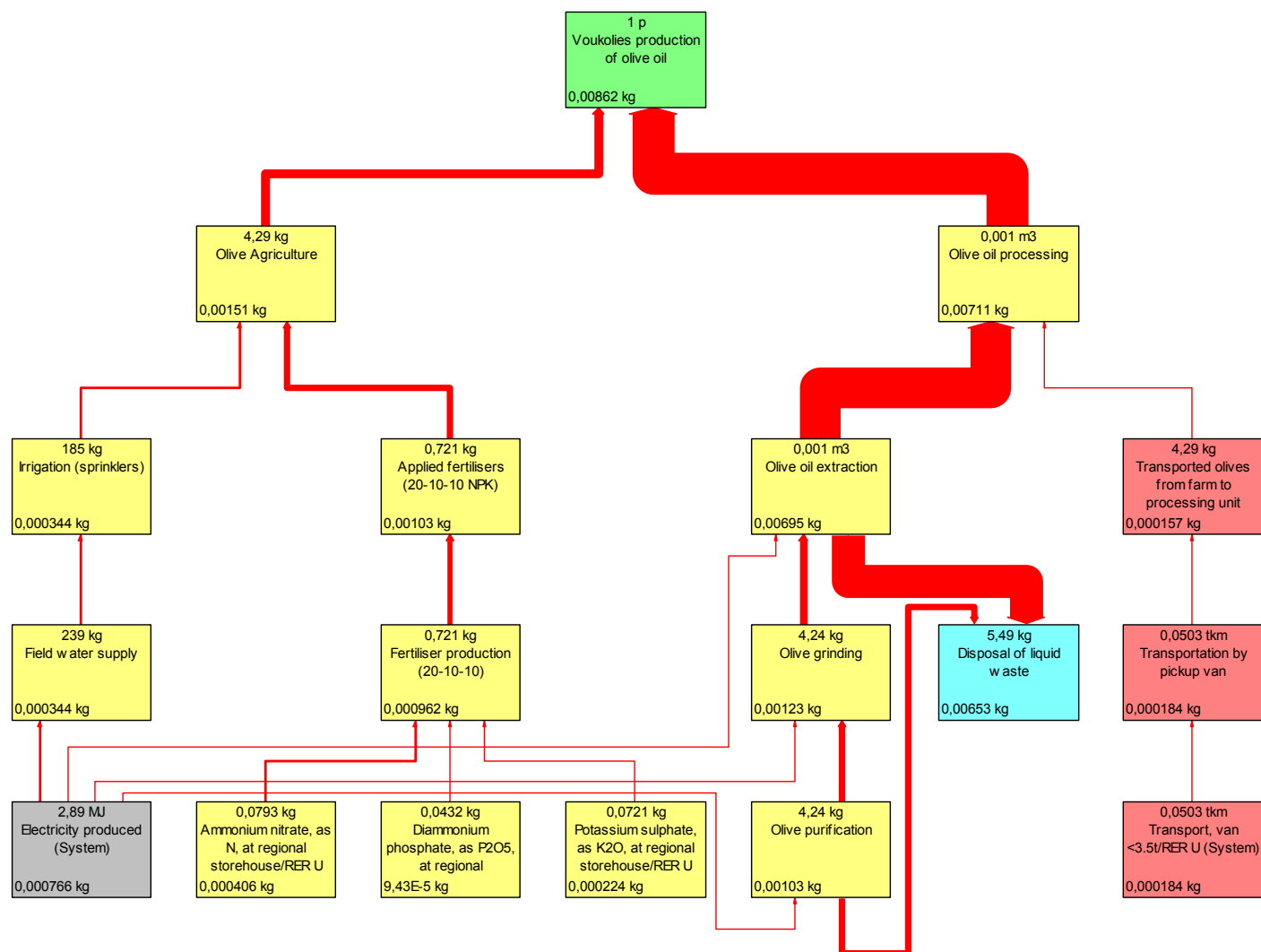


Figure 24: Flowchart for consumption of BOD in % (processes contributing more than 1%)

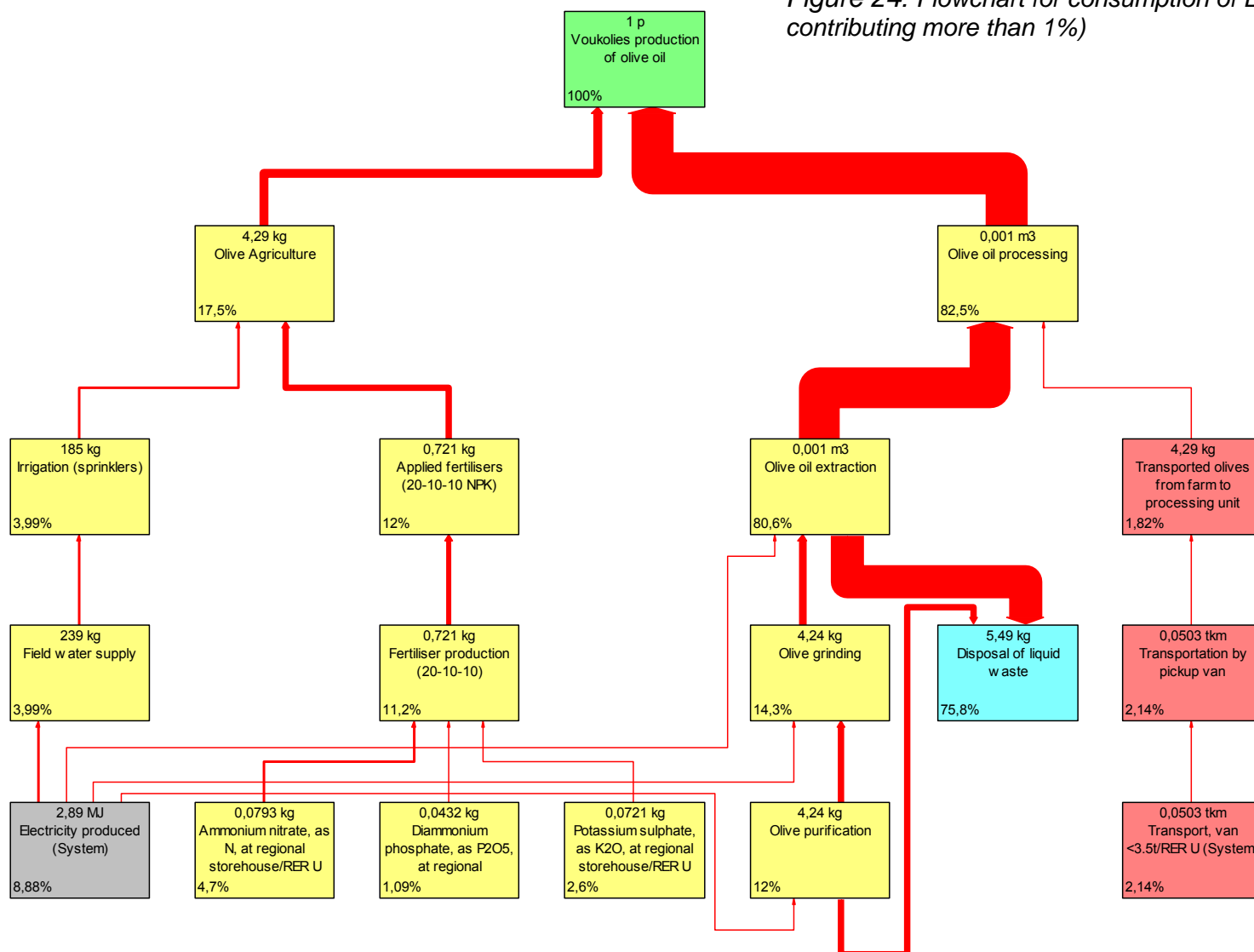
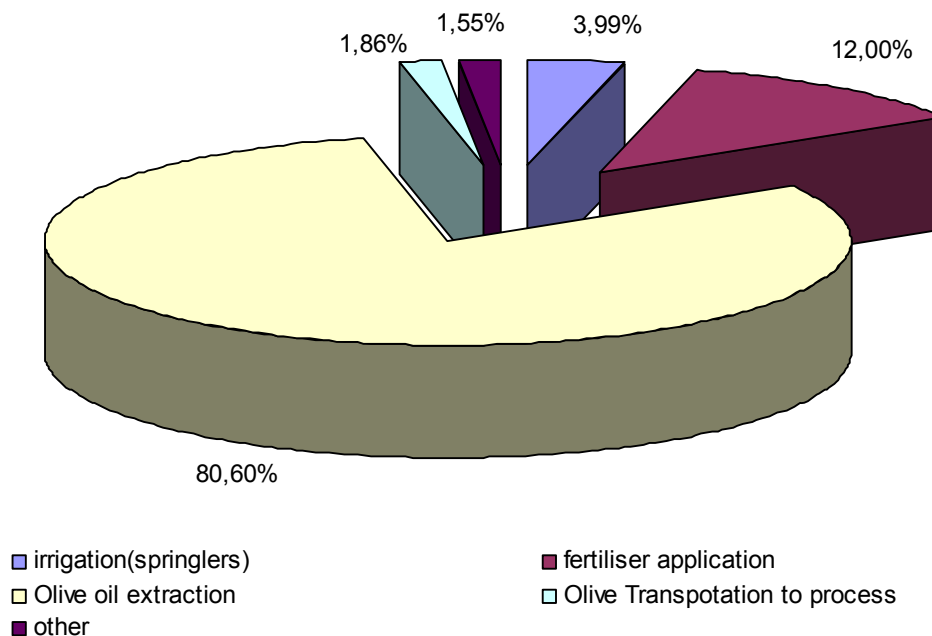


Diagram 14: Emissions of BOD in % process contribution to overall load



4.4 Emissions to soil

4.4.1 Lead

Lead is one of the most common heavy metal contaminants of soils. Although lead is naturally present in soils, generally in the range of 15 to 40 parts per million (University of Massachusetts Amherst, 2006), pollution can increase soil lead levels to greater than 300 to 500 parts per million (University of Maine, 2006) with adverse effects to human health.

According to the inventory analysis, the olive oil production system releases to soil 2.75mg of lead per litre of olive oil production, as shown in Figures 25,26.

Figure 25: Flowchart for consumption of Lead in Kgr (processes contributing more than 0.05%)

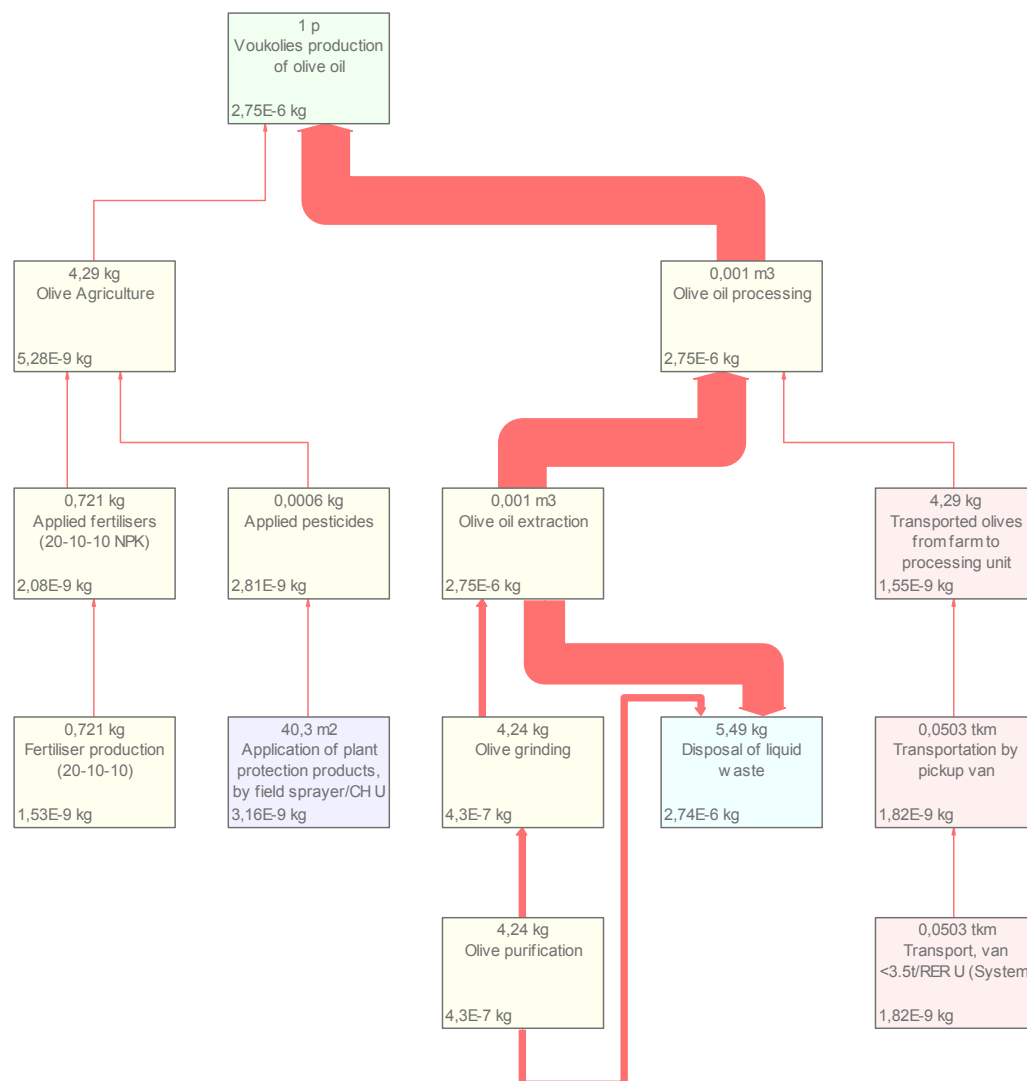
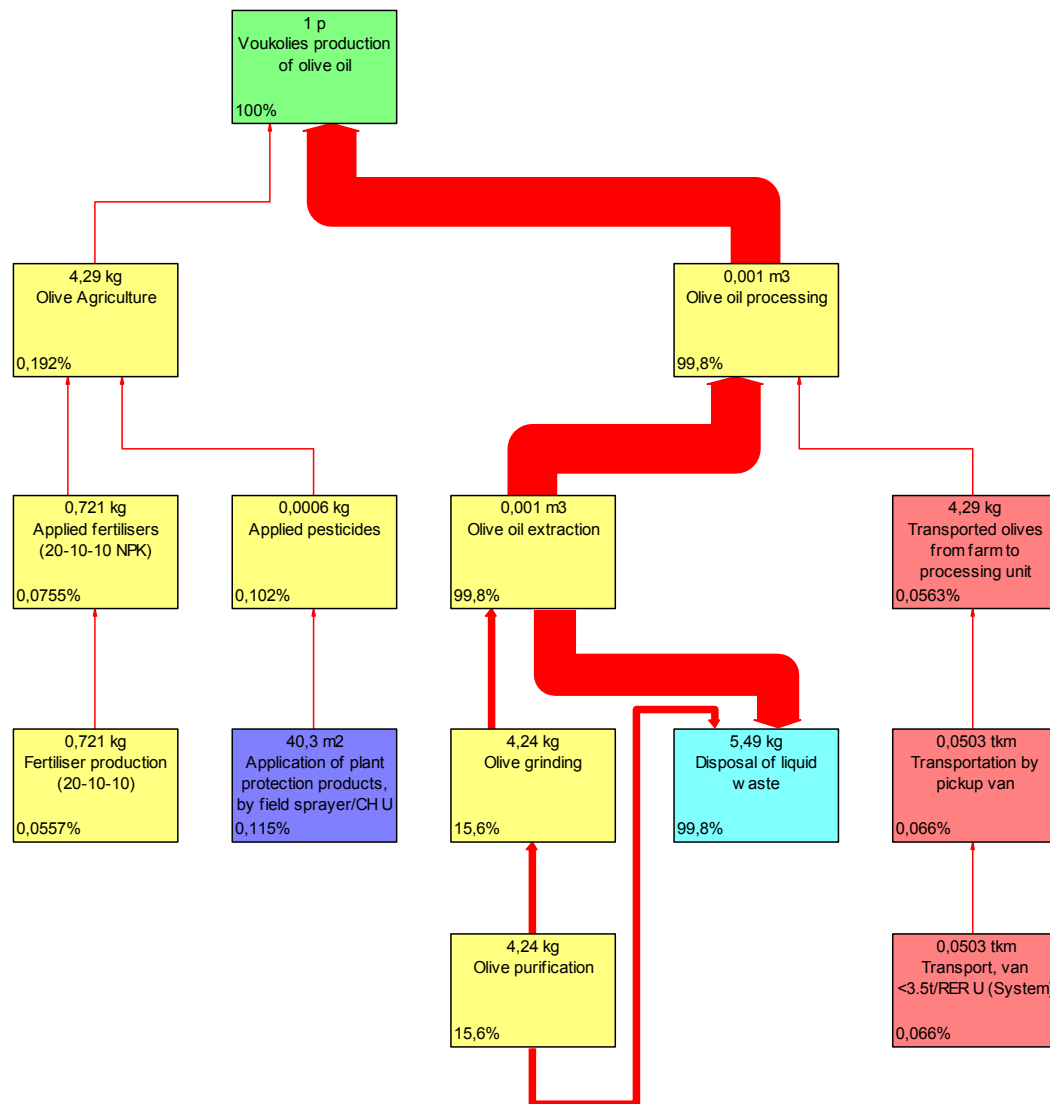
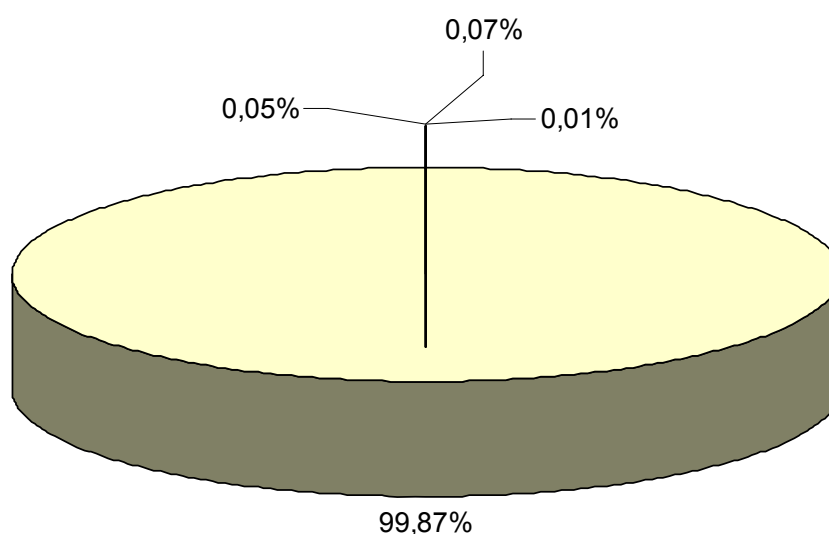


Figure 26: Flowchart for consumption of Lead in % (processes contributing more than 0.05%)



Within the system, the disposal of liquid waste from the processing stage into evaporation ponds accounts for 2,74mg of lead emissions, which is over 99,8% of the total load, as shown in Diagram 15. Furthermore, olive grinding and transportation by pickup van account for another 0,19mg of lead emissions. The next diagram shows the percentage contributions of the most important processes in this emission.

Diagram 15: Emissions of lead to soil in % process contribution to overall load



■ fertiliser application ■ pesticide application ■ olive oil extraction ■ transpotation to processing

4.4.2 Zinc

Zinc is a heavy metal, the toxicity concerns of which are associated more with plants than with animals or humans. This is because when accumulated in high concentrations most plants would die from its toxic effects long before accumulating a high enough concentration to pose a health risk to an animal (or human) eating that plant.

For the production of 1 litre of olive oil in Polemarchi, 67,1mg of zinc are emitted to soil, 6,46mg (9,62%) of which from agriculture related processes, as shown in Figures 27,28.

Figure 27: Flowchart for consumption of Zn in Kgr (processes contributing more than 0.1%)

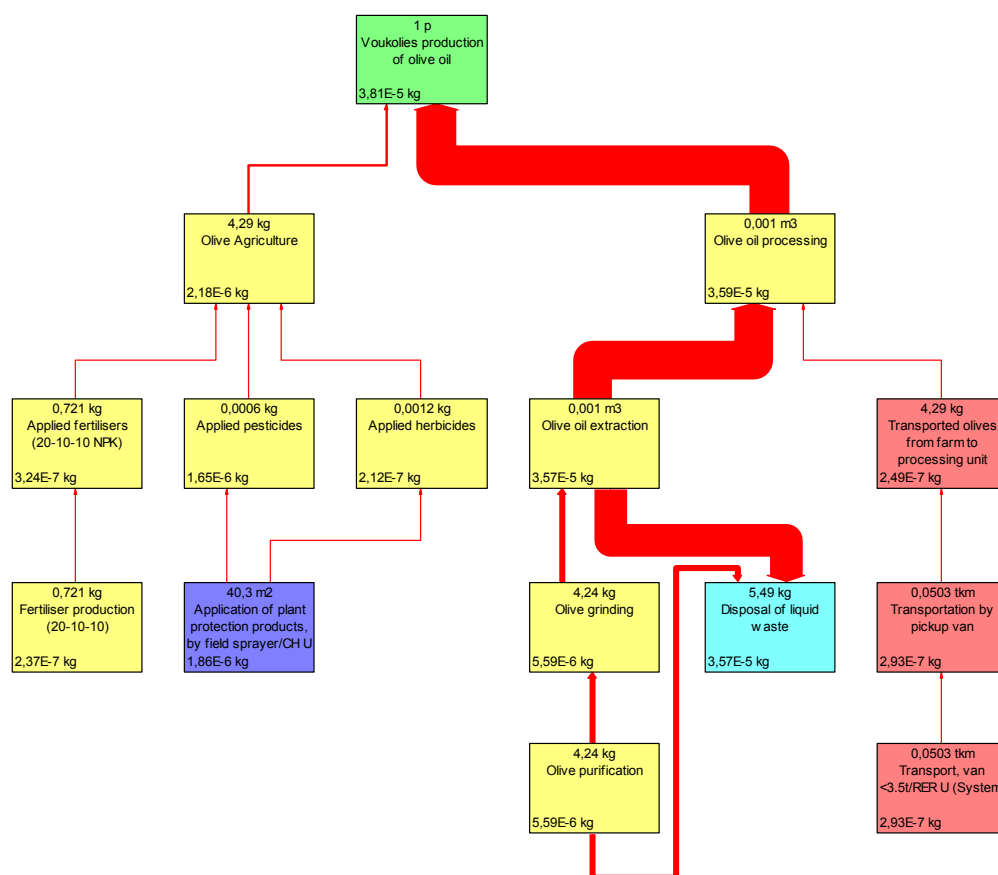


Figure 28: Flowchart for consumption of Zn in % (processes contributing more than 0.1%)

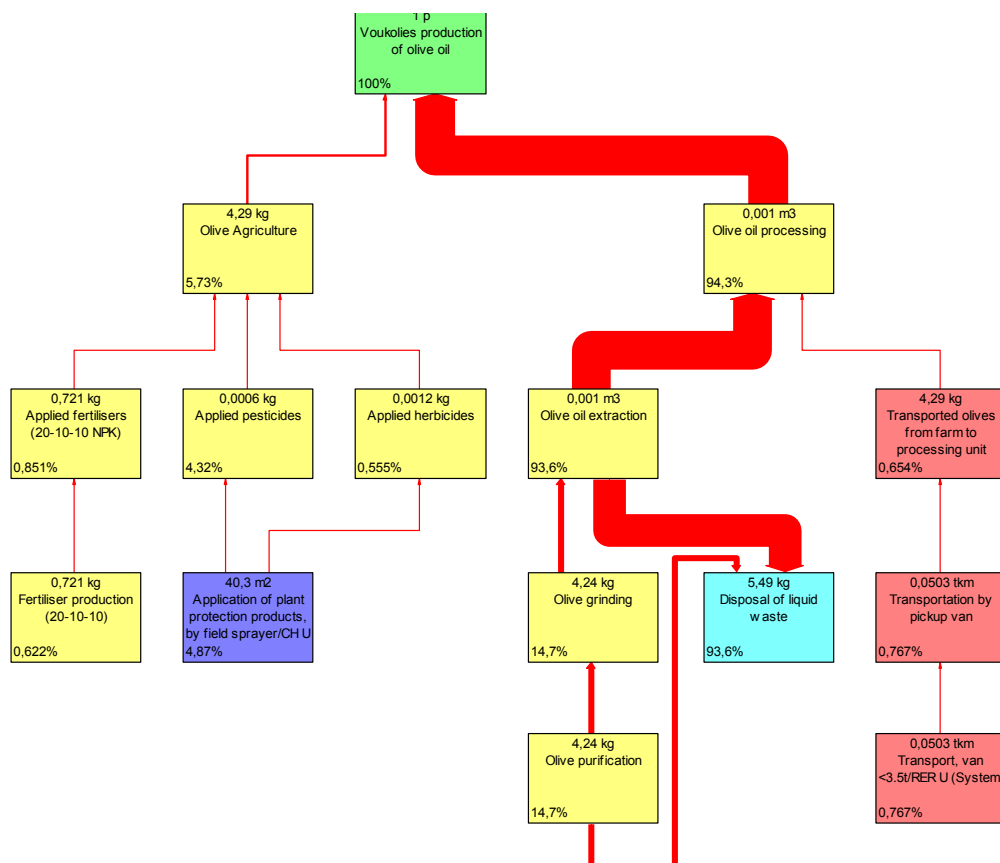
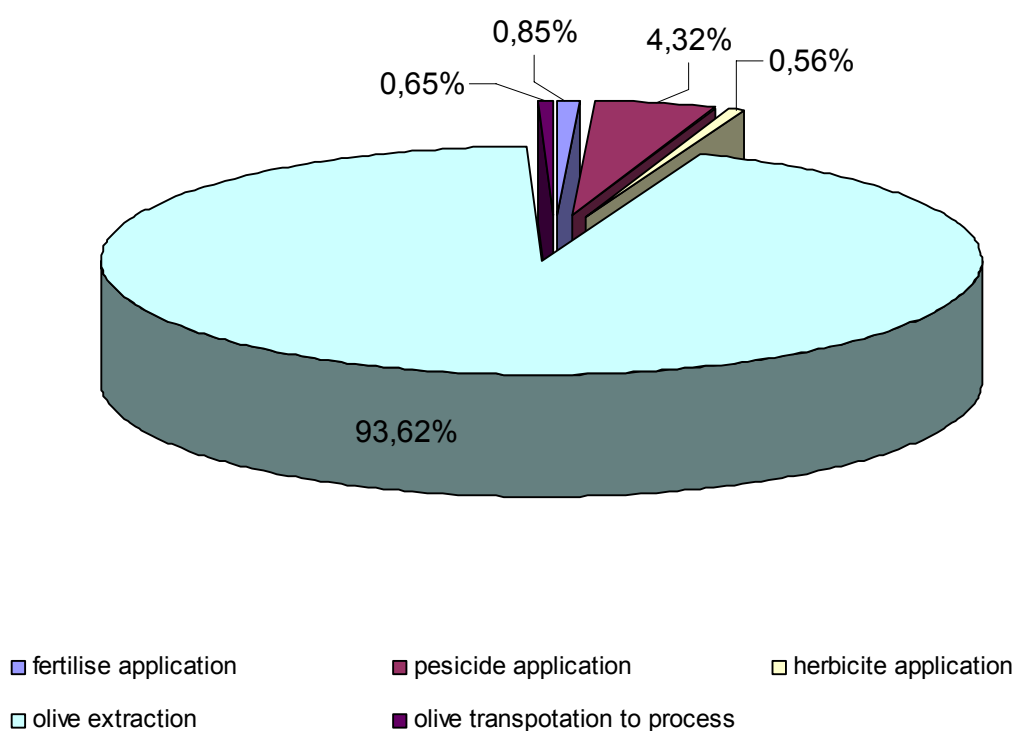


Diagram 16: Emissions of zinc in soil in % process contribution to overall load



4.5 Summary of results

All the above results are summarized in the next table (Table 5)

	Stage / Parameter	Crude Oil	fresh water	fossil CO2 to air	NOx to air	SO2 to air	COD to water	BOD to water	Lead to soil	Zinc to Soil
Agricultural Stage	Olive tree Planting									
	Irrigation	0,0248Kg (12,1%)	0,239m3(94,2%)	0,0834Kg(4,3 8%)		0,000659 Kg(8,57 %)	0,000346K g(1,191%)	3,44E-4Kg (3,99%)		
	applied fertilisers	0,0733Kg (35,9%)	0,0134m 3(5,32%)	0,512Kg (27,3%)	0,00183Kg(30,7 %)	0,00439 Kg(57,1 %)	0,00106Kg(5,86%)	0,00103Kg (12%)	2,08E-9Kg (0,0755%)	3,2E-7Kg (0,851%)
	applied pesticides	0,00822K g(4,02%)			0,000332Kg(3,6 8%)				2,81E-9Kg (0,102%)	1,66E-6Kg (4,32%)
	applied Herbicides									2,12E-7Kg (0,555%)
	prunning	0,0311Kg r(15,2%)		1,06Kg(56,7 %)	0,0046Kg(55,9 %)	0,00165 Kg(21,5 %)				
	Olive Collection	0,0149Kg r(7,28%)			0,00025Kg(3,03 %)	0,000808 Kg(10,5 %)				
Processing	olive oil extraction	0,0304Kg (14,9%)	5,55E- 5m3(0,02 2%)	0,101Kg (5,38%)			0,0164Kg(9 0,6%)	0,00695Kg(80 ,6%)	2,75E-6Kg (99,8%)	3,57E-5Kg (93,6%)
	olive transportation	0,0115Kg r(5,61%)		0,0367Kg (1,95%)	0,000225Kg(3,, 03%)		0,000158K g(0,87%)	1,57e-4Kg (1,82%)	1,55E-9Kg (0,0563%)	2,49E-7kg (0,654%)
Total	Agricultural	0,162Kg (79,5%)	0,252m3(99,7%)	1,74Kg(92,7 %)	0,00786Kg(95,6 %)	0,00683 Kg(88,8 %)	0,0154Kg(8 5,08%)	0,00151Kg (17,5%)	5,28E-9Kg (0,192%)	2,18E-6Kg (5,73%)
	Processing	0,0419Kg r(20,5%)	7,59E- 5m3(0,03 %)	0,138Kg(7,33 %)	0,000359Kg(4,3 7%)	0,000861 Kg(11,2 %)	0,00166Kg (9,17%)	0,00711Kg (82,5%)	2,75E-6Kg (99,8%)	3,59E-5Kg (94,3%)
	Total	0,204Kg(100%)	0,252m3(100%)	1,88Kg (100%)	0,00822Kg(100 %)	0,00759 Kg(100%)	0,0181Kgr (100%)	0,00862Kg(10 0%)	2,75E-6Kg (100%)	3,81E-5Kg (100%)



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6 Appendix A: Olive Agriculture Questionnaire

ΕΡΩΤΗΜΑΤΟΛΟΓΙΟ Αρ.1

ΠΡΟΣΔΙΟΡΙΣΜΟΣ ΧΑΡΑΚΤΗΡΙΣΤΙΚΗΣ ΑΛΥΣΙΔΑΣ ΠΑΡΑΓΩΓΗΣ ΕΛΑΙΟΛΑΔΟΥ - ΚΑΛΛΙΕΡΓΕΙΑ ΕΛΙΑΣ

Το ερωτηματολόγιο αυτό έχει ετοιμαστεί στα πλαίσια του ερευνητικού προγράμματος ECOIL, το οποίο συγχρηματοδοτείται από την Ε.Ε. και σε αυτό συμμετέχει μαζί με το Πολυτεχνείο Κρήτης και το Δημοτικό Διαμέρισμα Πολεμαρχίου. Στόχος είναι η υποβοήθηση όλων των παραγωγών στην υιοθέτηση κατάλληλων διαδικασιών για βελτίωση της περιβαλλοντικής απόδοσης της παραγωγής ελαιόλαδου. Τα στοιχεία που ζητούνται θα χρησιμοποιηθούν αποκλειστικά για τον σκοπό αυτό. Ο καλλιεργητής μπορεί εάν το επιθυμεί να διατηρήσει την ανωνυμία του. Με το τέλος του προγράμματος τα αποτελέσματα θα διαδοθούν σε όλους τους καλλιεργητές καθώς και σε άλλους ενδιαφερόμενους.

ΣΤΟΙΧΕΙΑ ΣΥΝΕΝΤΕΥΞΗΣ	
Αριθμός	
Ημερομηνία	

1. ΣΤΟΙΧΕΙΑ ΥΠΕΥΘΥΝΟΥ ΣΥΝΕΝΤΕΥΞΗΣ	
Ονοματεπώνυμο	
Τηλέφωνο	
Ηλεκτρονική Διεύθυνση	

Επάγγελμα (αγρότης, παραγωγός, άλλο)

2. ΣΤΟΙΧΕΙΑ ΚΑΛΛΙΕΡΓΗΤΗ	
Ονοματεπώνυμο	
Τηλέφωνο	
Επάγγελμα (αγρότης, παραγωγός, άλλο)	



3. ΓΕΝΙΚΑ ΣΤΟΙΧΕΙΑ ΚΑΛΛΙΕΡΓΕΙΑΣ		
3.1 Γεωγραφική θέση (περιοχή)	Δημοτικό Διαμέρισμα Πολεμαρχίου	
3.2 Ποικιλία		
3.3 Αριθμός συνολικών δένδρων (αναφέρατε αριθμό δένδρων ανά αγροτεμάχιο σε περίπτωση πολλών αγροτεμαχίων διαφορετικού υψόμετρου/επικλινούς/έκθεσης στο βοριά/ προσβασιμότητας)		
3.4 Έκταση καλλιέργειας (συνολικά)		'=m ²
3.5 Μέση παραγωγή ελαιοκάρπου ανά έτος για όλη την καλλιέργεια (μέση ετήσια τιμή τελευταίας τετραετίας)		'=kg ανά έτος
3.6 Μέση παραγωγή ελαιόλαδου ανά έτος για όλη την καλλιέργεια (μέση ετήσια τιμή τελευταίας τετραετίας)		'=kg ανά έτος
3.8 Μέση παραγωγική ηλικία δέντρων (π.χ. < 25, 25-50, >50)		'=χρόνια
3.9 Διάταξη φυτέματος (καλλιέργεια εκτατική < 10-20 δένδρα ανά στρέμμα , εντατική > 25)		
3.10 Κιλά λάδι στο κύκλο ζωής των δέντρων ανά Φυτεμένα δέντρα	'=Kg / αριθμό φυτεμένων δένδρων	(3.6) * (3.8) / (3.3)
3.11 Κιλά λαδιού που παράγονται από όλη τη καλλιέργεια ανά έτος	'=Kg /m ² ανά έτος	(3.6) / (3.4)
3.12 Κιλά λαδιού ανά Χρήση καλλιεργημένης γης (για τον υπολογισμό σε λίτρα χρησιμοποιήστε την πυκνότητα 0.916 kg/lit)	'=Kg /m ²	(3.6) * (3.8) / (3.4)



4. ΟΡΓΩΜΑ		
4.1 Εφαρμόζεται; Αν εφαρμόζεται Χλοοκοπή υπολογίζεται επιβάρυνση χοοκοπτικού	NAI / OXI (στο % της συνολικής έκτασης)	
4.2 Συχνότητα		"= No/year
4.3 Μέθοδος (π.χ. Φρέζα : τύπος μηχανήματος, βάθος 10-15 cm, μήνας εκτέλεσης)		
4.4 Όργωμα γης ανά Kg λάδι	"= m ² / Kg	(3.4)*(4.2)/(3.6)
5. ΑΡΔΕΥΣΗ		
5.1 Εφαρμόζεται;	NAI / OXI (στο % της συνολικής έκτασης)	
5.2 Προέλευση νερού (κόστος ανά m ³)	Γεώτρηση (Είδη μηχανικού εξοπλισμού π.χ. αντλίες) Υδατοπρομήθεια (δίκτυο.....) Ανακυκλωμένο	
5.3 Μέθοδος άρδευσης	Λίμναση / Αυλάκι (Furrow) Μπεκ (Sprinklers)/ Σταγόνες (Αναρτώμενο / Επιφανειακό / Υπόγειο)	
5.4 Απόσταση καλλιέργειας από πηγή		"= metres
5.5 Συχνότητα άρδευσης		"= no/year
5.6 Ποσότητα αρδευόμενου νερού κάθε φορά		"= m ³
5.7 Ποσότητα αρδευόμενου νερού ανά έτος	"= m ³ /year	(5.5)*(5.6)
5.8 Ποσότητα αρδευόμενου νερού ανά Kg λάδι	"= m ³ / kg	(5.7)/(3.6)

6. ΛΙΠΑΣΜΑΤΑ		
6.1 Εφαρμόζεται;	ΝΑΙ / ΟΧΙ (στο % της συνολικής έκτασης)	
6.2 Είδη λιπάσματος (ονομασία ή τύπος)		
6.3 Από πού φέρνετε το λίπασμα;		
6.4 Απόσταση		"=km
6.5 Τύπος & βάρος (για οδικά) μέσου μεταφοράς		
6.6 Μέθοδος εφαρμογής (έχει γίνει ποτέ ανάλυση απαιτήσεων μετά από εδαφολογική ανάλυση ή άλλη ανάλυση;)		
6.7 Συχνότητα εφαρμογής Συνήθης περίοδος εφαρμογής (μήνα)		"=no/year
6.8 Ποσότητα εφαρμογής κάθε φορά (ανά τύπο π.χ. 20:10:10, γίνεται σύμφωνα με συστάσεις καλής πρακτικής ;)		"=kg
6.9 Ποσότητα εφαρμογής ανά έτος	"=kg/year	(6.7)*(6.8)
6.10 Ποσότητα λιπάσματος ανά Kg λάδι	"=kg/ Kg λάδι	(6.9)/(3.6)
6.11. Μεταφορές λιπασμάτων από χώρο παρασκευής σε χώρο εφαρμογής ανά Kg λάδι		
Μέσο μεταφοράς (τύπος/ βάρος για οδικά)	Απόσταση (km)	Απόσταση*(6.10)/1000 (ton*km / kg)

7. ΜΕΘΟΔΟΣ ΑΝΤΙΜΕΤΩΠΙΣΗΣ ΕΧΘΡΩΝ ΚΑΙ ΑΣΘΕΝΕΙΩΝ		
7.1 Εφαρμόζεται; Ποιοί είναι οι εχθροί (έντομα π.χ. Πυρηνοτρήτης, Δάκος, άλλα, Ακάρεα) Ποιές είναι οι ασθένειες (μήκυτες, βακτήρια, ιοί)	NAI / OXI (στο % της συνολικής καλλιεργημένης έκτασης)	
7.2 Μέθοδος (ονομασία ή τύπος) Παγίδες / Ψεκασμός / άλλο		
7.3 Από πού το φέρνετε;		
7.4 Απόσταση		"=km
7.5 Τύπος & βάρος (για οδικά) μέσου μεταφοράς		
7.6 Μέθοδος εφαρμογής ψεκασμού: δολωματικός, διαβροχή		
7.7 Συχνότητα εφαρμογής συνολικά (ανά εχθρό)		"=no/year
7.8 Ποσότητα εφαρμογής δραστικής ουσίας (πριν τη αραιώση) κάθε φορά (ανά εχθρό)		"=kg
7.9 Ποσότητα εφαρμογής ανά έτος	"=kg/year	(7.7)*(7.8)
7.10 Ποσότητα δραστικής ουσίας (πριν τη αραιώση) ανά Kg λάδι	"=kg/kg λάδι	(7.9)/(3.6)
7.11. Μεταφορές εντομοκτόνων από χώρο παρασκευής σε χώρο εφαρμογής ανά kg λάδι		
Μέσο μεταφοράς (τύπος/ βάρος για οδικά)	Απόσταση (km)	Απόσταση*(7.10)/1000 (τόνοι*km/litre)

8. ΖΙΖΑΝΙΟΚΤΟΝΑ		
8.1 Εφαρμόζεται; Εφαρμόξετε εναλλακτικό τρόπο αντιμετώπισης; Π.χ. Φρέζα, χλοοκοπή, άλλο	NAI / OXI (στο % της συνολικής έκτασης)	
8.2 Είδος ζιζανιοκτόνα (ονομασία ή τύπος)		
8.3 Από πού φέρνετε τα ζιζανιοκτόνα ;		
8.4 Απόσταση		"=km
8.5 Τύπος & βάρος (για οδικά) μέσου μεταφοράς		
8.6 Μέθοδος εφαρμογής		
8.7 Συχνότητα εφαρμογής		"=no/year
8.8 Ποσότητα εφαρμογής κάθε φορά		"=kg
8.9 Ποσότητα εφαρμογής ανά έτος	"=kg/year	(8.7)*(8.8)
8.10 Ποσότητα ζιζανιοκτόνων ανά κιλό λάδι	"=kg/ kg	(8.9)/(3.6)
8.11. Μεταφορές ζιζανιοκτόνων από χώρο παρασκευής σε χώρο εφαρμογής ανά λίτρο λάδι		
Μέσο μεταφοράς (τύπος/ βάρος για οδικά)	Απόσταση (km)	Απόσταση*(8.10)/1000 (tonnes*km/litre)

9. ΚΛΑΔΕΜΑ		
9.1 Εφαρμόζεται;	ΝΑΙ / ΟΧΙ	
9.2 Συχνότητα εφαρμογής		"=no/year
9.3 Μέθοδος εφαρμογής (χρησιμοποιούμενα μέσα)		
9.4 Κλαδεμένα δέντρα ανά kg λάδι	$\frac{\text{αριθμός κλαδεμένων δέντρων}}{\text{kg λάδι}}$	$(3.3) \cdot (9.2) / (3.6)$
9.5 Ποσότητα "πράσινων αποβλήτων" ανά κλάδεμα ενός δέντρου		"=kg/tree
9.6 Παραγόμενα "πρ. απόβλητα" από κλάδεμα ανά kg λάδι	"=kg/ kg λάδι	$(9.4) \cdot (9.5)$
9.7 Μέθοδος διαχείρισης αποβλήτων		
10. ΣΥΛΛΟΓΗ		
10.1 Μέθοδος συλλογής καρπού		
10.2 Με ποιο ελαιοτριβείο συνεργάζεστε για τις ελιές; - Ιδιωτικό / συνεταιριστικό - Συμβατικό / ψυχρής άλεσης / άλλο		
10.3 Μέση απόσταση καλλιέργειών από ελαιοτριβείο		"=km
10.4 Τύπος και βάρος μέσου μεταφοράς		
10.5 Συλλεγόμενη ποσότητα ελιών ανά κιλό λάδι	"=kg/ kg λάδι	$(3.5) / (3.6)$
Μέσο μεταφοράς (τύπος/ βάρος για οδικά)	Tonnes*km / kg λάδι	
		$(10.5) \cdot (10.3) / 1000$

Σας ευχαριστούμε για τη συμμετοχή.



Appendix B : Analysis of Questionnaires

Q No	3.3 Total tree number	3.4 Area (Km ²)	3.5 Oil Fruit Production (Kg/yr)	3.6 Olive Oil Production (Kg/yr)	3.8 Tree age (years)	3.9 Tree plant formation (trees/Km ²)	3.10 Olive oil weight production during the tree life cycle per planted trees(Kg/total trees)	3.11 Olive Oil weight production per m ² per year (Kg/m ² * yr)	Land use per Kgr olive oil production (m ² *yr/kg)	3.12 Olive Oil production weight per land use (Kg/m ²)	4.1 Soil Management (%land coverage)	4.2 Tillage frequency (No/yr)	4.3 Method
1	270	13,5	11090	2219	30	20	246,56	0,16	6,08	4,93	-	0	-
2	430	20	19475	3726	25	22	216,63	0,19	5,37	4,66	50%	1	Fraise
3	330	16,5	11284	2229	30	20	202,64	0,14	7,40	4,05	50%	1	Fraise
4	325	16,1	6239	1456	30	20	134,40	0,09	11,06	2,71	-	0	-
5	540	24,9	17841	3736	40	22	276,74	0,15	6,66	6,00	-	0	-
6	390	19,4	8653	1908	25	20	122,31	0,10	10,17	2,46	50%	1	Fraise
7	830	41,6	30610	6865	35	20	289,49	0,17	6,06	5,78	30%	1	Fraise
8	540	26,9	32635	6759	30	20	375,50	0,25	3,98	7,54	50%	1	Fraise
9	480	24	9542	2200	40	20	183,33	0,09	10,91	3,67	-	0	-
10	285	13,6	10456	2005	30	21	211,05	0,15	6,78	4,42	-	0	-
11	710	34	18510	4264	35	21	210,20	0,13	7,97	4,39	50%	1	Fraise
12	650	33	12052	2867	30	20	132,32	0,09	11,51	2,61	50%	1	Fraise
13	700	38,5	8046	1563	25	18	55,82	0,04	24,63	1,01	80%	1	Fraise
14	450	22	11774	2465	35	20	191,72	0,11	8,92	3,92	40%	1	Fraise
15	140	5,9	3529	718	30	23	153,86	0,12	8,22	3,65	-	0	-
16	350	15,8	10217	1996	30	22	171,09	0,13	7,92	3,79	-	0	-
17	630	31,1	27388	5668	35	20	314,89	0,18	5,49	6,38	60%	1	Fraise
18	1000	41,7	13637	3022	40	24,0	120,88	0,07	13,80	2,90	50%	1	Fraise
19	550	26,9	15335	3318	35	20	211,15	0,12	8,11	4,32	30%	1	Fraise
20	325	16	19639	4378	35	20	471,48	0,27	3,65	9,58	20%	1	Fraise
21	660	30	5060	1086	30	22	49,36	0,04	27,62	1,09	30%	1	Fraise
22	1430	71,2	27986	6592	30	20	138,29	0,09	10,80	2,78	-	0	-
23	850	39	15502	3359	25	22	98,79	0,09	11,61	2,15	-	0	-
24	425	20,4	16902	3969	30	21	280,16	0,19	5,14	5,84	20%	1	Fraise
25	330	15,5	17498	3967	35	21	420,74	0,26	3,91	8,96	-	0	-
26	1390	68	60718	12388	25	20	222,81	0,18	5,49	4,55	20%	1	Fraise
Sum & Average	15010	725,5	441818	94723	31,5385	20,7300	211,6233	0,1382	9,2027	4,3895		0,6154	
	Sum	Sum	Sum	Sum	Average	Average	Average	Average	Average	Average		Average	



Q No	4.4 Soil Management per olive oil production (m ² /Kg Olive oil)	5.1 Irrigation (%land coverage)	5.2 Water Origin	5.3 Irrigation Method	5.4 Distance from source (m)	5.5 Irrigation frequency (No/yr)	5.6 Water used per tree (m ³ /tree)	5.7 Annual Irrigated water per tree (m ³ /tree/yr)	5.8 Irrigated water per olive oil production (m ³ /Kg)	6.1 Fertiliser Use(%land coverage)	6.2 fertiliser type	6.4 Distance (m)	6.6 Application Method
1	-	100%	Public water system	Adjustable Nozzle	50-150m	3	0,5	1,5	0,18	100%	20-10-10	2-2,5 km	Dispersion
2	2,68384	50%	Public water system	Adjustable Nozzle	50-150m	4	0,3	1,2	0,07	100%	11-15-15	2-2,5 km	Dispersion
3	3,70121	60%	Public water system	Adjustable Nozzle	50-150m	3	0,3	0,9	0,08	100%	20-10-10	2-2,5 km	Dispersion
4	-	100%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,22	100%	20-10-10	2-2,5 km	Dispersion
5	-	100%	Public water system	Adjustable Nozzle	50-150m	4	0,4	1,6	0,23	100%	20-10-10	2-2,5 km	Dispersion
6	5,08386	70%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,14	100%	20-10-10	2-2,5 km	Dispersion
7	1,81792	100%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,15	100%	11-15-15	2-2,5 km	Dispersion
8	1,98994	100%	Public water system	Adjustable Nozzle	50-150m	3	0,3	0,9	0,07	100%	20-10-10	2-2,5 km	Dispersion
9	-	100%	Public water system	Adjustable Nozzle	50-150m	4	1	4	0,87	100%	20-10-10	2-2,5 km	Dispersion
10	-	100%	Public water system	Adjustable Nozzle	50-150m	3	0,5	1,5	0,21	100%	20-10-10	2-2,5 km	Dispersion
11	3,98687	70%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,14	100%	20-10-10	2-2,5 km	Dispersion
12	5,75514	50%	Public water system	Adjustable Nozzle	50-150m	5	0,5	2,5	0,28	100%	Urea(1Kg)-K ₂ SO ₄ (4Kg)	2-2,5 km	Dispersion
13	19,70569	100%	Public water system	Adjustable Nozzle	50-150m	3	0,3	0,9	0,40	100%	20-10-10	2-2,5 km	Dispersion
14	3,56998	60%	Public water system	Adjustable Nozzle	50-150m	4	0,3	1,2	0,13	100%	Magnibor	2-2,5 km	Dispersion
15	-	100%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,19	100%	11-15-15	2-2,5 km	Dispersion
16	-	100%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,18	100%	11-15-15	2-2,5 km	Dispersion
17	3,29217	70%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,09	100%	20-10-10	2-2,5 km	Dispersion
18	6,89940	70%	Public water system	Adjustable Nozzle	50-150m	3	0,5	1,5	0,35	100%	20-10-10	2-2,5 km	Dispersion
19	2,43219	100%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,17	100%	20-10-10	2-2,5 km	Dispersion
20	0,73093	70%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,06	100%	20-10-10	2-2,5 km	Dispersion
21	8,28729	80%	Public water system	Adjustable Nozzle	50-150m	3	0,3	0,9	0,44	100%	20-10-10	2-2,5 km	Dispersion
22	-	60%	Public water system	Adjustable Nozzle	50-150m	3	0,3	0,9	0,12	100%	20-10-10	2-2,5 km	Dispersion
23	-	75%	Public water system	Adjustable Nozzle	50-150m	2	0,5	1	0,19	100%	Opyav.biollisa(4Kg)-manure- K ₂ SO ₄ (1-1.5Kg)	2-2,5 km	Dispersion
24	1,02797	50%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,06	100%	20-10-10	2-2,5 km	Dispersion
25	-	80%	Public water system	Adjustable Nozzle	50-150m	3	0,4	1,2	0,08	100%	20-10-10	2-2,5 km	Dispersion
26	1,09784	80%	Public water system	Adjustable Nozzle	50-150m	3	0,5	1,5	0,13	100%	20-10-10 & Potassium	2-2,5 km	Dispersion
Sum & Average	4,50389	81%				3	0,4385	1,3154	0,2020	100%	20-10-10		
	Average	Average				Average	Average	Average	Average	Average			



Q No	6.7 Frequency (No/yr)	6.8 Fertiliser use per tree(kg/tree)	6.8 Total use of fertiliser (kg)	6.9 Total use per year(Kg/yr)	6.10 Fertiliser Use per Kg olive oil production (Kg/Kg olive oil)	7.1 Pesticides use (%land use)	Pest	7.2 Application Method	7.4 Distance (km)	7.6 Application method tool	7.7 Open Application Frequency (No/yr)
1	1	4	1080	1080	0,49	100%-Municipality	Dacus	Spray Method	20	Tractor	3
2	1	4,5	1935	1935		100%-Municipality-Dessis	Dacus	Spray Method & Tractor coverage	1	Tractor	3
3	1	4	1320	1320	0,59	100%-Municipality	Dacus	Spray Method	1	Tractor	3
4	1	4	1300	1300	0,89	100%-Municipality	Dacus	Spray Method	1	Tractor	3
5	1	4	2160	2160	0,58	100%-Δήμος-Dessis	Dacus	Spray Method & Tractor coverage	1	Tractor	3
6	1	4	1560	1560	0,82	100%-Municipality	Dacus	Spray Method	1	Tractor	3
7	1	4	3320	3320		100%-Municipality-Dessis	Dacus	Spray method	1	Tractor-syringe	3
8	1	4	2160	2160	0,32	100%-Municipality-Dessis	Dacus	Spray Method & Tractor coverage	1	Tractor	3
9	1	4	1920	1920	0,87	100%-Municipality-Dessis	Dacus	Spray Method & Tractor coverage	1	Tractor	3
10	1	4,5	1282,5	1282,5	0,64	100%-Municipality	Dacus	Spray Method	1	Tractor	3
11	1	4	2840	2840	0,67	100%-Municipality	Dacus	Spray Method	1	Tractor	3
12	1	5	3250	3250		100%-Municipality	Dacus	Spray Method	1	Tractor	3
13	1	4	2800	2800	1,79	100%-Municipality	Dacus	Spray Method	1	Tractor	3
14	1	4	1800	1800		100%-Municipality	Dacus	Spray Method	1	Tractor	3
15	1	4,5	630	630		100%-Municipality	Dacus	Spray Method	1	Tractor	3
16	1	4	1400	1400		100%-Municipality	Dacus	Spray Method	1	Tractor	3
17	1	4	2520	2520	0,44	100%-Municipality	Dacus	Spray Method	1	Tractor	3
18	1	4	4000	4000	1,32	100%-Municipality	Dacus	Spray Method	1	Tractor	3
19	1	4	2200	2200	0,66	100%-Municipality	Dacus	Spray Method	1	Tractor	3
20	1	4	1300	1300	0,30	100%-Municipality	Dacus	Spray Method	1	Tractor	3
21	1	4	2640	2640	2,43	100%-Municipality	Dacus	Spray Method	1	Tractor	3
22	1	4	5720	5720	0,87	100%-Municipality	Dacus	Spray Method	1	Tractor	3
23	1	5	4250	4250		100%	Dacus	trap	1	-	0
24	1	4	1700	1700	0,43	100%-Municipality	Dacus	Spray Method	1	Tractor	3
25	1	4	1320	1320	0,33	100%-Municipality	Dacus	Spray Method	1	Tractor	3
26	1	4,5	6255	6255	0,50	100%-Municipality-Dessis	Dacus	Spray Method & Tractor coverage	1	Tractor	3
Sum & Average	1	4,1538	2410,0962	2410,0962	0,7868	100%-Municipality		Spray Method		Tractor	2,8846
	Average	Average	Average	Average	Average						Average



Q No	7.7 Individual application frequency (No/yr)	7.8 Pesticide compound composition (kg)	7.8 Pesticide compound composition per tree (municipality)(kg/tree)	7.8 Pesticide compound composition per tree (farmer)(kg/tree)	7.9 Quantity usage per year (Kg/yr)	7.10 Drastic (before dilution) compound quantity (πριν τη αραιωση) per olive oil production (Kg/Kg olive oil)	8.1 Herbicide application and land coverage (%land coverage)
1	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,6642	0,000299324	100%
2	1	700gr Dessis/1 ton H2O~130 trees	0,00082	0,00538	3,3712	0,000904777	50%
3	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,8118	0,000364199	10% Round-up-40% herbicide cutting
4	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,7995	0,000549107	100%
5	1	1Kg Dessis/1 ton H2O~130 trees	0,00082	0,00769	5,481	0,001467077	100%
6	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,9594	0,00050283	50%
7	2	70gr to nozzle (15 Kg H2O)~80 trees	0,00082	0,000875	3,4943	0,000509002	10%Round-up-60% herbicide cutting
8	1	1Kg Dessis/1 ton H2O	0,00082	0,00769	5,481	0,000810919	50%
9	1	1Kg Dessis/1 ton H2O	0,00082	0,00769	4,872	0,002214545	100%
10	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,7011	0,000349676	100%
11	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,7466	0,000409615	50%
12	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,599	0,000557726	15% Round-up-35% herbicide cutting
13	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,722	0,001101727	20%
14	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,107	0,000449087	60%
15	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,3444	0,000479666	100%
16	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,861	0,000431363	100%
17	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,5498	0,00027343	40%
18	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	2,46	0,00081403	40% Round-up-10% herbicide cutting
19	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,353	0,000407776	70%
20	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,7995	0,000182618	80%
21	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,6236	0,001495028	50% Round-up-20% herbicide cutting
22	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	3,5178	0,000533647	20%
23	0	0.5Kg, σύσταση: 3%NH4, 1-2%feromon, 1% borax, H2O	0	0	-	-	100%
24	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	1,0455	0,000263416	80%
25	0	3Kg/1ton H2O-3500~4000 trees	0,00082	0	0,8118	0,000204638	100%
26	2	700gr Dessis/1 ton H2O	0,00082	0,00538	18,3758	0,001483355	80%
Sum & Average	0,3077	3Kg/1ton H2O-3500~4000 trees			2,6221	0,00068	
	Average				Average	Average	



Q No	8.1 Round-up application method (%land coverage)	8.2 Herbicide application type	8.4 Distance (km)	8.6 Application method	8.7 Frequency (No/yr)	8.8 Compound composition (kg)	8.8 Quantity per use per tree (kg)	8.8 Total quantity per use(kg)	8.9 Quantity per year (Kg/yr)	8.10 Quantity used per olive oil production (Kg/Kg olive oil)
1	100%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	3,375	3,375	0,001520955
2	50%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	2,6875	2,6875	0,000721283
3	10%	Roundup-herbicide cutting	2-2.5 km	Spraying (tractor)-herbicide cutter	1	1Kg compound/500Kg H2O~80 trees	0,0125	0,4125	0,4125	0,000185061
4	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
5	100%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	6,75	6,75	0,001806745
6	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
7	10%	Roundup-herbicide cutting	2-2.5 km	Spraying (tractor)-herbicide cutter	1	1Kg compound/500Kg H2O~80 trees	0,0125	1,0375	1,0375	0,000151129
8	50%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	3,375	3,375	0,000499334
9	-	Maestro	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	-	-	-
10	100%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	3,5625	3,5625	0,001776808
11	50%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	4,4375	4,4375	0,001040689
12	15%	Roundup-herbicide cutting	2-2.5 km	Spraying (tractor)-herbicide cutter	1	1Kg compound/500Kg H2O~80 trees	0,0125	1,21875	1,21875	0,000425096
13	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
14	60%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	3,375	3,375	0,001369168
15	100%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	1,75	1,75	0,002437326
16	100%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	4,375	4,375	0,002191884
17	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
18	40%	Roundup-herbicide cutting	2-2.5 km	Spraying (tractor)-herbicide cutter	1	1Kg compound/500Kg H2O~80 trees	0,0125	5	5	0,001654533
19	70%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	4,8125	4,8125	0,001450422
20	80%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	3,25	3,25	0,000742348
21	50%	Roundup-herbicide cutting	2-2.5 km	Spraying (tractor)-herbicide cutter	1	1Kg compound/500Kg H2O~80 trees	0,0125	4,125	4,125	0,003798343
22	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
23	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
24	80%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	4,25	4,25	0,001070799
25	-	Herbicide cutting	-	Herbicide cutter	1	-	-	-	-	-
26	80%	Round-up	2-2.5 km	Spraying (tractor)	1	1Kg compound/500Kg H2O~80 trees	0,0125	13,9	13,9	0,001122054
Sum & Average		Roundup		Spraying (tractor)	1		0,01250	3,98299	3,98299	0,00133
					Average		Average	Average	Average	Average



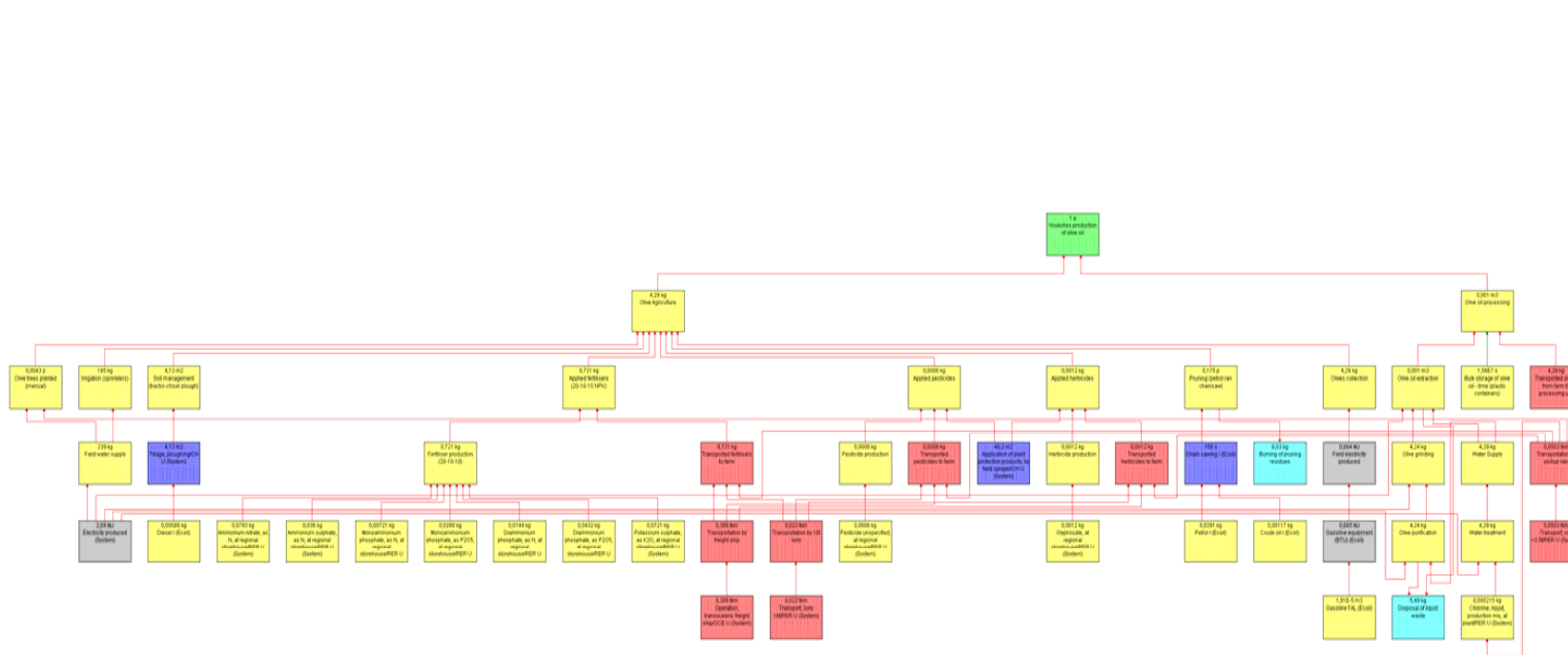
Q No	9.1 Pruning (Yes/No)	9.2 Pruning frequency(No/yr)	9.3 Pruning Method	9.4 Number of pruned trees per olive oil production (op.5./Kg olive oil)	9.5 "Green" waste per tree (kg/tree)	9.6 "Green" waste per olive oil production (Kg/Kg olive oil)	9.6 Burning produced waste per olive oil production (kg/kg olive oil)	9.7 Pruning residue management	10.1 Olive fruit collection method	10.2 Olive oil processing unit	10.3 Olive grove - Olive oil processing unit (mean value) (km)
1	Yes	1	Chainshaw	0,121676431	40	4,867057233	4,867057233	Burn	Pneumatic comps	Polemarchi-centrifugal	0,5-4 km
2	Yes	1	Chainshaw	0,11540526	50	5,770263017	5,770263017	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
3	Yes	1	Chainshaw	0,148048452	50	7,402422611	7,402422611	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
4	Yes	1	Chainshaw	0,223214286	30	6,696428571	6,696428571	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
5	Yes	1	Chainshaw	0,144539615	60	8,672376874	8,672376874	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
6	Yes	1	Chainshaw	0,204402516	30	6,132075472	6,132075472	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
7	Yes	1	Chainshaw	0,120903132	50	6,045156591	6,045156591	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
8	Yes	1	Chainshaw	0,079893475	60	4,793608522	4,793608522	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
9	Yes	1	Chainshaw	0,218181818	50	10,90909091	10,90909091	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
10	Yes	1	Chainshaw	0,142144638	40	5,685785536	5,685785536	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
11	Yes	1	Chainshaw	0,166510319	30	4,995309568	4,995309568	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
12	Yes	1	Chainshaw	0,226717824	40	9,06871294	9,06871294	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
13	Yes	1	Chainshaw	0,447856686	40	17,91426743	17,91426743	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
14	Yes	1	Chainshaw	0,182555781	60	10,95334686	10,95334686	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
15	Yes	1	Chainshaw	0,194986072	40	7,799442897	7,799442897	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
16	Yes	1	Chainshaw	0,175350701	40	7,014028056	7,014028056	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
17	Yes	1	Chainshaw	0,111150318	50	5,557515879	5,557515879	Burn	Pneumatic comps	Polemarchi-centrifugal	0,5-4 km
18	Yes	1	Chainshaw	0,330906684	50	16,54533422	16,54533422	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
19	Yes	1	Chainshaw	0,165762508	30	4,972875226	4,972875226	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
20	Yes	1	Chainshaw	0,07423481	40	2,969392417	2,969392417	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
21	Yes	1	Chainshaw	0,607734807	60	36,4640884	36,4640884	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
22	Yes	1	Chainshaw	0,216929612	40	8,677184466	8,677184466	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
23	Yes	1	Chainshaw	0,253051503	60	15,18309021	-	milling process	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
24	Yes	1	Chainshaw	0,107079869	40	4,283194759	4,283194759	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
25	Yes	1	Chainshaw	0,083186287	60	4,991177212	4,991177212	Burn	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
26	Yes	1	Chainshaw	0,11220536	50	5,610268001	-	milling process	Electric comps (generator)	Polemarchi-centrifugal	0,5-4 km
Sum & Average				0,19133	45,76923	8,84513	8,71584				
				Average	Average	Average	Average				

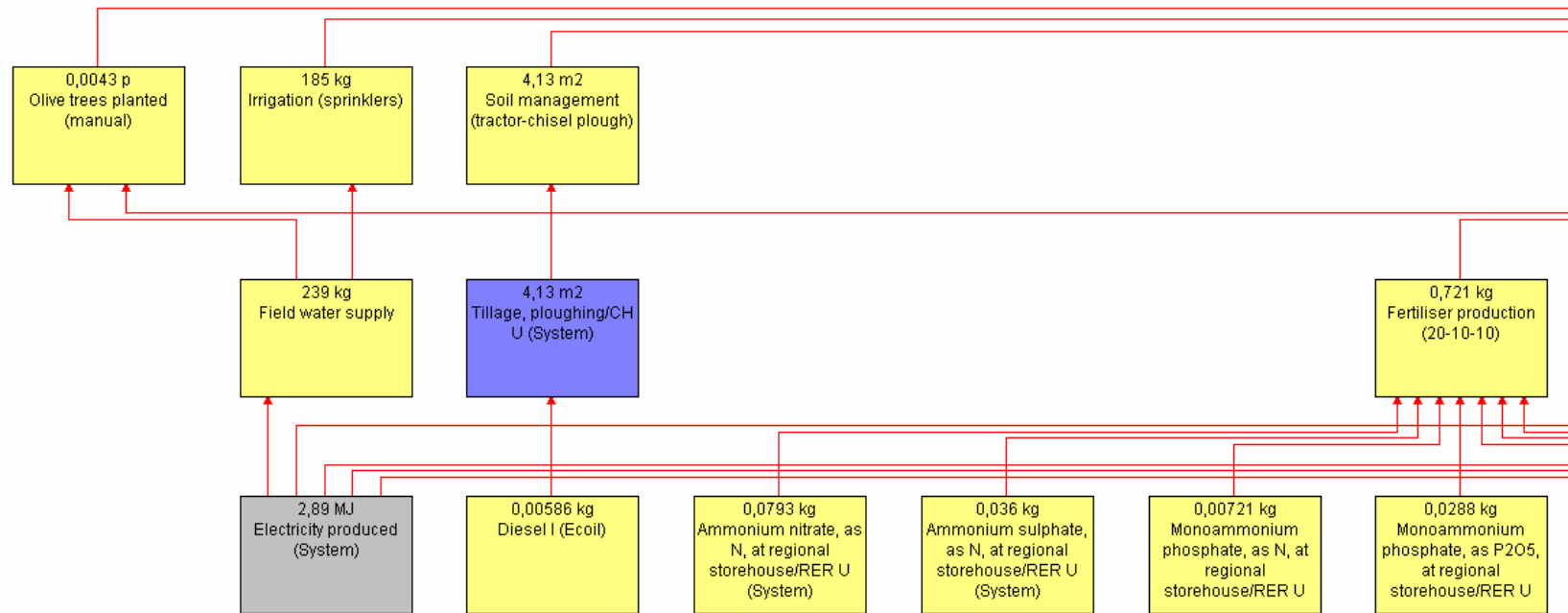


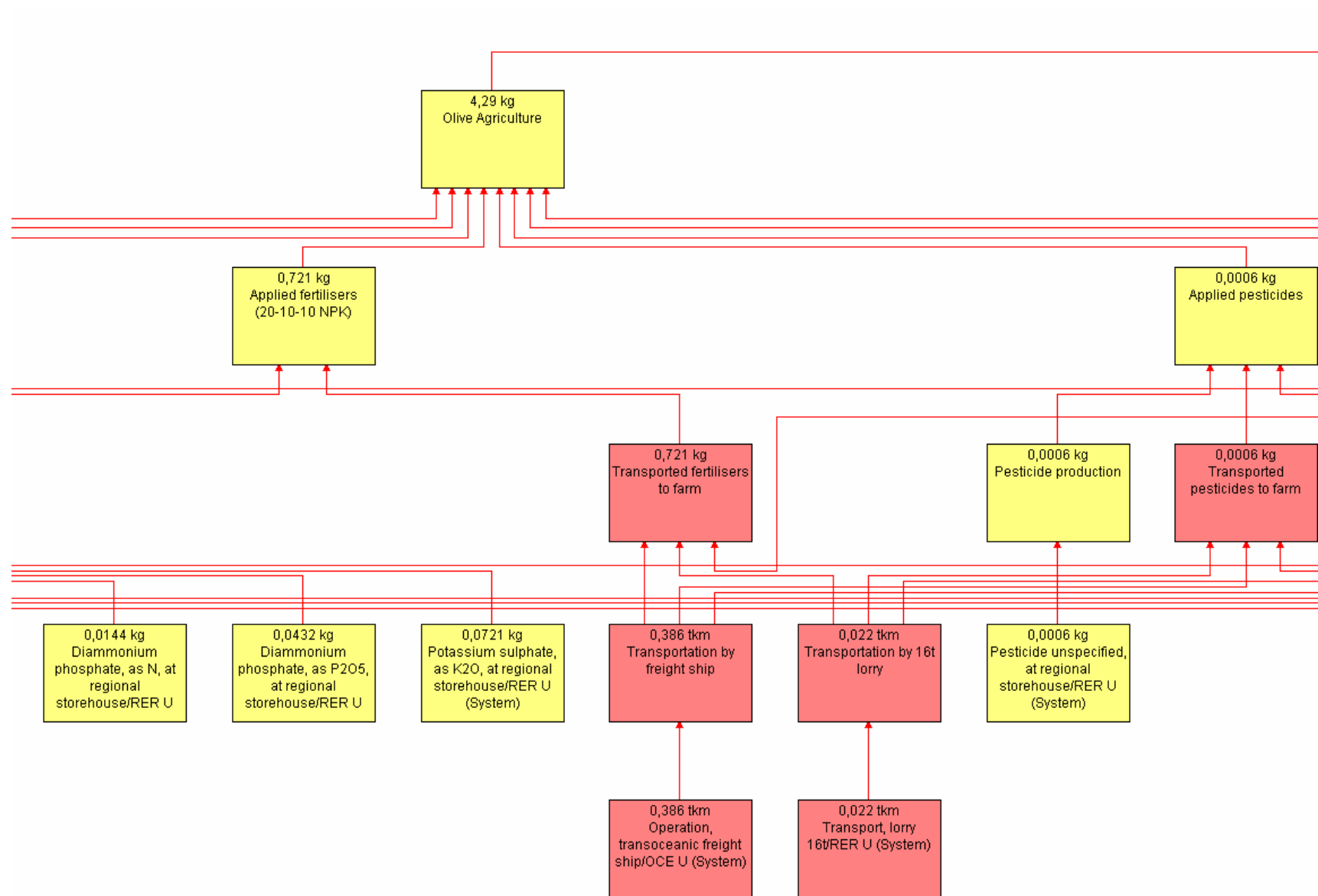
Q No	10.5 Collected olive fruits per olive oil production(Kg/Kg olive oil)
1	4,997746733
2	5,226784756
3	5,062359803
4	4,285027473
5	4,775428266
6	4,535115304
7	4,458849235
8	4,857967155
9	4,337272727
10	5,214962594
11	4,340994371
12	4,203697245
13	5,147792706
14	4,776470588
15	4,915041783
16	5,118737475
17	4,83203952
18	4,512574454
19	4,621760096
20	4,485838282
21	4,659300184
22	4,245449029
23	4,615064007
24	4,258503401
25	4,410889841
26	4,901356151
Sum & Average	4,68450
	Average

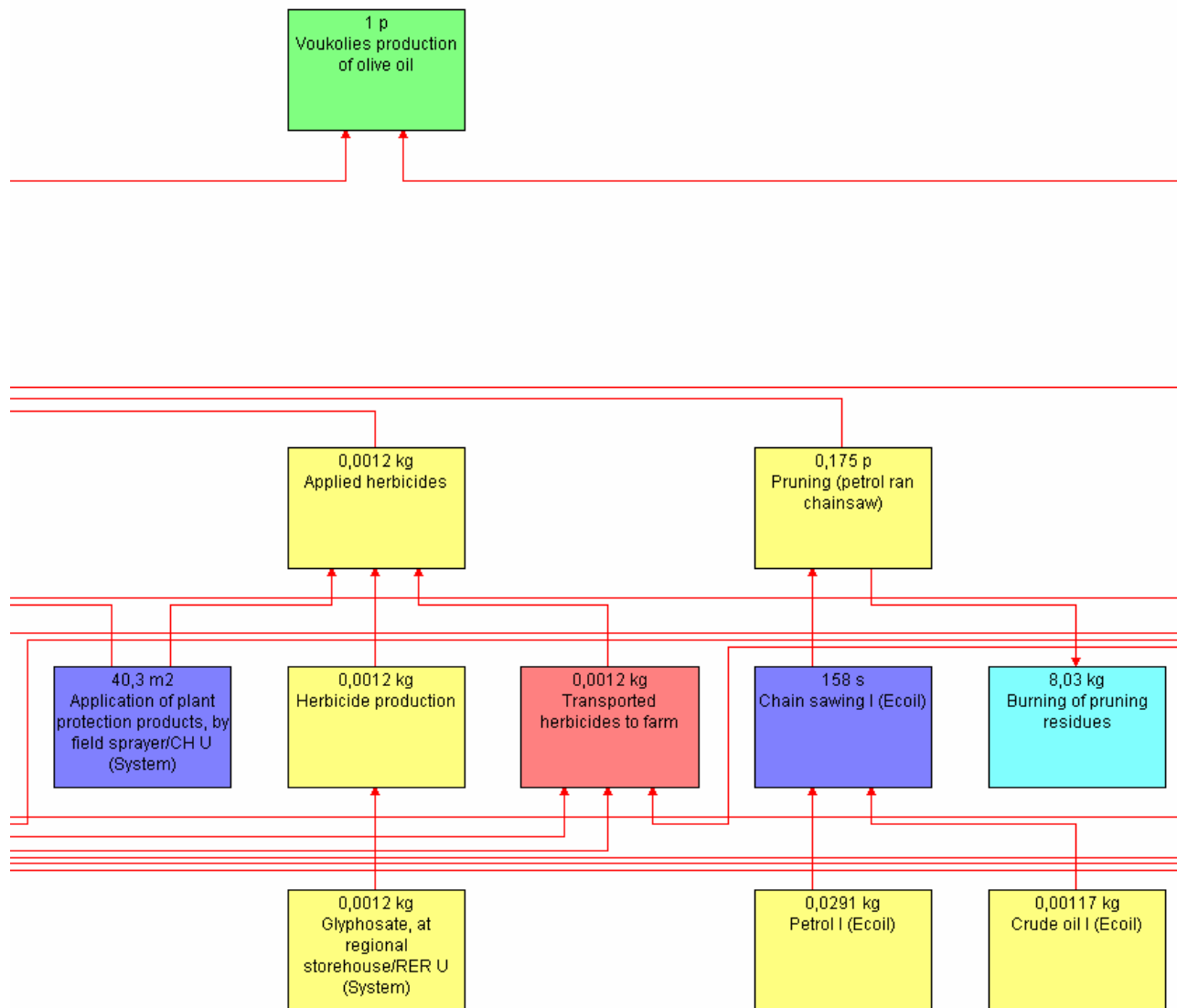


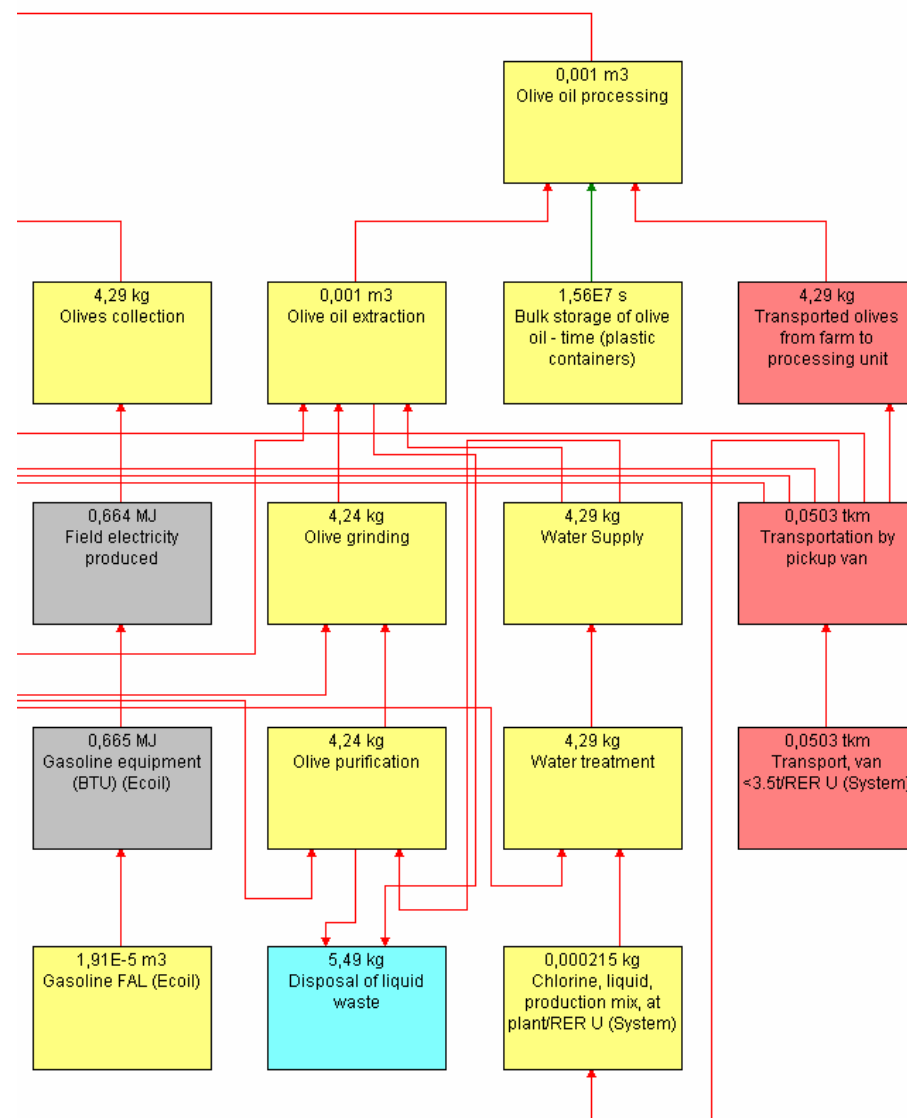
7 Appendix C :Polemarchi (Voukolies) Olive Oil Life Cycle Network Diagram











8 Appendix D: Polermarchi (Voukolies) Olive Oil Life Cycle Inventory

No	Substance	Compartment	Unit	Total	Olive Agriculture	Olive oil processing
1	Aluminium, 24% in bauxite, 11% in crude ore, in ground	Raw	mg	10,6	10,1	4,96E-01
2	Anhydrite, in ground	Raw	µg	1,81	0,951	8,56E-01
3	Barite, 15% in crude ore, in ground	Raw	mg	1,65	1,16	4,93E-01
4	Basalt, in ground	Raw	µg	96,3	93	3,25
5	Bauxite, in ground	Raw	mg	1,40E+01	1,40E+01	-2,23E-15
6	Borax, in ground	Raw	ng	354	342	1,13E+01
7	Calcite, in ground	Raw	g	17,9	16,2	1,63E+00
8	Carbon dioxide, in air	Raw	oz	-111	-111	9,86E-04
9	Chromium, 25.5 in chromite, 11.6% in crude ore, in ground	Raw	µg	451	436	1,47E+01
10	Chrysotile, in ground	Raw	µg	16,7	11,3	5,41E+00
11	Cinnabar, in ground	Raw	µg	1,54	1,04	0,498
12	Clay, bentonite, in ground	Raw	mg	4,77	4,61	1,66E-01
13	Clay, unspecified, in ground	Raw	mg	57,7	57,1	6,16E-01
14	Coal, 26.4 MJ per kg, in ground	Raw	mg	251	251	-4,30E-14
15	Coal, 29.3 MJ per kg, in ground	Raw	mg	39,8	39,8	-1,83E-15
16	Coal, brown, in ground	Raw	g	21,1	20,4	0,698
17	Coal, hard, unspecified, in ground	Raw	g	1,73E+01	1,69E+01	3,95E-01
18	Cobalt, in ground	Raw	ng	794	574	2,20E+02
19	Colemanite, in ground	Raw	µg	8,58	8,3	2,83E-01
20	Copper, 0.99% in sulfide, Cu 0.36% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	2,72	2,51	2,10E-01
21	Copper, 1.18% in sulfide, Cu 0.39% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	14,1	13,2	9,56E-01
22	Copper, 1.42% in sulfide, Cu 0.81% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	3,74	3,48	2,53E-01
23	Copper, 2.19% in sulfide, Cu 1.83% and Mo 8.2E-3% in crude ore, in ground	Raw	µg	18,6	17,3	1,26
24	Diatomite, in ground	Raw	pg	387	374	1,27E+01
25	Dolomite, in ground	Raw	µg	8,63	7,96	6,71E-01



26	Energy, gross calorific value, in biomass	Raw	kJ	17,1	16,8	3,14E-01
27	Energy, kinetic, flow, in wind	Raw	kJ	15,5	15	0,511
28	Energy, potential, stock, in barrage water	Raw	kJ	102	99	2,97
29	Energy, solar	Raw	J	2,05E+02	1,99E+02	6,74E+00
30	Energy, unspecified	Raw	kJ	101	101	-1,87E-14
31	Feldspar, in ground	Raw	ng	1,81	1,45	3,53E-01
32	Fluorine, 4.5% in apatite, 1% in crude ore, in ground	Raw	mg	2,93	2,9	0,0221
33	Fluorine, 4.5% in apatite, 3% in crude ore, in ground	Raw	g	8,68	8,68	9,69E-06
34	Fluorspar, 92%, in ground	Raw	mg	75,1	74,5	5,94E-01
35	Gas, mine, off-gas, process, coal mining/m3	Raw	cm3	170	166	3,88
36	Gas, natural, 30.3 MJ per kg, in ground	Raw	mg	445	445	-1,52E-14
37	Gas, natural, 36.6 MJ per m3, in ground	Raw	cu.in	115	115	-2,13E-14
38	Gas, natural, 46.8 MJ per kg, in ground	Raw	g	1,04	1,04	-1,77E-16
39	Gas, natural, in ground	Raw	dm3	147	145	2,06
40	Granite, in ground	Raw	ng	30,2	29,1	1,08
41	Gravel, in ground	Raw	g	1,65E+00	1,64E+00	3,09E-03
42	Gypsum, in ground	Raw	µg	9,27	8,64	6,33E-01
43	Iron ore, in ground	Raw	mg	6,64	6,64	-1,07E-15
44	Iron, 46% in ore, 25% in crude ore, in ground	Raw	mg	3,10E+00	2,95E+00	1,55E-01
45	Kaolinite, 24% in crude ore, in ground	Raw	µg	125	122	2,96
46	Kieserite, 25% in crude ore, in ground	Raw	ng	384	374	9,88E+00
47	Lead, 5%, in sulfide, Pb 2.97% and Zn 5.34% in crude ore, in ground	Raw	µg	43	42	0,991
48	Limestone, in ground	Raw	mg	15,4	15,4	-2,50E-15
49	Magnesite, 60% in crude ore, in ground	Raw	µg	84,3	82,9	1,43
50	Magnesium, 0.13% in water	Raw	pg	413	401	12
51	Manganese, 35.7% in sedimentary deposit, 14.2% in crude ore, in ground	Raw	µg	7,1	6,84	0,257
52	Molybdenum, 0.010% in sulfide, Mo 8.2E-3% and Cu 1.83% in crude ore, in ground	Raw	ng	345	322	23,4

53	Molybdenum, 0.014% in sulfide, Mo 8.2E-3% and Cu 0.81% in crude ore, in ground	Raw	ng	4,91E+01	4,58E+01	3,33E+00
54	Molybdenum, 0.022% in sulfide, Mo 8.2E-3% and Cu 0.36% in crude ore, in ground	Raw	µg	9,06	8,1	9,67E-01
55	Molybdenum, 0.025% in sulfide, Mo 8.2E-3% and Cu 0.39% in crude ore, in ground	Raw	ng	180	168	12,2
56	Molybdenum, 0.11% in sulfide, Mo 4.1E-2% and Cu 0.36% in crude ore, in ground	Raw	µg	1,83E+01	1,63E+01	1,95E+00
57	Nickel, 1.13% in sulfide, Ni 0.76% and Cu 0.76% in crude ore, in ground	Raw	mg	52,6	52,6	0,0295
58	Nickel, 1.98% in silicates, 1.04% in crude ore, in ground	Raw	µg	759	734	2,53E+01
59	Occupation, arable, non-irrigated	Raw	mm2a	0,274	0,265	0,00875
60	Occupation, construction site	Raw	mm2a	200	200	0,11
61	Occupation, dump site	Raw	mm2a	748	746	2,37
62	Occupation, dump site, benthos	Raw	mm2a	0,0176	0,0174	0,000257
63	Occupation, forest, intensive	Raw	mm2a	10,1	9,84	0,232
64	Occupation, forest, intensive, normal	Raw	mm2a	145	140	4,72
65	Occupation, industrial area	Raw	mm2a	2,30E+02	2,28E+02	1,77E+00
66	Occupation, industrial area, benthos	Raw	mm2a	1,58E-04	1,56E-04	2,28E-06
67	Occupation, industrial area, built up	Raw	mm2a	1,01E-01	9,80E-02	3,52E-03
68	Occupation, industrial area, vegetation	Raw	mm2a	0,0391	0,0378	0,00129
69	Occupation, mineral extraction site	Raw	cm2a	11,3	11,3	0,0196
70	Occupation, permanent crop, fruit	Raw	m2a	8,43	8,43	-1,20E-15
71	Occupation, permanent crop, fruit, intensive	Raw	mm2a	292	292	0,155
72	Occupation, shrub land, sclerophyllous	Raw	mm2a	107	107	0,0162
73	Occupation, traffic area, rail embankment	Raw	mm2a	4,54E-02	4,39E-02	1,56E-03
74	Occupation, traffic area, rail network	Raw	mm2a	0,0503	0,0485	0,00172
75	Occupation, traffic area, road embankment	Raw	mm2a	1,6	1,55	5,07E-02



76	Occupation, traffic area, road network	Raw	mm2a	0,204	0,201	0,00361
77	Occupation, urban, discontinuously built	Raw	mm2a	8,90E-06	8,70E-06	1,99E-07
78	Occupation, water bodies, artificial	Raw	mm2a	1,23E+02	1,19E+02	3,84E+00
79	Occupation, water courses, artificial	Raw	mm2a	6,18E+01	5,99E+01	1,91E+00
80	Oil, crude, in ground	Raw	g	2,04E+02	1,62E+02	4,19E+01
81	Olivine, in ground	Raw	ng	577	306	272
82	Pd, Pd 2.0E-4%, Pt 4.8E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	ng	323	193	129
83	Pd, Pd 7.3E-4%, Pt 2.5E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	ng	775	464	311
84	Peat, in ground	Raw	µg	154	153	1,20E+00
85	Phosphorus, 18% in apatite, 12% in crude ore, in ground	Raw	g	3,46E+01	3,46E+01	3,87E-05
86	Phosphorus, 18% in apatite, 4% in crude ore, in ground	Raw	mg	11,7	11,6	0,0884
87	Pt, Pt 2.5E-4%, Pd 7.3E-4%, Rh 2.0E-5%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	ng	7,43	4,45	2,98E+00
88	Pt, Pt 4.8E-4%, Pd 2.0E-4%, Rh 2.4E-5%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	ng	26,6	15,9	10,7
89	Rh, Rh 2.0E-5%, Pt 2.5E-4%, Pd 7.3E-4%, Ni 2.3E+0%, Cu 3.2E+0% in ore, in ground	Raw	ng	7,38E+00	4,42E+00	2,96E+00
90	Rh, Rh 2.4E-5%, Pt 4.8E-4%, Pd 2.0E-4%, Ni 3.7E-2%, Cu 5.2E-2% in ore, in ground	Raw	ng	2,31E+01	1,38E+01	9,27E+00
91	Rhenium, in crude ore, in ground	Raw	ng	19,8	8,52	11,3
92	Rutile, in ground	Raw	ng	1,81E+00	1,45E+00	3,52E-01
93	Sand, unspecified, in ground	Raw	µg	31,3	27,9	3,32
94	Shale, in ground	Raw	µg	5,12	2,7	2,42
95	Silver, 0.01% in crude ore, in ground	Raw	pg	7,48E+01	7,32E+01	1,55E+00
96	Sodium chloride, in ground	Raw	mg	796	605	1,91E+02
97	Sodium sulphate, various forms, in ground	Raw	mg	24,5	24,3	1,85E-01
98	Stibnite, in ground	Raw	pg	40,2	38,9	1,32



99	Sulfur, in ground	Raw	µg	34,1	22	12,1
100	Sylvite, 25 % in sylvinite, in ground	Raw	g	140	140	2,09E-05
101	Talc, in ground	Raw	µg	1,61E+01	1,57E+01	3,70E-01
102	Tin, 79% in cassiterite, 0.1% in crude ore, in ground	Raw	ng	9,76E+01	9,47E+01	2,98E+00
103	TiO ₂ , 45-60% in Ilmenite, in ground	Raw	mg	46,3	45,9	0,389
104	Transformation, from arable	Raw	mm ²	0,00219	0,00209	9,99E-05
105	Transformation, from arable, non-irrigated	Raw	mm ²	0,504	0,487	0,0161
106	Transformation, from arable, non-irrigated, fallow	Raw	mm ²	0,000684	0,000653	3,16E-05
107	Transformation, from dump site, inert material landfill	Raw	mm ²	1,75E-03	1,70E-03	4,83E-05
108	Transformation, from dump site, residual material landfill	Raw	mm ²	21,3	21,3	0,00173
109	Transformation, from dump site, sanitary landfill	Raw	mm ²	0,0189	0,0176	1,29E-03
110	Transformation, from dump site, slag compartment	Raw	mm ²	0,000904	0,000721	0,000182
111	Transformation, from forest	Raw	mm ²	0,163	0,152	0,0113
112	Transformation, from forest, extensive	Raw	mm ²	7,02	6,98	4,10E-02
113	Transformation, from industrial area	Raw	mm ²	1,36E-01	1,19E-01	1,77E-02
114	Transformation, from industrial area, benthos	Raw	mm ²	1,44E-06	1,42E-06	1,93E-08
115	Transformation, from industrial area, built up	Raw	mm ²	0,00418	0,00415	3,16E-05
116	Transformation, from industrial area, vegetation	Raw	mm ²	0,00713	0,00708	5,39E-05
117	Transformation, from mineral extraction site	Raw	mm ²	54,2	54,1	0,041
118	Transformation, from pasture and meadow	Raw	mm ²	74,8	74,8	3,06E-02
119	Transformation, from pasture and meadow, intensive	Raw	mm ²	4,06E-04	3,93E-04	1,30E-05
120	Transformation, from sea and ocean	Raw	mm ²	0,0177	0,0174	0,000257
121	Transformation, from shrub land, sclerophyllous	Raw	mm ²	21,7	21,7	1,52E-02
122	Transformation, from unknown	Raw	mm ²	3,77	3,68	8,99E-02
123	Transformation, to	Raw	mm ²	0,928	0,898	0,0297

	arable					
124	Transformation, to arable, non-irrigated	Raw	mm2	0,504	0,488	1,61E-02
125	Transformation, to arable, non-irrigated, fallow	Raw	mm2	9,49E-04	9,13E-04	3,63E-05
126	Transformation, to dump site	Raw	mm2	8,99E-01	8,80E-01	1,89E-02
127	Transformation, to dump site, benthos	Raw	mm2	0,0176	0,0174	0,000257
128	Transformation, to dump site, inert material landfill	Raw	mm2	0,00175	0,0017	4,83E-05
129	Transformation, to dump site, residual material landfill	Raw	mm2	21,3	21,3	1,73E-03
130	Transformation, to dump site, sanitary landfill	Raw	mm2	0,0189	0,0176	1,29E-03
131	Transformation, to dump site, slag compartment	Raw	mm2	9,04E-04	7,21E-04	1,82E-04
132	Transformation, to forest	Raw	mm2	21,6	21,6	1,42E-02
133	Transformation, to forest, intensive	Raw	mm2	0,0671	0,0655	1,54E-03
134	Transformation, to forest, intensive, normal	Raw	mm2	1,12	1,08	3,64E-02
135	Transformation, to heterogeneous, agricultural	Raw	mm2	0,00153	0,0015	2,46E-05
136	Transformation, to industrial area	Raw	mm2	0,561	0,539	0,0222
137	Transformation, to industrial area, benthos	Raw	mm2	1,00E-05	9,81E-06	2,26E-07
138	Transformation, to industrial area, built up	Raw	mm2	2,67E-02	2,60E-02	6,27E-04
139	Transformation, to industrial area, vegetation	Raw	mm2	0,00448	0,00443	5,40E-05
140	Transformation, to mineral extraction site	Raw	mm2	54,8	54,8	0,0501
141	Transformation, to pasture and meadow	Raw	mm2	53	53	3,31E-04
142	Transformation, to permanent crop, fruit, intensive	Raw	mm2	5,83	5,82	2,61E-03
143	Transformation, to sea and ocean	Raw	mm2	1,44E-06	1,42E-06	1,93E-08
144	Transformation, to shrub land, sclerophyllous	Raw	mm2	21,4	21,3	3,24E-03
145	Transformation, to traffic area, rail embankment	Raw	mm2	0,000106	0,000102	3,62E-06

146	Transformation, to traffic area, rail network	Raw	mm2	0,000116	0,000112	3,98E-06
147	Transformation, to traffic area, road embankment	Raw	mm2	0,0122	0,0118	0,000386
148	Transformation, to traffic area, road network	Raw	mm2	0,00218	0,00215	3,79E-05
149	Transformation, to unknown	Raw	mm2	0,146	0,128	1,78E-02
150	Transformation, to urban, discontinuously built	Raw	mm2	1,77E-07	1,73E-07	3,97E-09
151	Transformation, to water bodies, artificial	Raw	mm2	0,896	0,87	2,52E-02
152	Transformation, to water courses, artificial	Raw	mm2	0,765	0,741	0,0236
153	Ulexite, in ground	Raw	ng	6,43	6,3	1,33E-01
154	Uranium, 2291 GJ per kg, in ground	Raw	µg	1,01	1,01	-1,72E-16
155	Uranium, in ground	Raw	mg	1,09	1,05	0,0361
156	Vermiculite, in ground	Raw	ng	2,64	2,21	0,43
157	Volume occupied, final repository for low-active radioactive waste	Raw	mm3	2,26	2,18	0,0744
158	Volume occupied, final repository for radioactive waste	Raw	mm3	0,568	0,549	1,87E-02
159	Volume occupied, reservoir	Raw	l*day	579	563	15,9
160	Volume occupied, underground deposit	Raw	mm3	5,16	4,81	0,356
161	Water, cooling, unspecified natural origin/m3	Raw	dm3	30,2	18,3	1,19E+01
162	Water, lake	Raw	cm3	1,73	1,56	1,63E-01
163	Water, river	Raw	cm3	991	874	1,17E+02
164	Water, salt, ocean	Raw	cm3	218	203	15,2
165	Water, salt, sole	Raw	cm3	120	86,5	3,32E+01
166	Water, turbine use, unspecified natural origin	Raw	dm3	646	626	2,00E+01
167	Water, unspecified natural origin/kg	Raw	oz	151	0,0999	1,51E+02
168	Water, unspecified natural origin/m3	Raw	dm3	252	252	0,0759
169	Water, well, in ground	Raw	cm3	765	761	3,98E+00
170	Wood and wood waste, 9.5 MJ per kg	Raw	mg	10,6	10,6	-1,82E-15
171	Wood, hard, standing	Raw	mm3	256	248	8,38
172	Wood, soft, standing	Raw	mm3	680	658	22,1
173	Wood, unspecified, standing/m3	Raw	mm3	0,00268	0,00202	0,000661
174	Zinc 9%, in sulfide, Zn 5.34% and Pb 2.97% in	Raw	µg	62,2	52,9	9,31E+00



	crude ore, in ground					
175	Acenaphthene	Air	pg	141	137	4,65E+00
176	Acetaldehyde	Air	µg	770	526	244
177	Acetic acid	Air	g	16,9	16,9	1,01E-03
178	Acetone	Air	µg	774	529	2,45E+02
179	Acrolein	Air	ng	89,5	84,7	4,83E+00
180	Actinides, radioactive, unspecified	Air	nBq	24,1	23,3	0,798
181	Aerosols, radioactive, unspecified	Air	µBq	465	450	1,54E+01
182	Aldehydes, unspecified	Air	g	24,1	24,1	8,79E-08
183	Aluminum	Air	mg	83,9	83,8	5,40E-02
184	Ammonia	Air	g	13,4	13,4	1,14E-03
185	Ammonium carbonate	Air	ng	5,13	1,74	3,40E+00
186	Anthracene	Air	mg	80,3	80,3	-1,14E-14
187	Antimony	Air	ng	643	628	1,59E+01
188	Antimony-124	Air	nBq	2,34	2,27	7,16E-02
189	Antimony-125	Air	nBq	24,4	23,7	7,48E-01
190	Argon-41	Air	mBq	295	285	9,75E+00
191	Arsenic	Air	µg	70,5	50,5	2,00E+01
192	Barium	Air	µg	21,1	20,9	0,226
193	Barium-140	Air	µBq	1,59	1,54	0,0486
194	Benzaldehyde	Air	ng	36,4	34,1	2,34E+00
195	Benzene	Air	g	18,5	18,5	4,24E-03
196	Benzene, ethyl-	Air	µg	241	153	8,78E+01
197	Benzene, hexachloro-	Air	pg	128	106	2,19E+01
198	Benzene, pentachloro-	Air	pg	264	211	5,33E+01
199	Benzo(a)anthracene	Air	mg	9,63	9,63	-1,37E-15
200	Benzo(a)pyrene	Air	mg	21,3	21,3	7,16E-05
201	Benzo(b)fluoranthene	Air	mg	22,5	22,5	-3,19E-15
202	Benzo(ghi)perylene	Air	mg	44,3	44,3	-6,30E-15
203	Beryllium	Air	ng	280	215	6,52E+01
204	Boron	Air	µg	725	702	2,22E+01
205	Bromine	Air	mg	3,94	3,93	0,00137
206	Butadiene	Air	pg	56,8	34	2,28E+01
207	Butane	Air	mg	13,1	10,6	2,46
208	Butene	Air	µg	203	148	5,57E+01
209	Cadmium	Air	µg	91,4	80,5	1,08E+01
210	Calcium	Air	mg	76,4	76,3	4,18E-02
211	Carbon-14	Air	Bq	1,94	1,88	6,41E-02
212	Carbon dioxide, biogenic	Air	g	1,13	1,09	4,45E-02
213	Carbon dioxide, fossil	Air	oz	66,3	61,4	4,86
214	Carbon disulfide	Air	µg	344	340	4,26
215	Carbon monoxide	Air	oz	64,7	64,7	-9,22E-15
216	Carbon monoxide, biogenic	Air	µg	182	174	7,34E+00
217	Carbon monoxide, fossil	Air	g	1,51	0,547	0,961
218	Catechol	Air	g	4,01	4,01	-5,70E-16
219	Cerium-141	Air	nBq	385	373	11,8
220	Cesium-134	Air	nBq	18,4	17,9	5,65E-01



221	Cesium-137	Air	nBq	327	317	1,00E+01
222	Chlorine	Air	mg	883	883	7,40E-03
223	Chloroform	Air	ng	20,4	19,7	6,69E-01
224	Chromium	Air	mg	12,2	12,2	3,57E-02
225	Chromium-51	Air	nBq	24,7	23,9	0,756
226	Chromium VI	Air	µg	1,48	1,1	3,76E-01
227	Chrysene	Air	mg	42,2	42,2	-5,99E-15
228	Cobalt	Air	µg	310	206	1,04E+02
229	Cobalt-58	Air	nBq	34,4	33,3	1,05E+00
230	Cobalt-60	Air	nBq	304	294	9,29
231	Copper	Air	mg	33,3	33,2	0,154
232	Cumene	Air	µg	9,35	7,46	1,89E+00
233	Cyanide	Air	µg	3,6	3,5	9,63E-02
234	Deltamethrin	Air	mg	3,60E+02	3,60E+02	-5,11E-14
235	Desmedipham	Air	mg	5,22	5,22	-7,41E-16
236	Dibenz(a,h)anthracene	Air	mg	8,11	8,11	-1,15E-15
237	Dinitrogen monoxide	Air	g	4,19	4,17	0,0136
238	Dioxins, measured as 2,3,7,8- tetrachlorodibenzo-p- dioxin	Air	pg	34,6	22,1	1,25E+01
239	Ethane	Air	mg	26,4	2,56E+01	8,56E-01
240	Ethane, 1,1,1,2- tetrafluoro-, HFC-134a	Air	µg	83,3	82,8	4,79E-01
241	Ethane, 1,2-dichloro-	Air	µg	257	257	6,40E-02
242	Ethane, 1,2-dichloro- 1,1,2,2-tetrafluoro-, CFC-114	Air	ng	451	436	14,8
243	Ethane, hexafluoro-, HFC-116	Air	ng	25,3	24,7	0,601
244	Ethanol	Air	mg	1,55	1,05	4,99E-01
245	Ethene	Air	µg	759	647	1,13E+02
246	Ethene, chloro-	Air	ng	8,27E+02	8,03E+02	2,35E+01
247	Ethene, tetrachloro-	Air	ng	8,91	8,91	-1,53E-15
248	Ethene, trichloro-	Air	ng	8,68	8,68	-1,49E-15
249	Ethylene diamine	Air	pg	11,2	10,9	0,259
250	Ethylene oxide	Air	ng	135	110	24,6
251	Ethyne	Air	µg	58	5,79E+01	3,41E-02
252	Fluoranthene	Air	mg	161	161	-2,28E-14
253	Fluorene	Air	mg	68,2	68,2	-9,69E-15
254	Fluorine	Air	ng	3,90E+02	3,63E+02	2,71E+01
255	Fluosilicic acid	Air	ng	29,5	28,8	0,703
256	Formaldehyde	Air	mg	12,7	12	7,50E-01
257	Formic acid	Air	mg	562	562	-7,98E-14
258	Furan	Air	g	7,47	7,47	-1,06E-15
259	Glyphosate	Air	mg	600	6,00E+02	5,16E-28
260	Heat, waste	Air	MJ	12,1	10,9	1,19E+00
261	Helium	Air	µg	388	290	9,78E+01
262	Heptane	Air	mg	2,03	1,47	0,557
263	Hexane	Air	mg	4,51	3,3	1,21E+00
264	Hydrocarbons, aliphatic, alkanes, cyclic	Air	ng	3,82	3,4	4,19E-01



265	Hydrocarbons, aliphatic, alkanes, unspecified	Air	mg	5,86	3,95	1,91E+00
266	Hydrocarbons, aliphatic, unsaturated	Air	µg	4,92E+02	2,86E+02	2,06E+02
267	Hydrocarbons, aromatic	Air	mg	1,24	1,07	0,17
268	Hydrocarbons, chlorinated	Air	µg	1,54	1,53	1,19E-02
269	Hydrocarbons, unspecified	Air	g	10,6	10,6	-1,96E-15
270	Hydrogen	Air	mg	2,52	2,44	0,077
271	Hydrogen-3, Tritium	Air	Bq	11,2	1,08E+01	3,70E-01
272	Hydrogen chloride	Air	mg	12,1	11,8	2,41E-01
273	Hydrogen fluoride	Air	mg	7,06	6,99	6,83E-02
274	Hydrogen sulfide	Air	mg	3,54	3,54	0,0042
275	Iodine	Air	µg	23,9	23,1	7,48E-01
276	Iodine-129	Air	mBq	1,97	1,9	6,51E-02
277	Iodine-131	Air	mBq	117	113	3,86E+00
278	Iodine-133	Air	µBq	1,9	1,84	0,0582
279	Iron	Air	mg	2,23E+01	2,23E+01	8,92E-02
280	Isocyanic acid	Air	ng	7,55	7,39	1,61E-01
281	Kerosene	Air	ng	203	203	-3,48E-14
282	Krypton-85	Air	mBq	922	892	3,05E+01
283	Krypton-85m	Air	mBq	37,7	36,5	1,19E+00
284	Krypton-87	Air	mBq	16,3	1,58E+01	5,27E-01
285	Krypton-88	Air	mBq	15,5	15	0,496
286	Krypton-89	Air	mBq	3,59	3,48	0,112
287	Lanthanum-140	Air	nBq	136	132	4,16
288	Lead	Air	mg	12,8	12,7	1,02E-01
289	Lead-210	Air	mBq	249	249	2,83E-01
290	m-Xylene	Air	ng	824	797	2,69E+01
291	Magnesium	Air	mg	1,33E+01	1,33E+01	4,13E-04
292	Manganese	Air	mg	16,4	16,4	3,22E-02
293	Manganese-54	Air	nBq	12,6	12,3	3,87E-01
294	Mercury	Air	µg	4,99	4,26	7,26E-01
295	Metals, unspecified	Air	µg	22,4	22,4	-2,99E-15
296	Methane	Air	g	157	1,57E+02	1,21E-01
297	Methane, biogenic	Air	mg	10,7	10,7	2,20E-02
298	Methane, bromochlorodifluoro-, Halon 1211	Air	µg	7,19	7,17	1,70E-02
299	Methane, bromotrifluoro-, Halon 1301	Air	µg	5,33	3,89	1,44
300	Methane, chlorodifluoro-, HCFC-22	Air	µg	25,3	25,2	7,12E-02
301	Methane, dichloro-, HCC-30	Air	ng	41,7	41,7	2,03E-02
302	Methane, dichlorodifluoro-, CFC-12	Air	ng	80,5	80,3	2,12E-01
303	Methane, dichlorofluoro-, HCFC-21	Air	pg	3,34E-05	3,20E-05	1,41E-06



304	Methane, fossil	Air	g	1,13	1,06	7,48E-02
305	Methane, monochloro-, R-40	Air	pg	0,0021	0,00203	6,38E-05
306	Methane, tetrachloro-, CFC-10	Air	ng	924	430	4,94E+02
307	Methane, tetrafluoro-, FC-14	Air	ng	227	222	5,41
308	Methane, trichlorofluoro-, CFC-11	Air	pg	5,43E-05	5,20E-05	2,29E-06
309	Methane, trifluoro-, HFC-23	Air	pg	0,0106	0,0102	4,48E-04
310	Methanol	Air	mg	5,05	4,52	5,39E-01
311	Molybdenum	Air	µg	77,6	54,7	22,9
312	Monoethanolamine	Air	ng	129	125	4,27E+00
313	N-Nitrodimethylamine	Air	ng	1,92	1,92	-3,29E-16
314	Naphthalene	Air	g	7,39	7,39	-1,05E-15
315	Nickel	Air	mg	6,98	6,15	0,829
316	Niobium-95	Air	nBq	1,5	1,45	4,59E-02
317	Nitrate	Air	ng	103	101	2,39E+00
318	Nitrogen oxides	Air	g	8,22	7,86	3,59E-01
319	NMVOC, non-methane volatile organic compounds, unspecified origin	Air	mg	839	712	127
320	Noble gases, radioactive, unspecified	Air	Bq	1,89E+04	1,83E+04	6,25E+02
321	Organic substances, unspecified	Air	µg	594	594	-1,02E-13
322	Ozone	Air	µg	607	587	19,8
323	PAH, polycyclic aromatic hydrocarbons	Air	µg	80,6	77,7	2,88
324	Paraffins	Air	pg	0,4	0,387	1,36E-02
325	Particulates, < 10 µm	Air	mg	14,8	14,8	-2,53E-15
326	Particulates, < 2.5 µm	Air	mg	329	284	44,5
327	Particulates, > 10 µm	Air	mg	404	363	4,15E+01
328	Particulates, > 2.5 µm, and < 10µm	Air	mg	208	189	19,1
329	Particulates, SPM	Air	mg	11	11	-1,66E-15
330	Particulates, unspecified	Air	mg	3,24	3,24	-5,55E-16
331	Pentane	Air	mg	16,1	13,1	3,02
332	Phenanthrene	Air	mg	161	161	-2,28E-14
333	Phenol	Air	g	21	4,01	1,70E+01
334	Phenol, pentachloro-	Air	ng	702	679	23,2
335	Phosphorus	Air	µg	10,2	10	0,124
336	Platinum	Air	ng	1,11	0,164	9,47E-01
337	Plutonium-238	Air	nBq	0,269	0,26	8,88E-03
338	Plutonium-alpha	Air	nBq	0,616	0,595	0,0204
339	Polonium-210	Air	mBq	280	280	4,95E-01
340	Polychlorinated biphenyls	Air	pg	42,2	40,8	1,36
341	Potassium	Air	mg	321	321	5,45E-03
342	Potassium-40	Air	mBq	6,03	5,97	0,0575
343	Propanal	Air	ng	36,4	34,1	2,34E+00



344	Propane	Air	mg	17,1	14,5	2,54
345	Propene	Air	µg	474	362	112
346	Propionic acid	Air	µg	84,7	84,5	0,131
347	Propylene oxide	Air	ng	518	334	185
348	Protactinium-234	Air	µBq	267	258	8,81
349	Pyrene	Air	mg	161	161	-2,28E-14
350	Radioactive species, other beta emitters	Air	µBq	634	613	20,8
351	Radioactive species, unspecified	Air	Bq	13,8	13,8	-2,36E-15
352	Radium-226	Air	mBq	412	411	0,357
353	Radium-228	Air	mBq	8,16	8,14	2,51E-02
354	Radon-220	Air	µBq	116	116	0,0591
355	Radon-222	Air	kBq	35,7	34,5	1,17E+00
356	Ruthenium-103	Air	nBq	0,33	0,32	0,0101
357	Scandium	Air	ng	146	146	0,0744
358	Selenium	Air	µg	60	44,5	15,4
359	Silicon	Air	mg	162	162	0,00173
360	Silicon tetrafluoride	Air	ng	88,5	87,8	0,668
361	Silver	Air	ng	5,3	5,29	4,24E-03
362	Silver-110	Air	nBq	3,27	3,17	0,1
363	Sodium	Air	mg	82,7	82,3	0,384
364	Sodium chlorate	Air	ng	990	982	8,08
365	Sodium dichromate	Air	pg	519	507	12,1
366	Sodium formate	Air	ng	2,29	2,24	5,25E-02
367	Soot	Air	mg	70,1	70,1	-1,29E-14
368	Strontium	Air	µg	28,4	28,2	0,223
369	Styrene	Air	ng	8,93	8,64	0,296
370	Sulfate	Air	g	1,1	1,1	2,81E-05
371	Sulfur dioxide	Air	g	7,69	6,83	0,861
372	Sulfur hexafluoride	Air	µg	9,14	8,81	0,322
373	Sulfur oxides	Air	mg	73	73	-1,07E-14
374	t-Butyl methyl ether	Air	µg	8,97E+01	1,32E+01	7,65E+01
375	Thallium	Air	ng	185	185	1,53E-01
376	Thorium	Air	ng	220	220	0,112
377	Thorium-228	Air	mBq	1,67	1,66	0,0118
378	Thorium-230	Air	mBq	347	347	3,38E-02
379	Thorium-232	Air	mBq	4,63	4,61	0,0182
380	Thorium-234	Air	µBq	267	258	8,81
381	Tin	Air	ng	358	351	7,01
382	Titanium	Air	mg	12,2	12,2	2,31E-05
383	Toluene	Air	g	4,66	4,66	0,00386
384	Uranium	Air	ng	293	293	0,149
385	Uranium-234	Air	mBq	349	349	0,104
386	Uranium-235	Air	µBq	1,51E+02	1,46E+02	4,99E+00
387	Uranium-238	Air	mBq	354	354	1,51E-01
388	Uranium alpha	Air	mBq	14,6	14,1	0,481
389	Vanadium	Air	mg	26,9	23,9	2,95E+00
390	VOC, volatile organic compounds	Air	g	136	136	-1,94E-14
391	water	Air	lb	120	120	0,303
392	Xenon-131m	Air	mBq	74	71,6	2,38



393	Xenon-133	Air	Bq	2,32	2,24	0,0742
394	Xenon-133m	Air	mBq	1,09E+01	1,05E+01	3,58E-01
395	Xenon-135	Air	mBq	952	922	3,05E+01
396	Xenon-135m	Air	mBq	557	539	17,8
397	Xenon-137	Air	mBq	9,86	9,55	0,307
398	Xenon-138	Air	mBq	90,2	87,3	2,84E+00
399	Xylene	Air	mg	5,27	1,92	3,35
400	Zinc	Air	mg	35,3	35,1	0,143
401	Zinc-65	Air	nBq	63,1	61,2	1,93E+00
402	Zirconium	Air	pg	11,9	11,4	0,438
403	Zirconium-95	Air	nBq	61,7	59,8	1,89
404	Acenaphthene	Water	ng	60	43,4	16,6
405	Acenaphthylene	Water	ng	3,75	2,71	1,04
406	Acetic acid	Water	µg	1,89E+00	1,49E+00	3,97E-01
407	Acidity, unspecified	Water	µg	6,42	4,21	2,21E+00
408	Actinides, radioactive, unspecified	Water	mBq	3,20E+00	3,09	0,106
409	Aluminum	Water	mg	68,6	66	2,60E+00
410	Ammonia	Water	µg	318	318	-5,84E-14
411	Ammonium, ion	Water	mg	60,3	60,1	0,142
412	Antimony	Water	µg	24,9	23,7	1,21
413	Antimony-122	Water	nBq	944	915	28,9
414	Antimony-124	Water	µBq	503	486	16,5
415	Antimony-125	Water	µBq	430	416	14,1
416	AOX, Adsorbable Organic Halogen as Cl	Water	µg	18	10,7	7,35
417	Arsenic, ion	Water	mg	5,28	5,28	0,0028
418	Barite	Water	µg	11	10,8	1,60E-01
419	Barium	Water	mg	9,48E+00	7,12E+00	2,36E+00
420	Barium-140	Water	µBq	4,13E+00	4,01	1,27E-01
421	Benzene	Water	µg	676	491	1,85E+02
422	Benzene, ethyl-	Water	µg	231	167	64,1
423	Beryllium	Water	µg	8,37	8,12	0,253
424	BOD5, Biological Oxygen Demand	Water	g	8,62	1,51	7,11
425	Boron	Water	mg	1,54	1,48	0,0586
426	Bromate	Water	µg	88	59,4	2,85E+01
427	Bromine	Water	mg	6,8	4,93	1,87E+00
428	Butene	Water	ng	9,98E+02	997	0,598
429	Cadmium, ion	Water	mg	3,28	2,18	1,1
430	Calcium, ion	Water	g	87,3	87,1	0,146
431	Carbonate	Water	µg	6,10E+01	4,94E+01	1,16E+01
432	Carboxylic acids, unspecified	Water	mg	41,3	29,9	1,15E+01
433	Cerium-141	Water	µBq	1,65	1,6	5,06E-02
434	Cerium-144	Water	nBq	503	488	1,54E+01
435	Cesium	Water	µg	9,64	6,97	2,67
436	Cesium-134	Water	µBq	395	382	13
437	Cesium-136	Water	nBq	293	284	8,98
438	Cesium-137	Water	mBq	368	356	1,22E+01
439	Chlorate	Water	µg	721	502	2,19E+02
440	Chloride	Water	g	1,84E+02	183	1,37E+00



441	Chlorinated solvents, unspecified	Water	ng	232	169	63,5
442	Chlorine	Water	mg	17	0,00846	17
443	Chloroform	Water	pg	3,34E-05	3,20E-05	1,41E-06
444	Chromate	Water	ng	190	190	-3,25E-14
445	Chromium	Water	mg	1,1	0,00251	1,1
446	Chromium-51	Water	μBq	498	482	1,57E+01
447	Chromium VI	Water	μg	59,3	5,76E+01	1,76
448	Chromium, ion	Water	mg	2,18	2,17	0,0135
449	Cobalt	Water	μg	192	188	4,47
450	Cobalt-57	Water	μBq	9,31	9,03	0,285
451	Cobalt-58	Water	mBq	3,84	3,71E+00	0,124
452	Cobalt-60	Water	mBq	3	2,9	9,65E-02
453	COD, Chemical Oxygen Demand	Water	g	1,81E+01	1,54	16,6
454	Copper, ion	Water	mg	3,31	2,72	0,593
455	Crude oil	Water	μg	41,1	41,1	-7,58E-15
456	Cumene	Water	μg	22,5	17,9	4,54
457	Cyanide	Water	μg	37,8	32,6	5,19
458	Deltamethrin	Water	μg	660	660	-9,38E-14
459	Dichromate	Water	pg	654	6,22E+02	31,4
460	DOC, Dissolved Organic Carbon	Water	mg	649	474	1,75E+02
461	Ethane, 1,2-dichloro-	Water	μg	613	613	0,00819
462	Ethene	Water	μg	9,23	7,32	1,9
463	Ethene, chloro-	Water	ng	2,59	2,12E+00	0,473
464	Ethylene diamine	Water	pg	27	26,4	6,29E-01
465	Ethylene oxide	Water	pg	1,90E+02	183	6,28
466	Fluoride	Water	mg	894	893	0,405
467	Fluosilicic acid	Water	ng	53,1	5,19E+01	1,26
468	Formaldehyde	Water	μg	4,7	1,58	3,12
469	Glutaraldehyde	Water	ng	1,36	1,34	0,0198
470	Glyphosate	Water	mg	1,32	1,32	1,14E-30
471	Heat, waste	Water	kJ	662	367	2,95E+02
472	Hydrocarbons, aliphatic, alkanes, unspecified	Water	mg	1,25	0,907	3,47E-01
473	Hydrocarbons, aliphatic, unsaturated	Water	μg	116	83,7	32
474	Hydrocarbons, aromatic	Water	mg	5,12	3,71	1,41
475	Hydrocarbons, unspecified	Water	μg	864	803	60,3
476	Hydrogen	Water	μg	240	2,40E+02	-1,19E-14
477	Hydrogen-3, Tritium	Water	Bq	842	814	2,78E+01
478	Hydrogen peroxide	Water	ng	86,5	85,6	0,916
479	Hydrogen sulfide	Water	μg	152	8,77E+01	63,8
480	Hydroxide	Water	ng	1,26	1,23	0,026
481	Hypochlorite	Water	mg	1,54	0,722	0,817
482	Iodide	Water	μg	968	701	267
483	Iodine-131	Water	μBq	90,5	87,6	2,97E+00
484	Iodine-133	Water	μBq	2,6	2,52	0,0794
485	Iron	Water	mg	3,88	0,0366	3,84E+00
486	Iron-59	Water	nBq	714	692	21,8



487	Iron, ion	Water	mg	73,8	70,8	3,01
488	Lanthanum-140	Water	μBq	4,4	4,27E+00	0,135
489	Lead	Water	mg	1,93	1,9	2,94E-02
490	Lead-210	Water	Bq	225	225	0,00037
491	Magnesium	Water	g	2,86	2,82	0,0461
492	Manganese	Water	mg	5,33	4,10E+00	1,24
493	Manganese-54	Water	μBq	233	225	7,52
494	Mercury	Water	μg	303	303	0,223
495	Metallic ions, unspecified	Water	μg	407	407	-6,51E-14
496	Methane, dichloro-, HCC-30	Water	ng	18,7	18,4	0,297
497	Methanol	Water	μg	99,3	98,2	1,11E+00
498	Molybdenum	Water	μg	59,6	57,5	2,14
499	Molybdenum-99	Water	μBq	1,52	1,47	0,0465
500	Nickel	Water	mg	1,1	-9,21E-17	1,1
501	Nickel, ion	Water	mg	5,2	5,09E+00	0,104
502	Niobium-95	Water	μBq	29,8	28,8	0,974
503	Nitrate	Water	g	47,8	4,78E+01	0,000357
504	Nitrite	Water	μg	26,6	2,57E+01	0,903
505	Nitrogen	Water	g	1,43	0,046	1,38
506	Nitrogen, organic bound	Water	mg	2,29	1,83	0,46
507	Nitrogen, total	Water	μg	5,86	5,86E+00	x
508	Oils, unspecified	Water	mg	651	469	1,82E+02
509	Organic substances, unspecified	Water	μg	164	1,64E+02	-2,82E-14
510	PAH, polycyclic aromatic hydrocarbons	Water	μg	56,6	41,1	1,56E+01
511	Paraffins	Water	pg	1,16	1,12	3,95E-02
512	Phenol	Water	mg	385	0,684	3,85E+02
513	Phosphate	Water	g	3,8	3,80E+00	7,80E-05
514	Phosphorus	Water	g	4,49	4,43	0,0571
515	Polonium-210	Water	Bq	343	3,43E+02	0,000502
516	Potassium	Water	mg	268	-2,25E-14	268
517	Potassium-40	Water	Bq	27,2	27,2	0,000179
518	Potassium, ion	Water	g	2,33	2,32	0,0114
519	Propene	Water	μg	11,6	9,53E+00	2,02
520	Propylene oxide	Water	μg	1,25	0,803	4,44E-01
521	Protactinium-234	Water	mBq	4,94	4,78E+00	0,163
522	Radioactive species, alpha emitters	Water	mBq	121	121	7,57E-04
523	Radioactive species, Nuclides, unspecified	Water	Bq	1,92	1,85E+00	0,0634
524	Radium-224	Water	mBq	482	349	1,34E+02
525	Radium-226	Water	Bq	257	257	3,15E-01
526	Radium-228	Water	mBq	964	697	267
527	Rubidium	Water	μg	96,6	6,99E+01	26,7
528	Ruthenium-103	Water	nBq	320	311	9,80E+00
529	Scandium	Water	μg	18,1	1,77E+01	0,374
530	Selenium	Water	μg	17,4	16,5	8,81E-01
531	Silicon	Water	mg	520	503	16,6
532	Silver-110	Water	mBq	2,88	2,78	9,25E-02



533	Silver, ion	Water	µg	8,73	6,59E+00	2,14E+00
534	Sodium-24	Water	µBq	11,5	11,1	3,52E-01
535	Sodium formate	Water	ng	5,51	5,39E+00	0,126
536	Sodium, ion	Water	g	107	107	0,876
537	Solids, inorganic	Water	mg	86,7	83,9	2,79
538	Solved solids	Water	mg	327	327	9,22E-02
539	Strontium	Water	mg	58,9	4,28E+01	16,1
540	Strontium-89	Water	µBq	45	43,6	1,43E+00
541	Strontium-90	Water	Bq	3,22	3,11E+00	0,106
542	Sulfate	Water	g	223	222	2,55E-01
543	Sulfide	Water	µg	132	6,66E+01	65,6
544	Sulfite	Water	mg	3,97	1,86	2,11E+00
545	Sulfur	Water	mg	938	929	9,21E+00
546	Sulfuric acid	Water	µg	13,5	1,35E+01	-2,31E-15
547	Suspended solids, unspecified	Water	mg	278	2,73E+02	4,54
548	t-Butyl methyl ether	Water	µg	29,6	2,26E+01	7
549	Technetium-99m	Water	µBq	35,2	34,2	1,08
550	Tellurium-123m	Water	µBq	52,6	50,9	1,74E+00
551	Tellurium-132	Water	nBq	87,9	85,2	2,69
552	Thallium	Water	µg	9,22	4,87E+00	4,35
553	Thorium-228	Water	Bq	4,68	4,15E+00	5,34E-01
554	Thorium-230	Water	mBq	674	6,52E+02	2,23E+01
555	Thorium-232	Water	µBq	841	8,13E+02	2,77E+01
556	Thorium-234	Water	mBq	4,94	4,78	0,163
557	Tin, ion	Water	µg	44,6	4,29E+01	1,73E+00
558	Titanium, ion	Water	mg	2,66	2,60E+00	5,56E-02
559	TOC, Total Organic Carbon	Water	mg	657	4,80E+02	176
560	Toluene	Water	mg	1,23	9,02E-01	0,332
561	Tributyltin compounds	Water	µg	17,2	14,6	2,56
562	Triethylene glycol	Water	µg	81,2	81,1	0,146
563	Tungsten	Water	µg	14,9	1,45E+01	0,434
564	Uranium-234	Water	mBq	5,93	5,73E+00	0,196
565	Uranium-235	Water	mBq	9,78	9,46E+00	3,23E-01
566	Uranium-238	Water	Bq	115	1,15E+02	6,79E-04
567	Uranium alpha	Water	mBq	285	275	9,40E+00
568	Vanadium, ion	Water	µg	354	266	88
569	VOC, volatile organic compounds, unspecified origin	Water	mg	3,39	2,45E+00	9,35E-01
570	Water	Water	oz	189	-1,58E-14	1,89E+02
571	Xylene	Water	µg	992	718	274
572	Zinc	Water	mg	1,1	-9,21E-17	1,1
573	Zinc-65	Water	µBq	156	1,51E+02	4,77
574	Zinc, ion	Water	mg	8,89	8,4	0,486
575	Zirconium-95	Water	µBq	1,8	1,75E+00	0,0552
576	Impurities (leaves, dust, others)	Waste	g	50	5,28E-15	50
577	Mineral waste	Waste	mg	5,72	5,72E+00	-1,05E-15
578	Pomace	Waste	oz	74,8	4,94E-31	74,8
579	Slags	Waste	mg	16,1	16,1	-2,69E-16



580	Waste, final, inert	Waste	mg	12,9	1,29E+01	x
581	Waste, solid	Waste	mg	258	258	-4,42E-14
582	Wood ashes	Waste	g	36,1	36,1	-5,13E-15
583	Aclonifen	Soil	pg	322	3,05E+02	1,71E+01
584	Aluminum	Soil	µg	27,8	2,58E+01	1,93
585	Antimony	Soil	pg	0,778	7,52E-01	0,0257
586	Arsenic	Soil	ng	7,25	6,93	0,321
587	Atrazine	Soil	pg	77	75,3	1,78
588	Barium	Soil	ng	456	4,25E+02	31,2
589	Bentazone	Soil	pg	164	1,55E+02	8,69
590	Boron	Soil	ng	35,4	2,82E+01	7,28
591	Cadmium	Soil	mg	42,8	0,00113	4,28E+01
592	Calcium	Soil	g	2,13	2,79E-04	2,13
593	Carbetamide	Soil	pg	116	111	4,4
594	Carbon	Soil	µg	118	99,8	18
595	Chloride	Soil	µg	17,5	1,71E+01	4,10E-01
596	Chlorine	Soil	mg	664	-5,57E-14	664
597	Chlorothalonil	Soil	ng	57,5	56,2	1,33
598	Chromium	Soil	mg	48,3	3,88E-03	48,3
599	Chromium VI	Soil	ng	21,1	20,7	0,429
600	Cobalt	Soil	ng	20	1,89E+01	1,02
601	Copper	Soil	mg	18,7	0,0094	18,7
602	Cypermethrin	Soil	pg	4,19	4,06E+00	0,134
603	Deltamethrin	Soil	mg	226	2,26E+02	-3,21E-14
604	Dinoseb	Soil	ng	15,6	15,3	0,361
605	Fenpiclonil	Soil	ng	2,27	2,22E+00	0,0529
606	Fluoride	Soil	ng	51,3	50,4	0,877
607	Glyphosate	Soil	mg	599	599	1,12E-07
608	Heat, waste	Soil	kJ	8,89	8,64E+00	0,252
609	Iron	Soil	mg	180	38	142
610	Lead	Soil	mg	2,75	5,28E-03	2,75
611	Linuron	Soil	ng	2,49	2,36	0,132
612	Magnesium	Soil	g	1,2	3,14E-05	1,2
613	Mancozeb	Soil	ng	74,9	73,1	1,73
614	Manganese	Soil	mg	34,6	1,77E-02	34,6
615	Mercury	Soil	pg	748	6,60E+02	87,5
616	Metaldehyde	Soil	pg	36,3	35,2	1,16
617	Metolachlor	Soil	ng	18,1	1,71E+01	0,957
618	Metribuzin	Soil	ng	2,63	2,57	0,0608
619	Molybdenum	Soil	ng	5,53	5,13	0,396
620	Napropamide	Soil	pg	64,3	6,23E+01	2,06
621	Nickel	Soil	mg	32,9	0,00332	32,9
622	Nitrogen	Soil	g	53,5	-4,49E-15	53,5
623	Oils, biogenic	Soil	µg	1,69	1,64	0,055
624	Oils, unspecified	Soil	mg	825	633	193
625	Orbencarb	Soil	ng	14,2	13,9	0,328
626	Phenol	Soil	g	15,2	-1,27E-15	15,2
627	Phosphorus	Soil	g	2,22	8,60E-06	2,22
628	Pirimicarb	Soil	pg	15,6	14,7	0,824
629	Potassium	Soil	g	10,4	4,79E-05	10,4
630	Silicon	Soil	mg	96,7	0,0841	96,6



631	Silver	Soil	pg	66	63,8	2,24
632	Sodium	Soil	g	2,52	1,47E-06	2,52
633	Strontium	Soil	ng	326	233	93,1
634	Sulfur	Soil	mg	337	0,0147	337
635	Tebutam	Soil	pg	152	148	4,88
636	Teflubenzuron	Soil	pg	175	171	4,05
637	Tin	Soil	ng	9,18	7,98	1,2
638	Titanium	Soil	µg	1,25	1,21	0,0407
639	Vanadium	Soil	ng	35,7	34,5	1,17
640	Zinc	Soil	mg	38,1	2,18	35,9

