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A comparative life cycle assessment of organic and conventional wine

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Abstract

In this report, an attributional comparative Life Cycle Assessment (LCA) of an organic red wine from Spain and a conventional red wine from Italy was conducted in order to compare the impacts with respect to the hierarchical ReCiPe framework.

The relevant assemblies were two cradle-to-gate accounting LCAs of the two wines, through the production of the raw material, processing, packaging, and distribution. The assessed functional unit was one 750ml container of wine as part of a shipment of 6x6 wine bottles.

Analysis of the impact assessment results through categorization and normalization of the scores showed that the conventional wine had greater impacts throughout all the impact categories in the ReCiPe framework apart from agricultural land occupation. Different bottling scenarios also showed that using glass containers in the bottling phase generally has the highest impact scores, whilst carton has the lowest.

The significant processes in the assemblies were found to be the bottling, viticulture, and transport stage. Mitigating the effects by applying a suitable bottling scenario for the suggested product, and distributing locally would yield the greatest reduction in impact scores. Further study is needed to incorporate the heterogeneity of the production and processing phase of various conventional and organic vineyards.

Keywords: organic wine, organic agriculture, life cycle assessment, comparative

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1. Introduction

Production and consumption of agricultural products were once highly dependent on the surrounding ecosystem, climate, and biodiversity, which limited the natural outputs of an area. Advancements in agricultural methodology and technology allow more efficient food production and greater yields, almost independent of any seasonality or location. A wide range of environmental impacts has surged alongside these advances, such as ozone depletion, water scarcity, climate change, loss of biodiversity, and pollutants. As the demand and thus production increases, the environmental impacts are expected to increase alongside with it (Pimentel, 2004; Foster et al., 2006).

According to Kramer et al. (1999), food production is one of the most environmentally damaging activities, accounting for 15-20% of the world's total energy consumption. The wine sector is no exception, and as an important export in many countries (e.g. Spain and France), consumer interest in more environmentally friendly production over the entire product stage is increasing. Significant environmental impacts can be observed throughout the viticulture, vinification, and bottling process, as well as the packaging and international distribution processes (OIV, 2012).

It has been suggested that the production of organic wine could reduce the severity of the environmental impacts, as a regulated organic wine must be created from organically produced grapes, lacking pesticides or other chemical agents (Organic Wine Company, 2016). Organic agriculture has thus far been shown to reduce ecotoxicological impacts, but it generally requires twice as much area per unit of food according to Mattson (1999). This raises an interest to determine and compare the environmental impacts organic and conventional agriculture through the lens of a holistic impact assessment.

In this report, a comparative and attributional Life Cycle Assessment (LCA) of an organic red wine from Spain and a conventional red wine from Italy is made in order to conclude which wine has the lowest environmental impact, and analyse the impacts throughout the product life until the distribution, otherwise known as a cradle-to-gate life cycle assessment. The report could and should be used as decision support for making environmentally sound decisions with respect to food industry and other commodities.

2. Goal and Scope

2.1 Goal of study

The study was conceptualized due to the significant turnover of wine products in an eco-conscious market, as found in Sweden. The homogenous and otherwise state-controlled market allows streamlined decisions to be made, and the availability of information to consumers can influence purchases.

The problem was defined in order to augment the availability of information for consumers to make informed choices about the environmental impact of their wine choices by comparing the life cycle of a conventional wine to a clearly labelled organic wine. The LCA is classified as comparative and attributional, as it compares two different wines with the same function and describes the wine production system with respect to the environmental impacts.

The goal of the study is to capture quantifiable differences of material, energy, and their respective environmental impacts from production to distribution of a conventional wine compared to an organic wine through the use of two cradle-to-gate accounting LCAs. The aim of the project is to determine which of the wine production methodologies is the best environmental alternative. The intended audience is the end-user of the wine bottle, through the marketing channels of the state controlled retailers.

2.2 Scope of study

2.2.1 Functional unit

The functional unit is 1 bottle of 750 ml wine. The LCA will account for all of the parts of the wine bottle; the wine content, the glass bottle, the cork, the label and the protective cardboard case used during transport. The LCA model will be a cradle-to-gate model, starting with the planting of the grape seed and ending on the shelves of a branch of Systembolaget in Hammarby Sjöstad. The amount of wine is produced to meet the market demand of consumption of organic and conventional wine; the functional unit is then conceptualized to be a part of a box of 6 wines, scaleable in multiples of 6.

2.2.2 System boundaries

The LCA system was chosen to be a cradle-to-gate system from the viticulture until the distribution of the wine as seen in Figure 1. The boundaries of this system include all major material, energy inputs, and outputs associated with the production and distribution of wine, and are based on reports from Point et al. (2012) and Castells et al. (2016).

Viticulture, the production of the grapes, starts the life cycle of the wine production and has several inputs such as fertilizers and pesticides. The vinification step describes the winemaking process from the grape harvest until ready for bottling. The bottling process has several inputs; container manufacturing, the making of labels and corks, and the bottling process. This is followed by the distribution of the wine, following the predetermined land and sea route to Sweden.

Due to the low attribution of environmental impacts and their relatively long life-time, the contributions from winemaking equipment was excluded from this LCA (Mattsson, 1999). In addition, the exclusion of waste scenarios means that the study overlooks landfills impacts.

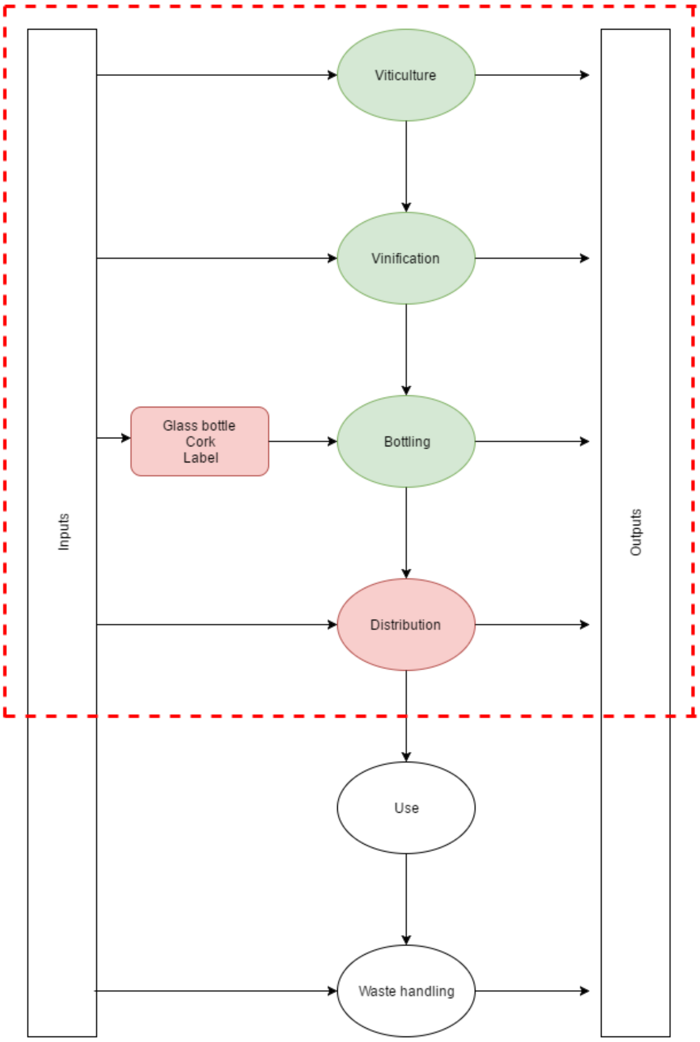

Figure 1. Simplified flow chart over the life cycle of wine. The red dotted line describes the system boundary. The green process stages represent the foreground system and the red process stages represent the background system.

The foreground system includes the process stages at the vineyard, such as the viticulture, vinification, and bottling process. The background system includes the production and transport of cork, glass bottles, and labels, as they are not produced onsite. The distribution of wine is also included in the background system since it occurs outside of the managerial authority of the vineyard. The use and waste handling is excluded due to the life cycle assessment being cradle-to-gate rather than cradle-to-grave.

2.2.3 *Time boundaries*

For the LCA to be a contemporary representation of winemaking, relatively recent data was collected to reflect that the methodology and machinery for farming and production steadily becomes more efficient.

The two wines have different time boundaries, partly because organic products have limited shelf-lives compared to conventional products, due to the reduction of effective pesticide usage. The average duration of production at the organic vineyard is 45.5 years, which includes the lifespan of the plants minus the first year of production (Castells et al., 2016); the following study assumes that the same lifespan applies for both organic and conventional wines. The time duration can differ a lot, between 45 and 100 years depending on the grape, soil conditions, pesticides used, if the grapevines are unseeded or not (Echensperger et el., 2011).

2.2.4 *Geographical boundaries*

The organic and conventional vineyards are located in Catalonia, Spain and Apulia, Italy, respectively. As the two regions are relatively near and at approximately the same latitude, the climate and geology is assumed to be standardized, discounting any climatological and pedological factors on the productivity of the grapevines.

In order to standardize the transport distance, both wineries were considered to be in Castel del Monte, Apulia, Italy and Hammarby Sjöstad, Stockholm, Sweden. This assumption was made mainly because the focus of the study is to assess the impacts between an organically produced wine and a non-organic wine rather than impact differences depending on location and transportation. However, maintaining the transport processes in the LCA allows their consideration in determining the cycle hot spots.

2.2.5 *Allocation procedure*

Certain steps during the life cycle of the wine could append emissions to different functions, or place certain functions responsible for other emissions, thus leading to allocation problems; therefore, the emissions and functions responsible have been considered solely for the stated functional unit.

An allocation problem arises when considering the grape waste from the crushing process; the crushing step causing an open-loop recycling problem as this waste could be used as fertilizer in the organic farm. This was solved with a system expansion to include the grape waste and then subtracting the grape waste from the applied fertilizers (Curran, 2015). The calculations are detailed in *3.2 Data*.

2.3 Assumptions and limitations

Assumptions were made quantifying that using an organic fertilizer on the organic vineyard yields approximately 6 tons/ha (Castells et al., 2016), whilst using an inorganic fertilizer with pesticides yields approximately 12 tons/ha (Notarnicola et al., 2003). Effectively, this means that the conventional vineyard will need half of the land compared to the organic vineyard to produce the same amount of wine.

As the study exclusively considers the differences between organic and conventional wine, an important distinction should be made that the vineyard is not ecological or otherwise sustainably managed. The vineyard operations, such as with regards to fuels and machinery, are assumed to be the same. In addition, carbon dioxide capture by the flora is neglected as it is assumed to be cancelled out later in the life cycle (Castells et al., 2016).

The imported glass bottles and other container materials are assumed to be imported from the same place for both vineyards, and they are made from the same material and processes. The same is assumed for the rest of the materials used for the bottles, i.e. cork, paper labels and aluminium sealing tape. Further, the bottles are assumed to be transported in packages of 6, which is why ⅙ of the burdens from the packaging material have been allocated to the functional unit.

Assumptions regarding transportation in the distribution step are that both wines are transported the same distance and by the same means (lorry and ferry), detailed under *3.2 Data*. Furthermore, the filtration step in the organic vinification is excluded, since filtration is used to remove bacteria from conventional wine and not necessary for organic wine (More than Organic, 2016).

Excluding the waste scenario is justified as the waste handling will not differ between the two wines, due to it being up to the discretion of the consumer. While this could be studied further through a social aspect, it is not within the scope of the study.

2.4 Impact categories and impact assessment method

In this report, the LCA was performed with the help of the programme SimaPro (Version 8.1.1; Pré Consultants, 2015), in which ReCiPe Midpoint Hierarchist V1.05 was used as the impact assessment method in order to interpret the results (LCIA-recipe, 2010). The method was developed in the Netherlands (Finnveden, 2016), and is therefore suitable for this project which is based in europe.

The life cycle impact assessment method ReCiPe divides the inventory results into 18 different midpoint indicators, which designate the significance for each impact category and helps create a holistic overview on the environmental impacts of the life cycle of the product. Each of the impact categories will be assessed in the report. ReCiPe Midpoint Hierarchist contains the following impact categories:

1. Climate change
2. Ozone depletion
3. Human toxicity
4. Photochemical oxidant formation
5. Particulate matter formation
6. Ionizing radiation
7. Terrestrial acidification
8. Freshwater eutrophication
9. Marine eutrophication
10. Terrestrial ecotoxicity
11. Freshwater ecotoxicity
12. Marine ecotoxicity
13. Agricultural land occupation
14. Urban land occupation
15. Natural land transformation
16. Water depletion
17. Metal depletion
18. Fossil depletion

2.5 Normalization and weighting

In the impact assessment, normalization is used as a method of evaluating the results. Normalization facilitates the comparison between the wines since the impacts are compared to each other by a linkage of all the category indicator results to a reference value. This means that the impacts with different units are measured using the same scale in CO2-equivalents (Hoffmann et al., 2005). The ReCiPe Midpoint (Hierarchist) method (see 2.2.4 *Impact categories and impact assessment method*) is used to compare the normalized results. Weighting of the impact categories is not done in this study.

3. Life Cycle Inventory Analysis

3.1 Subsystems

The process flow chart has been divided into three different subsystems. The subsystems are viticulture, vinification, and bottling and distribution, as defined in the 2.2.2 *System boundaries* (Figure 1).

3.1.1 Viticultural subsystem

The main differences between the conventional and organic wine viticulture is the use of pesticides and synthetic nutrients. In conventional viticulture, the pesticides and synthetic nutrients stand for the biggest environmental impact from this subsystem (Notarnicola et al., 2003). In organic viticulture, no pesticides or synthetic nutrients are used; however, some organic fertilizers are used. More precisely, to avoid allocation problem that comes from grape waste (see 2.2.2 *System boundaries*), the waste from the grapes was used as fertilizers alongside sunflower silage, thus reducing the amount of purchased organic fertilizers.

The viticultural step (Figure 2) starts before the planting of the grape, by planting barley grains in order to enrich the soil with nutrients. The year after the barley grains have been planted, the grapevine is planted; it then takes four to five years of growth of the grapes before the rest of the viticultural process begin, which includes tillage, irrigation, fertilization, pesticides for conventional winemaking, pruning and harvesting (Castells et al., 2016).

The tillage process is where the land is prepared for growing grapes, important for fighting weeds that otherwise would use water and nutrients. At normal precipitation of around 5529 m^3/ha, irrigation is not needed. In both vineyards, rainwater is otherwise collected from the mountains by a gravity-driven drip irrigation system. Fertilizers are then used to ensure a yield of between 6 and 12 ton/ha depending on whether organic or conventional fertilizer is used. In the conventional viticulture, pesticides such as copper and sulphur are used to protect against harmful agents, like fungus. Pruning is done once a year, sometime between November and February, before the grapes are harvested in September and October (Castells et al., 2016).

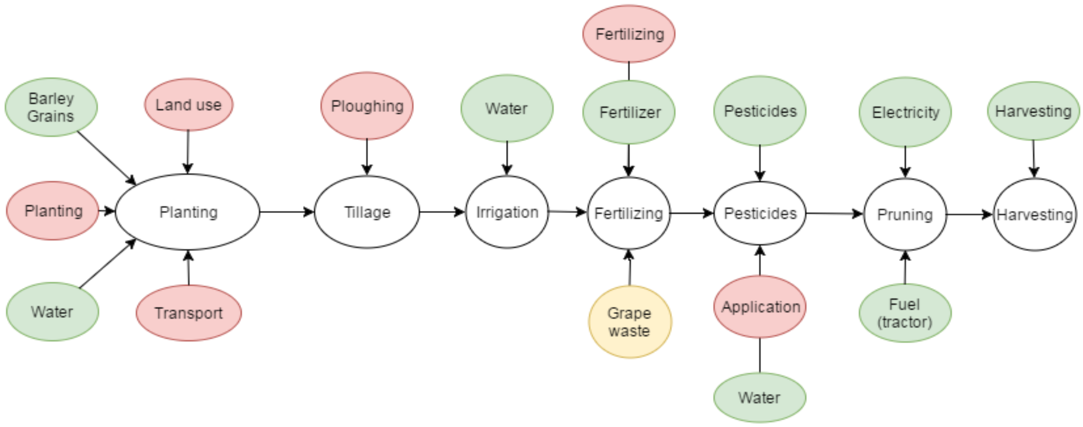

Figure 2. The viticulture and relevant processes and materials, starting from planting. Processes are colored in red, and materials are colored in green.

3.1.2 *Vinification subsystem*

The vinification subsystem processes the harvested grapes into wine ready for bottling, illustrated with a flow chart in Figure 3. It starts with the process of crushing, where the grapes are crushed and de-stemmed. Industrial yeast cells are then added and mechanically mixed in the fermentation stage.

The second fermentation is malolactic and slower than the first one; it takes place in oak wood barrels and steel vessels, transported to the vineyard by lorry. The content of the vessels and barrels are mechanically mixed together and stored for a year in oak barrels. Every fourth year the barrels are replaced to maintain a high standard. Allocation to the wine is made to account for the environmental loads from the barrels.

The two last steps are addition of preservatives and filtration (Castells et al., 2016). Preservatives were not able to be processed through the study, as none of the databases analyzed contained a suitable representative input. The filtration stage requires electricity (Castells et al., 2016), and is exclusive to the production of conventional wine since filtration is unnecessary for organic wine (More than Organic, 2016).

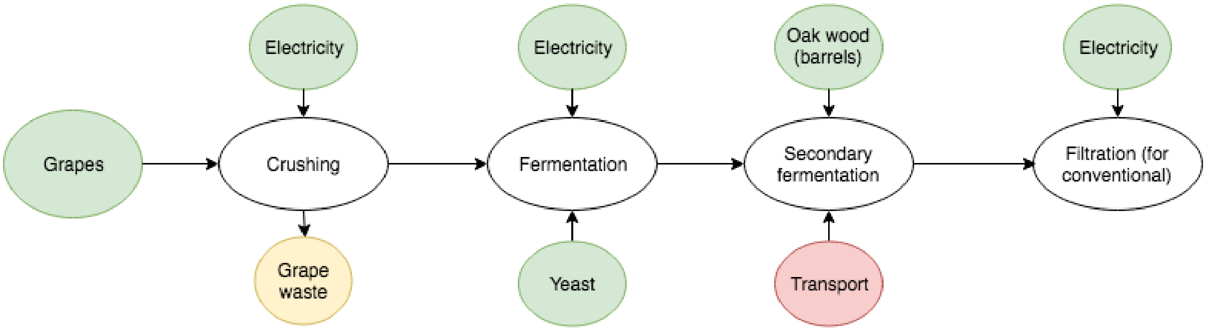

Figure 3. The vinification, and relevant processes and materials, starting from planting. Processes are colored in red, and materials are colored in green.

3.1.3 *Bottling and distribution subsystem*

The wine is bottled in 750 ml containers on the vineyard. The study considers glass to be the standard container, as it is by far the most ubiquitous container sold. The bottling process considers that the label, aluminium seal, and cork is bottled using machinery, thus requiring electricity input (Figure 4).

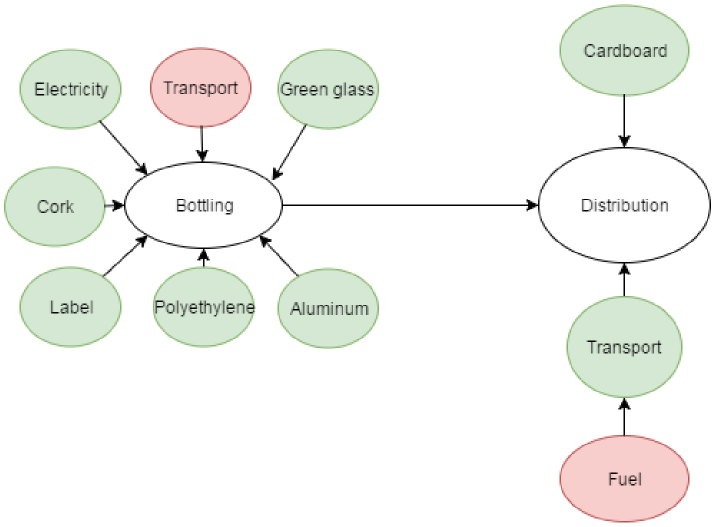

Figure 4. The bottling of the wine, and relevant processes and materials, starting from planting. Processes are colored in red, and materials are colored in green.

The green glass bottle, the label, the cork, and the aluminium capsule are considered background subsystems as they are all purchased separately and brought to the farm for manufacturing of the finished wine bottle. For this reason, the global market values are used, which borrows their individual life cycle assessment for use in this project.

The wine bottles are then packaged in a package board container with room for 6 bottles, made of polyethylene to be shipped to Sweden by lorry and ship. Details about transportation distances can be found in 3.2 *Data*.

4. Data

Much of the data used for this project is derived from Castells et al. (2016) but some of it is estimated or calculated. This section presents and justifies the input data calculations and allocation problems, as well as a finalised table of input values for SimaPro (Version 8.1.1; Pré Consultants, 2015) (see Table 1).

4.1 Land Occupation

The conventional vineyard needs half the land the organic vineyard does to produce the same amount of wine. An assumption that input data for conventional vineyard processes is halved from the organic vineyard applied for several input values where area is a unit. Therefore, the data for conventional winemaking have been assumed to be half of the data value given for the organic winemaking in Castells et al. (2016) article. Inputs that have been handled in this way are the amount of barley seeds, water use for irrigation and use of machinery.

4.2 Transportation

The finished product is transported by lorry to Germany, and then by freight ship to Denmark. The product is transported by lorry to Stockholm, Sweden. The transportation distances were derived from Google Earth (2015) in order of transportation way:

1. Castel del Monte, Apulia, Italy - Rostock, Germany: 1768 km (by lorry)
2. Rostock, Germany - Gedser, Denmark: 65.6 km (by ferry)
3. Gedser, Denmark - Hammarby Sjöstad, Stockholm, Sweden: 797 km (by lorry)

Calculations were made to derive values in tonne-kilometers (tkm), which relates the distance to the weight transferred. One 750ml glass bottle of wine has been measured to weigh 1.3kg. The distances are derived from Google Earth and illustrated in Figure 5. Since there are two different means of transportation two different calculations were necessary, one for transportation by lorry and one for transportation by ship.

Figure 5. The transport route as described in 3.2 Data. The red route illustrates the lorry transport and the green route illustrates ferry transport. (Google Earth, 2015)

Total transportation by lorry in tonne-kilometers:

$$\text{Total distance: } 1768\ km\ +\ 797\ km\ =\ 2565\ km$$
$$\text{Weight of functional unit: } 1.3\ kg$$
$$2565\ km\ *\ 1.3\ kg\ =\ 3.3345\ tkm$$

Total transportation by ship in tonne-kilometers:

$$\text{Total distance: } 65.6\ km$$
$$\text{Weight of functional unit: } 1{,}3\ kg$$
$$65.5\ km\ *\ 1.3\ kg\ =\ 0.08515\ tkm$$

4.3 Allocation problem calculation

The open loop recycling allocation problem in the production of organic wine is that the grape waste fulfills a function in the fertilizing process, as it acts as a fertilizer replacement. According to Ferrer et al. (2001), a dose of 3000 kg grape waste/ha is needed for fertilize the farm adequately. According to the Notarnicola (2003), the amount of grapes needed for one 750ml bottle of wine corresponds to 1.2kg of grapes, and from that a total waste output of 0,39 kg can be collected.

Therefore, the percentage of waste from grapes is:

$$0.39kg/1.20kg\ =\ 32.5\%$$

The organic farm yields 6000 kg grapes/ha. With a waste percentage of 32,5 %, the grape waste per hectare amounts to:

$$0{,}325 * 6000\ =\ 1950\ kg/ha.$$

The area fertilized for 1bottle of wine is 0.000113 ha. The amount of purchased fertilizer needed for that area and for 1 bottle is 0.0283 kg, therefore the amount of organic fertilizer used per hectare is:

$$0.0283/0.000113 = 250\ kg/ha$$

Assuming that the grape waste fulfills the same function as the organic fertilizer, then it can be assumed that the total area fertilized by grape waste is proportional to the amount of purchased organic fertilizer needed, therefore:

$$\frac{1950kg}{3000kg} = 0.65$$

$$250 * 0{,}65 = 162.5\ kg$$

As it can be seen that the grape waste corresponds to 162.5kg of purchased fertilizer, then the amount of added fertilizer per hectare needed to solve the allocation problem is:

$$250kg - 162.5kg = 87.5\ kg$$

Which per bottle of wine corresponds to:

$$87.5kg * 0.000113ha = 0{,}009905\ kg/ha$$

0.009905kg/ha of purchased fertilizer is required for one bottle of organic wine.

4.4 Inventory list

The inputs of the manufacturing process of both the organic and conventional wines, and respective container is shown below in Table 1. All inputs has been accessed through Ecoinvent version 3.0 (Frischknecht et al., 2007) and then implemented in SimaPro (Version 8.1.1; Pré Consultants, 2015). An explanation for calculated values can be shown in either 3.2.1 *Land occupation* and 3.2.2 *Transportation*. According to the Organic Wine Company (2016), organic wine is not farmed with pesticides or other chemical compounds, making these values zero as shown below.

Table 1. Input process values of the organic and conventional wine manufacturing process in SimaPro Classroom 8.1.1.16.

Subsystem	Process	Input	Conventional	Organic	Unit	Source
Viticulture	**Planting and fertilising**	Barley seed	24	48	mg	Castells et al., 2016, Calculated
		Planting	249	498	cm^2	Castells et al., 2016, Calculated
		Phosphate fertiliser, as P2O5	1.93	0	g	Organic Wine Company, 2016
		Potassium fertiliser, as K2O	4.82	0	g	Organic Wine Company, 2016
		Nitrogen fertiliser, as N	8.24	0	g	Organic Wine Company, 2016
		Organic fertilizer Sunflower silage	0	9,905	g	Calculated, Organic Wine Company, 2016
		Fertilising	0.565	1.13	m^2	Castells et al., 2016, Calculated
		Land	1.14	2.27	m^2a	Castells et al., 2016, Calculated
	Tillage	Ploughing	2.84	5.67	m^2	Castells et al., 2016, Calculated
	Irrigation	Water	1.13	2.26	L	Calculated, Foster et al., 2006
	Pesticides	Application of pesticides	3.4	0	m^2	Organic Wine Company, 2016, Castells et al., 2006
		Folpet pestisides	340	0	mg	Organic Wine Company, 2016, Foster et al., 2006
		Pestisides overall	5.54	0	g	Organic Wine Company, 2016, Castells et al., 2006
		Water	9.52	0	kg	Castells et al., 2016
	Fermentation	Yeast	18.8	18,8	mg	PriceWaterhouseCoopers, 2012
	Electricity overall	Electricity, high voltage	2.646	2,646	kJ	Castells et al., 2016
	Transport overall	Transport	0.29	0,29	kg/km	Castells et al., 2016
Vinification	**Secondary fermentation**	Cleft timber	50	50	g	Castells et al., 2016
	Electricity	Electricity, high voltage	442.998	437,454	kJ	Castells et al., 2016
	Transport	Lorry	42.89	42.89	kg/km	Castells et al., 2016
	Fuel	Diesel	2.3	2.3	g	Castells et al., 2016
Bottling	**Bottling**	Cork	4.15	4.15	g	Castells et al., 2016
		Electricity, high voltage	3.888	3.888	kJ	Castells et al., 2016
		Graphic paper,	1.4	1.4	g	Castells et al., 2016
		Liquid packaging board container	35.6	35.6	g	Castells et al., 2016
		Packaging film	998	998	mg	Castells et al., 2016
		Sealing tape	50	50	mm	Castells et al., 2016
		Transport	214	214	kgkm	Castells et al., 2016
		Transport, freight, sea	85.15	85.15	kgkm	Calculated
	Glass	Packaging glass	580	580	g	Castells et al., 2016
	Plastic	Polyethylene terephthalate	54.4	54.4	g	Le Geurn and Tostivin, 2010
	Carton	Waste paperboard	35	35	g	Le Geurn and Tostivin, 2010
		Ethylvinylacetate foil	3	3	g	Le Geurn and Tostivin, 2010

5. Life cycle interpretation

The following impacts were categorized from the life cycle assessment comparisons of the conventional and organic wine as produced in Italy and as distributed to Sweden. The impact framework used was the hierarchical ReCiPe impact framework. The organic and conventional wine products were compared using different packaging scenarios other than glass: plastic and carton as commonly sold to end-users.

Figure 6 compares the organic and conventional wine during their cradle to gate through normalized values. The figure shows that the organic wine production has less total impacts across the categories, even though the impact for agricultural land occupation is higher for the organic wine. The largest differences are shown to be in marine ecotoxicity, freshwater ecotoxicity, and agricultural land occupation. The natural land transformation required to produce both wines is high due to the agricultural land needed, as well as the land transformation required to produce the fuel costs.

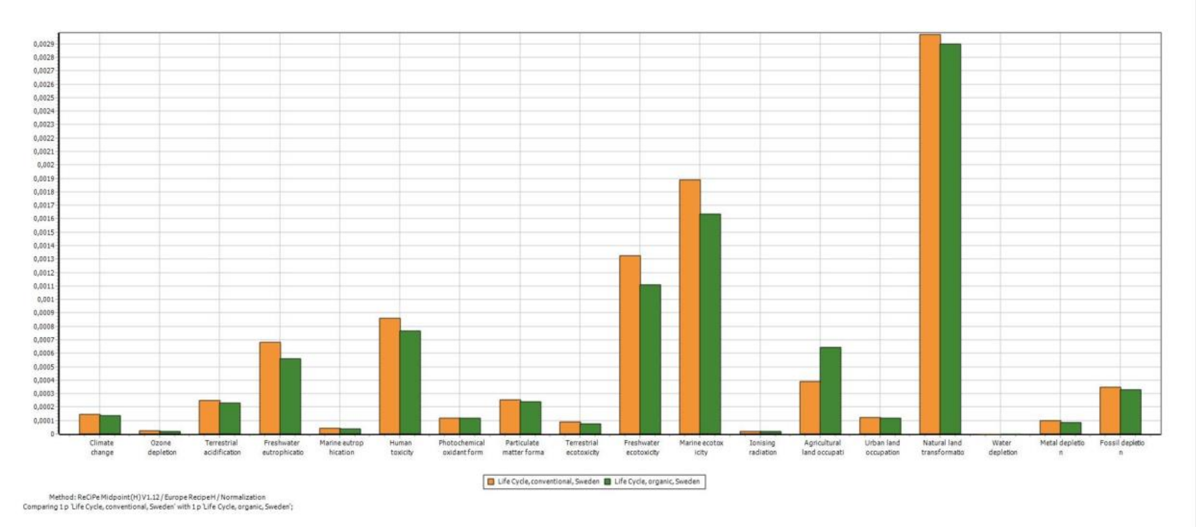

Figure 6. Normalization of the impact scores between the organic and conventional wine, as shipped to Sweden and packaged in glass. Modeled in SimaPro Classroom 8.1.1.16 (2015).

Figure 7 shows that the impact results between the organic wines that are internationally and locally distributed have greater differences than between the organic and conventional wines (Figure 6), suggesting that the distribution and international sourcing of the product plays a larger role than the characteristics and environmental footprint of its constituents.

In Figure 8, the impact hotspot of the Natural Land Transformation of the ReCiPe framework is in the manufacturing of the glass bottle and the distribution.

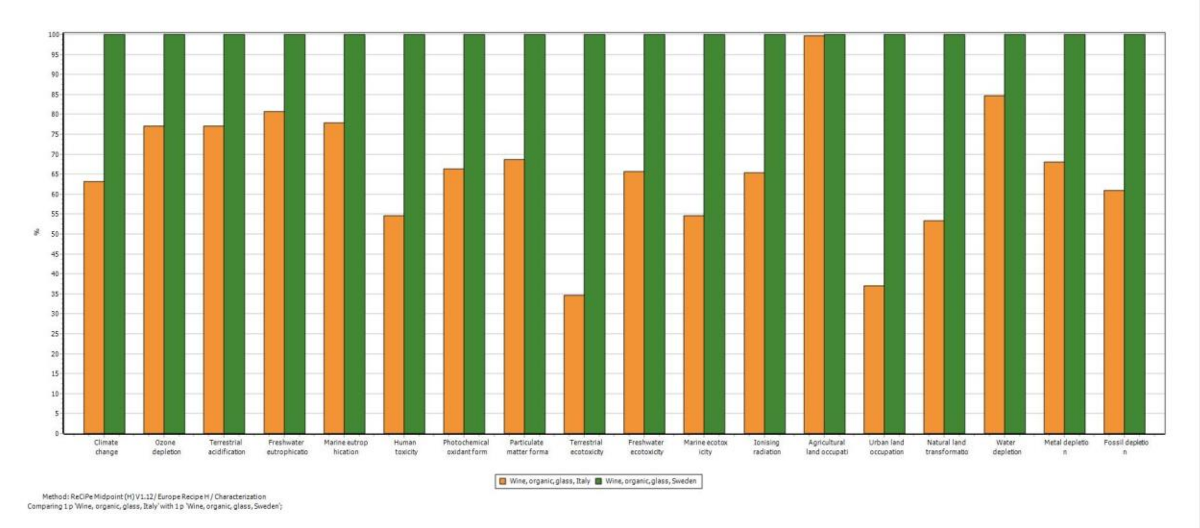

Figure 7. Characterization of the impact scores between the organic wines, both as produced in Italy and as shipped to Sweden. Modeled in SimaPro Classroom 8.1.1.16 (2015).

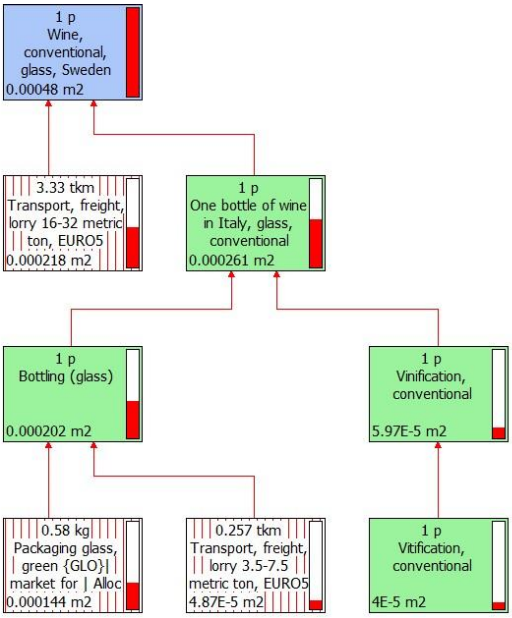

Figure 8. Flow chart of the distribution of effects on the Natural Land Transformation impact category for the conventional wine in a glass bottle. Modeled in SimaPro Classroom 8.1.1.16 (2015).

In Figure 9, the impact hotspot of the Natural Land Transformation of the ReCiPe framework shows similar results as Figure 8, with the largest effects in the manufacturing of the glass bottle and the distribution. The impacts are weighted slightly more towards the manufacturing of the wine bottle.

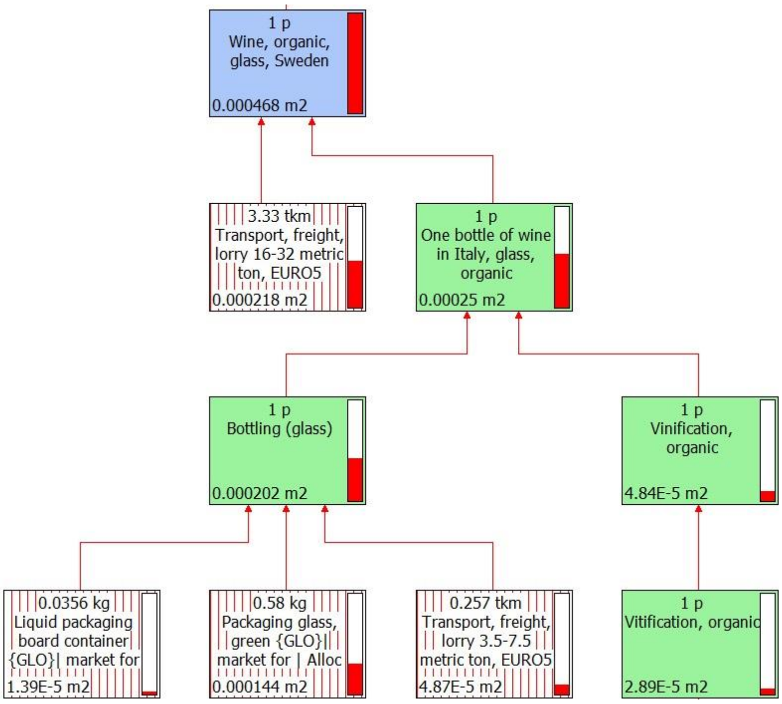

Figure 9. Flow chart of the distribution of effects on the Natural Land Transformation impact category for the organic wine in a glass bottle. Modeled in SimaPro Classroom 8.1.1.16 (2015).

Discounting the fuel costs and looking at the impacts of solely producing the organic wine in glass, plastic, and carton boxes (Figure 10) through the normalization results shows that the organic wine production in glass bottles generally dominates the impact assessment scores throughout all the categories present in the ReCiPe framework, with a significant lead on the Natural Land Transformation impact category. The carton alternative has the least impact in all categories.

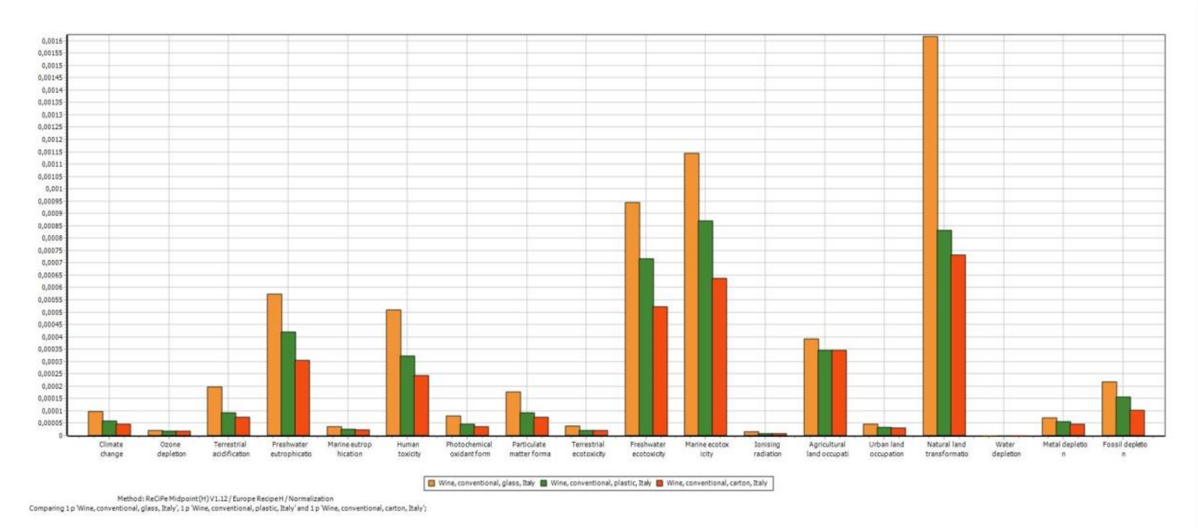

Figure 10. Normalization of the impact scores between the organic wines with different packaging processes, as produced in Italy. Modeled in SimaPro Classroom 8.1.1.16 (2015).

In Figure 11, the impact scores are normalized across organic and conventional wines to draw a conclusion on the impacts of the manufacturing process; therefore a glass bottle is compared to carton, the arguably least environmentally damaging manufacturing process. As the shipping to Sweden was calculated to be a significant source of impact, Figure 11 also shows that the manufacture of the glass bottle is also a significant source of the impact scores, and should be heavily considered to reduce the footprint of organic wines.

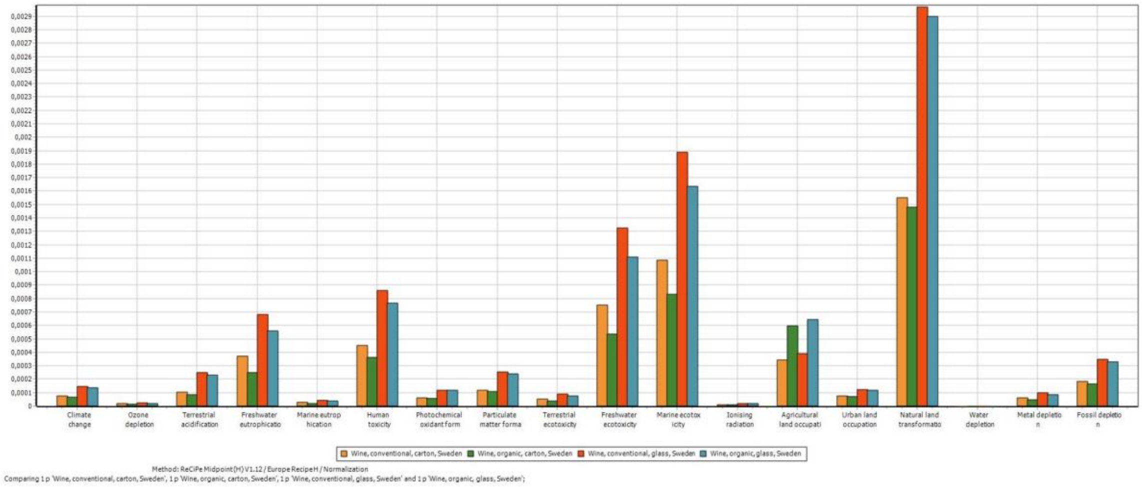

Figure 11. Normalization of the impact scores between the organic and conventional wines packaged in carton and glass, as shipped to Sweden. Modeled in SimaPro Classroom 8.1.1.16 (2015).

6. Discussion

The largest differences in the impact scoring between the production of organic and conventional wine can be seen in the impact categories marine ecotoxicity, freshwater ecotoxicity, and agricultural land occupation. The organic wine has the largest impact only for agricultural land occupation, attributed to the greater land area needed for the organic agricultural process to yield similar amounts as conventional viticulture.

Although the impact for agricultural land occupation for the organic wine exceeds the conventional wine by 40 %, the total impacts on the ecotoxicity categories are still larger for the conventional wine as shown in the normalization diagram (Figure 6). This could mean that the eventual loss of biodiversity caused by the organic wine production could be overshadowed by the impacts on biodiversity through ecotoxicological channels caused by the conventional wine due to the use of pesticides.

Another potentially large impact from large land use except biodiversity loss is the reduced agricultural land left for food production. Since this is not a social LCA, this aspect is not accounted for in this report. However, using conventional farming could increase space for food production, which may be incorporated into the decision support model considering the increased threat to food security due to climate change and expected lower yields. The effects of organic and conventional viticulture may not play a large role on food security in Europe, but it may in South American and African countries with a shortage of food and at risk of climate change effects.

There is a stated difference between organic and ecological products. The focus of the report has been on the wine production, and does not guarantee that the vineyard practices are ecological or sustainably, through the use of environmentally friendly fuels, machinery and materials. For example, the agricultural machines used diesel in both vineyards, and the manufacturing materials and processes for the containers are not sustainable. There would probably have been a bigger difference between the impacts of the two wines if the assessment of organic wine was replaced with the assessment of a ecological wine that places focus on sustainable agricultural methods.

The hotspot analysis shown in Figures 8 and 9 showed that the glass bottle had the greatest impact on the environment and therefore an analysis were made where the material of the bottle was changed to plastic and carton. The results showed that there was a significant difference in impact between using glass for the bottle and using plastic or carton, as seen in Figure 10. Since this small change made a quite big impact on the results, it is safe to assume that a completely ecological vineyard would change the results even further and that organic vineyards can take actions to become even more environmental friendly.

The lifespan of the organic and conventional grapevines was assumed to be the same in this study. However, in many cases the shelf life of a conventionally grown grapevine is longer because pesticides and more effective fertilizers are used. If the longer production time was considered, then the results could have looked different since the environmental burdens that follow from the planting of new vines would be more frequent for the organic grapevines.

It is important to note that this study only includes two specific vineyards, one of them conventionally grown and the other organically grown. If two other vineyards with different farming practices were to be studied, the results could look different. However, since several assumptions have been made, which should reflect the reality of any given vineyard, it is the author's' opinions that this study can be viewed as a general take on conventional and organic wine production.

7. Conclusions and recommendations

The conventional wine shows larger impact for all impact categories except for agricultural land occupation, which makes the total impacts on the environment greater for the conventional wine in comparison to the organic wine. Therefore, the organic wine is a better option from an environmental point of view. The total differences between the two wines may not be significant, and would require a larger meta-study to assess. The greatest differences can be seen in the impact categories of marine ecotoxicity, freshwater ecotoxicity and agricultural land occupation, but the overall impact contributing to biodiversity loss is probably larger for the conventional wine due to the use of pesticides. Further expanding the comparative life cycle assessment between organic and conventional wines could include looking at different the winemaking standards of different vineyards.

From the sensitivity analysis, it can be seen that glass has a significant bigger impact compared to the other materials, especially for the impact category natural land transformation. Natural land transformation is the impact category that has the biggest impact on the environment in for both organic and conventional wine in this LCA, and can be a viable issue to focus on in the attempt to reduce the total environmental burden. Since the carton alternative for wine bottle has the least impact in all categories, it should be chosen as the material for the organic wine bottle.

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Appendix A

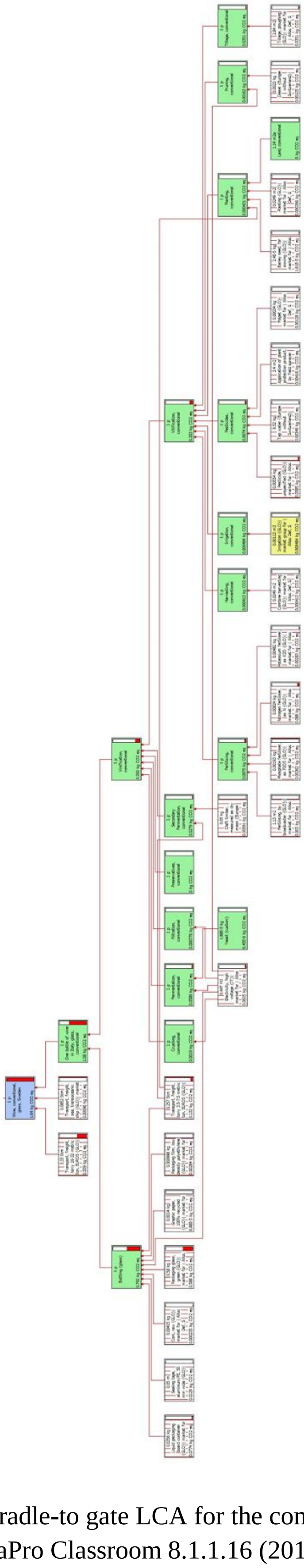

Figure A1. Flowchart for the total cradle-to gate LCA for the conventional wine, using glass bottle. SimaPro Classroom 8.1.1.16 (2016).