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The environmental impact of a Sardinian wine by partial Life Cycle Assessment

Graziella Benedetto*

Department of Science for Nature and Environmental Resources University of Sassari, Sardinia, Italy

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Abstract

Purpose: The aim of this study was to evaluate the environmental emissions associated with the production of a typical white wine produced in Sardinia, with particular reference to CO_2 emissions. The main objective is to determine the main environmental impacts of the overall production process and to identify what steps have the greatest level of criticity.
Methods: An attributional and partial Life Cycle Assessment analysis was used with GaBi software.
Results: The analysis shows that the main problems were the production and combustion of diesel in the viticulture phase, above all during the vine planting phase, and the production of glass bottles in the phase of wine bottling within the winery processes.
Conclusions and recommendations: To overcome these critical points, some suggestions come from the most recent literature, such as the use of biofuels in the first case and the use of lighter bottles in the second. More in-depth analysis is needed to compare these alternatives in order to assess the effective reduction of environmental emissions.

Keywords: Viticulture; Wine; LCA; CO_2 emission; Sardinia

1. Introduction

Food production, as detailed in the study conducted by Horrigan et al. (2002), has quite an impact on the environment; the use of fertilizers, pesticides, soil and land, water and energy[1] , as well as pollutant gas emissions, contribute to the phenomenon of climate change and global warming. Infact, according to estimates by the Intergovernmental Panel on Climate Change (p. 448) agriculture has been noted to be directly responsible for approximately 20% of greenhouse gas emission. Similarly, the wine business and the process of transforming grapes into wine and marketing them, all take their toll on the environment. These agricultural and industrial practices seem particularly harmful not only for Global Warming Potential (GWP) but also for other impact categories such as Abiotic Depletion (ADP), Acidification Potential (AP) and Eutrophication Potential (EP) (e.g. the use of fertilizers or electricity for irrigation). These negative externalities are transferred from the private to the public sphere as environmental costs that society has to bear (Colman and Paster, 2009; Idda et al., 2007).

Simultaneously, over the past two decades, worldwide environmental awareness has been growing dramatically (Barber et al., 2009). The effect has been the increasing involvement of all those who, for various reasons, are interested in the production and consumption of food and beverages. Consumers have introduced environmental concerns into their purchasing processes, selecting producers who show sensitivity towards the environment (Barber et al., 2009; Hardie, 2000); distribution chains have responded promptly to

*Tel.: +39 079229355; fax: +39 079229356.
E-mail address: gbenedet@uniss.it
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[1]"The food production system accounts for 17% of all fossil fuel use in the United States, and the average is 3 kcal of fossil energy in producing 1 kcal of food energy" (p. 448).

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this request [e.g. the British Tesco, (Rigby et al., 2007) and Wal-Mart (Finnveden et al., 2009)]; the world wine market includes countries which are particularly sensitive to the issue of environmental emissions associated with the production and transport of wine up to the final consumer such as the United Kingdom, the United States, Australia, New Zealand, South Africa and France (Waye, 2008).

From the supply side, producers' associations, individual companies, local government institutions involved in protecting large areas (e.g. the *Lodi Rules* in California and the spread of the *Bilan Carbone* in France) have shown a remarkable sensitivity to this issue (CIVB, 2010). The effects of such business policies at the international level have been surprising and able to motivate the research activities developed around the solution of various aspects relating to specific environmental issues.

Important decisions will be taken in assessing environmental emissions of wine, such as the International Wine Carbon Calculator (IWCC) in Australia, USA, New Zealand and South Africa, Bilan Carbone in France, Carbon Trust in the UK, Huella de Carbon and Ita.Ca respectively in Spain and Italy; the OIV (International Organisation of Vine and Wine) Protocol currently the OIV is being validated. Similarly the Life Cycle Assessment (LCA) approach became a key reference for the international scientific community (Zamagni, 2012) involved in the sustainability assessment of economic activities.

As a part of the international wine market and a country which has played a key role in the history of wine, Italy, with its deep rooted tradition, is one of the top exporters in the world. Sardinia plays a secondary role in the national wine sector and, according to figures from Istat (2010), its vineyards and wine production stood at 3% and 1% respectively.

However, this is a sector which has an important historical, cultural, environmental, economic and social role in the regional context. The Sardinian viticulture produces many positive benefits (*recreational*, associated with the maintenance and management of the land in and around the vineyard; *social*, related to the maintenance of the agricultural population in areas where it can be a source of income support; *environmental*, aimed at preserving the countryside) as well as a negative environmental impacts; for the reasons given, it is useful to monitor and evaluate the extent of such adverse effects. The goal is to introduce the use of eco-friendly farming practices and ensure the agriculturist broadens horizons in terms of yield quantity and quality.

The main objective of this study is to assess the multiple environmental impacts of a typical white wine (Vermentino di Sardegna) produced by a Winery, located in the north of Sardinia, so as to identify the main hot-spots and improvement opportunities within the product process.

2. Background and aims

The scientific context of this study looks at the relationship between development economics, environmental economics, with specific reference to the problems generated by overestimates of production activities on the availability of environmental resources and international trade. Infact, the progressive development of productive activities in general, particularly associated with the agri-food, was accompanied by an increasing growth in emissions pollutants impairing the quality of renewable resources, such as air. Globalization has also proceeded to aggravate this process of deterioration.

The connection with the theme of sustainable development is inevitable as is its evolution from the well known Brundtland Report, not to mention the impact it has had on international environmental policy since 1992.

From a theoretical viewpoint, the reference is to the "*tragedy of the commons*" (Hardin, 1968) by moving the field of observation from the traditional category of *commons* to those that include the *global common*s: "*areas outside the jurisdiction of any nation or group of nations*" (Clancy, 1998, p. 603) including the atmosphere, outer space, water, high seas, deep sea beds, forestry, and so on. On several occasions, Hardin's theory has been adapted to different categories of common goods from those to which the author refers to in his famous example of pastures: a call to the *global tragedy of the commons* is also to be found in Colman and Paster (2009) with reference to the wine industry and its externalized costs such as Carbon dioxide emissions, chemical effluent and other wastes.

Wine is considered to be one of the agricultural practices affected by climate change although to a lesser extent.

For this reason studies have been considered from two points of view: the impact of climate change on the global wine industry and on viticulture (see among others Tate, 2001; Jones et al., 2005; Jones, 2006, 2007; Anderson et al., 2008; Ramos et al., 2008; White et al., 2009; Mira de Orduna, 2010; Bernetti et al., 2012), on the one hand; the analysis of how wine contributes to climate change, on the other hand, by the identification and application of tools which are able to estimate only one impact, the effect on global warming (International Wine Carbon Calculator, Bilan Carbone), or multiple impacts (LCA) (e.g. Zabalza et al., 2003; Notarnicola et al., 2003; Aranda et al., 2005; Montedonico, 2005; Carta, 2009; Fearne et al., 2009, Barry, 2011; Gonzalez et al, 2006; Ardente et al., 2006; Petti et al., 2006; Rugani et al., 2009; Schlich, 2010; Gazulla et al., 2010; Bosco et al., 2011; Pattara et al., 2012a, 2012b; Point et al., 2012; Vàzquez-Rowe et al., 2012; Comandaru et al., 2012; Neto et al., 2013; Vàzquez-Rowe et al., 2013).

This contribution is part of the line of study and research focused on this second aspect.

Infact, the aim of this study is to assess the multiple environmental impacts of one of the most important wineries operating in northern Sardinia, with reference to a category of white wine of great importance within the company's product portfolio. This is only an exercise to test the potential of an instrument such as LCA: its application within a specific wine company will highlight any problems (e.g. in data collection due to the precision with which inputs should be considered for quantity and quality). It will also be possible to describe the major categories of environmental impacts, as well as identify the stages of the production process that are most responsible for each impact category. The ultimate goal is to promote the spread of this methodology in Sardinia, as this is poorly implemented in the wine sector.

Our Cradle-to-Gate[2] begins with the assessment of the vine planting phase and ends with the packaging of the wine bottle ready for sale. Despite the importance of transportation regarding environmental emissions, we have escluded this phase from the scope of the study because of peculiarity of the distribution market and some lack of information. In other words, the wine market is highly fragmented: 33% of wines are sold in Sardinia, 22% are sold in the rest of Italy and 48% are exported outside of Italy. Each of these geographical areas, in turn, is extremely dispersed in a multitude of other destinations. This makes it difficult to make a precise and transparent calculation of the impact associated with the transport phase, also the fact that the company was not able to specify the means of transport and shipping companies that export the wine to countries such as the USA (43% of total exports).

The quantification of emissions also includes those phases associated with the production of inputs purchased from the market and used in the production process as fixed and variable factors (e.g. the production of glass used for the production of bottles or the steel used for the production of agricultural machinery, or the cement used for the production of end posts and inter-row and so on).

There are many economic benefits that the industry can gain from the implementation of LCA: for example reference can be made to a reduction of the enterprise's total costs (Binswanger, 2001), since the same amount of wine is obtained through an optimization of input requirements (for example due to a reduction in the consumption of energy, water, pesticides, etc.) and a better organization of production factors. Secondly the possibility of stating on the label the level of emissions (for example CO_2) and using this information as a marketing tool eco-friendly to the environment therefore as a means of promoting the product.

3. Data and methodology

As specified in the Handbook for Life Cycle Assessment (2009) "There are two LCA standards created by International Organization for Standardization (ISO, ISO, 2006): the ISO 14040 and ISO 14044. Life Cycle Assessment, as defined by the ISO 14040 and 14044, is the compiling and evaluation of the inputs and outputs and the potential environmental impacts of a product system during a product's lifetime" (p. 8). In this guide it is also indicated that, according to the previous standards, LCAs consist of four steps: (1) Goal and Scope Definition; (2) Inventory Analysis; (3) Impact Assessment and (4) Interpretation.

The analysis was performed with the GaBi4 software package (GaBi Education, 2009 version) and the GaBi4 database (EDIP—Environmental Development of Industrial Products) was employed as the principal source of background data whereas data for the foreground system were directly obtained by the author from a wine industry (the Sella and Mosca), located in Sardinia, and can therefore be considered of very high quality according to the criteria of reliability, completeness, and temporal and geographic representativeness. The preliminary phase of LCA is the analysis of inventory (LCI) where each step of the production process and the related flows of energy and matter is identified accurately. Data collection is done by the completion of a specific questionnaire and supplemented by interviews with the heads of the three areas (vineyard, cellar and bottling). Processed data refer to 2009; for each of the steps previously described, consumption values of matter and energy input were calculated with reference to the functional unit (0.75 L of wine). For each of the primary data input process, the database provided by EDIP GaBi4 was used taking into account the secondary processes upstream of each input (raw materials) so as to supplement the corporate data in a comprehensive manner. Human labor was calculated by estimating the energy metabolism of the daily equivalent to 1.25E+02 kcal/h; 1 kcal = 418E−03 MJ, the energy expenditure per hour of work can be equal to 0.523 MJ/h. To estimate the contribution of agricultural machinery, reference was made to the work of Erzinger and Nemecek (2005).

The data were then divided by the number of acres for the lifetime of the means used (30 years of the vineyards) in order to obtain the final input in kg of material to be used as primary analysis of flow inventory. For the construction of output streams, the company provided information on the quantity of grapes harvested on average, the percentage of wine and waste (stalks, skins and seeds) that are obtained from their work at the winery. The CO_2 emitted as a result of fermentation was not considered in the analysis (as in Ardente et al., 2006) as the net emissions are zero. Notarnicola et al. (2003), in his work, addresses the issue by pointing out that the amount of CO_2 removed from the atmosphere through photosynthesis is exactly the same.

4. Results: the case study

In this section a "*cradle to gate*" LCA has been carried out on winery located in the north of Sardinia, the Sella and Mosca, in the Alghero area which traditionally devotes itself to viticulture. This company produces a number of different wines, both medium and premium, with its annual production reaching more than 55,000 hL. The analysis is limited to a single wine, a typical Sardinia white wine "Vermentino di Sardegna"—"*La Cala*" *mark* which is exported around the world, which is sold to the consumer for around 7.00 €/bottle. The Goal of the study is to build up the environmental profile of this wine, in order to identify the hot spots of the system.

4.1. Goal and scope definition

A block diagram of the whole life cycle is illustrated in Fig. 1.

[2]The system boundaries, which define the stages of the process included in the assessment, may be different; can affect all phases of the "life cycle" of a bottle of wine, starting from the stage of the vineyard planting to the final disposal of materials used, or only some of them.

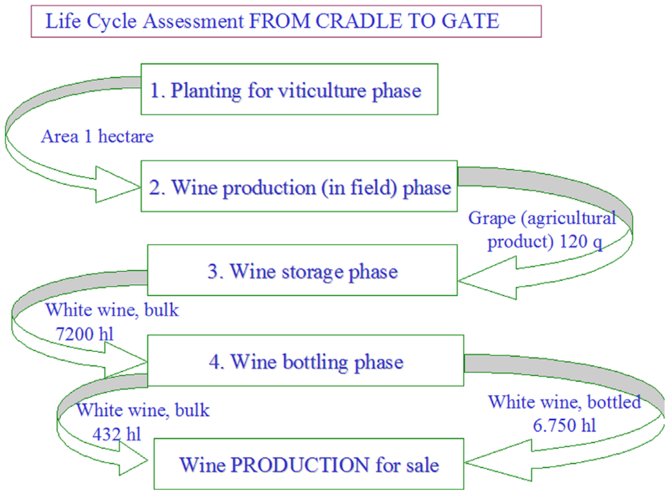

Fig. 1. Conventional white wine production in Sardinia. GaBi 4 process plan: reference quantities; the name of the basic processes are shown.

The life cycle of wine is organized in four main stages: (1) vine planting, (2) grape production and harvesting, (3) wine production, and (4) wine bottling. The chosen functional unit for the study was one bottle (0.75 L). Stages of plant and production will be reported to their product, grapes, expressed in quintals per hectare; the phases of winery and bottling wine in liter per hectare; at the end, the functional unit remains the same for every underprocess of cycle and the reference work is a bottle of wine.

Centrum voor Millieukunden Leiden (CML) 2001 (Guinée et al., 2001) a problem-oriented impact assessment method was used for classification and characterization. Impact category selection was based on a combination of commonly used categories in previous literature (among others, Aranda et al., 2005; Gazulla et al., 2010; Petti et al, 2010; Point et al., 2012; Vàzquez-Rowe et al., 2012) such as Acidification Potential (AP), Eutrophication Potential (EP), Abiotic Depletion (ADP) and Global Warming Potential 100 years (GWP 100 years) which are also considered to be quite sensitive in characterizing the life-cycle impact of Sardinian white wine production. ADP is accounted in kg-equivalents of a reference metal (antimony, Sb), and defines the potential impact caused by extraction of minerals and fossil fuels. AP calculates the potential impact due to emissions of acidifying substances to the air, and is quantified in kg equivalents of sulfur dioxide (SO_2). Moreover, EP is the category indicator for eutrophication, which covers all potential impacts of excessively high environmental levels of macronutrients, whereas the most important are nitrogen (N) and phosphorus (P). Infact, EP is quantified in kg of PO_4-equivalents, and it accounts for emissions of nutrients in the air, water, and soil. Finally, GWP, with a time horizon of 100 years was taken into account, being one of the most used indicators of life-cycle impact, i.e. on climate change. It includes all greenhouse gas emissions in each process and is quantified in kg equivalents of carbon dioxide (CO_2).

4.2. Life Cycle Inventory (LCI)

Table 1 shows only primary inputs and outputs, which refer to site-specific data collected directly from the farm. Secondary data are not listed in Table 1, because they were derived from a specific database (i.e. EDIP), to complete the Life Cycle Inventory, and were included in the GaBi4 calculation as aggregated values inventoried for each sub-process of the white wine lifecycle, and their contribution was integrated in the impact assessment step. Because of a lack of specific information in the database used for their production, upstream processes of some material were not included in the system boundary of the study. This is the case for wine yeasts, sulfur dioxide, pectolitic enzymes, ascorbic acid, nitrogen (liquid), gelatine, and fossil flours. In Table 2 the mass balance of the life cycle inventory (LCI) of the wine production is reported, after elaboration in GaBi4.

The balance allowed us to identify the use of resources (inputs balance) and the quantity of emissions and wastes (outputs balance) in each phase of the wine life-cycle from cradle to gate. Accordingly, the highest use of resources (about 82%) was observed in the wine bottling phase, mostly due to the consumption of water when producing glass bottles (about 78% of total resource use). With concern to the outputs mass balance, the highest quantity of emissions were again found in the bottling phase, due to the production upstream of glass bottles (with CO_2 emissions about 25% of total mass outputs). Also the phase of vine planting recorded quite high quantities of emissions (CO_2 in air for about 13% on the total) due to the combustion of diesel in machineries (e.g. tractors). Finally, even if the phase of grape production and harvesting highlighted more than 40% of outputs, these are mostly accounted as grape (valuable substances about 37%, see Table 2).

4.3. Life Cycle Impact Assessment (LCIA)

Results of impacts assessment are shown both in Fig. 2 and in Table 3. The percentage contribution of each indicator in the wine production phases is expressed in Fig. 2.

Impacts on ADP, AP and GWP100 were observed to be higher in the wine bottling phase than in the other three phases. In particular, Abiotic Depletion (ADP) and Global Warming Potential (GWP 100 years) reached in—that specific phase—about 54% and 57%, respectively, of their total contribution, while Acidification Potential (AP) reached almost 50%. ADP is mostly due to the use of non renewable energy resources (e.g. crude oil, hard coal, lignite, and natural gas), whereas its highest contribution (about 20% of total ADP) is indirectly caused by the consumption of natural gas during production of glass bottles. AP has the highest dominance in the bottling phase due to nitrogen oxides and sulfur dioxide emissions during upstream processes of glass bottles (around 20%) and steel (around 22%) productions. However, also the first phase of the life cycle showed quite a high contribution of AP, in particular for the diesel combustion process (about 30%). Moreover, the highest contribution of EP was observed in that particular process of vine planting (around 52%), mainly due

Table 1
'Cradle to gate' Life Cycle Inventory (LCI) of primary inputs and outputs occurred in the production of Sardinian white wine.

Primary inputs	Unit	Quantity/L	Quantity/ha	Primary outputs	Unit	Quantity/L	Quantity/ha
Vine planting							
Steel (machineries and other)	kg	1.29E−03	9.28E+00	Area of land, for viticulture	m^2	1.39E+00	1.00E+04
Rubber (machineries)	kg	1.39E−05	1.00E−01				
Glass (machineries)	kg	4.19E−06	3.02E−02				
Manure	kg	3.70E−03	2.67E+01				
Human labor	h	4.83E−03	3.48E+01				
Diesel	kg	1.05E−01	7.53E+02				
Lubricating oil	kg	3.12E−03	2.25E+01				
Wood	kg	5.95E−03	4.28E+01				
Concrete	kg	1.04E−01	7.51E+02				
Fertilizers	kg	2.78E−03	2.00E+01				
Insecticide	kg	6.02E−04	4.33E+00				
Herbicide	kg	2.78E−05	2.00E−01				
Polyethylene high density	kg	4.75E−03	3.42E+01				
Zinc	kg	1.16E−02	8.33E+01				
Grape production and harvesting							
Area of land, for viticulture	m^2	1.39E+00	1.00E+04	Harvested grape	kg	1.67E+00	1.20E+04
Steel (machineries and other)	kg	1.71E−04	1.23E+00				
Rubber (machineries)	kg	8.13E−06	5.85E−02				
Plastics (machineries)	kg	1.97E−06	1.42E−02				
Glass (machineries)	kg	8.89E−04	6.40E+00				
Manure	kg	2.78E−02	2.00E+02				
Human labor	h	7.24E−02	5.21E+02				
Diesel	kg	1.62E−02	1.17E+02				
Lubricating oil	kg	4.84E−04	3.48E+00				
Insecticide	kg	6.94E−03	5.00E+01				
Herbicide	kg	2.78E−04	2.00E+00				
Polyethylene high density	kg	4.17E−02	3.00E+02				
Wine production							
Harvested grape	kg	1.67E+00	1.20E+04	White wine, total production	L	1.00E+00	7.20E+03
Steel	kg	1.60E−04	1.15E+00	Waste, biomass (stem and mark)	kg	2.50E−01	1.80E+03
Human labor	h	3.79E−02	2.73E+02				
Wine yeasts	kg	3.00E−04	2.16E+00				
Sulfur dioxide	kg	1.00E−04	7.20E−01				
Pectolitic enzymes	kg	1.25E−05	9.00E−02				
Ascorbic acid	kg	5.00E−05	3.60E−01				
Nitrogen, liquid	kg	5.88E−04	4.23E+00				
Benthonite	kg	5.38E−04	3.87E+00				
Gelatine	kg	5.00E−06	3.60E−02				
Fossil flours	kg	2.38E−03	1.71E+01				
Liquified Petroleum Gas	kg	9.75E−04	7.02E+00				
Wine bottling							
White wine, total production	L	1.00E+00	7.20E+03	White wine bottled	L	9.38E−01	6.75E+03
Human labor	h	1.67E−03	1.20E+01	White wine bulk	L	6.00E−02	4.32E+02
Steel	kg	1.39E−01	1.00E+03				
Cork	kg	4.38E−03	3.15E+01				
Polylaminate	kg	1.88E−03	1.35E+01				
Paper and cardboard	kg	8.58E−02	6.18E+02				
Glass bottles	kg	6.88E−01	4.95E+03				
Electric power	MJ	1.80E−01	1.30E+03				
Water use	L	1.59E+00	1.14E+04				

to nitrogen oxides emitted in the air. In general, to produce 1 bottle of Sardinian white wine (0.75 L), about 1.64 kg CO_2-eq. are emitted. This is mainly due to the production of glass bottles for the wine bottling phase and to the combustion of diesel during the first phase of the grape production.

Fig. 3 shows in detail the contribution of sub-processes in each phase of Sardinian white wine's lifecycle, whereas category indicators are normalized to 100% for the sake of clarity. The aggregated process of production and combustion of diesel provided the highest impacts during the phase of vine

Table 2
Mass balance of the life cycle inventory of Sardinian white wine (GaBi4 elaboration): relative contributions for each phase.

Inputs	**Conventional white wine production (%)**	**Vine planting (%)**	**Grape production and harvesting (%)**	**Wine production (%)**	**Wine bottling (%)**
Flows	100	4.36	3.24	10.00	82.40
Resources	90.02	4.36	3.24	0.02	82.40
Energy resources	5.72	1.27	0.75	0.01	3.69
Material Resources	84.30	3.09	2.49	0.01	78.71
Valuable substances	9.98			9.98	0.00
Outputs					
Flows	100.00	13.98	41.36	5.56	39.10
Deposited goods	10.09	0.62	0.10	5.47	3.90
Ecoinvent	0.00	0.00	0.00	0.00	0.00
Emissions to air	43.80	13.30	4.85	0.08	25.57
Emissions to fresh water	7.62	0.05	0.01	0.00	7.56
Production residues in life cycle	0.81	0.01	0.00	0.01	0.79
Resources	1.28				1.28
Valuable substances	36.40		36.40		

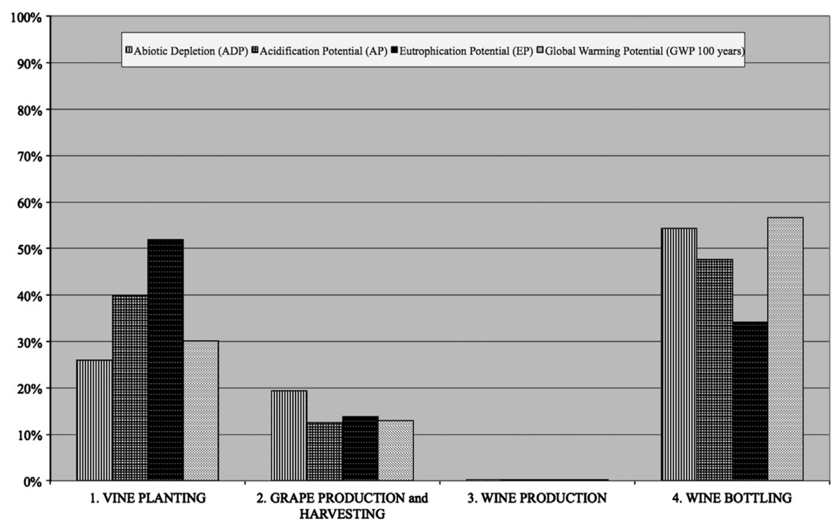

Fig. 2. Impacts characterization of Sardinian white wine's life-cycle 'from cradle to gate'. Relative contribution of category indicators (CML 2001 method) among each phase production.

planting, followed by the production of concrete. With regard to the second phase of grape production and harvesting, processes of diesel (production and combustion), polyethylene high density, and glass for machineries are those with highest contributions to each category indicators. The combustion of gas in phase 3 (for heating and other uses during the phase of wine storage and production) had dominance to all impacts, although in absolute values (see Table 3) their contribution is 2/3 order of magnitude lower compared to the other life cycle phases. Finally, the production of glass bottles and steel confirmed the main contributions to all four impacts quantified in the last phase of the life cycle; i.e. wine bottling. Results of LCIA are perfectly related to those observed in the mass balance of LCI, since the impacts of the life cycle increase with consumption of resources and quantity of emissions i.e whereas the bottling phase highlighted the highest contribution due to the production of glass bottles.

The main problems were the production and combustion of diesel, in the vine planting, and the glass production, which is then used for the manufacture of bottles used in the winery processes. The results obtained in this exercise confirm what has already been noted in the recent literature.

An example relating to the first problem can be seen in Petti et al. (2006). The use of biodiesel fuel could be an option to improve the wine environmental performance (Fukuda et al., 2001).

The problem concerning glass essentially confirms what has already been observed in other contexts (e.g. Ardente et al., 2006; Petti et al., 2006; Gonzalez et al., 2006; Gazulla et al., 2010). An examination of recent literature reveals some solutions that would

Table 3
Characterization results of the Life Cycle Impact Assessment (LCIA) of Sardinian white wine values refer to the functional unit of 1 bottle of wine (0.75 L) at farm gate.

Life cycle impact indicators (CML 2001 method)	Unit	Total	Vine planting	Grape production and harvesting	Wine production	Wine bottling
Abiotic Depletion (ADP)	kg Sb-eq.	1.03E−02	2.69E−03	2.00E−03	2.04E−05	5.62E−03
Acidification Potential (AP)	kg SO_2-eq.	1.19E−02	4.73E−03	1.49E−03	9.65E−06	5.66E−03
Eutrophication Potential (EP)	kg PO_4-eq.	1.50E−03	7.78E−04	2.06E−04	1.02E−06	5.12E−04
Global Warming Potential (GWP 100 yearss)	kg CO_2-eq.	1.64E+00	4.95E−01	2.13E−01	2.86E−03	9.31E−01
	Vine planting (%)	Grape production and harvesting (%)	Wine production (%)	Wine bottling (%)		
Abiotic Depletion (ADP)	26.05	19.37	0.20	54.39		
Acidification Potential (AP)	39.81	12.52	0.08	47.58		
Eutrophication Potential (EP)	51.95	13.78	0.07	34.20		
Global Warming Potential (GWP 100 years)	30.12	12.99	0.17	56.71		

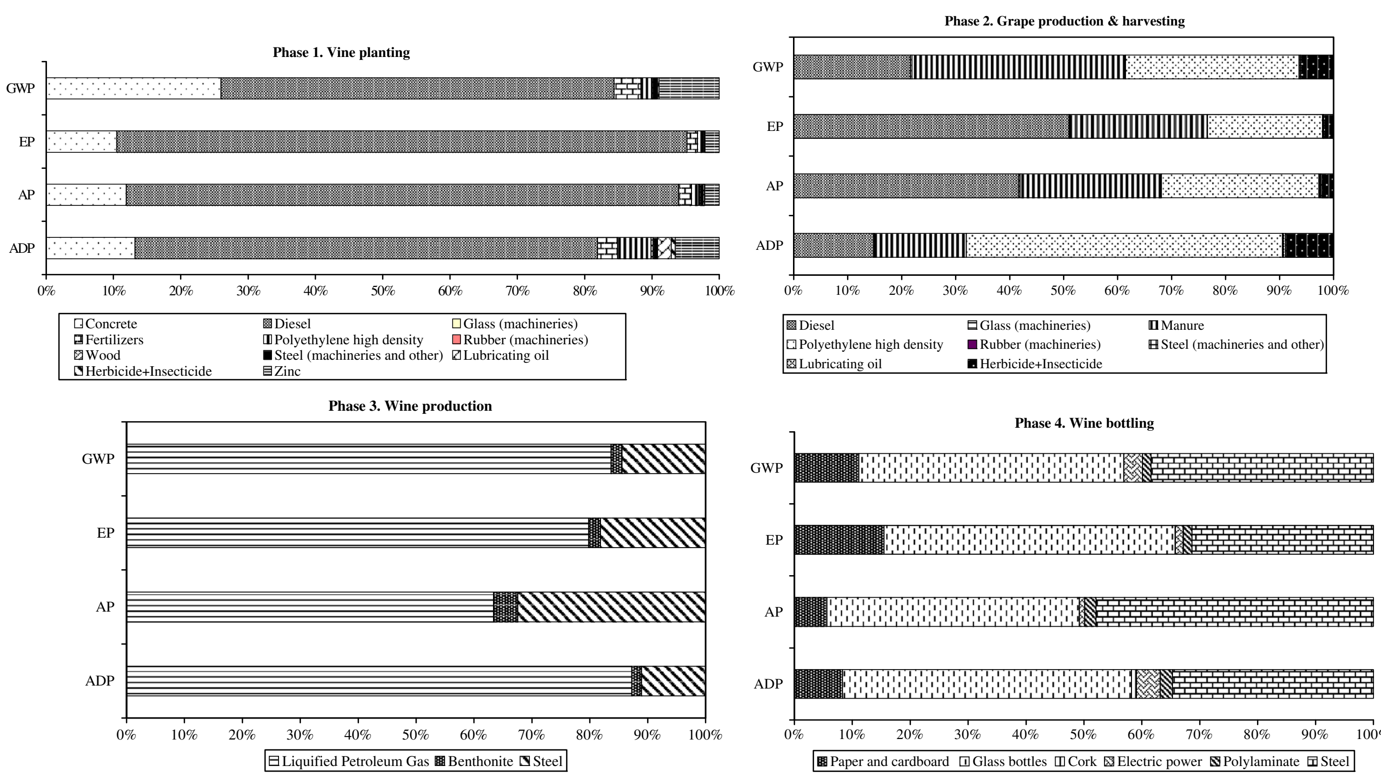

Fig. 3. Impact contribution of sub-processes in each phase of Sardinian white wine's life cycle ‘from cradle to gate’. Indicators (GWP = Global Warming Potential 100 years, EP = Eutrophication Potential, AP = Acidification Potential and ADP = Abiotic Depletion; CML 2001 method (Guinée et al., 2001) are normalized to 100%.

allow the company to improve their business performance. For example the use of lighter bottles as suggested by Ardente et al (2006), Petti et al. (2006), Point (2008); different WRAP's report recalled by Garnett (2007), Colman and Paster (2009), Point et al. (2012), or increasing recycling rate of bottles at source (Wrap Material change for a better environment, 2007, 2010).

Conclusions

This paper presents the results of an evaluation exercise on the environmental emissions associated with the production of wine in Sardinia, with the aim of contributing to a development of this approach at regional level.

Hence the reason why we used the Life Cycle Assessment (LCA) tool applied to a typical wine produced in Sardinia, in an area with a specific viticultural and touristic vocation. Data were collected in 2010 within an integrated cycle wine industry, which has about 600 ha of vineyards, 55,000 hL of wine per year and sells in markets that play a fundamental role as the main importers in the framework of the international interchanges.

In general to produce 1 bottle of typical Sardinian white wine (0.75 L), as seen in this study, about 1.64 kg CO_2-eq. are emitted. This is mainly a consequence of the production of glass bottles for the wine bottling phase or diesel combustion. The aggregated process of production and combustion of diesel provided the highest impacts during the phase of vine planting, followed by the production of concrete.

There are some considerations to bear in mind about the process improvement using results in the literature. For example reduced contributions to impact categories were illustrated through the use of lighter bottles; also the use of biodiesel fuel could be a solution to the problem of environmental impact resulting from the use of agricultural machinery during the mechanical operations carried out in the vineyard.

Finally, we would like to emphasize that this is a preliminary assessment, which requires further efforts to improve data quality and system boundaries: the next steps will be aimed at a more detailed assessment of the environmental emissions associated with the production of *La Cala* wine, expanding the system boundaries to include the sale and the end of life taking into account the emissions caused by the use of pesticides. A second advancement of knowledge, programmed in accordance with the management company, will aim to support the *environmental* LCA with the *social* and *economic*, in line with recent developments in the theoretical literature and application of LCA methodology that is evolving into LCSA (Life Cycle Sustainability Assessment) framework.

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