Regional Resource Flow Model Wine Sector Report

Analysis of GHG Emissions of Western Cape wine grape production

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List of acronyms

CCC	Confronting Climate Change
IPW	Integrated Production of Wine
LCA	Life Cycle Assessment
RRFM	Regional resource flow model
SAM	Social Accounting Matrix
SAWIS	South African Wine Information & Systems

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1. Introduction

This report forms part of the Regional Resource Flow Model (RRFM) project[1] of GreenCape, the goal of the RRFM is to provide strategic analysis of the provincial economy to identify key sectors and to consider resource constraints within these sectors. This information is required to assist in identifying opportunities to improve resource productivity, and thus competitiveness. This work consists of two components; a "top-down' Economic analysis using a Social Accounting Matrix (SAM) (Janse van Vuuren, 2015) and a "bottom-up' consideration of resource needs using Life Cycle Thinking as shown in Figure 1. The SAM has been built on the Western Cape Social Accounting Matrix (SAM) to allow sectoral comparisons considering different inputs and impacts, while taking into consideration the interconnectedness of the sectors. This work is detailed in the SAM analysis report, which focussed the scope of the Life Cycle Assessment (LCA) based or "resource needs' work, of which this forms part. The "resource-needs approach" determines the resource efficiency within the subsectors of the SAM, and provides more reliable sectoral data on possible environmental impacts with a focus on Green House Gas (GHG) emissions. This is done by gathering sector specific data and is thus a more "bottom-up" approach than the macro-economic SAM analysis.

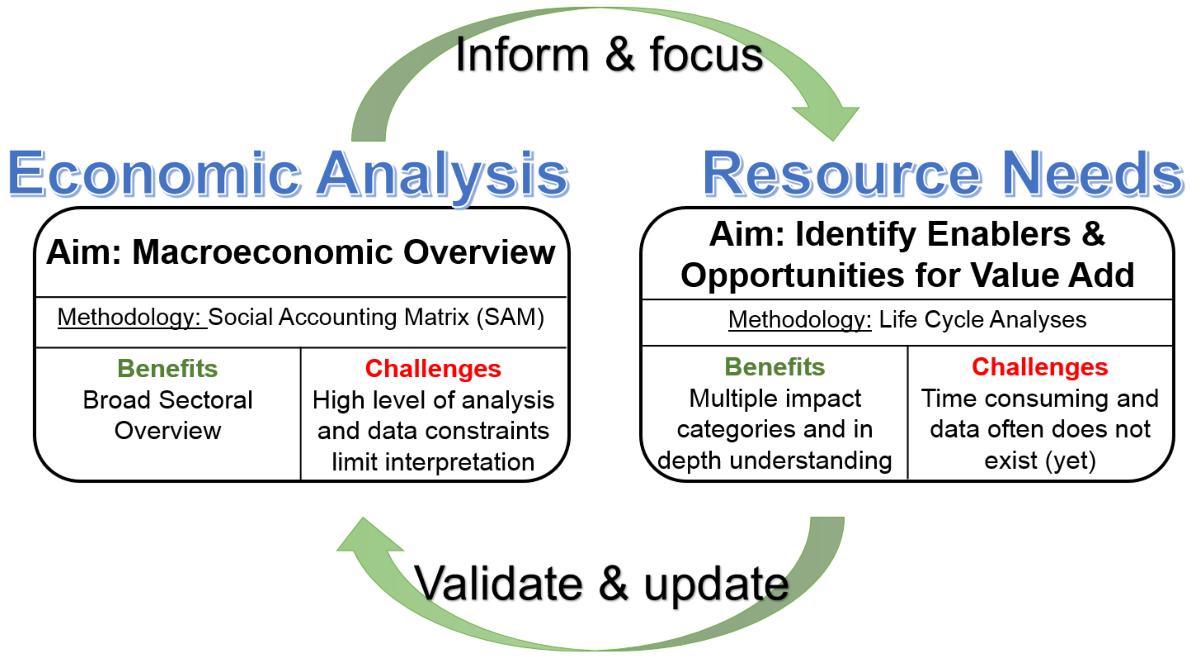

Figure 1: Regional Resource Flow Project Overview

This report forms part of the initial focus on the agricultural sector which the SAM breaks down into 10 subsectors. While initial data used in the SAM analysis was aggregated agricultural data, this report will help update subsector emissions. The agricultural sector in the SAM is broken into 10 subsectors as shown in Figure 2 overleaf.

[1] For most recently released reports see RRFM webpage on GreenCape's website: green-cape.co.za/what-we-do/projects/regional-resource-flow-model/

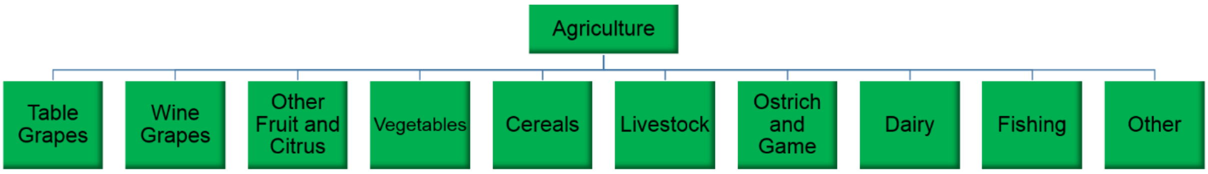

Figure 2: Agriculture subsectors in Social Accounting Matrix (SAM)

This report aims to provide an overview of the wine grape farming sector, and touches on the wine subsector of agro-processing as the data available naturally lends itself to this extension. The objective of this report is to get an indication of the GHG emissions of the sector using the carbon footprints calculated by Confronting Climate Change (CCC). CCC, has developed a carbon footprinting tool based on British standards Publically Available Specification (PAS) 2050, in line with other carbon footprinting tools used in the wine sector including the International Wine Industry Greenhouse Gas Protocol and Accounting Tool. These footprints are currently completely voluntary, though there has been some pressure from international export markets to have carbon footprints calculated. Additionally, Integrated Production of Wine (IPW) certification, (discussed further under green labelling) awards points for having a carbon footprint calculated, though currently it is not mandatory and points are not awarded based on the carbon footprint results. CCC's industry reports provide a regional breakdown of the carbon footprints but do not link management practices or cultivars to these carbon footprints. These industry reports are also used to update the carbon footprint of the sector for the SAM "top-down" analysis.

2. South African Wine Industry

South Africa's wine industry is a key player globally; comprising of 4% of the world's wine production with 60% of South African wine being exported (van Niekerk, 2014). The Western Cape produces 95%[2] of South African wine (SAWIS, 2014) and the industry is an important source of employment in the province, accounting for 8.8% of total employment as well as 2.2% nationally. This employment is also strongly aligned towards unskilled labour, with 58% of the employment opportunities targeting unskilled labour, 29% semi-skilled and 13% skilled (Conningarth Economists, 2009). With total employment impact increasing from 275 000 to just under 290 000 from 2008 to 2013 (Conningarth Economists, 2015, p. 20).This report highlights the broad trends that have emerged from the life cycle analysis of wine by summarising international studies, as well as examining regional information gathered by CCC who have conducted carbon footprints for South African wine farms and producers.

2.1. Variety in the Wine Grape Industry

Internationally the wine industry has conducted numerous LCA studies, including some meta-analyses (Rugani, et al., 2013). Generally these have been at a much smaller scale than the Western Cape, making it easier to draw out general trends from the analysis. In contrast the sheer scale of the Western Cape wine industry makes it difficult to highlight general trends. This scale is illustrated by the fact that in 2013, the province had 99 680 hectares of land under viticulture and produced 1,16 billion litres of wine (SAWIS, 2014)[3]. There is also a large amount of variation in the factors that impact LCA results. These include a variety of cultivars, rootstocks, trellising systems and farming area. As such, no wine sector LCA has been completed in the Province.

The wine industry has developed a conceptual approach to understanding and describing the influence that the environment has on the production in wine. This concept is referred to as a *terroir*, a French term used to describe the relationship of soil, climate, topography and all other factors that influence the vine and the character of the wine. There is however no set criteria for a *terroir,* with abstract concepts such as a "presence of place" sometimes being included[4]. The diversity of *terroirs* in the Western Cape is highlighted in the work of Carey et al. (2008) who found 1389 *natural terroir units*[5] in the Stellenbosch region alone, one of 9 wine growing regions in South Africa (8 of which are in the Western Cape) (SAWIS, 2014). *Terroirs* are used in part to identify wine strategies for vines and, in contrast to most other agricultural systems productivity, increased yields are often less important than increased quality or taste of the wine. Improved yield production may come at the expense of the quality and taste. This reflects the complexity of the wine industry, which makes it difficult to get a representative measure of wine grape production and value. This is also reflected in Vinpro[6] explicitly moving away from describing "representative farms" within their reporting structure. Instead, their budgets consider average financial expenditure per farming areas and they that the Malmesbury region is inherently different to the other areas as it is the only area where dryland viticulture is prevalent (van Niekerk & van Zyl, 2014). Which would need to be accounted for if considering a more explicit LCA approach.

[2]According to hectares and excluding Sultana, with 4.67% being in the Northern Cape.
[3]In comparison Nova Scotia has 350 acres (141ha) producing 750 000 litres in 2006 (Point, et al., 2012)
[4] See Mouton (2006) for a full discussion on *terroir*.
[5] Considering only natural environmental variables: terrain, aspect, altitude, soil and geology.
[6] "VinPro is the service organisation for 3 600 South African wine producer and cellar members, striving towards their commercial sustainability, as well as that of the broader producer industry and its strategic role-players. As such, it is their mouthpiece and representative at all relevant forums and in dealings with Government." (Vinpro, 2014)

3. Life Cycle Thinking and Wine Grapes

Life Cycle Assessments (LCA) are composed of four phases as shown in Figure 3: goal and scope, inventory analysis, impact assessment and interpretation. Key ideas of this approach are used but as mentioned earlier a complete LCA is not undertaken due to a constraint on data availability to construct detailed Life Cycle Inventories (LCI) to undertake inventory analysis.

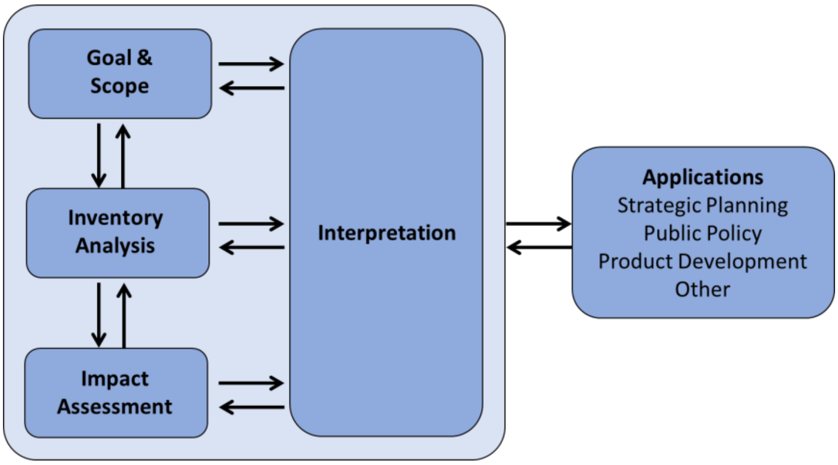

Figure 3: The four phases of life cycle assessment and their applications (ISO, 2006)

Using the impact assessment results (GHG emissions from production) compiled by CCC this report provides some interpretation of the results with some international benchmarks to inform decision making. This information is also used to get an estimate of wine grape production's GHG emissions to update the macro-economic work. The results are also unpacked to consider the drivers of GHG emissions using industry research and knowledge rather than explicit modelling. Thus this report makes use of LCA thinking but does not involve any explicit LCA.

3.1. An overview of LCA challenges for grape production

Grapes are a perennial crop and thus the resource use and potential environmental impacts of the production system need to be assessed over the lifetime of a vineyard, including different stages/years of production according to best practice guidelines (Cerutti, et al., 2014). The importance of considering impacts over a vineyard's lifetime is highlighted in previous studies, which indicate that the vineyard's establishment impacts are an important component of the carbon footprint of production (Benedetto, 2013). Additionally, seasonal variation has also been shown to be important in terms of carbon footprints for a number of reasons: yields will vary per year, the amount of pesticides will vary per year as certain weather patterns encourage certain pests, aggravated to some extent by the fact that the lack of genetic variation makes wine grapes more vulnerable to pests. This is particularly problematic for wine as harvest year is a marketable difference, thus a lower yield year will have a larger carbon footprint but it may also have a higher value (Vázquez-Rowe, et al., 2012, p. 81).

The PAS 2050 guidelines recommend that a 3-year moving average is used to account for the seasonal and production variations. However, CCC carbon footprints have only been done for two years, so the industry benchmarks are not yet in line with the recommendations, but will be when more data is available (Confronting Climate Change, 2014, p. 1).

Ideally, LCAs of wine grapes LCAs should include all stages of production including the nursery stage, although data constraints often make this difficult and result in its exclusion (Cerutti, et al., 2014). This issue has yet to be explored in the South African context for a wine grape LCA (to the best of the author's knowledge) and may be a useful area for further research.

4. Carbon footprint analysis

Despite the challenges in examining the resource intensity and potential impact of wine production systems, there have been numerous studies considering the sustainability of wine, either using carbon footprinting or more sophisticated LCAs. Industry-specific carbon footprinting tools have being developed, both internationally e.g. the International Wine Carbon Calculator and locally e.g. the CCC, developed as part of the national Fruit and Wine Initiative, both in compliance with British standard PAS 2050 (Rugani, et al., 2013, pp. 69-70; Confronting Climate Change, 2014).

The numerous LCA studies have allowed the undertaking of meta-analyses[7], such as one done by Rugani *et al.* (2013) which considered 35 different LCA studies' of wine grapes from a variety of countries, detailed in Table 2and Figure 9 in the appendix. CCC has data from carbon footprints calculated with participating farmers and wine producers using their online tool. Results are validated before they are included in their industry report. The results from these two sources are compared in Figure 4 with the green sections representing the viticulture (wine grape production), blue the viniculture (wine production) and orange the bottling.[8] The detailed disaggregated results are shown in Table 3 in the appendix, with South African (as opposed to Western Cape) results shown in Figure 10 with a detailed breakdown in Table 4.

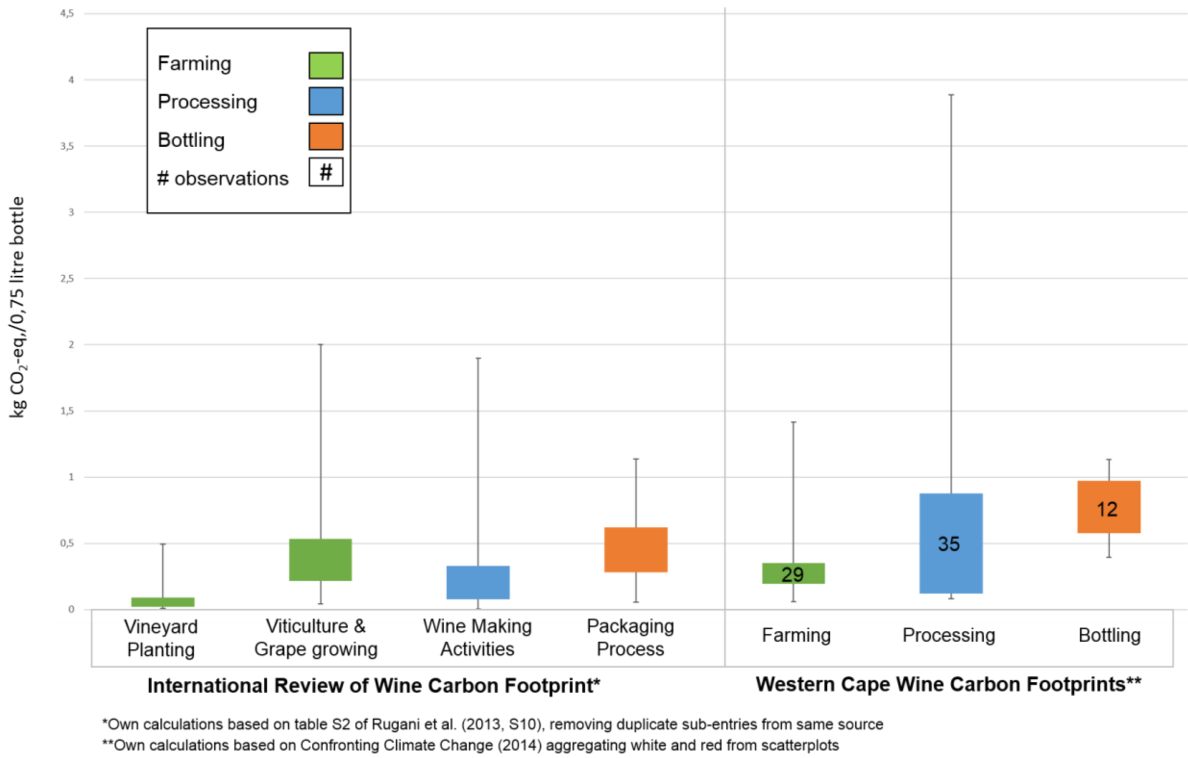

Figure 4: Comparison of International and Western Cape Carbon Footprints

The results show that carbon footprints of Western Cape farming practices fall within the lower end of the range of the international studies. The carbon footprints of wine processing in the Western Cape are however less competitive in terms of carbon emissions, probably due to the use of the high carbon

[7] See also the meta-analysis of Petti *et al.* (2015)

[8] Original category names are kept as in sources the figure is constructed from.

footprint of South Africa's electricity mix. The bottling of wine generally has the largest impact on the carbon footprint, highlighting the importance of considering the entire value chain. It also highlights the importance of considering the different agro-processing sectors found within the SAM - which includes a wine production sector.

4.1. Viticulture/Wine Grape Farming

As highlighted above, the farming, or viticulture, component of the carbon footprints in question falls within the lower range of carbon footprints calculated internationally. This seems to indicate that growing grapes in South Africa is less carbon intense than farming elsewhere. However, this could be partially driven by sample bias, as the farms volunteering to determine their carbon footprints are likely to be those that are already more conscientious regarding improving the overall sustainability of their farms.

4.1.1. Artificial propagation and Herbicide and pesticide use

In agriculture, herbicide and pesticide use has been highlighted as significant in terms of both emissions and eco-toxicity. While important in most agricultural products, the use of pesticides and herbicides is particularly relevant in the wine industry, as the industry has aimed to produce consistent wines and has therefore limited the scope for genetic variation. For example, all wine in South Africa is being produced from scions grafted onto rootstocks[9] that are able to resist the root louse phylloxera (Teubes, 2014). These artificial propagation methods have inhibited the evolution that would allow natural resistance to develop in plants, thus making them more susceptible to many diseases and more reliant of herbicides and pesticides. There is however research being done on developing more resistant hybrid varieties (Hesseling, 2013). This highlights the importance of the nursery stage in considering an LCA of wine grapes, as different rootstock-scion combinations have different resistances and susceptibilities resulting in different herbicide and pesticide needs. It also highlights the need to manage herbicide and pesticide use carefully as their impacts are far ranging.

4.1.2. Cover Cropping

The study of more efficient farming methods in South Africa has resulted in the establishment of the South African Journal of Enology and Viticulture[10] providing scientific backing for best farming practices. Cover cropping is the practice of planting crops to manage the soil with a number of advantages: weed control, reducing water runoff and erosion, decreasing soil surface evaporation, conserving water and reducing soil temperature fluctuations (Fourie, 2012, p. 14). Most significantly for GHG emissions it reduces weeds that require chemical control and increases the soil organic matter in fields, in some instances removing the need for nitrogen fertiliser completely (Fourie, 2012). This will clearly reduce the carbon footprint of grapes, as nitrogen fertiliser production has a large carbon footprint. Cover cropping has become common practice in the wine grape industry.

4.1.3. Water and energy use in irrigation

Most vineyards are irrigated with the irrigation control being a key component of micro-climates management in vineyards with a great potential to impact yield and thus a vital component of wine grape farming. Irrigation is the main user of electricity at a farm level when excluding housing, making it a key factor to consider when considering carbon footprints (Confronting Climate Change, 2014, p. 20). Given the water and energy constraints that South Africa and the Western Cape face, it is also important to use water as efficiently as possible.. It is promising to note that the use of drip irrigation,

[9] Vineyards in Europe and South Africa were decimated by the introduction of phloxera in the late 19th century as they had no natural resistance in contrast to the American vines on which vines have been grafted since then.
[10] http://www.sawislibrary.co.za/dbtw-wpd/textbase/sajev.htm.

which is generally seen as the most energy and water efficient system, has shown a rise in uptake to 59% in 2012, up from below 30% in 1996 (van Niekerk & van Zyl, 2014, p. 34). Other interventions include variable speed drives[11] that decrease energy needs through managing power output of pumps and has been shown to save 71% of energy (Confronting Climate Change, 2014, p. 20).

Additionally, the trellising systems are key influencers of evapotranspiration as they shade the ground where water is applied and help keep water needs relatively low (van Zyl & van Huyssteen, 1980).

Recognising the importance of the Province's water resources for agriculture, the Western Cape Department of Agriculture has developed the "Fruitlook" online platform, which utilises satellite imagery to help farmers manage water use effectively by measuring growth, moisture and minerals[12]. This data helps recognise areas of over and under irrigation, with weekly updates, thus allowing more efficient water use. This results in two positive impacts: farmers are able to avoid unnecessary consumption of water and related energy use, and are able to avoid stunted growth from under watering. This system is just one of many tools at farmers' disposal to use water efficiently and is generally suggested to be used with soil probes.

4.1.4. Farming practises and production yields

Organic farming practices have been shown to have lower carbon footprints per hectare. However, conventional wine grape farming practices have higher yields, resulting in the carbon footprints per unit of production not being clearly higher or lower for either practice (Rugani, et al., 2013, p. 67)[13]. Additionally there are limited methods available to control pests with the lack of viable weed control necessitating multiple tillage, a carbon intense and expensive exercises (Theron, 2014).

Regarding wine grapes, yields are also affected by the goals that farmers have for specific blocks which at times reduces yield to achieve a specific taste. The yields are also closely linked to the trellising systems used. For example Teubes (2014) states that Ramsey rootstock can yield 30-35 tons/ha on Perold trellises, and 60-70 tons/ha on Double Gables - with up to 100 tons/ha being attained in some instances. Trellising systems are clearly an important component of farming grapes with long-term implications for farmers, and are thus a key component to consider in a more detailed analysis of wine grape's life cycle. Innovative grapevine training measures are being implemented for more vigorous cultivars that establish vines faster, thus increasing the vines' profitability and efficiency (Bosman, 2013). The efficiency of production is key to evaluating the carbon footprint of grape production, as highlighted by the lack of a clear advantage of organic farming in terms of grapes' carbon footprint.

4.2. Viniculture/ Wine Making

4.2.1. Energy use

The viniculture, or wine making component of production, is clearly an important component of the carbon footprint of wine, especially in the Western Cape context where the results are highly variable as shown by the large range of results in Figure 1 including very large outliers. This is linked to the large carbon footprint of South Africa's highly coal dependant energy mix. In response, some farmers have moved towards using renewable energy such as solar energy which has been shown to be able to supply all day time electricity needs including; pumping, cellar, guest house and offices, with night time electricity needs being dependant on Eskom (Confronting Climate Change, 2014, p. 21).

Additionally, Energy Management Guideline (Brent, et al., 2014) has recently been released to help the industry reduce energy needs. They also show a typical breakdown of energy use for a winery as

[11] See: http://www.sabi.co.za/sabisasol/vsd.pdf for a technical overview
[12] Fruitlook (originally GrapeLook) focused on the grape growing but has since expanded to consider other fruits though the areas it analyses are still limited (http://www.fruitlook.co.za/).
[13] See also Figure 9 in the appendix.

replicated in Figure 5. It is clear that the area that will have the largest opportunity in terms of reducing energy demand would be improving the efficiency of cooling, whilst significant improvements are also possible from more efficient pumps and lighting.

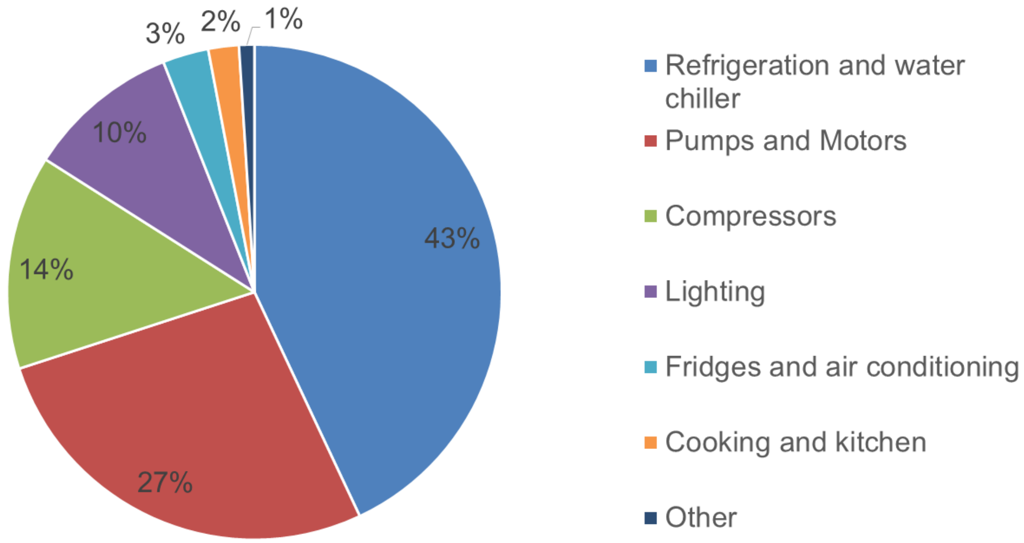

Figure 5: Typical Energy Balance for a Winery (Brent, et al., 2014, p. 17)

4.2.2. Wastewater

Winery wastewater has high organic concentration and pollution loads that can have large detrimental effects, especially when the water enters the water table or streams. Ninety percent of winery effluent is currently being disposed of through land application (Mulidzi, 2006). While the use of wastewater in irrigation is useful in carrying organic carbon to micro-organisms in the soil it is not always an appropriate measure, as soils that drain too well will not allow sufficient contact time, resulting in a build-up of organic material in the water table (Mulidzi, 2001, pp. 105-106). Additionally, common inorganic pollutants are Phosphorus, Sodium, Potassium and sometimes Boron (Mulidzi, 2006).

There are additional opportunities in the bio-remediation of winery wastewater, to extract valuable chemicals such as Gypsum, Potassium, glycerol and germ oil as well as use of dried content used as animal feed (Melamane, et al., 2007, p. 28). Melamane, Strong & Burgess (2007) provide a good overview of the different treatments that are possible to ensure that wine wastewater's pollution loads are within those mandated by law. They also note that there have been some unsuccessful digester trials that hint at the high organic loading adversely affecting digester performance. They also note that high energy and wastewater disposal costs result in treatment processes with the lowest operational and maintenance costs, rather than capital costs, being the most attractive thus the capital costs are not seen a constraint to wine distillery wastewater treatment. It also important to note that as the composition of the wastewater differs from winery to winery as methods differ so the optimal wastewater management will differ (Bories & Sire, 2010, p. 43).

4.3. Bottling

The bottling process is a carbon intense component of the production of wine. This is largely linked to the packaging materials used. Glass making requires very high temperatures and thus energy. This has resulted in some innovative packaging strategies. However, the wine industry continues to resist change due to the market view that alternatively packaged or sealed wine is of a lower quality. This is illustrated by the debate around replacing corks with screw caps (Goode, 2004). Nevertheless, there has been a move towards lightweight glass, and lightweight plastic for short-lived products. While reducing package material will decrease carbon footprints, there are also issues of branding value-add, as shifting to bulk wine exports will decrease the carbon footprints of the wine, but will also result in a decrease in the value of the wine to the Western Cape. While alternative packaged wine is sold, most wine is still packed in glass and the share of natural wine packaged in glass has actually been rising slightly (SAWIS, 2014, p. 24)[14].

4.3.1. Integrated Production of Wine/ Green Labelling

The carbon footprints conducted by CCC are also linked to the Integrated Production of Wine Scheme (IPW) which works closely with farmers to encourage sustainable farming practices, with annual audits. As part of the IPW, audit points are awarded simply for having a carbon footprint calculated. The IPW's work is indicative of the emphasis placed on sustainable practices within the wine industry in all three areas examined here, namely farming, wine making and bottling. The 2000 vintage was the first to be certified. The IPW has also developed a label to help consumers make informed decisions:

Figure 6: Seal guaranteeing compliance with IPW criteria

It is clear that the industry has prioritised sustainability, backed by audited criteria, and has been able to develop a meaningful "green label". The uptake of sustainable practices is evidenced by the increase in share of IPW certified wine from 70% in 2010 to 92% in 2014[15]. General certification has also risen over time and was at almost 65% in 2013, as shown in Figure 7.

[14] See Table 5 in the appendix.
[15] Share of bottle stock of which seal is issued from correspondence with SAWIS.

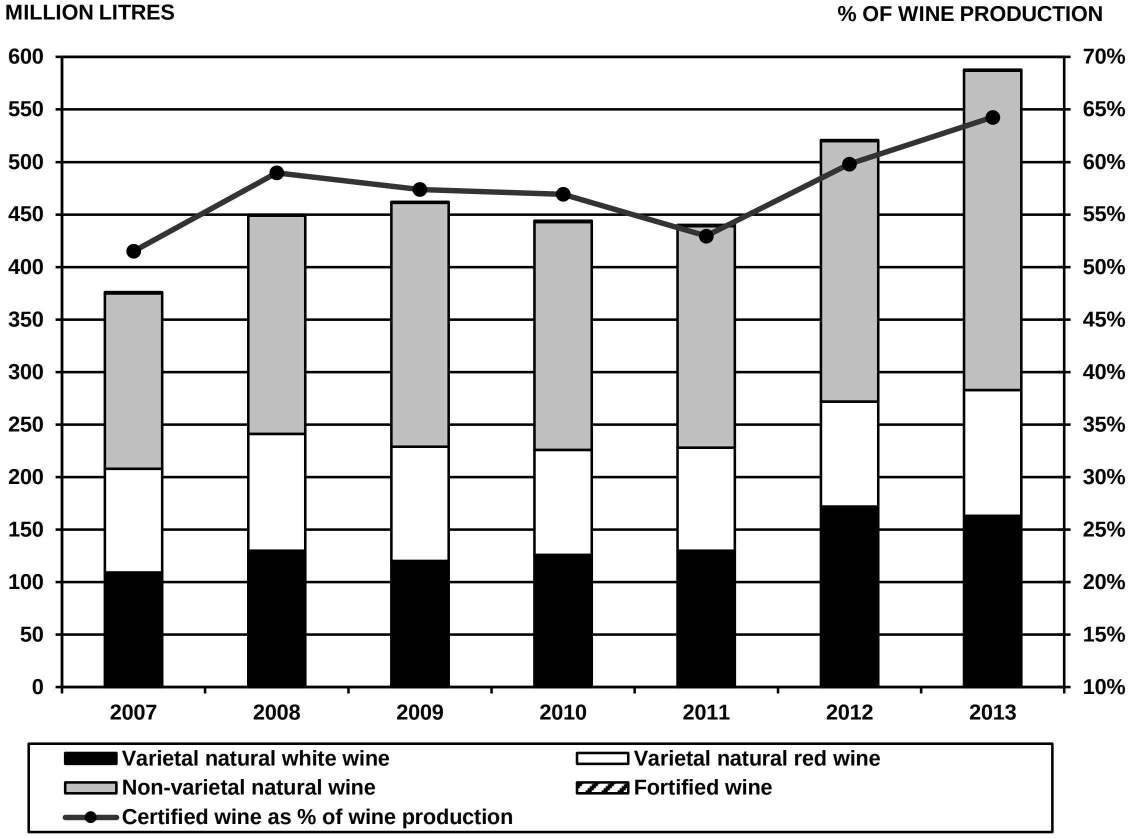

Figure 7: Certified wine per category (2007-2013) (SAWIS, 2014, p. 21)

5. Reconciliation to SAM

Having examined the various components of the wine value chain, the carbon footprints can be linked back to the sectors in the SAM analysis as shown in Figure 1 and provide more accurate estimates of emissions for these sectors. The sectors that are relevant from the SAM are wine grape farming and wine production. The wine production sector will need additional information to consider the different wine products such as brandy and grape juice, but at least an estimate is possible given the data currently available. However, given the focus on the farming sector this was not explored further at this stage.

5.1. Estimating Carbon Footprint

The production figures from SAWIS (2014) and the carbon footprints from CCC (2014) are broken down into red and white cultivars. The carbon footprints for red and white wine grapes in the Western Cape are shown in Figure 8 below[16]. It is clear that they follow similar distributions. There also appear to be larger outliers on the upper scale, especially for processing. Although bottling does not appear to have a great deal of variation, it should be noted that this production phase has the smallest sample size (7 and 5 bottling plants for red and white wine respectively). Given the fact that carbon footprints are still voluntary and more likely to be undertaken by farmers with an interest in improving sustainability, the mean was used as it is sensitive to the outliers on the upper side, which are deemed important[17].

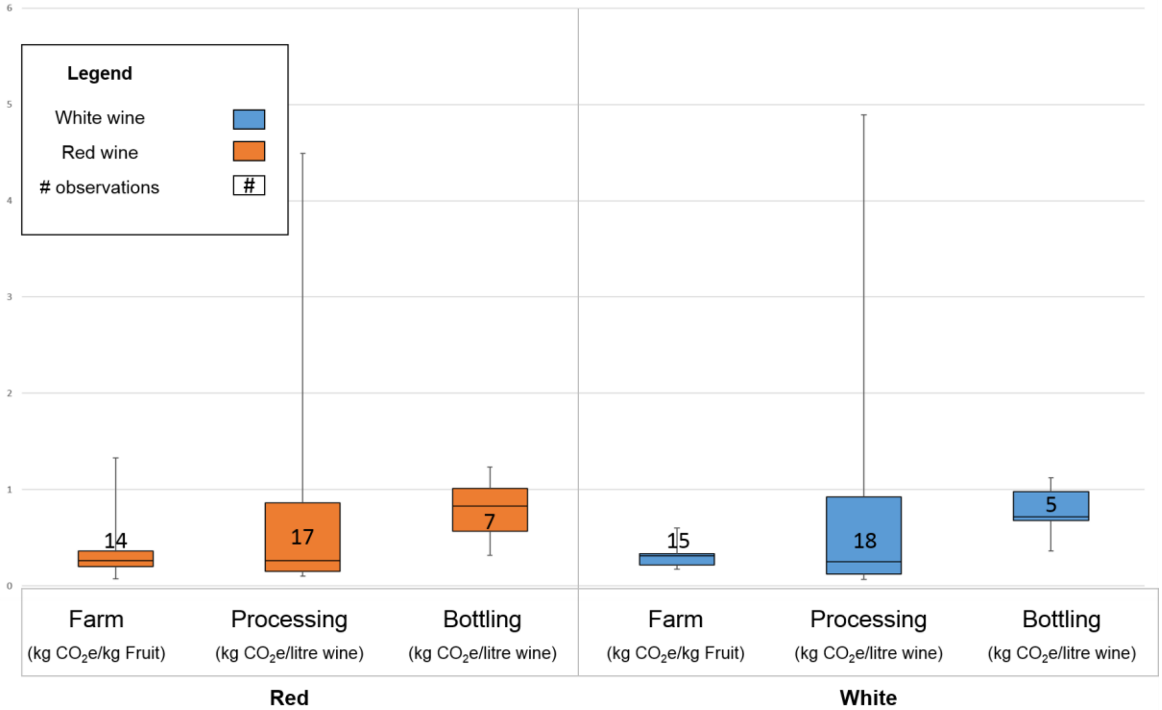

Figure 8: Confronting Climate Change (CCC) Carbon Footprints - Red versus White WC Wines

[16] Emissions per sector as reported by CCC is also shown in the appendix in Figure 11 and Figure 12 as well as a similar comparison including farms from Orange River (non-WC) in Figure 13.
[17] The upper outliers may be less outliers than they appear if the sample is biased downwards due to the non-mandatory nature of the carbon footprints.

These carbon footprints were then used to estimate a carbon footprint for the wine grape farming subsector, 1 of 10 Agricultural subsectors as shown in Figure 2. This was done by taking the total wine grapes crushed as reported by SAWIS (2014) and using the mean Carbon footprint, as shown in Figure 8 above, as the emissions factor. Additionally, the first and third quartile were used to get a reasonable range of the carbon footprint for the sector, in an attempt to account for the variance in results. The results are shown in Table 1.

Table 1: GHG estimates for Western Cape Wine Grape Farming (Gg CO_2e)

	2013
lower	285
estimated	417
upper	460

Own calculations using SAWIS (2014) and Confronting Climate Change (2014)

5.2. Previous SAM Estimate

The initial SAM emissions for the wine grape sector was calculated using total EORA[18] emissions as this database considered more than just energy emissions. However, the database was at a national level and only had an aggregated agricultural sector. This was scaled first from national to provincial using PERO (2013) data that had the financial size of national and Western Cape broken down in 23 sectors[19]. The emissions were then allocated to the subsectors using the output shares in the SAM. This approach provides a rough estimate of sector emissions profiles (as it assumes that the carbon intensity per output is the same). The result was an estimate of 2800 Gg CO_2e per annum[20] . Since then the more accurate, national GHG inventory has been released, and the use of a similar scaling method estimated 660 Gg CO_2e for the wine grape sector when including land, and 1100 when excluding land[21]. However, estimates from the “bottom-up” approach (Table 1) are significantly smaller than this. The result is not entirely unexpected as the wine grape sector is large financially and low in terms of relative emissions (Stoessel, et al., 2012). This is especially true as within agriculture, one of the largest sources of emissions is the livestock sector as highlighted by the FAO report: Livestock’s Long Shadow, with livestock contributing 18% of anthropogenic GHG emissions globally when indirect emissions are included (Steinfeld, et al., 2006, p. 112). Thus scaling emissions per economic value will under-estimate livestock and over-estimate other sectors, especially those that are high value add.

[18] worldmrio.com (Lenzen, et al., 2013; Lenzen, et al., 2012).
[19] For more detail see the SAM report.
[20] Including land use, land use change and forestry (LULUCF) 1000 Gg CO_2e if LULUCF included.
[21] Land is seen as an overall carbon sink in the national GHG inventory in contrast to the Eora database with differences driven by different inclusions and exclusions within land use, land use change and forestry (LULUCF).

6. Possible Further Research

6.1. Adding the nursery component to wine studies

As highlighted previously, "best practice" suggests the consideration of establishment of vineyards when conducting LCA analysis. There is a clear opportunity to calculate more life-cycle explicit measures that consider the nurseries as well. However, previous studies highlight the difficulty of getting accurate data regarding the establishment of vineyards. Nevertheless, industry experts have pointed out that if primary data capturing is undertaken, a fairly representative sample can be gained from the few large nurseries that dominate the market.

6.2. Linking wine industry data to obtain a regional overview of resource use

To consider the industry as a whole, there are a few key industries that have information that could unlock a better understanding of the drivers of carbon intensity within wine grapes. The South African Wine Information & Systems (SAWIS) has data on field areas and includes data on the production, irrigation type, cultivar, rootstock and trellising systems of wine grapes. They also have information on the wine production in areas possibly linked to the grape production areas.

This data is also linked to the IPW reports that have detailed herbicide and pesticide use data which, as mentioned earlier, is a key determinant of carbon footprints and in LCAs more broadly, eco-toxicity. The CCC data could also potentially be linked to this information system to enable an accurate industry level carbon footprint analysis exploring the carbon intensity of different areas and cultivars and if possibly production methods. Additionally, the Western Cape Agricultural Department's land use survey could link to the SAWIS data as a control thereby allowing an update to the GIS component of SAWIS data.

6.2.1. Interrogating regional variation within carbon footprint studies

The CCC carbon footprints of farms and wineries have been motivated to take part by IPW by awarding IPW points for having their carbon emissions calculated. However, the data currently has no information on the factors that would drive the changes in carbon emissions except in terms of total fuel or electricity use, with no indication as to the purpose for which energy was consumed. Linking these data sources could potentially help yield new insight.

Furthermore, the data could provide more accurate industry benchmarks, as it will allow comparisons of the carbon footprints of similar. This requires describing typical characteristics[22] prior to an actual carbon footprint being calculated, and provides a benchmark off which to consider the results thus making the carbon footprint report more valuable to the farmer that receives it.

[22] Possibly using statistical p-value on characteristics identified as key determinants of carbon footprints.

7. Conclusion

This report has given an indication of the resource GHG emissions, or carbon footprint, of wine grape farming in the Western Cape both at a sector level as well as trying to unpack the drivers of emissions. While no explicit Life Cycle Assessment was done, elements of life cycle thinking were used.

The estimated carbon footprint for the sector, 285-460 Gg CO_2e per annum, was significantly smaller than original estimates based on scaling national emissions to province and then to wine grapes from total agriculture. Additionally this estimate was based on Confronting Climate Change's carbon footprint tool that may not be representative of the entire wine grape farming sample as it completely voluntary. Having a carbon footprint calculated does however increase a farm's Integrated Production of Wine score which is part of the certified sustainable labelling that has seen a large uptake in the South African wine industry up from 70% in 2010 to 92% in 2014[23]. While calculating a carbon footprint is still voluntary there has been a push by international consumers to have this information included, this is a significant driver for South African wine as over 60% of wine being exported.

As well as being a large source of exports, the wine industry makes significant contributions to the economy most notably in terms employment, with a strong focus on un-skilled labour with 58% of employment opportunities focused on unskilled labour as well increasing total employment in recent years. The large scale of the South African wine industry is further complicated by the variety wine grapes and regions with large variation in environment even within regions highlighted by over 1389 *natural terroir units*[24] in the Stellenbosch region alone.

Considering the carbon footprints of farms it was interesting to note that the carbon footprints fell within the lower range of international carbon footprints, though this may be driven by sample bias to some extent. Additionally, best practice for perennial crops such as grapes require the consideration of each life cycle stage of the crop, with establishment costs shown to make a significant contribution to the carbon footprint of grapes. Additionally linking carbon footprints to key characteristics of grapes could unlock a greater understanding of the carbon intensity of regions and cultivars allowing more informed decision making and planning. With an integral decision of wine objectives and yield being the trellising system used, with the same cultivars reporting yields more than doubling on different trellising systems with the general consensus being that there is a trade-off between yield and quality.

One of the key drivers of wine grape carbon footprints is irrigation with increased efficiency also helping to address water shortages. The drive for efficiency has been significant, shown by an uptake of drip irrigation as well as the development of innovative tools that make use of satellite imagery to increase water use efficiency. Another key driver of wine grape carbon footprints is herbicide and pesticide use, as the drive for uniform wines resulted in decreased genetic variation as artificial propagation is the norm. This inhibited the evolution that would allow natural resistance to develop, making vineyards more reliant of herbicides and pesticides. While organic farming techniques have been shown to have lower potential environmental impacts per hectare, higher yields of conventional farming mean that neither dominates in terms of carbon footprints per ton of grapes. Additionally, intelligent use of cover crops have been shown to reduce weeds that require chemical control as well increasing soil organic matter, in some instances removing the need for nitrogen fertiliser completely.

While wine grapes were in the lower range of estimated carbon footprints, winery carbon footprints were in the upper range with some observations for processing being higher than the range of international studies' results. One of the key drivers of South Africa's emissions is the high carbon intensity of the grid electricity. Coupled with the high cost of energy this has already driven some farms to implement alternative renewable energy programmes such as installing photovoltaics. With

[23] Share of bottle stock of which seal is issued from correspondence with SAWIS.
[24] Considering only natural environmental variables: terrain, aspect, altitude, soil and geology.

the largest energy need for a winery being cooling with significant demands arising from pumping and lighting. Winery waste water also has high organic concentrations and pollution loads that can be detrimental if it enters the water table, there have however been studies to consider anaerobic digester that found that the organic loads may be too high to be economical. Other studies are considering the bio-remediation of key valuable chemicals from the wastewater.
Within the wine value chain the sector with the highest intensity is the bottling component driven to a large extent by the packaging materials, with glass production requiring high temperatures and thus energy. There have been drives to use alternative packaging with lower quality products packed in plastic bottles. Though the perception of lower quality of alternatively packaged wine has limited uptake of non-glass packaging.

Thus, overall the South African wine production seems to have a larger carbon footprint than its international competitors, this is especially true if additional emissions from transport to international markets are added in as well. As the farming component is actually within the lower range this seems to be driven largely by the carbon intensity of the South African energy mix. If international consumers of wine demand low carbon wine, more wineries will switch to alternative energy sources and possibly alternatively packaged products. There may however be a trade-off of value add and decreasing carbon footprints if bulk wine is transported overseas and packaged there which seems to be happening to some extent already.

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Appendix

8.1. A1. International Review

More detailed results of Rugani (2013) are shown in Figure 9 below for completeness.

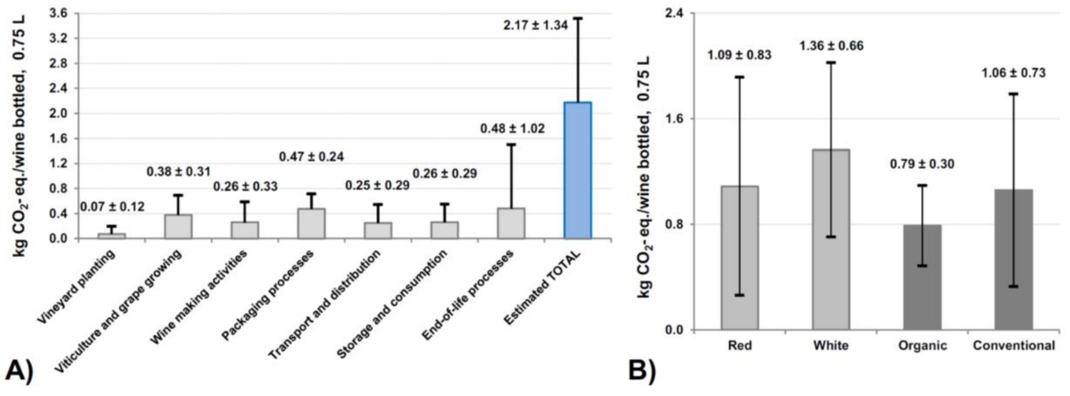


Figure 9: A) average values and standard deviation range of the carbon footprint (CF) of wine per life cycle phase from a cradle to grave approach (29 studies are considered) B) average values and standard deviation range of the CF of different wine typologies (red vs. white) and agricultural practices of wine production (organic vs. conventional); the average CF scores are quantified from cradle to gate (i.e. wine bottled at winery gate) starting from a selection of 22 studies

The results show a slight (not statistically significant) difference between white and red grapes carbon footprint. The article does not provide insight into the cause of this possible difference but discussions with viticulture experts have highlighted greater cooling requirements of white grape cultivars as a possible cause. It is also interesting to note that the standard deviation of conventional farming shows that it is possible for conventional farming to have a lower carbon footprint than organic.

Table 2: Carbon Footprint per section from Rugani et al. appendix

Study	Vineyard planting	Viticulture and grape growing	Wine making activities	Packaging processes	Transport and distribution	Storage and consumption	End-of-life processes	kg CO_2-eq./bottle 75 cl	Comment
Aranda et al. (2005)	-	0.245	0.284	-	0.260	-	-	**0.789**	see footnotes
Ardente et al. (2006)	-	0.155	0.356	1.001	0.135	-	-	**1.647**	
Barry (2011)	-	0.071	0.099	0.677	0.494	-	0.071	**1.410**	
Barry (2011)	-	0.086	0.043	0.744	0.472	-	0.086	**1.430**	
Benedetto (2010)	0.495	0.213	0.003	0.931	-	-	-	**1.642**	
Bosco et al. (2011)	0.110	0.220	0.220	0.460	0.040	-	0.030	**1.080**	vineyard planting and pre-production have been put together in the vineyard planting phase, while bottling and packaging in the bottling process
Bosco et al. (2011)	0.020	0.200	0.040	0.540	0.440	-	0.030	**1.270**	
Bosco et al. (2011)	0.050	0.070	0.090	0.320	0.090	-	0.020	**0.640**	
Bosco et al. (2011)	0.090	0.100	0.050	0.610	0.020	-	0.030	**0.900**	
Carballo Penela et al. (2009)	-	-	-	-	-	-	-	**3.817**	
Carta (2009), in: Vázquez-Rowe et al. (2013)	0.078	0.273	0.140	0.280	-	-	-	**0.771**	red wine-Cannonau di Sardegna
Carta (2009), in: Vázquez-Rowe et al. (2013)	0.089	0.124	0.295	0.334	-	-	-	**0.842**	mixed wine-Marche region
CIV (2008)		0.307	0.116	0.589	0.671	-	-	**1.682**	see footnotes
Colman and Päster (2009)	-	-	-	-	-	-	-	**2.300**[#]	[#] average of 1.90-2.70 [##] average of 2.10-2.50
Colman and Päster (2009)	-	-	-	-	-	-	-	**2.300**[##]	
Colman and Päster (2009)	-	-	-	-	-	-	-	**2.120**	
Colman and Päster (2009)	-	-	-	-	-	-	-	**4.600**	
Colman and Päster (2009)	-	-	-	-	-	-	-	**4.500**	not possible to allocate the CF per life-cycle phase; apparently, all the life cycle phases are considered except storage and consumption
Colman and Päster (2009)	-	-	-	-	-	-	-	**2.230**	
Gazulla et al. (2010)	-	0.503	0.112	0.319	0.076	-	-	**1.010**	see footnotes
Gazulla et al. (2010)	-	0.503	0.112	0.319	0.161	-	-	**1.095**	
Gonzalez et al. (2006)	-	1.454	1.898	0.570	0.592	-	-	**4.514**	see footnotes
Greenhaigh et al. (2011)	-	0.253	0.235	0.458	0.270	0.027	-	**1.243**	see footnotes
Kavargiris et al. (2009)	-	0.207	-	-	-	-	-	-	see footnotes
Kavargiris et al. (2009)	-	0.147	-	-	-	-	-	-	
Neto et al. (2013)	-	2.000	0.440	0.240	0.232	-	-	**2.912**	
Pattara et al. (2012)	-	0.045	0.020	1.138	0.086	-	-	**1.289**	see footnotes
Petti et al. (2006)	-	0.059	-	0.788	0.315	-	-	**1.162**	see footnotes
Pizzigallo et al. (2008)	0.008	0.063	0.029	0.249	-	-	0.012	**0.360**	see footnotes
Pizzigallo et al. (2008)	0.020	0.290	0.028	0.370	-	-	0.018	**0.726**	
Point et al. (2012)	0.089	0.732	0.337	0.434	0.394	1.203	0.038	**3.226**	
Reich-Weiser et al. (2010)	-	-	-	-	0.210	-	-	-	
Reich-Weiser et al. (2010)	-	-	-	-	1.600	-	-	-	
Reich-Weiser et al. (2010)	-	-	-	-	0.070	-	-	-	
Reich-Weiser et al. (2010)	-	-	-	-	0.540	-	-	-	
Rugani et al. (2009)	0.022	0.438	0.047	0.271	-	-	-	**0.779**	see footnotes
Ruggieri et al. (2009)	-	-	-	-	-	-	0.047	-	see footnotes
Ruggieri et al. (2009)	-	-	-	-	-	-	0.127	-	
Ruggieri et al. (2009)	-	-	-	-	-	-	3.437	-	
Ruggieri et al. (2009)	-	-	-	-	-	-	0.034	-	
Ruggieri et al. (2009)	-	-	-	-	-	-	0.123	-	
Ruggieri et al. (2009)	-	-	-	-	-	-	3.877	-	
SAWIA (2004)	-	0.161	0.186	0.056	-	-	-	**0.404**	see footnotes
Soja et al. (2010)	-	0.535	0.293	0.673	0.207	-	0.017	**1.725**	see footnotes
Vázquez-Rowe et al. (2012a)[†]	-	0.749	0.496	0.628	-	-	1.062	**2.935**	see footnotes
Vázquez-Rowe et al. (2012a)[†]	-	0.862	0.497	0.628	-	-	1.222	**3.209**	
Vázquez-Rowe et al. (2012a)[†]	-	0.856	0.445	0.628	-	-	1.214	**3.144**	
Vázquez-Rowe et al. (2012a)[†]	-	0.704	0.314	0.628	-	-	0.998	**2.643**	
Vázquez-Rowe et al. (2012b)[†]	-	0.454	-	-	-	-	-	-	vineyard planting and viticulture have been put together in the viticulture phase
Vázquez-Rowe et al. (2012b)[†]	-	0.784	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.808	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.318	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.530	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.565	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.563	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.509	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.519	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.456	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b)[†]	-	0.310	-	-	-	-	-	-	

Table 2 Cont.: Carbon Footprint per section from R et al. appendix

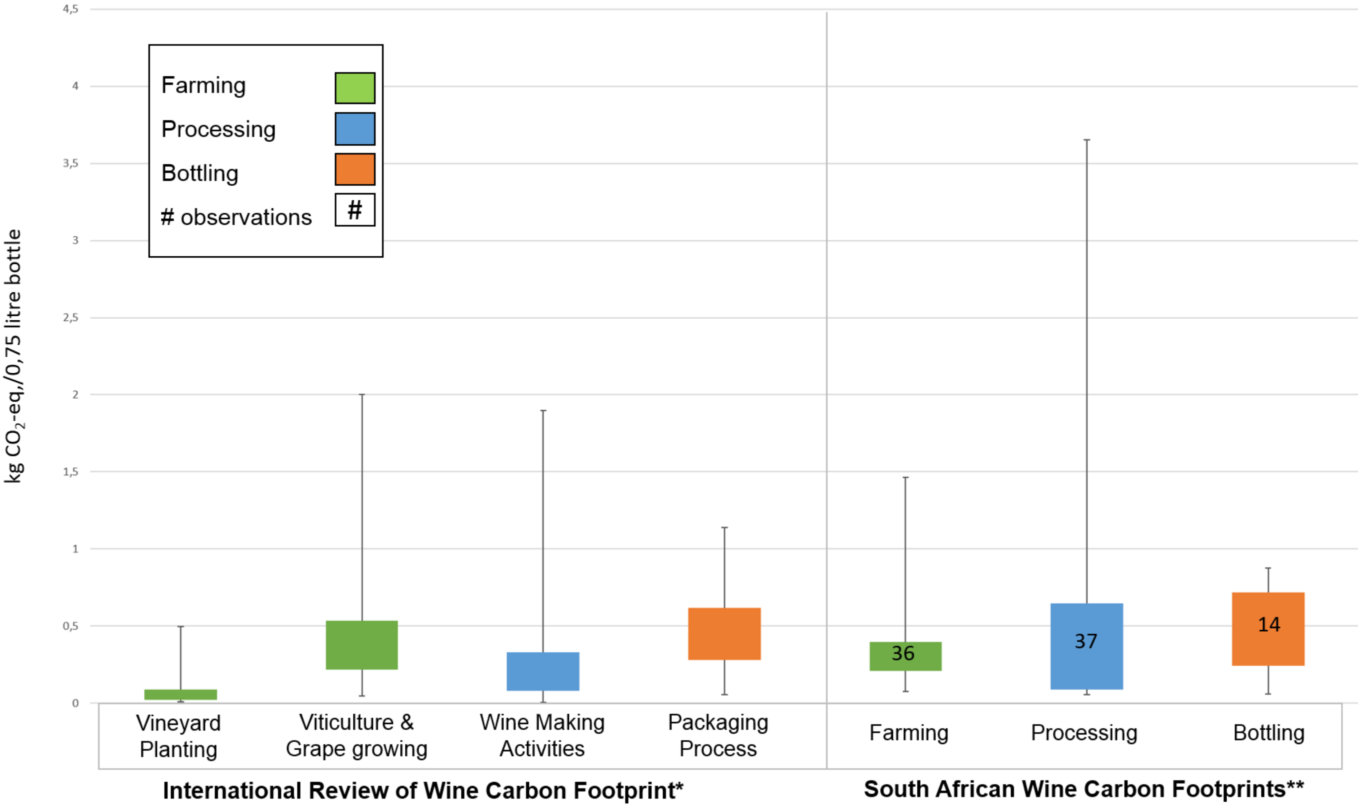
Vázquez-Rowe et al. (2012b) †	-	0.335	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.465	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.309	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.268	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.212	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.910	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.543	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.798	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.683	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.264	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.374	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.623	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.519	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.159	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.637	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.648	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.914	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.524	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.235	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.256	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.340	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.521	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.282	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.354	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.329	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.192	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.307	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.393	-	-	-	-	-	-	
Vázquez-Rowe et al. (2012b) †	-	0.296	-	-	-	-	-	-	
Vázquez-Rowe et al. (2013)	-	-	0.325	0.172	-	-	-	**0.497**	(red wine-Luxembourg)
Vázquez-Rowe et al. (2013)	-	-	1.160	0.172	-	-	-	**1.332**	(sparkling wine-Luxembourg)
Vázquez-Rowe et al. (2013)	-	-	0.121	0.172	-	-	-	**0.293**	(white wine-Luxembourg)
Venkat (2012)	-	0.293	-	-	-	-	-	-	see footnotes
Venkat (2012)	-	0.055	-	-	-	-	-	-	
Venkat (2012)	-	0.327	-	-	-	-	-	-	
Venkat (2012)	-	0.218	-	-	-	-	-	-	
Venkat (2012)	-	0.215	-	-	-	-	-	-	
Venkat (2012)	-	0.250	-	-	-	-	-	-	
WRAP (2007)	-	0.153	0.178	-	0.269	0.347	-	**0.947**	(data are taken from Garnett, 2007)
WRAP (2007)	-	0.153	0.178	0.415	0.433	0.347	-	**1.526**	"
WRAP (2007)	-	0.153	0.178	0.342	0.405	0.347	-	**1.425**	" CO_2-impact lightweighting bottles-sc.1
WRAP (2007)	-	0.153	0.178	0.270	0.343	0.347	-	**1.291**	" CO_2-impact lightweighting bottles-sc.2
WRAP (2007)	-	0.153	0.178	-	0.089	0.347	-	**0.767**	"
WRAP (2007)	-	0.153	0.178	-	0.073	0.347	-	**0.751**	"
WRAP (2007)	-	0.153	0.178	-	0.065	0.347	-	**0.743**	"
WRAP (2007)	-	0.153	0.178	0.415	0.120	0.347	-	**1.213**	"
WRAP (2007)	-	0.153	0.178	0.415	0.100	0.347	-	**1.193**	"
WRAP (2007)	-	0.153	0.178	0.415	0.087	0.347	-	**1.180**	"
Zabalza et al. (2003)	-	0.426	0.314	0.281	0.101	-	-	**1.122**	see footnotes
Mean	0.071	0.379	0.260	0.472	0.249	0.261	0.481	**2.173***	
Standard deviation (σ)	±1.734	±0.821	±1.252	±0.512	±1.175	±1.108	±2.122	**±1.343****	

* sum of the row items

** square root of weighted variances

† CF values have been allocated only to the viticulture and grape-growing stage due to the difficulty of discriminating between «vineyard planting» and «viticulture»

8.2. A2. South African Wine Grape Carbon Footprint



*Own calculations based on table S2 of Rugani et al. (2013, S10), removing duplicate sub-entries from same source

**Own calculations based on Confronting Climate Change (2014) aggregating white and red from scatterplots

Figure 10: Comparison of International and South African Carbon Footprints

A more detailed breakdown of the Western Cape carbon footprints shown in Figure 4, is shown in Table 3 below:

Table 3: Breakdown of Carbon Footprint Distributions WC Farms

	Red			White		
	Farm	**Processing**	**Bottling**	**Farm**	**Processing**	**Bottling**
	(kg CO_2e/kg Fruit)	**(kg CO_2e/litre wine)**	**(kg CO2e/later wine)**	**(kg CO_2e/kg Fruit)**	**(kg CO_2e/litre wine)**	**(kg CO_2e/litre wine)**
min	0,07	0,07	0,08	0,14	0,07	0,09
Q1	0,2025	0,12	0,335	0,1825	0,125	0,41
median	0,255	0,22	0,815	0,31	0,2	0,7
Mean	0,34	0,68	0,70	0,29	0,68	0,64
Q3	0,3375	0,795	0,9475	0,335	0,9	0,915
max	1,33	4,43	1,17	0,6	4,87	1,06
data points	14	18	8	22	19	6

If farms from the Orange River region (non-Western Cape) are included the distributions change slightly as shown in Table 4:

Table 4: Breakdown of Carbon Footprint Distributions SA Farms

	Red			White		
	Farm	Processing	Bottling	Farm	Processing	Bottling
	(kg CO2e/kg Fruit)	(kg CO2e/litre wine)	(kg CO2e/later wine)	(kg CO2e/kg Fruit)	(kg CO2e/litre wine)	(kg CO2e/litre wine)
min	0,07	0,07	0,08	0,14	0,07	0,09
Q1	0,2025	0,12	0,335	0,1825	0,125	0,41
median	0,255	0,22	0,815	0,31	0,2	0,7
Mean	0,34	0,68	0,70	0,29	0,68	0,64
Q3	0,3375	0,795	0,9475	0,335	0,9	0,915
max	1,33	4,43	1,17	0,6	4,87	1,06
data points	14	18	8	22	19	6

The breakdown per process as reported by Confronting Climate Change (2014) are shown in Figure 11 and Figure 12 below for white and red wine respectively.

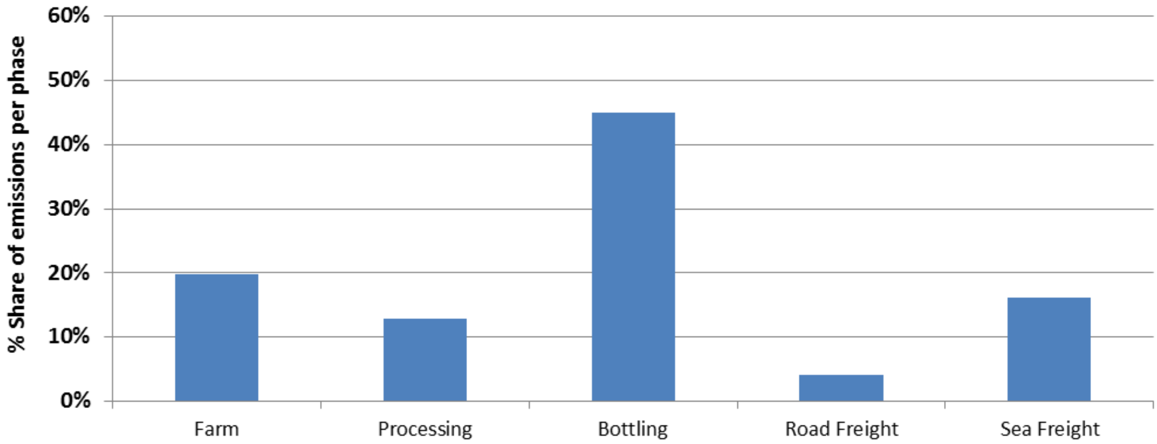


Figure 11: White Wine Emissions per phase from Farm to Overseas Seaport

(Confronting Climate Change, 2014, p. 5)

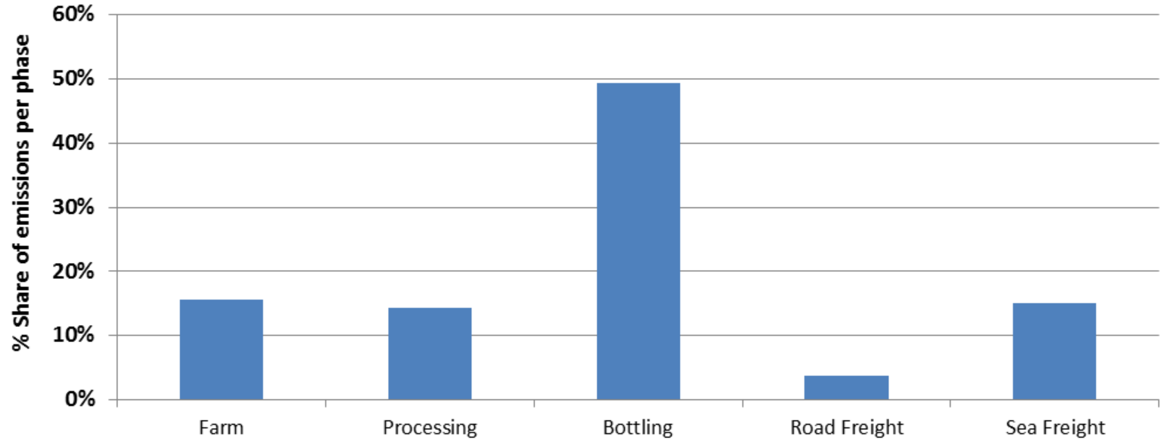


Figure 12: Red Wine Emissions per phase from Farm to Overseas Seaport

(Confronting Climate Change, 2014, p. 5)

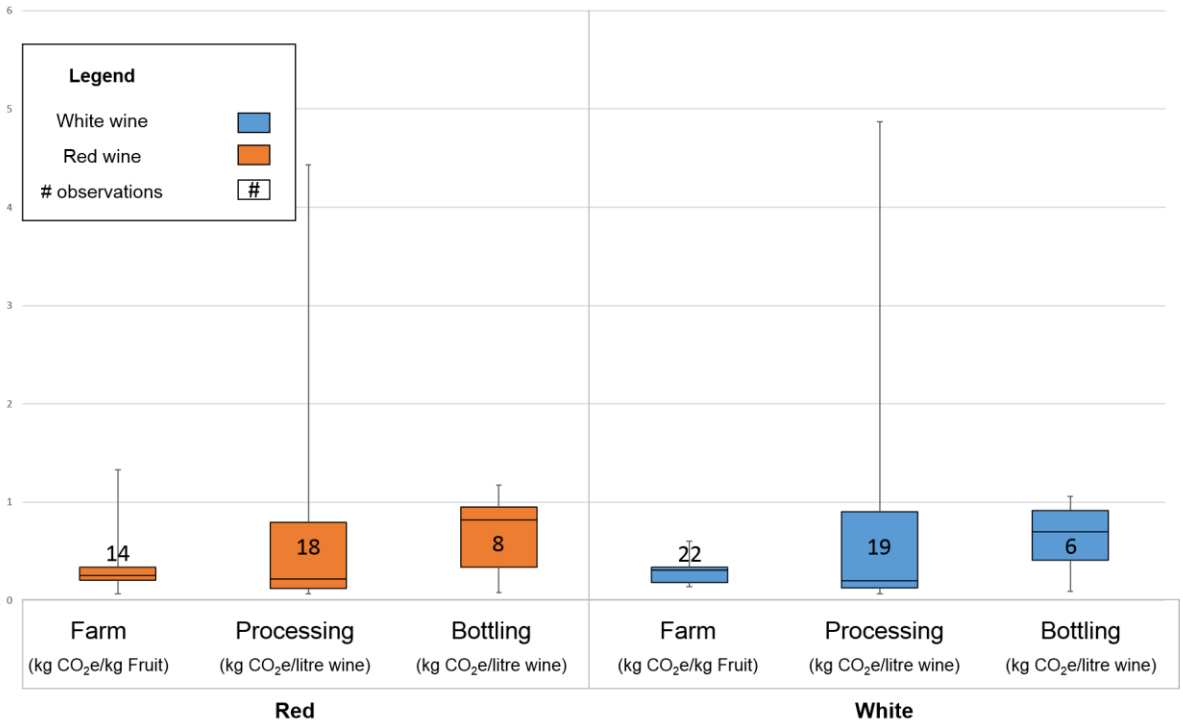


Figure 13: Confronting Climate Change (CCC) Carbon Footprints - Red versus White SA Wines

Table 5: Natural Wine per Packaging method

	2007	2008	2009	2010	2011	2012	2013
GLASS	45%	48%	48%	48%	49%	49%	50%
PLASTIC	20%	22%	21%	23%	23%	22%	21%
BAG-IN-BOX	24%	26%	27%	26%	25%	27%	26%
FOIL BAGS	9%	3,5%	2,7%	1,0%	0,8%	0,3%	0,7%
TETRA PACKS	1,4%	1,5%	1,5%	1,9%	2,2%	1,8%	1,9%
TOTAL	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**
*Own Calculations based on (SAWIS, 2014, p. 24)							