

Life Cycle Assessment: Organic and Biodynamic Wine

A. Abstract

This paper aims to investigate the inputs and outputs behind different wine production strategies. Using the Life Cycle Assessment concept, we examined the effects organics and biodynamic practices might have on the overall life of a bottle of wine. Using literature and some previously conducted LCA's, we were able to compare three different viticulture life cycles: industrial, organic and biodynamic. First, we found that biodynamic wines were, for the purpose of LCA comparison, identical in inputs and outputs to organic wines. Second, despite the innovation present in industrial farms, the collection of data present here suggests that organic and biodynamic vineyards use less resources and produce less byproduct by factors of between 6 and 48. Nearly every category of inputs and outputs favored organic and biodynamic systems over industrial ones. From this we were able to conclude that, despite a price difference, organic wines are almost always the best choice for consumers, and more wine producers should switch to organic practices.

B. Introduction

The goal of this survey is to utilize the concept of Life Cycle Assessment to assess the value of two "green" viticulture practices: organic and biodynamic. By looking at the differences in inputs and outputs throughout the life cycle of these processes, we can more definitely consider whether "green" wine options are indeed more sustainable. The Life Cycle Assessment allows us to examine the product as it progresses through it's metaphorical "life," from growing the grapes to bottling and transporting the finished wine, and can educate not only growers but

consumers on the benefits and drawbacks of industrial, organic and biodynamic wine respectively. This study will also pinpoint areas in which more information is needed about the benefits and drawbacks of each system.

Wine comes in two main varieties, red and white, and start as grapes on vineyards all over the world. Wine grapes, compared to other agricultural products, have a distinct resource profile. Grapes have a relatively low output per hectare when relative to other agricultural products, and often require large amounts of pesticides and water compared to their output (Colman 2009). Because wine is a specific product that requires specialized land use and processing, it is often grown either alone in a monoculture, or with very few other products (Reeve 2005). Like other agricultural products, the exact amount of resource use often depends heavily on local climate, weather patterns and local resource regulations.

Organic wines follow the standard organic practices: no artificial fertilizers or pesticides (United States Department of Agriculture 2002). Instead, they utilize natural defenses against pests, and use manure or compost for fertilizer. Not only does the ban on chemicals apply to the plating and growth stages, but organic wines also avoid chemicals during the fermentation and aging process (Pizzigallo 2006). Organics are becoming more and more popular, particularly in the United States, and are perceived to be more sustainable than their conventionally grown counterparts (United States Department of Agriculture 2002).

Biodynamic wine is a relatively niche product, founded in the 1920's by Dr. Rudolf Steiner (Demeter Organics, 2004). Biodynamic farmers see the soil and farm as organisms, and work

towards self contained cycling (Reeve 2005). The goal of a biodynamic farm is to eventually create a closed loops system, one in which everything the farm needs, from manure, to compost, to pest control, is internally sourced from the farm itself. To that end, the process for growing and processing biodynamic wine is very similar to organics in that there are no synthetic chemical fertilizers and pesticides, but with nine special soil treatments and a few extra rules on land practices (Phillips 2006). These treatments are numbered BD 500-508, and are as follows:

BD 500 – cow manure fermented in a cow horn that is buried through the soil for six months through autumn and winter

BD 501 – powdered quartz packed inside a cow horn and buried in the soil for six months through spring and summer

(502-507 are used to make compost)

BD 502 – Yarrow blossoms

BD 503 – chamomiles blossoms

BD 504 – stinging nettle (whole plant in full bloom)

BD 505 – Oak bark

BD 506 – Dandelion flowers

BD 507 – Valerian flowers

(508 is used as a spray to suppress fungal diseases in plants)

BD 508 – horsetail plant

Biodynamic wines have often been accused of being a bunch of hocus pocus (Reeve 2005).

However, many studies have found that biodynamically grown wines are consistently ranked higher than their industrial, and even organic counterparts in taste tests (Ross 2009). Of course, taste is not a factor in the LCA of any wine, yet the boosted taste does indicate that there is something special going on in biodynamic settings, if only the byproduct of increased attention to the plants as some have suggested (Reeve 2005). This study looks to investigate whether or not biodynamic or organic wines actually have a smaller ecological footprint.

In order to really assess the resource use of both organic and biodynamic wines, we have to compare them with industrially or semi-industrially grown counterparts. Because our question is

not the LCA of the organic or biodynamic grapes in and of themselves, but rather how they compare with their non-organic competitors, we can exclude parts of the life cycle that do not change between the three. This includes bottling and transportation, the former of which is standardized and the latter of which is so highly variable within and between groups that it is generally inconclusive (Gonzalez 2006).

Excluding the bottling and transportation processes, wine production can be divided into three stages: Planting, Growing, and Storage, as defined in the following section.

Planting: the process of taking uncultivated lands and planting the vineyard. (Pizzigallo 2006).

Growing: any work undertaken in the vineyard, including irrigation, fertilization, pruning, vine-shoot tying, organic fertilizing, pest control activities, ploughing and general maintenance (Gonzalez 2006).

Storage: the processes that involve refining grapes into wine and aging. First, the grapes are crushed and stemmed, either by hand or through machines. This juice is then fermented with yeast, and then clarified (Petti 2008).

To keep the data standard, we'll define our functional unit as 1 liter – the equivalent of the average wine bottle.

C. Life Cycle Assessment Inventory Analysis

Within these processes, there are a number of inputs and outputs that we will consider for this Life Cycle Assessment. Figure 1 shows the life cycle of wine grapes, and inputs and outputs of each step. Processes below the dotted line are not considered in this LCA comparison. These inputs and outputs are separated by process (Planting, Growing, Storage) and all converted to express the amount required or emitted from producing 1 liter of wine (Figure 2).

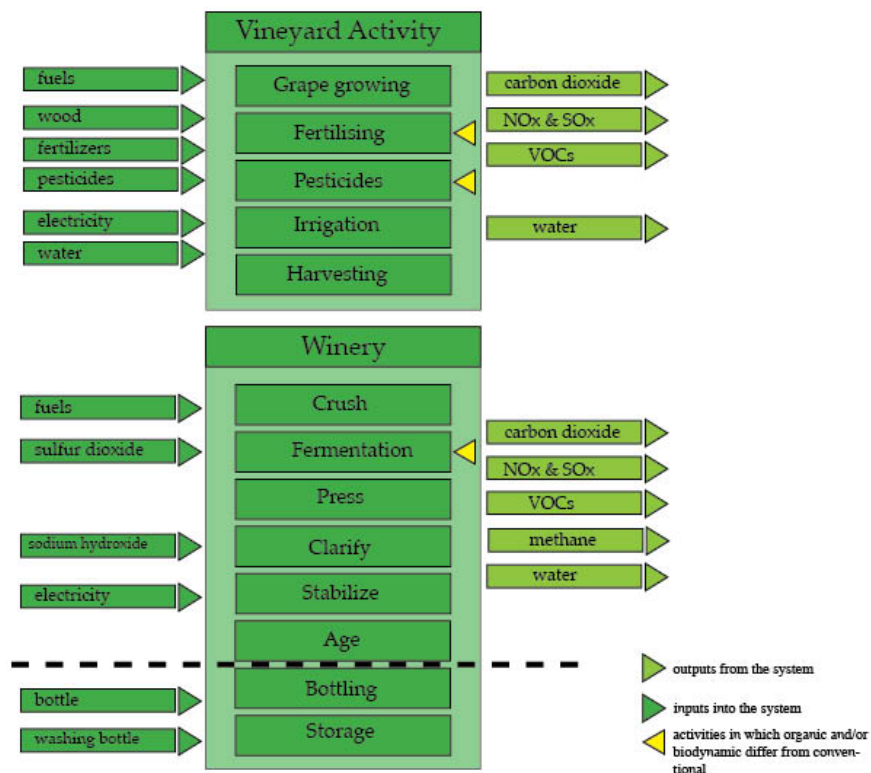


Figure 1: The Life Cycle of viticulture grapes.

INDUSTRIAL		
Planting		
Input	Amount (g)	Reference/Source
Steel	0.2189	Pizzigallo, 2006
Fuels	2.334	Pizzigallo, 2006
Fertilizers	2.517	Pizzigallo, 2006
Output	Amount (g)	Reference/Source
Nox	0.1447	Pizzigallo, 2006
VOC	0.02472	Pizzigallo, 2006
CO	0.0459	Pizzigallo, 2006
H2O	3.7786	Pizzigallo, 2006
CO2	9.7115	Pizzigallo, 2006
Sox	0.01765	Pizzigallo, 2006
Growing		
Input	Amount (g)	Reference/Source
Wood	22.7	Gonzalez, 2006
Nitrogen Fertilizer	15	Gonzalez, 2006
Phosphorous Fertilizer	37	Gonzalez, 2006
Pesticides	3.02	Gonzalez, 2006
Fuels	16.5	Gonzalez, 2006
Steel	no data	

Output	Amount (g)	Reference/Source
Carbon Dioxide	952	Gonzalez, 2006
CFCs	0.6	Gonzalez, 2006
Hydrogen	356	Gonzalez, 2006
Oxygen	80.6	Gonzalez, 2006
Methane	1.8	Gonzalez, 2006
Wood Posts	16	Gonzalez, 2006
Nox	2.1753	Pizzigallo, 2006
VOC	0.332	Pizzigallo, 2006
CO	0.7063	Pizzigallo, 2006
H2O	56.50352	Pizzigallo, 2006
Sox	0.2231	Pizzigallo, 2006
Storage		
Input	Amount (g)	Reference/Source
Chemicals	0.007632	Gonzalez, 2006
Grapes	2000	Gonzalez, 2006
Fuel	21.476	Gonzalez, 2006
Steel	4.944	Pizzigallo, 2006
Output	Amount (g)	Reference/Source
Carbon Dioxide	1665	Gonzalez, 2006
CFC	5.9	Gonzalez, 2006
Hydrogen	0.429	Gonzalez, 2006
Oxygen	257	Gonzalez, 2006
Methane	1.6	Gonzalez, 2006
Packaging waste	11.6	Gonzalez, 2006
Waste	56.6	Gonzalez, 2006
Nox	10.6	Pizzigallo, 2006
VOC	81.22	Pizzigallo, 2006
CO	7.06	Pizzigallo, 2006
Sox	56.5	Pizzigallo, 2006
ORGANIC		
Planting		
Input	Amount (g)	Reference/Source
Steel	0.0565	Pizzigallo, 2006
Fuels	1.1547	Pizzigallo, 2006
Fertilizers	0	Pizzigallo, 2006
Output	Amount (g)	Reference/Source
Nox	0.0565	Pizzigallo, 2006
VOC	0.0106	Pizzigallo, 2006
CO	0.0176	Pizzigallo, 2006
H2O	1.4655	Pizzigallo, 2006
Carbon Dioxide	3.6727	Pizzigallo, 2006
Sox	0.00706	Pizzigallo, 2006
Growing		
Input	Amount (g)	Reference/Source
Wood	no data	
Nitrogen Fertilizer	0	Pizzigallo, 2006

Phosphorous Fertilizer	0	Pizzigallo, 2006
Pesticides	5.7916	Pizzigallo, 2006
Fuels	8.7933	Pizzigallo, 2006
Steel	0.505	Pizzigallo, 2006
Output	Amount (g)	Reference/Source
Carbon Dioxide	30.229	Pizzigallo, 2006
CFCs	no data	
Hydrogen	no data	
Oxygen	no data	
Methane	no data	
Wood Posts	no data	
Nox	0.4767	Pizzigallo, 2006
VOC	0.0706	Pizzigallo, 2006
CO	0.1554	Pizzigallo, 2006
H2O	12.431	Pizzigallo, 2006
Sox	0.04944	Pizzigallo, 2006
Storage		
Input	Amount (g)	Reference/Source
Chemicals	0.00353	Pizzigallo, 2006
Grapes	2000	Gonzalez, 2006
Fuel	no data	
Steel	3.9199	Pizzigallo, 2006
Output	Amount (g)	Reference/Source
Carbon Dioxide	10.2766	Pizzigallo, 2006
CFC	no data	
Hydrogen	no data	
Oxygen	no data	
Methane	no data	
Packaging waste	no data	
Waste	no data	
Nox	0.01413	Pizzigallo, 2006
VOC	0.0565	Pizzigallo, 2006
CO	0.00353	Pizzigallo, 2006
Sox	0.03515	Pizzigallo, 2006
BIODYNAMIC		
Planting		
Input	Amount	Reference/Source
Steel	0.0565	**
Fuels	1.1547	**
Fertilizers	0	Demeter
Output	Amount	Reference/Source
Nox	0.0565	**
VOC	0.0106	**
CO	0.0176	**
H2O	1.4655	**
Carbon Dioxide	3.6727	**
Sox	0.00706	**

Growing		
Input	Amount	Reference/Source
Wood	no data	
Nitrogen Fertilizer	0	Demeter
Phosphorous Fertilizer	0	Demeter
Pesticides	0	Demeter
Fuels	8.562	Demeter
Steel	no data	
Output		
Input	Amount	Reference/Source
Carbon Dioxide	30.229	**
CFCs	no data	
Hydrogen	no data	
Oxygen	no data	
Methane	no data	
Wood Posts	no data	
Nox	0.4767	**
VOC	0.0706	**
CO	0.1554	**
H2O	12.431	**
Sox	0.04944	**
Storage		
Input	Amount	Reference/Source
Chemicals	0.00353 g	**
Grapes	no data	
LPG fuel	no data	
Steel	3.9199 g	**
Output		
Input	Amount	Reference/Source
Carbon Dioxide	10.2766 g	**
CFC	no data	
Hydrogen	no data	
Oxygen	no data	
Methane	no data	
Packaging waste	no data	
Waste	no data	
Nox	0.01413 g	**
VOC	0.0565 g	**
CO	0.00353 g	**
Sox	0.03515 g	**

Figure 2: Total Inputs and Outputs for all three systems

Because there is so little data on biodynamic wines and the resource quantities that go into them, I utilized the international regulating body on biodynamic to highlight areas that would be different between organics and biodynamic farms. Areas that would not show any difference,

because the rules and regulations are the same, are indicated in the table by a ** symbol in the “Source” column. If all the inputs were the same as the organic column, the outputs were duplicated as well.

The inputs and their corresponding outputs each have different environmental profiles. Those inputs and outputs for which data exists for both industrial and organic forms of viticulture are compiled in Figure 3. Each of these should be considered for its environmental impact (Colman 2009).

Inputs:

Steel – used for farm equipment and maintenance, steel is a resource that comes from ore. It can be recycled, but the extraction of iron ore from the earth is a dangerous and unsustainable.

Fuels – fossil fuels are used to power farm machinery, including tractors, and viticulture devices like fermentors, extractors and strainers.

Nitrogen Fertilizer – in this case chemically synthesized nitrogen fertilizers are made from chemicals and minerals.

Phosphorous Fertilizer – chemically synthesized fertilizer made with a phosphorous base, rather than nitrogen.

Pesticides – compounds synthesized to deter or kill pests, often with adverse health effects on those who come in contact with them.

Outputs:

Carbon Dioxide – one of the most well known and abundant greenhouse gasses, CO₂ contributes to global warming more than any other atmospheric chemical.

NO_x – Nitrous oxides are known pollutants that cause acid rain and is harmful to human health.

Volatile Organic Compounds – VOC’s are a large class of organic compounds that often have chronic negative health effects such as respiratory disease and sensory irritation.

Carbon Monoxide – a highly toxic gas produced through combustion of engines.

Water – a byproduct of runoff, and machinery.

SO_x – Sulfur oxides are, much like Nitrous oxides, take many forms and can be hazardous to human health.

Input	INDUSTRIAL		ORGANIC		BIODYNAMIC	
	Total (g)	> Sector	Total (g)	> Sector	Total	> Sector
Steel	5.1629	Storage	4.4814	Storage	4.4814	Storage
Fuels	40.31	Storage	9.948	Growing	9.948	Growing
N Fertilizer	15	Growing	0		0	
P Fertilizer	37	Growing	0		0	

Pesticides	3.02	Growing	0		0	
NET INPUTS	100.4929		14.4294		14.4294	
Output						
CO ₂	2626.7115	Storage	44.1783	Growing	44.1783	Growing
Nox	12.7753	Storage	0.54733	Storage	0.54733	Storage
VOC	81.57672	Storage	0.1377	Growing	0.1377	Growing
CO	7.8122	Storage	0.17653	Growing	0.17653	Growing
H ₂ O	60.28212	Growing	13.8965	Growing	13.8965	Growing
Sox	56.74075	Storage	0.09165	Growing	0.09165	Growing
NET OUTPUTS	2845.89859		59.02801		59.02801	

Figure 3: Consolidated Inputs and Outputs for all three systems

Figure 4 describes the risks and environmental impacts associated with each input and output.

You might notice that water is not one of the inputs to this LCA. Because viticulture is so widespread, grape species are so variable, and local water regulations are so different, it is impossible to draw meaningful conclusions from the differences in water inputs in different systems (Petti 2008).

Input	Environmental Impact Category
Steel	Non-Renewable Resource Use
Fuels	Non-Renewable Resource Use
Nitrogen Fertilizer	Human Health Risks
Phosphorous Fertilizer	Human Health Risks
Pesticides	Human Health Risks
Output	
Carbon Dioxide	Global Climate Change
Nox	Global Climate Change
VOC	Human Health Risks
CO	Human Health Risks
H ₂ O	Global Climate Change
Sox	Human Health Risks

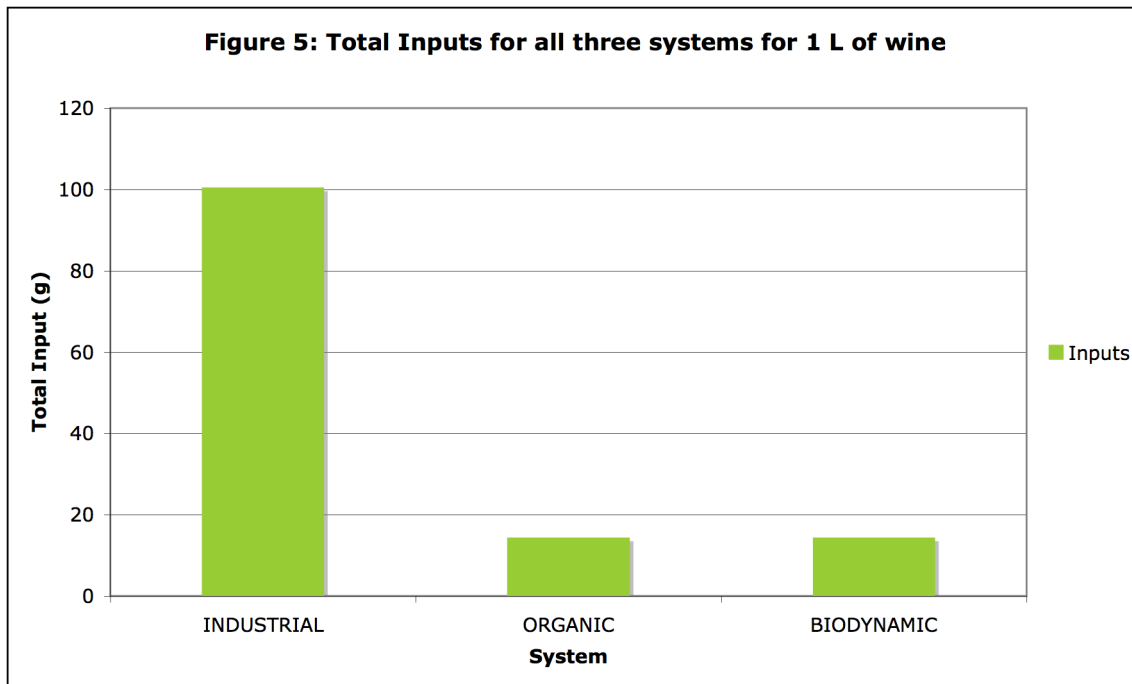
Figure 4: Risks associated with viticulture inputs and outputs

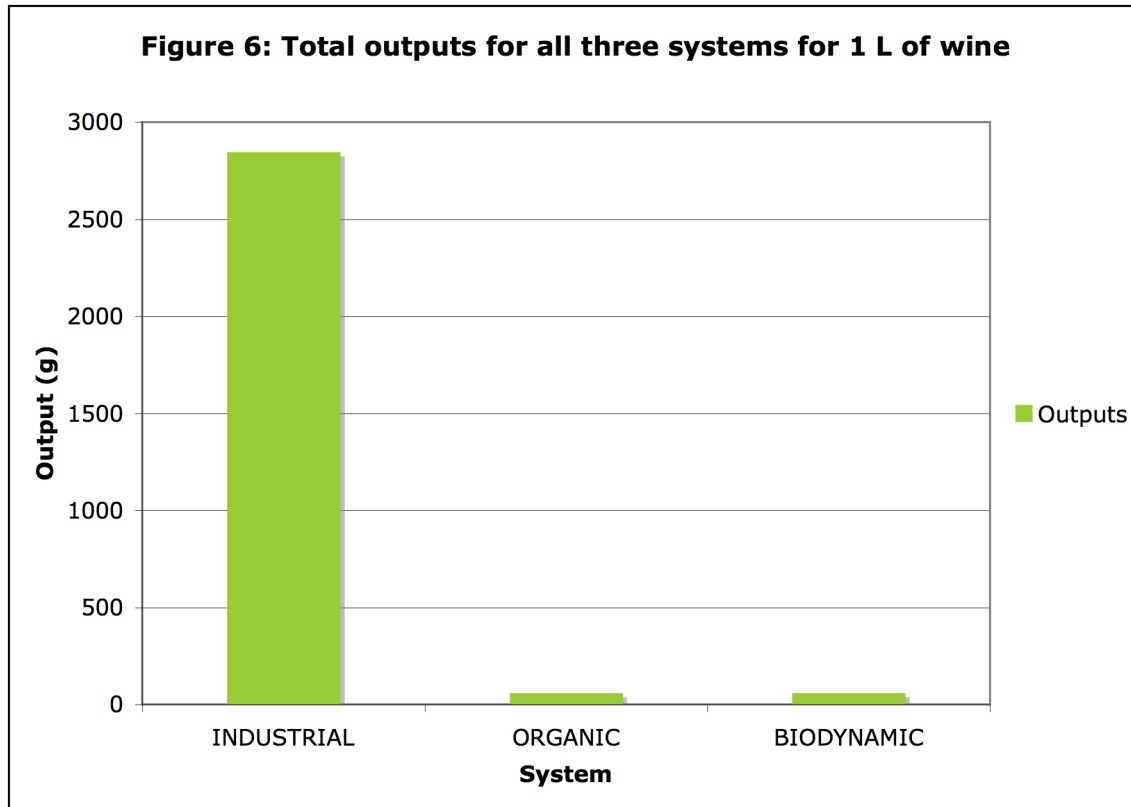
D. Life Cycle Assessment Impact Analysis

In all components of this LCA, biodynamic wine was identical to organic wine. The factors and additions that biodynamic farmers make to their practices, are simply not accounted for in an

LCA, and as such do not seem to effect the overall inputs and outputs of the farm. As such, the biodynamic and organic inputs and outputs mirrored one another, and for the rest of this analysis we will consider the two as interchangeable.

Figures 5 and 6 illustrate the disparity between industrial and organic/biodynamic inputs and outputs. Industrial vineyards had increased inputs by about 6 fold, and increased outputs by about 48 fold. They were higher in almost every output category, except pesticides. Organic farms have to invest more in natural pest deterrents than industrial farms do on synthetic versions. The result is a higher rate of pesticide use, but a much lower rate of VOC's in the output stage.





It is no surprise that the biggest component – both in input and output – to the viticulture systems we examined is fuel and carbon dioxide. Fuel made up 40% of industrial input, and CO₂ 92% of its output, while organic farms saw fuel as 68% of their input and CO₂ as 74% of their output. This suggests that on organic farms it is easy to remove secondary sources of CO₂ production such as synthetic fertilizers and chemicals, but much harder to remove something as basic as fuel for machines simply because there are very few options. Viticulture is, more than many agricultural products, heavily reliant on machinery to reach an end product. Both organic and industrial vineyards rely on fuel to power their wine production facilities, whether that's crushing grapes or extracting skins or clarifying the resulting liquids (Phillips 2006). After that, volatile organic compounds from the fertilizers and pesticides used on the industrial farms posed the second biggest risk to human health in the process of wine making.

E. Interpretation

First, biodynamic wine seems to be no more sustainable than organic wine. In all aspects of this LCA, the two were completely identical, and the components of biodynamic farming that make it biodynamic, do not address the areas in which organic farms still have unsustainable inputs and outputs. That said, the results of this study showed that organic wine was far superior in its ecological footprint to its industrial counterpart. In fact, industrial viticulture had inputs of about 6 times that of organic, and outputs of about 48 times that of organic.

Of course there are input and outputs that could not be fully considered here, such as water and energy. Some studies suggest that organic vineyards use more electricity because they have older, less efficient machinery (Colman 2009). If this is the case, providing incentive for organic farms to update their equipment could certainly be an option, however the sheer magnitude by which organics seem to trump the possible downside to electricity inefficiency. Organic wines appear to be much less environmentally damaging.

Biodynamic wine appears to be no more sustainable than organics, despite their claims (Phillips 2006). In all parts of the LCA that make organic or biodynamic wines different from industrial versions, the principles of biodynamics didn't effect the quantitative inputs and outputs to the system. The goal of biodynamics, however, is to create a system without external inputs (Demeter 2002). If biodynamic vineyards could indeed do that – and it has yet to be done – then they would certainly be worth looking at again. Perhaps a more thorough and in depth LCA would be able to parse out some of the more specific details between organic and biodynamic, and quantitate the effects biodynamic farming can have on the life cycle of wine.

Overall, organics certainly seemed to prove environmentally superior to industrial vineyards. If this is indeed the case with most organic vineyards, the case could certainly be made for more wineries to make the switch to organic. It can also inform consumers that while organic wine might cost a little more, it may be worth it to simply save 2582 grams of CO₂ from escaping into the atmosphere for each bottle of wine they buy. This LCA certainly seems to come out in favor of organics, although more information is certainly necessary about both organic viticulture and the impacts biodynamics might have on the life cycle of a bottle of wine.

F. Bibliography

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