

Life Cycle Assessment of Coffee Production

Ben Salinas

December 18, 2008

Abstract

A Life Cycle Assessment was performed of green coffee production at Finca Vista Hermosa, a sustainable minded farm in Guatemala. The analysis of these results, generated using the Eco-Indicator 99 LCA tool, showed that the majority of the impact in production of coffee occurred during transportation. When compared to the impact due to other coffee processes such as roasting and brewing coffee as espresso, it was determined that the farming of coffee is a small percentage of the overall impact. Recommendations were then made about how the overall impact could be reduced.

Introduction

Annually, more than 7 billion kg of coffee is produced making coffee one of the world's largest traded commodities, and the second most valuable to oil[6].

Within the Specialty Coffee Industry, there is a large push for environmental sustainability among coffee production and consumption. Part of this stems from a desire to have less environmental impact, but part of this stems from the realization that oftentimes coffee which has less environmental impact has a better flavor profile. Today, it is hard to find a Specialty Coffee Shop without being bombarded with fliers about Fair Trade, Organic, Direct Trade, or Rainforest Alliance. And yet, few have looked at the actual environmental impact of growing and producing coffee.

1 Goal and Scope

The goal of this paper was to present a Life Cycle Assessment(LCA) of green coffee production at Finca Vista Hermosa(FVH), a sustainability minded farm in Guatemala which has been recognized by Anacafe, the national coffee organization in Guatemala, several times for producing the best coffee in the region. As other high end coffee farms, have similar practices to FVH, it is a good representative case study. These results will be used to determine high impact areas of coffee production and to make recommendations as to how to reduce the environmental

impact of producing coffee. Additionally, performing a LCA allows for comparison to other areas of the coffee chain (such as roasting and brewing). Finally, this quantification is useful for coffee roasters in communication with consumers about environmental impact.

For this study, the adopted functional unit was production of 1 kg of green coffee. The system boundaries adopted build upon the commonly used "cradle to gate" system to include transportation due to exporting the coffee, as shown in Figure 1. The inputs and outputs considered in this study were only those relating directly to the coffee production and transportation. The impact of the production and transportation of fertilizers and pesticides were not included. Likewise, due to the long life of the coffee trees at FVH (most trees were found to be 30-55 years old), impact associated with planting of trees was not included. The impact associated with day to day life of farmers and employees was also not included in this study. Finally, due to the long life of this farm and a similar vegetation style to surrounding areas, land use was not considered.

2 Method

Information collected for this study came from secondary research from published papers as well as primary research in the form of interviews. A special thanks is given to Edwin Martinez, third generation farmer at FVH, who provided a great deal of the information utilized. Many of the Life Cycle Inventory results were compared to *Environmental Profile of Brazilian Green Coffee* in which a Life Cycle Inventory was performed for Brazilian Coffee [2].

For the Assessment, the Eco-Indicator 99 Manual for Designers was utilized. This tool, developed in the Netherlands, provides a single factor result measured in Eco-Indicator 99 millipoints (EI99 mP) where a higher value means more environmental impact. Eco-Indicator 99 specifically looks at environmental damage in three categories: Human Health, Ecosystem Quality, and Resources. Additional data was provided from SimaPro, another LCA tool which can export data on the Eco-Indicator 99 scale.

3 Results

Coffee Production at FVH

FVH is considered to be “ecologically sound and healthy, a model for many shade grown and organic plantations[4].” Because of this, it is necessary to describe how coffee is produced at FVH. An overview of this information is shown in Figure 1, the System Map used for the LCA. This information was gathered from interviews via e-mail with Edwin Martinez. The system has been divided into three main phases: Growing, Processing, and Transportation.

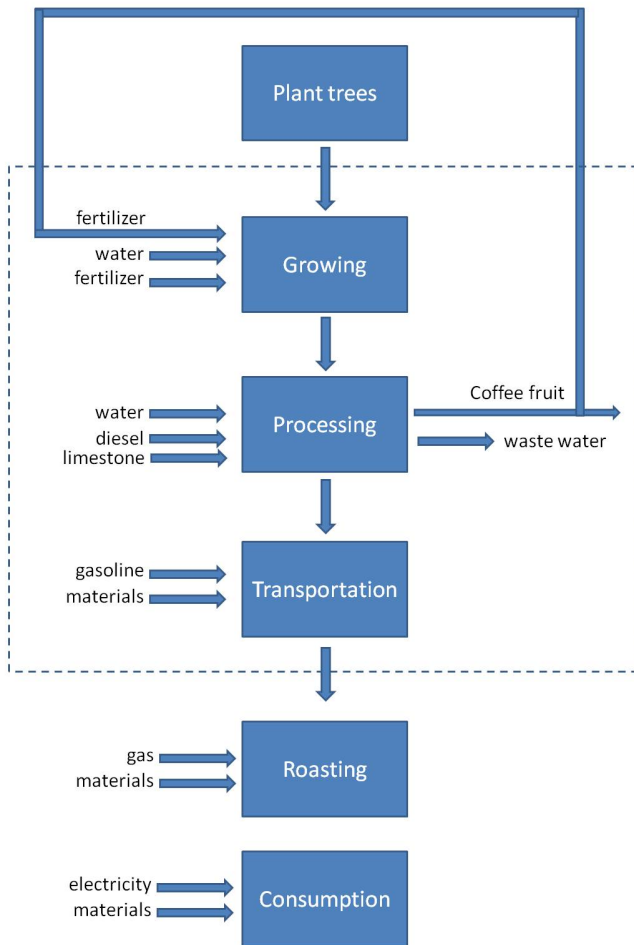


Figure 1: System map including system boundaries (dashed line) for coffee production at FVH

Growing

Coffee trees at FVH are between 30 and 55 years of age. Fruit is produced once per year with a harvest season



Figure 2: An overview of the transportation of coffee from Finca Vista Hermosa to Boston.

starting in January. FVH has chosen to not use any pesticides or fungicides, which is possible in large part due to their elevation. Additionally, FVH offsets their chemical fertilizer use by recycling the nutrient rich coffee fruit from the processing phase and using it as a fertilizer. FVH uses about 30% of the typical fertilizer use in Guatemala. Additionally, no water is used for irrigation, as all the water comes from rainwater.

The coffee cherries are picked by hand. Annually, approximately 135,000 kg of coffee cherries are picked from approximately 27,000 trees. After processing, this corresponds to between 35,000 and 45,000 kg of green coffee exported annually.

Processing

Daily, after being harvested, the coffee cherries are soaked in a pre-fermentation tank before being transferred for a depulper. The depulper is a diesel powered device which has a very long life (the ones used at FVH are on average 25 years old). The depulper uses about 1 L of diesel per day for 90 days plus a few other liters at other times. The pulped coffee, which still has mucilage on it, are put into a fermentation tank before being washed in a washing canal. Water for the washing canal, which is used for 20 minutes each day, is spring fed and then reused in the other parts of processing. The pulp and mucilage are used for fertilizer while the waste water from these processes goes to an evaporation lagoon. Green coffee is then dried in the sun upon which it is stored in jute bags before being transported.

Transportation

At FVH, processed coffee is loaded on any pickup truck which is headed to town for any reason. This is to prevent any of their trucks from driving without a load at any time. Once coffee leaves the farm, it is stored in a warehouse in the town of Huehuetenango, a 1.5 hour drive from the farm, where it is further processed using a dry mill just before shipment. Any coffee which has not been transported at the end of the season is taken by semi to Huehuetenango. From Huehuetenango, after being dry milled, the coffee is loaded into commercial trailers to a port which is 5 hours away. The coffee is then loaded onto a boat and transported to the country of destination. An overview of the transportation is provided in Figure 2.

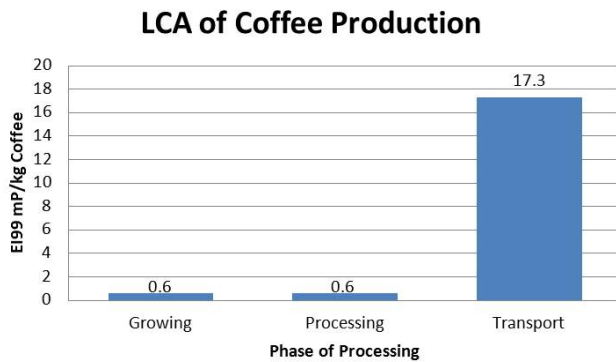


Figure 3: Results of LCA in Eco-indicator 99 millipoints. This data represents coffee production at FVH including transport to a roaster in Boston, MA.

4 Analysis and Recommendations

With the data gathered, a Life Cycle Inventory was performed. Results from this are shown in Table 1. With this, Eco-Indicator 99 was used to perform the LCA. It is apparent from the results of the LCA, shown in Figure 3 that the large bulk of the environmental impact of producing coffee at FVH is in the transportation. This is a reasonable result because FVH has very environmentally sound farming practices (not using pesticides, limited fertilizer use, shade grown coffee, etc). Based on the results presented as well as some additional research, I have recommendations made in several categories.

Local Environmental Health Issues

Waste Water

Not included in the LCA is the waste water from the coffee processing. This is in part due to not enough information provided in the EI99 tool and in part because not enough information is known about the contents of this waste water. In a study done in Vietnam by GTZ, a sustainable development organization based in Germany, it was determined that waste water from coffee processing has significant potential for damage to the environment[5]. They determined that wastewater from fermentation has a pH as low as 3.4, making it highly acidic and damaging to many animals and plants. Additionally, they looked at the Biological Oxygen Demand (BOD), the amount of oxygen needed to break down the organic matter in water, and found that it was approximately 20 g/l, meaning it required more oxygen than distillery wastewater, meat-works waste water, and paper mill wastewater. Their first recommendation was to limit the amount of water used in processing. In order to deal with the high acidity of the water, it was recommended that finely

ground limestone (a base) be mixed in to raise the pH to above 6.0. Finally, to take care of the high BOD levels, it was recommended that a biogas plant be installed. In the pilot project, it was shown that up to 1 liter of methane per liter of wastewater was yielded while reducing the BOD level by 90%.

Based on this study, it is recommended that special attention be placed to the waste water treatment in coffee farms. Additionally, the addition of a biogas collector has the potential to reduce to environmental impact by offsetting the diesel needed for processing, and preventing the release of methane, a potent greenhouse gas, into the atmosphere.

Human Health

Ochratoxin A in Coffee

Ochratoxin A(OTA) is carcinogen which can be introduced into coffee. According to an article in Tea and Coffee Trade Journal, OTA can be introduced to coffee in growing, processing, and storage[8]. Overripe cherries often contain a fungus which produces OTA, and so the risk of OTA can be greatly reduced by only picking ripe cherries (a process that FVH already uses). Drying of the coffee is another source of mold which can lead to OTA contamination. Finally, if beans are stored in high humidity environments, it is possible to introduce OTA during storage. In this article, it is suggested that screening for OTA within the EU is irregular due to wanting to reduce the amount of coffee wasted due to contamination with OTA. However, a small amount of contaminated coffee can quickly infect non-contaminated coffee.

Climate Change

Transportation Within Country of Origin

It was shown in this LCA that the vast majority of the environmental impact was due to transportation of coffee beans, both inside the country of origin, and to the country of consumption. FVH already reduces their impact in this category by transporting coffee whenever vehicles would be traveling empty to town (to return full of supplies). The use of a more fuel efficient vehicle has the potential to reduce the impact from the farm to Huehuetenango by a significant factor.

While the transportation within the country of origin was a considerable factor, when put in perspective it is not where effort should be placed to reduce the impact. If anything, the fact that the majority of the environmental impact of farming coffee at FVH comes from transportation to the roaster, FVH should be applauded from their low environmental impact. For a point of comparison the environmental impact association with transporting 1 kg of coffee from a roaster in Portland to a consumer in

Boston is 96 EI99 mP. This tells us that effort should not be spent looking to reduce transport impacts within the country of origin, (a location where the high price of fuel already becomes a reason to conserve fuel), but should instead effort should be spent examining the other portions of the coffee production chain, as discussed below.

Transport From Country of Origin

Some 32% of the overall impact of producing coffee at FVH was due to transportation of coffee from the country of origin to the country of consumption. This is not due to a high impact method being used, but rather due to the relatively long distance the coffee must travel. In fact, oceanic freighters are one of the most environmentally efficient methods of transport. For the sake of comparison, if instead of being transported to the port via truck and then to the United States via boat, the coffee was air shipped from Huehuetenango to Boston the impact would have been 33 times higher. We have recently seen a trend of roasters getting fresher coffee (at a much higher price) by air shipping the coffee from the country of origin. While this can produce better tasting coffee, this increase in environmental impact is significant.

Additionally, a comparison based on distance can be made based on the distance from the farm to the coast and the distance of the country of origin to the country of consumption, but is weighted in such a way that the distance from the farm to the coast has a higher environmental impact than the travel by boat. For instance, a farm that was in Kenya, at a similar distance from the coast as FVH, would have roughly twice the environmental impact due to the extra distance the boat would have to travel. However, if the same farm was located in Brazil further from the coast, while a closer distance to the country of consumption, the impact would be considerably higher.

Comparison to Coffee Use

While the goal of this LCA was not to calculate the overall impact of coffee use, in order to provide context, some cursory comparisons can be made. Figure 4 shows the breakdown of the environmental impact into categories including transportation, roasting, production, and brewing. Based on the scenario of coffee being shipped from the roaster in Boston to a consumer in Miami, we see that the largest percentage of the impact is in transportation, much of which takes place in the country of consumption. Additionally, we see that aside from transportation, the impact of brewing is the key factor.

Brewing Espresso

It has been shown that the vast majority of the environmental impact of brewing espresso is in the electricity use

Breakdown of Impact

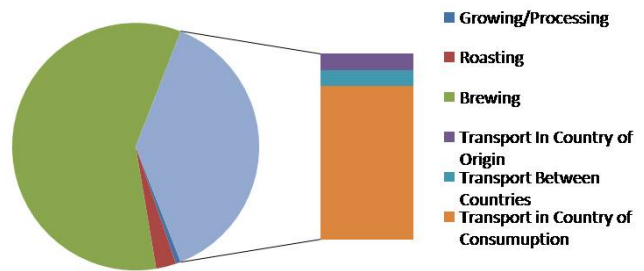


Figure 4: Results of a comprehensive LCA which involves coffee production, transportation to Boston for roasting, and transportation to Miami for consumption as espresso. The overall impact for this scenario was 183.91 EI99 mP.

and that an espresso machine in a high volume commercial setting can be approximated as a 26 kWh power draw for every 350 drinks (one day)[3]. With a drink consisting of approximately 18 g of coffee, each kg of coffee makes approximately 56 espresso based beverages. Thus, the impact found in this LCA shifted to a functional unit of 1 drink results in 0.33 EI99 mP. Compared to the 1.93 EI99 mP due to brewing espresso, this is negligible.

Since a large amount of power is lost as ambient heat, and due to the large amount of power consumed, there is a great opportunity to greatly reduce the overall impact of coffee consumption.

Roasting Coffee

A cursory LCA of a commercial coffee roaster suggests that the impact will be entirely in the use phase, since it is used for a long period of time. These large machines roast anywhere from 8 to 400 lbs at a time, but often-times fall in the 20-50 lb range. The roasters typically heat coffee up to approximately 450°F using natural gas. Data from manufacturers' websites give power consumption of approximately 125 MJ/hr for roasting 140 kg/hr. This implies that approximately 0.90 MJ/kg of energy is imparted to roast coffee. This correlates to 4.85 EI99 mP per kg of coffee. Per shot of espresso, this translates to a mere 0.0865 EI99 mP, suggesting that transportation from the roastery to the coffee shop or consumer could play a large role in the impact.

Transportation within Country of Consumption

From the results in Figure 4 we can see that the transportation within the country of consumption can play a large role in the overall environmental impact of coffee. This means that coffee is a product which consumers

have a lot of control over the impact, simply by choosing where their roaster is located. Additionally, by opting for air transport from the roastery, the impact due to transportation from the roaster to the consumer will be multiplied by a factor of 6. In the scenario of shipping coffee from Boston to Miami, this would multiply the overall impact of coffee production, roasting and brewing by a factor of 2.5. Air shipping coffee to Seattle from Boston would bring the total impact per kg of coffee to over 700 EI99 mP, up from 235 EI99 mP if it was shipped via ground transportation.

5 Conclusions

After performing an LCA of coffee production at FVH, it became apparent that in the growing, processing, and transport phases of coffee until the time it gets into the hands of the roaster, the overall impact is largely due to transportation. It was recommended that farmers looking to reduce their overall impact should consider purchasing more fuel efficient vehicles as well as be aware of other potential environmental impacts, such as chemicals in coffee wastewater. By comparing the results of the LCA to data for coffee roasting and espresso brewing, it was determined that in cases where the coffee travels a relatively small distance in the country of consumption, brewing is the key area of impact, but that this can be diluted by excessive transport distances.

A consumer who is interested in reducing their environmental impact when drinking coffee should talk with their roaster about the practices of the farm their coffee is grown at, the location of the farm (how far it is from the coast and how the coffee gets from the farm to the coast), as well as the travel the coffee undergoes once within the country. A very easy first step is for a consumer to switch to a local roaster.

In the future, a more detailed LCA should be performed with fewer assumptions. Additionally, a more powerful LCA tool would allow for specific identification of areas of impact. These results could also be compared to results from other farms, for an analysis of the difference in various styles of farms.

6 Acknowledgments

Special acknowledgments are given to Edwin Martinez of Finca Vista Hermosa, for his input to this study. Additionally, special thanks is given to Professor Ben Linder of Olin College of Engineering for acting as a mentor for the project. Questions and comments can be directed to the author at ben.salinas@gmail.com

Works Cited

- (1) Barefoot Coffee Roasters. "Farm Profile: Finca Vista Hermosa." Barefoot Coffee Roasters. 14 Dec. 2008 <<http://barefootcoffee.com/life/country-profile-guatemala/farm-profile-finca-vista-hermosa/>>.
- (2) Coltro, Leda, Anna L. Mourad, Paula Oliveira, Jose Paulo Baddini, and Rojane M. Kletecke. "Environmental Profile of Brazilian Green Coffee." *International Journal of Life Cycle Assessments* 11 (2006): 16-21.
- (3) Crowther, Molly, Chester Macklin, Ben Salinas, and Devaja Shafer. *LCA of Commercial Espresso Machines*.
- (4) Cup of Excellence. "Finca Vista Hermosa Farm Details." Cup of Excellence. 2007. 8 Dec. 2008 <<http://www.cupofexcellence.org/countryprograms/guatemala/2007program/auctionsresults/tabid/381/ctl/farmdetails/mid/688/itemid/746/default.aspx>>.
- (5) GTZ Worldwide. *Coffee Wastewater Treatment*. Brochure. Author. Jan von Enden. 8 Dec. 2008 <<http://www.venden.de/postharvestprocessing.htm>>.
- (6) International Coffee Organization. *Trade Statistics*. International Coffee Organization. 8 Dec. 2008 <http://www.ico.org/trade_statistics.asp>.
- (7) Martinez, Edwin. "Coffee Production at Finca Vista Hermosa." E-mail interview. 19 Nov. 2008.
- (8) Sibanda, Dr. Liberty. "Auto-Control Of Ochratoxin-A Levels In Green Coffee." *Tea and Coffee Trade Journal* 2006 (2006). *Tea & Coffee Trade Online*. Jan. 2006. *Tea and Coffee Trade Journal*. 14 Dec. 2008 <<http://www.teaandcoffee.net/0106/coffee.htm>>.
- (9) Titus, Dr. Anand, and Geeta Pereira. "Nitrogen Economy Inside Coffee Plantations." *I Need Coffee*. 14 Dec. 2008 <<http://www.ineedcoffee.com/06/nitrogen/>>.

Appendix

Parameter	Unit	Value	Comments	Source
Growing				
N Fertilizer	kg	0.0039	Offset by cherry pulp	[7],[9]
P Fertilizer	kg	0.00069	Offset by cherry pulp	[7],[9]
Water	kg	0	Only rainwater is used	[7]
Pesticides	kg	0	no pesticides used	[7]
Processing				
Water	kg	4	Fresh water comes from a spring	[5]
Diesel	l	0.002753	Assumed 130 l/season	[7]
Machinery	-	-	Disregarded due to long life	[7]
Limestone	kg	0.0012	For use in Wastewater processing	[5]
Transport				
Semi Distance	km	72	Calculated by estimated 48 km/hr	[7]
Truck Distance	km	172	For transport to San Jose	
Boat Distance	km	5361	For transport to New York	
Truck Distance	km	346	For transport to Boston	
Outputs				
Green Coffee	kg	1	Functional Unit	
Organic Waste	kg	2.4	Coffee fruit, used as fertilizer	[7]
Waste Water	l	4	From Processing	[5]

Table 1: Life Cycle Inventory of Coffee Production