Estimating the Carbon Footprint of Florida Orange Juice

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Abstract

This study is a part of a comprehensive study which attempts to create a baseline of global warming impact (expressed in total greenhouse gas emission and measured in terms of carbon equivalent) associated with the production and consumption of a gallon of orange juice available in the form of NFC (Not from Concentrate) and FCOJ (Frozen Concentrated Orange Juice) in Florida. A detailed life-cycle approach is adopted and greenhouse gas emissions of all the steps in the supply chain starting from citrus nursery management to the point where customer purchases juice from a food store are considered. This study reports total greenhouse gas emission related with the management of an acre orange grove under the two scenarios of with and without resetting of trees lost due to normal attrition. It was found that total emission of greenhouse gas (carbon equivalent) for one gallon of orange juice produced under the scenarios of without and with resetting was 1.92 and 1.60 pounds, respectively. Carbon sequestered in orange trees was not considered in the present study.

Keywords: *Greenhouse Gas Emission, Orange Juice, Life-Cycle Analysis, Florida*

1 Introduction

The consumption of various fossil-based energy sources has considerably expanded the carbon footprint of the state of Florida. Total carbon dioxide emission of the state in 2005 was estimated to be 263 million MT which was 38.9% higher than the total carbon dioxide emission of the state in 1990 (EIA, 2008). Alarmed by the existing situation, state government initiated various mechanisms to reduce the carbon footprint of the state. For instance, the Florida Renewable Energy Technologies & Energy Efficiency Act of 2006 provided monetary support to people who were interested in adopting energy efficient appliances. Monetary support was also provided to those residential and commercial building owners who were interested in adopting photovoltaic and solar thermal technologies. The Renewable Energy Technologies Grant Program was also initiated to promote research in various renewable energy technologies. Similarly, Renewable Energy Technologies Tax Incentives were announced to improve production, develop distribution infrastructure, and increase availability of clean fuels including biodiesel and ethanol (DEP, 2009). To further strengthen the whole initiative, the governor of the state signed an executive order in 2007 through which a target of reducing Florida's emission of greenhouse gases to 2000 levels by 2017, to 1990 levels by 2025, and by 80% of 1990 levels by 2050 was set.

The citrus industry of the state of Florida is second largest in the world. It contributed about US$8.9 billion to the state's economy in 2007-08 (Rahmani and Hodges, 2008). Farmers produced 170.2 million 90 pound boxes of orange in 2007-08. This led to the production of about 547 million single strength equivalent (SSE) gallons of orange juice in the form of NFC (not-from-concentrate) and about 537 million SSE gallons of FCOJ (frozen concentrated orange juice) in 2007-08 (FDOC, 2009). Various energy and material inputs are needed in the entire supply chain of orange juice production and subsequent consumption. The use of energy and material inputs produce greenhouse gases which are assumed to be responsible for global warming. Greenhouse gas reduction targets are dependent on a baseline. In the case of the Florida orange juice industry, the greenhouse gas emission baseline does not exist conclusively. Tropicana, the largest citrus processing company in Florida, conducted their own study related to the carbon footprint of their main brand Tropicana Pure Premium in 2009 (Barnett and Vogel, 2009). They have chosen, however, not to release the particulars of their study. Therefore, this study attempts to develop a baseline of greenhouse gas emissions associated with the production and consumption of a gallon of orange juice available in the form of NFC and FCOJ. It is expected that this information will help the industry in improving its environmental performance and thus, will help the state in achieving set policy targets.

Note that this study is a part of a comprehensive study which attempts to capture greenhouse gas emission associated with all the stages of orange juice supply chain. Figure 1 summarizes the full supply chain for which data will be collected and analyzed. In the present study, greenhouse gas emissions associated with orange production at the grove level are considered. The next section details methods. The third section reports preliminary results. The results are discussed in the fourth section and finally, concluding remarks comprise the fifth section.

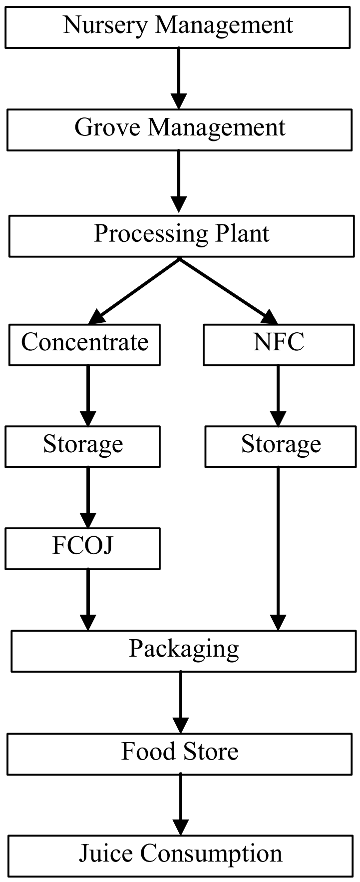

Figure 1. System boundary of the proposed comprehensive study*
(*All intermediate transportation steps were also included in the analysis)

2 Methods

The maximum age of an orange grove was assumed to be 30 years. The yields of Hamlin orange and Valencia orange were obtained from FASS (2009) starting from year 1 to 30.[1] These two orange varieties were selected as these varieties form the majority of total orange acreage in the state of Florida i.e., 86% of total land area in 2007 (FASS, 2008). The average yield was estimated from the individual yields of both the orange varieties and was used for further analysis. The original plantation density of grove was assumed to be 150 trees/acre. The annual normal mortality rate of orange trees was estimated based on consultation with farmers and extension agents. The number of living trees was estimated for each year based on annual mortality rates. The estimated yield (boxes/tree) was multiplied with number of living trees/acre to obtain total annual orange production from an acre of grove. The individual production of each year was summed and it was found that about 7,460.26 boxes of orange fruit can be produced from an acre of orange grove aver 30 years without resetting. The data on projected annual yield, annual natural mortality rate, number of living orange trees, and total annual yield are reported in Table 1.

Table 1. Model parameters for assessing global warming impact of orange juice production in Florida

	Yield (boxes/live tree)			Mortality Rate of Trees	Live trees per acre	Total Yield	Reduction Ratio
Grove Age	Hamlin Oranges	Valencia Oranges	Average	(%)		(boxes/acre)	
0	0	0	0	0	150	0.00	0
1	0	0	0	1	149	0.00	0.5
2	0	0	0	1	148	0.00	0.55
3	1.35	1.03	1.19	1	147	174.93	0.6
4	1.35	1.03	1.19	1.5	145	172.55	0.65
5	1.35	1.03	1.19	1.5	143	170.17	0.7
6	1.8	1.7	1.75	1.5	141	246.75	0.75
7	1.8	1.7	1.75	1.5	139	243.25	0.8
8	1.8	1.7	1.75	1.5	137	239.75	0.85
9	2.47	2.06	2.265	1.5	135	305.78	0.9
10	2.47	2.06	2.265	1.5	133	301.25	1
11	2.47	2.06	2.265	1.5	132	298.98	1
12	2.47	2.06	2.265	1.5	131	296.72	1
13	2.47	2.06	2.265	3	128	289.92	1
14	3.15	2.26	2.705	3	125	338.13	1
15	3.15	2.26	2.705	3	122	330.01	1
16	3.15	2.26	2.705	3	119	321.90	1
17	3.15	2.26	2.705	3	116	313.78	1
18	3.15	2.26	2.705	3	113	305.67	1
19	3.15	2.26	2.705	3	110	297.55	1
20	3.15	2.26	2.705	3	107	289.44	1
21	3.15	2.26	2.705	3	104	281.32	1
22	3.15	2.26	2.705	3	101	273.21	1
23	3.15	2.26	2.705	3	98	265.09	1
24	3.15	2.26	2.705	3	96	259.68	1
25	3.15	2.26	2.705	3	94	254.27	1
26	3.15	2.26	2.705	3	92	248.86	1
27	3.15	2.26	2.705	3	90	243.45	1
28	3.15	2.26	2.705	3	88	238.04	1
29	3.15	2.26	2.705	3	86	232.63	1
30	3.15	2.26	2.705	3	84	227.22	1

1. The unit of yield curve was number of boxes/tree. The weight of a box of oranges in the state of Florida is 90 pounds. The average yield for the state was taken for both varieties.

Muraro (2008) reported about various cultural practices that are undertaken by a farmer in a year to manage a mature orange grove[1] in the central Florida (ridge) production region. The reported cultural practices are—*weed management*, *pest management*, *pruning*, *irrigation*, and *fertilizer application*. Based on the information provided, the material balance of a mature orange grove was estimated for following cultural practices—*weed management*, *pest management*, and *fertilizer application*. This literature does not provide any information about the various energy products consumed to accomplish various cultural activities. Therefore, the amount of various energy products (e.g., diesel, gasoline, etc.) used for accomplishing different cultural practices were ascertained by interviewing farmers, extension agents, and experts. Material balance of practices—*pruning* and *irrigation* were also ascertained. For instance, the average annual consumption of diesel and gasoline for *irrigation* practice was found to be 23 and 9.2 gallons/acre, respectively. Additionally, energy and material use related with the practice of *site preparation* was also estimated. The practice of *site preparation* included following activities—mowing (mechanical), mowing (chemical), disking, soil shaping, and planting. The total diesel consumed to collect fruit and transport it to a nearest processing plant (60 miles)[2] was also ascertained for each year of orange production.

For estimating total greenhouse gas emission, estimated use of various energy products and materials was divided into three categories i.e., site preparation, grove management, and transportation of fruit to a processing plant. The greenhouse gas emissions (carbon dioxide equivalent) associated with the production and consumption of a unit quantity of an energy or a material input were derived from Franklin Environmental Database as available in the SimaPro software. For example, it was found that about 8.76 pounds of carbon dioxide equivalent greenhouse gas is emitted during the production of a pound of nitrogen fertilizer. These values are called emission factor. The emission factor of different energy products and material were multiplied by their respective quantities to ascertain the total greenhouse gas emission (carbon dioxide equivalent) of each category.
Note that the value of calculated greenhouse gas emission for site preparation category does not change with grove's age. Similarly, it was found that greenhouse gas emissions related with transportation of fruit from grove to a nearby processing plant were varies by the volume of fruit delivered annually. Emission values of each year were summed to obtain total greenhouse gas emission (carbon dioxide equivalent) for each category. The rate of material and energy use at the grove level changes, however, with respect to grove age. The rate of energy and material use is less for an immature plantation (year 1 to 9). Therefore, greenhouse gas emissions (carbon dioxide equivalent) calculated for a mature grove under the category of grove management were reduced using suitable reduction ratios for each year. These reduction ratios are based on expert consultation and are reported in Table 1. The sum of greenhouse gas emitted (carbon dioxide equivalent) for the category of grove management was obtained by adding greenhouse emission of each year. The final value of greenhouse gas emission (carbon dioxide equivalent) was obtained by adding greenhouse gas emission of all the three categories i.e., site preparation, grove management, and transportation of fruit to a processing plant. The final value of greenhouse gas emission was converted from carbon dioxide equivalent to carbon equivalent by multiplying by 12/44 i.e., mass of carbon in a molecule of carbon dioxide.

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1. For this study, we are assume that a mature grove are those groves with trees from age 10 to 30.
2. This figure is based upon an informal survey of three Florida citrus processing companies.

Assuming that about 7 gallons of orange juice can be produced from a box of oranges (FASS, 2009), the total volume of orange juice that can be produced from 7,460.26 boxes was estimated. The final value of greenhouse gas emission (carbon equivalent) was divided by the total volume of orange juice to ascertain the average amount of greenhouse gas emission (carbon equivalent) for every gallon of orange juice produced under the scenario of without resetting. Resetting is the practice of replacing trees lost due to weather, disease, or random events. In Florida, most growers choose to reset lost trees even in mature plantings to minimize the number of open spaces in a grove. In the case of resetting, same procedure was used but emissions related to plant new trees each year were also accounted. Also, yields from new trees were accommodated in the analysis to calculate net greenhouse gas emission (carbon equivalent) for every gallon of orange juice produced. The total number of boxes that can be produced under the scenario of resetting were found to be 9,002.90 per acre over the assumed 30-year life of a grove.

3 Preliminary Results

The total amount of greenhouse gas emission (carbon equivalent) for the scenario of without resetting over the life of grove was found to be 49.94 tons per acre of production. This includes emission from site preparation (0.103 tons), grove management (47.67 tons), and transportation of fruit from grove to a nearby processing plant (2.17 tons). In the grove management category, the total greenhouse gas emission (carbon equivalent) due to material (herbicide, pesticide, fertilizers) and energy use (diesel and gasoline) was 32 tons and 15.67 tons, respectively. It was found that the volume of orange juice that can be produced from 7,460.26 boxes of orange fruit is 52,221.82 gallons. This implies that the average carbon emitted for every gallon of orange juice produced under the scenario of without resetting is about 1.92 pounds. The total amount of additional greenhouse gas emission (carbon equivalent) due to resetting was found as 0.27 tons implying that the total greenhouse gas emission (carbon equivalent) in the presence of resetting is about 50.22 tons. It was found that total orange juice that can be produced from 9,002.90 boxes of orange fruit is about 63,020.30 gallons. This implies that the average carbon emitted for every gallon of orange juice produced under the scenario of with resetting is about 1.60 pounds. By comparison, the Tropicana study estimated that 1.7 kg (3.74 pounds) of carbon is emitted to produce one-half gallon of orange juice (Barnett and Vogel). They attribute 60% of the emissions to the production of oranges. After adjusting for differences in units, their figure suggests that 4.5 pounds of carbon are emitted per gallon of orange juice produced, a figure far higher than our estimate. Since the details of the Tropicana study are not available, we are unable to explain why our results differ. Figure 2 details the distribution of greenhouse gas emission (carbon equivalent) for both the scenarios.

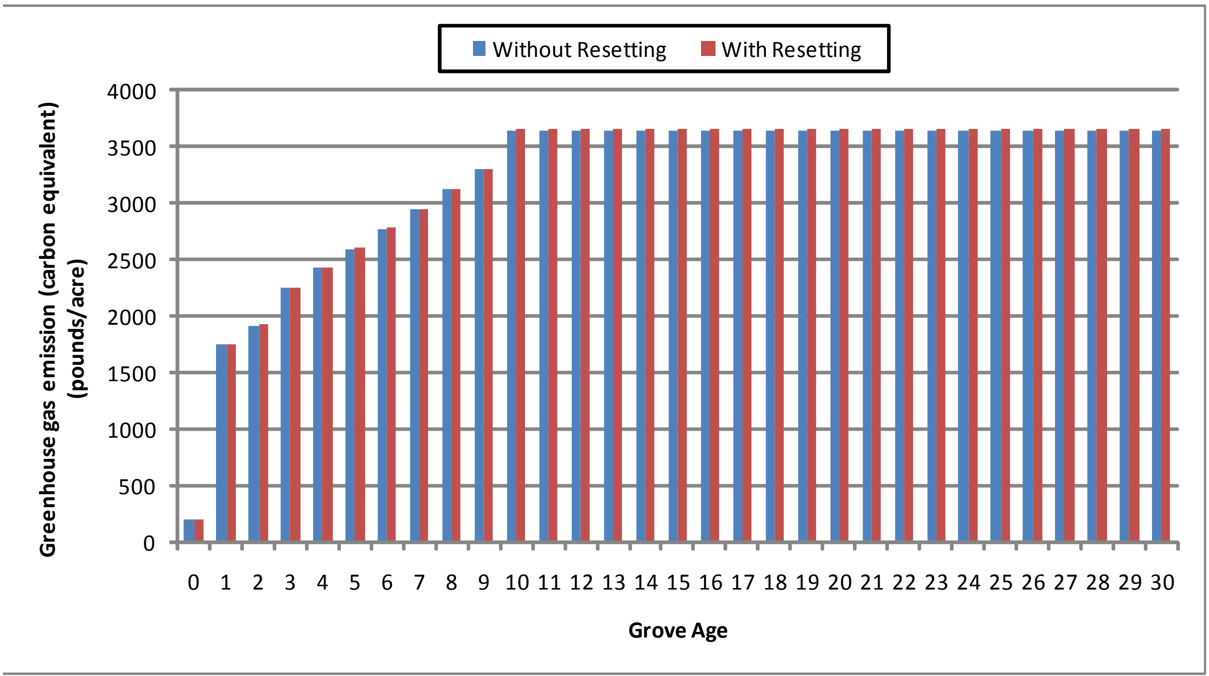

Figure 2. Distribution of greenhouse gas emission (pounds/acre) for both the scenarios

4 Discussion

The results indicate that under the scenario of with resetting, the greenhouse gas emission (carbon equivalent) increase by about 0.54% when compared with scenario of without resetting. However, the total availability of orange juice from an acre of grove increases by about 20.67% under the scenario of with resetting when compared with the scenario of without resetting. This further helps in reducing the total carbon intensity of orange juice produced from a grove where resetting was performed as compared to a grove where no resetting was performed. For instance, the total carbon intensity of orange juice produced under the scenario of with resetting was about 17% less than the carbon intensity of orange juice produced under the scenario of without resetting. This clearly implies that resetting helps in reducing the carbon footprint of orange juice.

5 Concluding Remarks

This study presents a snapshot of a comprehensive study which attempts to create a baseline the carbon emissions associated with orange juice production in the state of Florida. Data collection from processors regarding carbon emissions associated with fruit juice, pasteurization, storage, packing, and transport to retail outlets is on-going.
In this study, we have failed to account for the carbon sequestered in orange trees over their life cycle. Limited data is available regarding the biomass estimates of orange trees. As some point, however, the carbon sequestration issue must be confronted and incorporated into the analysis.

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