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Study of the Sustainability of Frozen Concentrated Orange Juice Production through Emergy Analysis. Part 1: Processing in Brazil

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ABSTRACT

Emergy analysis was used to assess the sustainability of the frozen concentrated orange juice (FCOJ) production chain, including the orchard, processing, and transport steps through arrival at Santos port. FCOJ was chosen because it is one of the main agricultural products of the São Paulo state. Brazil is the major world producer of FCOJ and almost all of Brazilian production is exported (98 percent), mainly to Europe. The Brazilian orchards have a very high production per hectare as a consequence of intensive use of inputs, especially herbicides and pesticides, labor, and energy for irrigation. The orange produced by this system presents a transformity value of 1.76 E+05 sej/j, renewability of only 27.7 percent, Emergy Yield Ratio (EYR) of 1.51, and an Emergy Loading Ratio (ELR) of .61. These results alone are important since they show that the agro-chemical model adopted is not sustainable. FCOJ demands a huge amount of non-renewable energy in its manufacturing and transport, mainly through the use of machinery and energy, especially for the process of concentrating the juice and for frozen storage. Renewability of FCOJ decreases to 17 percent (compared to raw oranges) and FCOJ transformity increases to 2.98 E+05 sej/j. These are preliminary results as they do not include waste treatment and will be refined as more detailed data is obtained.

INTRODUCTION

The citrus sector is of crucial social and economical importance to Brazil, the major orange producer in world (FAO 2007), especially to the state of São Paulo. In 2004 the Brazilian orchards produced 18.3 million tons of oranges, which represents 26 percent of the world's production, occupying a total of 823 thousand hectares in Brazil (of which 587 thousand hectares were located in Sao Paulo which represented 9.4 percent of the total cultivated area of the state) (FAO 2007; IBGE 2007). In this same year orange production took place on approximately 10,000 farms in the state and directly employed 400 thousand people. The majority of the oranges produced (72 percent) were crushed to make frozen concentrated orange juice (FCOJ) (Neves and Lopes 2005).

The Brazilian citrus agro-industrial system is highly developed and competitive. The high production per hectare observed, 37 ton/ha in 2003/2004 for the main producers (Neves and Lopes 2005), is the result of intensive fertilization and use of pest control agents, as well as crop irrigation and machinery operation. Due to the adoption of this intensive technology, continuous increases in production costs, energy use and environmental problems related to citrus crop have been observed, together with a decrease in labor needs (Amaro et al. 2001; Ghilardi et al. 2002; Neves and Lopes 2005).

The Brazilian FCOJ industry is concentrated in four top companies, which operate several plants in the state of São Paulo. These four companies are able to deliver their product at a competitive price due to a high scale production. The process is nearly the same for all of them: reception, cleaning, extraction, finishing, concentration, cooling, and storage. This industry, although an intensive energy consumer, is very efficient both in energy use and in exploiting production residues (transforming residues into several by-products such as essential oils, *d'limonene*, and feed pellets). This sector, however, depends entirely on the international market conditions; Florida's citrus performance, also a major orange and FCOJ producer, is particularly important (Neves and Lopes 2005).

FCOJ production chain includes agriculture, industry and long distance transport steps. In each one of these there are resource consumption and environmental impacts, summarized in Table 1. Therefore, to truly assess FCOJ impacts and sustainability the whole chain should be addressed.

The combined use of emergy analysis (EA) and life cycle assessment (LCA) methods has been proposed by some authors studying different products (Bargigli and Ulgiati 2003; Bakshi 2000; and Bastianoni and Marchettini 1996). LCA focuses on the impact of industrial production on the environment, but does not consider nature's services consumed by the system, while EA focuses on nature's services that are used by the system. Both methods are complementary and can be used in an integrated way since EA is deficient in the evaluation of undesired impacts to the environment.

The European Union is the world's second largest orange juice market, behind the United States, being the main destination of Brazilian FCOJ exports. Although the average per capita consumption is about 4.2 liters, in some countries the per capita consumptions is as high as 19.4 liters (Germany). The sales of orange juice in central and eastern Europe have been growing in the last few years (FAO 2007).

The present work assesses the sustainability of the FCOJ chain through the use of EA, adopting life cycle assessment concepts, which include all subsystems involved in production, transport, and consumption of the product.

METHODS

Although the complete FCOJ chain is composed of crop production, transport from farm to processing plant, industrial processing, transport from factory to port, maritime transport, port reprocessing and storage, transport to factory, reprocessing, distribution to consumer, consumption and final disposal of residues, this paper only addresses the processing that happens within Brazil. Brazil's FCOJ processing includes crop production, transport to industry, processing, and transport to Santos Port. Figure 1 presents the abbreviated FCOJ production and consumption diagram, including the portion taking place in Brazil that is assessed by this paper.

Table 1. Summary of FCOJ chain phases and their main characteristics.

Phases	Main Resources Used	High Consumption of Fossil Fuels for:	Possible Environmental Damage
Orchard	• Water • Soil • Fuel • Pesticides/ herbicides • Labor	• Machinery operations • Irrigation • Input transportation	• Ecosystems destruction • Topsoil loss • Biodiversity loss • Resource depletion • Water contamination • Gas emissions
FCOJ Processing	• Fuel • Electricity • Water • Material • Labor	• Concentration (water evaporation) • Juice freezing • Juice storage	• Resource depletion • Solid residues • Water contamination • Gas emissions
Transport	• Fuels • Materials	• Truck transport	• Resource depletion • Gas emissions

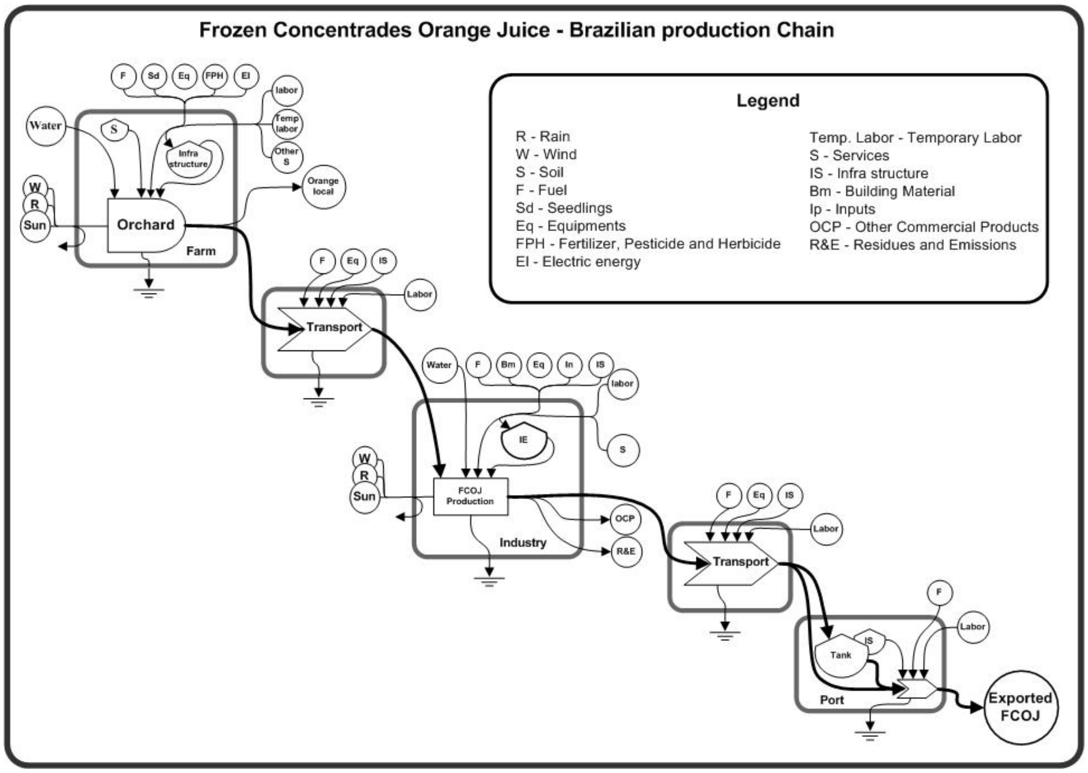

Figure 1. *The Brazilian portion of FCOJ production chain.*

Through emergy analysis, each sub-system (represented by a rectangle in Figure 1) was evaluated separately as an independent system and then integrated as a new and bigger system in accordance with the LCA framework.

Emergy evaluation of the FCOJ production and consumption chain was accomplished as described by Odum (1996). The renewable portion of resources supplied by the economic system was considered for modified renewability calculations, as described by Ulgiati et al. (1994) and Ortega et 11 al. (2002 and 2005)."

Orchard

Data from a typical orange farm located in the São Paulo orange growing region was used for farm phase calculations. This orchard occupies 131 hectares of the total farm area of 180 hectares, contains approximately 331 trees/ha, and has an average production of 40.5 ton/ha. The use of chemical fertilizers and pest control agents, as well as the handling procedures adopted, follow the average state-of-the-art recommendation for orange production. Underground water is used for irrigation. Oranges are sold mainly to the FCOJ industry, but, depending on market conditions, they can be sold for direct consumption as well. Figure 2 represents the orchard emergy flow. Data from the 2003/2004 harvest was used. In order to analyze industry and transport operations, the results were extended for a total of 8,250 hectares of orchard, or the necessary area required to produce the volume of oranges needed to the run the production plant.

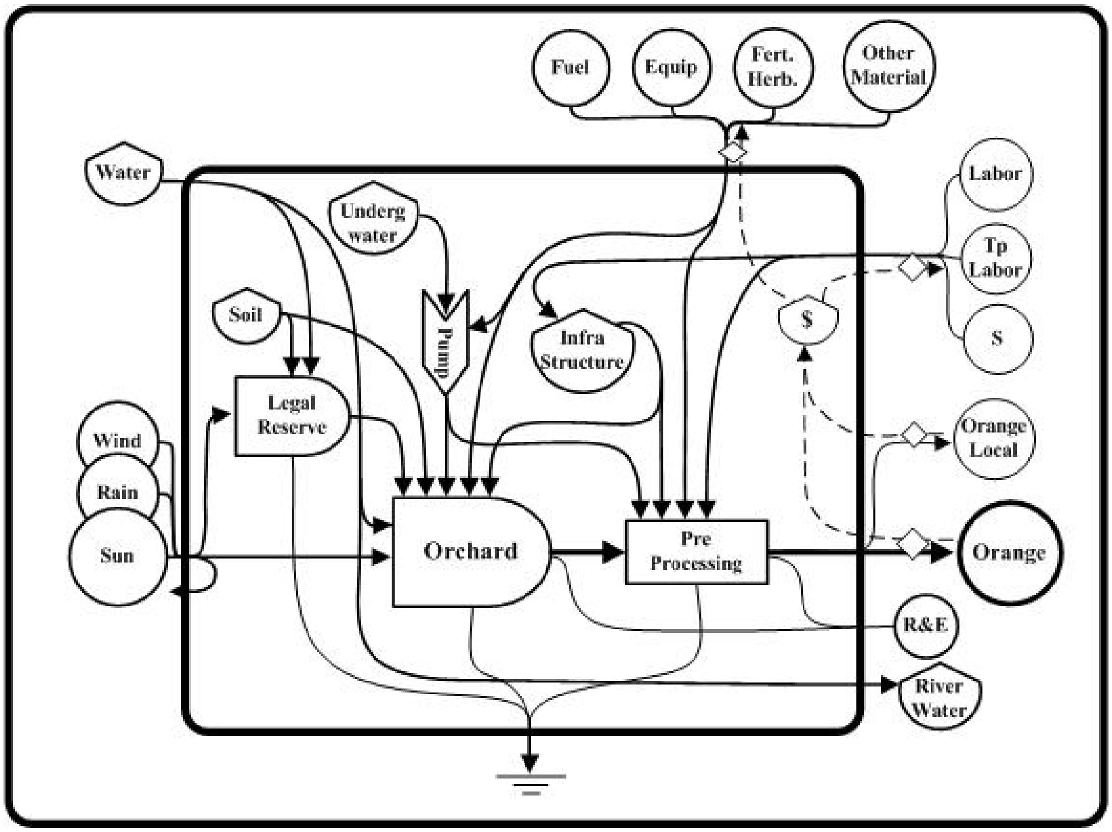

Figure 2. *Orchard emergy flow. Underg Water = underground water; Equip = equipment; Fert. Herb = fertilizers and herbicides; Tp Labor = temporary labor; S = services; and R&E = residues and emissions.*

Transport to Processing

The oranges are transported by truck from the orchard to the processing plant a distance of approximately 100 km. For calculations it was considered that 65 percent of the oranges were transported by 25 ton trucks and 35 percent by 14 ton trucks according to information provided by orange producers.

FCOJ Processing

The FCOJ industry is very intensive in energy use due to evaporation, feed production, and frozen storage. In particular, the concentration step requires a considerable amount of large equipment and must therefore process huge volumes in order to be energy efficient. The data used in this work was obtained from literature, interviews with industry technicians, and is based on a standard FCOJ plant project with the capacity to process 1,500 boxes/hr of oranges or 61 ton/hr which produces 5.6 ton/hr of standard FCOJ (66 brix concentration) stored at -10^0 Celsius. Figure 3 represents the FCOJ production emergy flow.

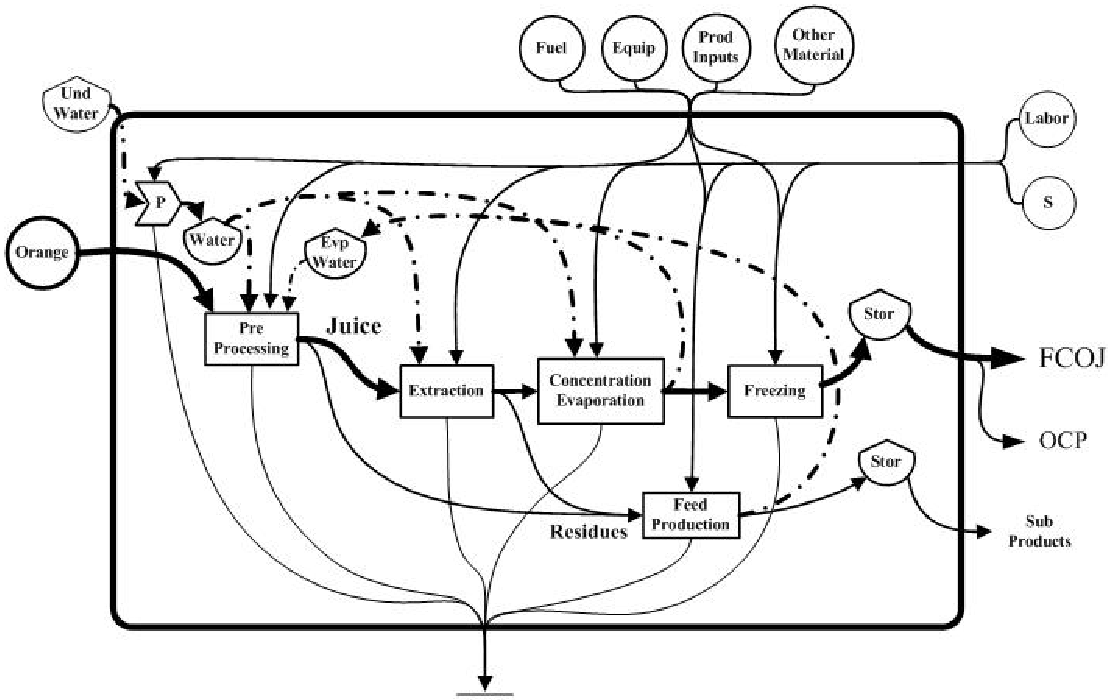

Figure 3: *FCOJ industrial production emergy flow. Where Und water. = underground water; P = pump; Evp Water = evaporated water; Equip. = equipment; ¨Prod. = Products; Stor = storage; OCP = other commercial products; S = services*

Transport to Port

FCOJ is bulk transported by special 26-ton capacity insolated tank trucks from the juice processing plant to Santos Port. It was assumed to be an average transportation distance of 400 km from the plant to the port. At Santos Port the juice is either pumped directly to bulk tankers ship or stored in farm tanks located at privet port facilities

RESULTS AND DISCUSSION

Table 2 represents the emergy table for FCOJ processing and transport to port. Orchard and plant processing operations were the main contributing steps, accounting for 61 percent and 36 percent respectively, of all flows used for processing and delivering FCOJ to Santos Port. Transport steps, at this point, represented only three percent of emergy flows. When the complete chain is considered, resources from economy, Services (44.4 %) and Materials (44.8 %), were the main flows used by the system

The same pattern was observed when considering each subsystem separately: for the orchard subsystem the main contributions were labor (13.8 percent) and diesel (five percent) and limestone (five percent); for the industrial subsystem the main contributions were taxes (17 percent), fuel (seven percent), electricity (six percent), and labor (four percent).

Table 3 presents emergy indices calculated for the subsequent FCOJ production steps. The transformity of oranges increased from 1.76 E+5 sej/j leaving the farm, to 7.45 E5 sej/j as FCOJ at Santos Port. This value dropped to 2.98E5 sej/j when all by products were considered, indicating the

Table 2. Emergy table of Brazilian FCOJ production chain.

Note	Flow	% R	Amount (unit/y)	Unit	seJ/unit	Solar Emergy (E17 sej/y)		
						Ren	Non Ren	Total
Renewable Flows (R)								
	Agricultural phase							
1	Sunlight	100	4.41E+17	J	1	4.5	0	4.5
2	Rain	100	6.56E+14	J	3.06E+04	200.7	0	200.7
3	Water	100	6.01E+13	J	1.85E+05	111.1	0	111.1
	Industrial phase							
4	Water	100	3.56E+11	J	1.85E+05	0.7	0	0.7
Non Renewable Flows (N)								
	Agricultural phase							
5	Top Soil losses	0	5.73E+13	J	1.24E+5	0	71.1	71.1
TOTAL FROM NATURE (I)						**317.0**	**71.1**	**388.1**
Purchased Goods (M)								
	Agricultural phase							
6	Limestone	0	3.69E+12	J	2.72E+06	0	100.3	100.3
7	Phosphate	0	1.11E+08	g	6.55E+09	0	7.3	7.3
8	Potassium	0	6.09E+07	g	2.92E+09	0	1.8	1.8
9	Urea	0	8.33E+08	g	6.38E+09	0	53.2	53.2
10	Herbicides	0	5.79E+07	g	2.48E+10	0	14.4	14.4
11	Other inputs	0	1.25E+05	U$	3.70E+12	0	4.6	4.6
12	Electricity	68	1.21E+13	J	2.77E+05	22.8	10.8	10.8
13	Installation depr.	0	3.59E+05	U$	3.70E+12	0	13.3	13.3
14	Machinery (steel)	0	1.81E+08	g	1.13E+10	0	20.5	20.5
15	Diesel	0	1.85E+14	J	5.50E+04	0	101.7	101.7
	Transport Farm- Processing Plant							
16	Diesel	0	3.56E+13	J	5.50E+04	0	19.6	19.6
17	Machinery (steel)	0	4.59E+04	g	1.13E+10	0	0,0	0,0
18	Tires	0	2.25E+04	kg	4.30E12	0	1.0	1.0
	Industrial phase							
19	Machinery (steel)	0	1.34E+07	g	1.13E+10	0	1.5	1.5
20	Fuel (oil)	0	2.46E+14	J	5.50E+05	0	135.5	135.5
21	Other equipment	0	8.22E+04	U$	3.70E+12	0	3.0	3.0
22	Electricity	68	4.03E+13	J	2.77E+05	75.9	35.7	111.6
23	Installation deprec.	0	5.60E+05	U$	3.70E+12	0	20.7	20.7
	Transport Processing Plant -Port							
24	Diesel	0	8,85E+12	J	5.50E+04	0	4.9	4.9
25	Truck (steel)	0	1.65E+07	g	1.13E+10	0	1.9	1.9
26	Tires	0	5.04E+03	kg	4.30E+12	0	0.2	0.2

Services (S)								
	Agricultural phase							
27	Labor	39	6.24E+06	U$	3.70E+12	90.1	140.9	231.0
28	Temporary Labor	39	7.01E+05	U$	3.70E+12	10.1	15.8	25.9
29	Administ. expenses	0	1.60E+06	U$	3.70E+12	0	59.0	59.0
30	Governmental taxes	0	2.34E+06	U$	3.70E+12	0	86.4	86.4
	Transport Farm-Processing Plant							
31	Labor	39	1.29E+05	U$	3.70E+12	1.9	2.9	4.8
32	Taxes	0	3.09E+05	U$	3.70E+12	0	11.4	11.4
	Industrial phase							
33	Labor	39	2.13E+06	U$	3.70E+12	31.5	47.3	78.8
34	Other services	0	2.92E+05	U$	3.70E+12	0	10.8	10.8
35	Governmental taxes	0	8.48E+06	U$	3.70E+12	0	313.9	313.9
	Transport Processing Plant-Port							
36	Labor	39	6.00E+04	U$	3.70E+12	0.9	1.3	2.2
37	Taxes	0	1,47E+05	U$	3.70E+12	0	5.5	5.5
TOTAL FROM ECONOMY (F)						**233.3**	**1247.0**	**1480.3**
TOTAL (Y)						**550.2**	**1318.1**	**1868.3**

FCOJ

Mass	22.6 thousand ton/year
Energy	2.50E+14 J/year

Other Products

Mass	29.6 thousand ton/year
Energy	3.75E+14 J/year

Reference for transformity values used: Notes 1,8 – Odum, 1996;
Notes 2, 3,4, 5, 6, 7, 9,10,17,19, 22, 25 - Brown and Ulgiati, 2004;
Notes 11,13,21,23,27,28, 29, 30, 31, 32, 33, 34, 35, 36, 37- Coelho et al. 2003
Notes 15, 16, 20,24 from Bastianoni et al. 2006;
Notes 12 and 22 (electricity) from Brown and Ulgiati, 2004, and Odum, 1996;
Notes 18 and 26from LEIA, 2005

importance of residues exploitation. Transport did not increase the transformity of oranges significantly, but the industrial process did.

Renewability, or the degree of sustainability, decreased from 27.7 percent for oranges (orchard system) to 17 percent for FCOJ at Santos Port. Though intensive in fuel use, the transport steps did not decrease the renewability significantly at this point. When the renewable portion of purchased goods and services was included, renewability increased to 38.5 percent and 29.5 percent for the farm subsystem and at Santos Port, respectively.

The Emergy Yield Ratio (EYR) decreased from 1.51 for the farm system to 1.26 at Santos Port, indicating that further processing consumed needed more nonrenewable inputs without increasing the ability to use natural resources.

Table 3. Emergy indices for FCOJ Brazilian production chain.

Indices	Oranges	Transported oranges [a]	FCOJ leaving industry gate	FCOJ at Brazilian port [b]
Transformity (sej/j)	1.76E+05	1.82E+05	7.41E+05 [c] 2.97E+05 [d]	7.45E+05 [c] 2.98E+05 [d]
Ren (%)	27.7	26.9	17.1	17.0
Ren* (%)	38.5	37.5	29.6	29.5
EYR	1.51	1.49	1.27	1.26
ELR	2.61	2.72	4.85	4.88
EER	1.47		1.70	

[a] Transport from orchard to industrial plant; [b] including transport from industrial plant to Santos Port; [c] considering only FCOJ; [d] considering the totality of products and byproducts; Ren = renewability; Ren* = renewability considering the renewable portion of materials and services.

The Environmental Loading Ratio (ELR), a measure of ecosystem stress due to the process, significantly increased with orange processing, changing from 2.61 (farm system) to 4.88 (FCOJ at Santos Port). These results indicate the high environmental impact due to industrial and transport operations.

The EER, the Emergy Exchange Ratio in a trade operation, was 1.47 for orange producers and 1.70 for FCOJ producers. The results indicate that both, orange producers and the FCOJ industry, were delivering higher amounts of emergy than receiving back in the trade operation.

Surprisingly the farm subsystem presented poor indices, but they are similar to the ones calculated to Florida orchards by Brandt-Williams (2002): renewability of 22 percent, EYR of 1.24 and ELR of 4.17. This outcome was due to the use of large amounts of lime and diesel in orchard operations. Showing that this system is highly dependent, and sensitive, to market prices and, especially, to fuel availability. The adopted agricultural technology results in important environmental impacts, decreasing the chances of prevailing in the long run. As expected, industrial operations, as well as transport steps, are intensive in purchased materials and use of services.

Since Florida and São Paulo are the two main orange producers, adopting basically the same technology for both orange growth and FCOJ processing, these results indicate that the FCOJ chain, though highly integrated in terms of energy use and residue use, presents a very low renewability and, therefore, is not sustainable in the long run. These are preliminary results, and do not include further steps in the LCA, such as industrial waste treatment. It will be refined as more data is obtained for the subsequent steps, and the complete chain is addressed.

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APPENDIX A: TABLE 2 FOOTNOTES

1 –	Solar energy, J	
	Orchard area = 8250 ha	
	Average annual insolation = 6.6E+9 $J/m^2.y$	NASA 2005
	Albedo = 17 %	NASA 2005
	Solar energy = (orchard area)*(average insolation)*(1-albedo) = 4.51E+17 J/year	
	Transformity = 1 seJ/J	Definition
2 –	Rain chemical potential, J	
	Rain (average) = 16050 $m^3/m^2.y$	INMET 2005
	Rain energy (J) = (orchard area)*(rain)*(Gibbs energy of water)* (density) = 6.56E+14 J/year	
	Transformity = 3.06E+04seJ/J	Brown and Ulgiati 2004
3 –	Underground water, J	
	Water consumption = 1.5E+06 l/ha.yr	
	Water energy (J) = (orchard area)*(water consumption)*(Gibbs energy of water)*(density) = 6.01E+13 J/year	
	Transformity = 1.85E+05seJ/J	Brown and Ulgiati 2004
4 –	Underground water used by processing plant, J	
	Water consumption = 7.21E+04 m^3/year	
	Water energy (J) = (water consumption)*(Gibbs energy of water) *(density) = 3.56E11 J/year	
	Transformity = 1.85E+05seJ/J	Brown and Ulgiati 2004
5 -	Loss of top soil, J	
	Erosion rate = 10.0 t / ha.year	Bertoni et al. 1972
	% organic in soil = 4%	Our estimate
	Topsoil energy = (orchard area)*(erosion rate)*(% mat. Org.)* (Energy per g of organic material) = 5.73E+13 J/year	
	Transformity = 1.24E+05seJ/J	Brown and Ulgiati 2004
6 –	Limestone, J	
	Lime consumption = 1 t/ha.year	
	Limestone energy = 611 J/g	
	Energy = (orchard area)*(used volume)*(Gibbs free energy) = 3.69E+12 J/year	Brown and Ulgiati 2004
	Transformity = 2.72E+06 seJ/J	Brown and Ulgiati 2004
7 –	Phosphate, g of P	
	Phosphate mixture consumption = 130 kg/ha. y	
	Concentration of P in the mixture = 20%	
	Grams of P = (orchard area)*(volume of mixture)*(P concentration) = 1.11E08 g of P/year	

Transformity = 6.55E+09 seJ/g of P — Brown and Ulgiati 2004

8 – Potassium, g of K
Potassium consumption = 18 kg / ha year
Concentration of K in the mixture = 52%
Grams of K = (orchard area)*(used volume)*(K concentration)
= 6.10 E+07 g of K/year
Transformity = 2.92E+09 seJ/g of K — Brown and Ulgiati 2004

9 – Urea, g of N
Urea consumption = 0.3 tones/ha.year
Concentration of N = 46%
Grams of N = (orchard area)*(used volume)*(N concentration)
= 8.33 E+08 g of N/year
Transformity = 6.38E+09 seJ/g of N — Brown and Ulgiati 2004

10 – Herbicides and Pesticides, g
Used volume = 7 kg/ha.year
Grams of herbicides = (orchard area)*(used volume)
= 5.79E +07 g of herbicides/ year
Transformity = 2.48E+10 seJ/g of herbicides — Brown and Ulgiati 2004

11 – Other inputs, U$
Cost of other inputs = U$ 25.00/ha.year
Total Cost = (orchard area)*(cost/ha.year)
= 1.25E+05 U$/year
Transformity = 3.70E+12 seJ/U$ (Brazilian Emdollar) — Coelho et al. 2003

12 - Electricity, J
Consumption = 0.5 MWh/ha.year
Electricity = (orchard area)*(consumption)
= 1.21E+13 J/year
Transformity = 2.77E+05seJ/J — Our estimate from Brown and Ulgiati 2004, and Odum 1996

13- Installation depreciation- farm infrastructure, U$
Annual depreciation = U$ 25.00/ha
= (orchard area)*(annual depreciation/ha)
= 3.59E+05 U$/year

14 – Machinery (steel) - farm operations, g
Machinery weight = 300 tones
Machinery useful time = 15 years
Machinery = (machinery weight)/(useful time)
= 1.81E+08 g
Transformity = 1.13E+10 seJ/g — Brown and Ulgiati 2004

15 – Fuel (Diesel) – Farm operations, J
Consumption = 840 l/ha.year

Fuel energy = (orchard area)*(consumption)* (density)*
(Diesel Energy/weight)
= 1.85E+14 J/year
Transformity = 5.50E+04 seJ/J — Bastianoni et al. 2006.

16 – Fuel (Diesel) – orange transport, J
Trips = 11400 trips
Distance=200km
Consumption = 2.5 km/l
Fuel energy = (no trips)*[(distance)/(consumption)]* (density)*
(Diesel Energy/weight)
= 3.56E+13 J/year

17 - Machinery (steel) for orange transport, g
Truck Weight = 10,000 kg
Truck useful mileage = 500,000 km
Machinery = [(truck weight)/(truck mileages)]*[(no trips)*(distance)]
= 4.59E+04 g/year
Transformity = 1.13E+10 seJ/g — Brown and Ulgiati 2004

18 – Tires for orange transport, kg
Tires weight= 1100 kg
Tires useful mileage= 100,000 km
Tires = [(tires weight)/(tires mileage)]*[(no trips)*(distance)]
= 2.25E+04 kg/year
Transformity = 4.30E+12 seJ/kg — LEIA 2005

19 – Industry Machinery (mainly steel), g
Total weight = 400 tones
Life time = 30 years
Machinery = (total weight)/(life time)
= 1.34E+07 g/year
Transformity = 1.13E+10 seJ/g — Brown and Ulgiati 2004

20 - Fuel (oil) used by industrial plant, J
Fuel consumption = 6.5E+06 l/year
Fuel energy = (consumption)* (density)*(Diesel Energy/weight)
= 2.46E+14 J/year
Transformity = 5.50E+04 seJ/J — Bastianoni et al. 2006

21 - Other equipment used by industrial plant, U$
Total investments = U$ 2 500 000.00
Life time = 30 years
Other equipment investments = (total investments)/(life time)
= 8.22E+04 U$/year

Transformity = 3.70E+12 seJ/U$ — Coelho et al. 2003

22 - Electricity used by industrial plant, J
Annual consumption = 1.1E+07 KW*hour
= 4.03E+13 J

23 - Industrial plant Installation depreciation, U$
Annual depreciation = U$ 560 000/year

24 - Fuel (Diesel) – Orange juice transport to Santos port, J
Trips = 870 trips
Distance = 800km
Consumption = 2.8 km/l
Fuel energy = (no trips)*[(distance)/(consumption)]* (density)*
(Diesel Energy/weight)
= 8.85E+12 J/year

25 - Machinery (steel) for orange juice transport to Santos port, g
Truck Weight = 14,500 kg
Truck useful mileage = 600,000 km
Machinery = [(truck weight)/(truck mileages)]*[(no trips)*(distance)]
= 1.65E+07 g/year
Transformity = 1.13E+10 seJ/g Brown and Ulgiati 2004

26 – Tires for orange juice transport to Santos port, kg
Tires weight= 1100 kg
Tires useful mileage= 150,000 km
Tires = [(tires weight)/(tires mileage)]*[(no trips)*(distance)]
= 5.04E+03 kg/year

27 – Labor for farm operations (regular), U$
Monthly expenses with labor = U$ 500 000.00
Annual expenses with labor = 6.24E+06 U$/year

28 – Temporary Labor for harvest, U$
Harvest cost = U$ 0.11/box
Total harvest = 6,000,000 boxes
Annual expenses with harvest = (harvest cost)*(total harvest)
= 7.01E+05 U$/year

29 – Farm administrative expenses, U$
Monthly administrative expenses = U$ 183/ha
Annual administrative expenses = (Monthly expenses)*(orchard area)
= 1.60E+06 U$/year

30 – Governmental taxes, U$
Taxes = U$ 283.00/ha.year
Total taxes = 2.34E+06 U$/year

31 – Labor, orange transport, U$
Trip cost (labor) = U$ 11.00
Trips = 11400 trips
Annual expenses with labor = (trip cost)*(trips)
= 1.29E+05 U$/year

32 – Transport taxes (oranges), U$
Taxes = U$ 0.05/box

Total taxes = 3.09E+05U$/year

33 – Labor, industrial operations (regular), U$
Labor cost = U$ 93.00/ton of FCOJ
Total production = 23 000 tones/year
Total labor cost = (total production)*(labor cost)
= 2.13E+06 U$/year

34 – Other Services (project and technical assistance), U$
Cost = U$ 8,800,000.00
Plant life time = 30 years
Services cost = 2.92E+05 U$/year

35 – Governmental taxes, U$
Taxes = U$ 8,500,000.00/year

36 – Labor, orange juice transport to Santos port, U$
Trip cost (labor) = U$ 69.00
Trips = 870 trips
Annual expenses with labor = (trip cost)*(trips)
= 6.00E+04 U$/year

37– Transport taxes (orange juice), U$
Taxes = U$ 6.20/tones
Total taxes = 1.47E+05 U$/year