Impact of transportation on the environmental performance of Brazilian banana production

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ABSTRACT

The increase of consumer's ecological awareness has forced decision-makers and producers to search for scientific information about environmental performance of agricultural production systems. LCA studies on tropical perennial agricultural products are still scarce; furthermore, the great diversity of these products contrasts with the reduced available environmental data in Brazil. As fifth largest banana producer in de world, Brazilian production is almost entirely directed towards the domestic market through small-scale banana producers widely distributed throughout the country. The objective of this study is to evaluate the environmental performance of banana transportation stage through environmental indicators, considering Brazilian largest production regions. In the domestic market most bananas are consumed near its production centers, except for Northern Minas Gerais and Bom Jesus da Lapa - BA regions which distances from the consumers are approx. 1,000 km. The banana consumed in São Paulo has the lowest environmental impact in relation to the transport stage: 23.20 kg CO_2 eq/t, 50.10 MJ/t and 8.41 kg of non-renewable resources/t in the empty return scenario. Exports impact was larger for MERCOSUR than Europe due to the use of different transportation modes.

Keywords: banana, Brazil, transport, environmental impact, GHG emissions

1. Introduction

The Brazilian banana crop in 2013 was 6,931,137 tons, occupied a harvested area of 523,315 hectares and had an average yield of 13.2 tons per hectare (IBGE, 2014a). In 2012, the value of the Brazilian banana production was estimated at 4,396 billion reais (IBGE, 2014b). Brazil features as the fifth largest producer of bananas in the world (FAO, 2012). However, Brazil is not even among the top ten exporters of the product, exporting 110,054 tons in 2011 (FAO, 2014), since its production is almost entirely directed to the domestic market. With the exception of the states of São Paulo, Paraná and Santa Catarina, where crops of Cavendish bananas prevail, most of the national production of bananas is from the subgroup *Prata*, preferred by most Brazilian consumers and more resistant to postharvest injuries and illness, but not well accepted in the export markets (Lichtemberg, Lichtemberg, 2011).

The ten municipalities that stand out in the national banana production account for less than 20% of the Brazilian production. This indicates the wide geographic distribution of small-scale banana producers throughout the country, with only a few poles that stand out as major producers, namely: North of Santa Catarina, the Vale do Ribeira in São Paulo´s Southern coast, North of Minas Gerais, Bom Jesus da Lapa in Bahia, Vale do Submédio do São Francisco, Vale do Açu in Rio Grande do Norte and Vale do Jaguaribe in Ceará. While states in the South and Southeast region export to MERCOSUR countries, especially for Argentina and Uruguay, the northeastern states, notably Rio Grande do Norte and Ceará, have had a growing market share in Europe (Germany, UK, Netherlands, Poland, Spain and Italy) (Vieira , 2009).

The increase of consumer's ecological awareness has forced decision-makers and producers to search for scientific information about environmental performance of agricultural production systems through Life Cycle Assessment (LCA) studies on food products. Nevertheless, additional work is required, as well as the development of a methodology to continue improving LCA studies on tropical perennial agricultural products, which great diversity contrasts with the reduced data, either because these data do not exist or because they have not been published.

A number of studies have reinforced the belief that the stage with the most significant impact for the banana industry is transportation, mainly because of the overseas transport. Craig et al. (2012) estimated the carbon footprint of bananas produced by Chiquita Brands International in Central and South America, and sold to the USA, at approximately 1 kg of CO_2eq/kg of bananas sold. The transportation stage represented the largest part (36%) of emissions by the supply chain, primarily due to overseas transport, followed by the stages of production (22%) and retail (22%).

Ecuador is the largest exporter of bananas in the world (FAO, 2014). Iriarte et al. (2014) analyzed the carbon footprint of Ecuador's Premium bananas for export (Musa AAA – *Cavendish*) using a considerable amount of field data (harvests of 2009, 2010 and 2011). The system boundaries considered from agricultural production to delivery in a European destination port, simulating two scenarios: the best-case scenario, where the refrigerated containers of the ships did not return empty from their trip to Europe and the worst-case scenario, where they returned empty. Accordingly, the carbon footprint of Ecuador's bananas for export ranged between 0.45 kg (best-case) and 1.04 kg CO_2-eq/kg of bananas (worst-case), as shown in Table 1. The study demonstrated the importance of using efficient transportation, i.e. the simple use of containers during the return stage makes possible to reduce the carbon footprint by 57%. The study concludes that the overseas transport stage has the highest contribution to the carbon footprint (27% to 67%) followed by agricultural production (23% to 53%).

Table 1. Contribution of life cycle stages to the carbon footprint of Ecuadorian export bananas (Iriarte et al., 2014).

Life Cycle Stage	2009	2010	2011
	(kg of CO_2eq/kg)	(kg of CO_2eq/kg)	(kg of CO_2eq/kg)
On farm	0.21	0.24	0.26
Post-harvest fruit handling	0.001	0.001	0.005
Packaging	0.08	0.09	0.09
National transport	0.008	0.008	0.008
Overseas transport[a]	0.12/0.71	0.12/0.70	0.12/0.70
Total carbon footprint[a]	0.42/1.01	0.46/1.04	0.48/1.06

[a] The first value shown represents the Best-case scenario for overseas transport while the second value shows the worst-case scenario.

Therefore, the aim of this study is to evaluate the environmental performance of banana transportation stage through environmental indicators, namely climate change, energy use and non-renewable resources, considering Brazilian largest production regions. Both domestic consumption and exports are taken into account in this study.

2. Methods

The LCA methodology employed was based on standards ISO 14040 and 14044 (2006). The modeling of transport data was carried out using Brazilian data on fuel consumption by the fleet and IPCC emission factors for GHG emissions (Ministério, 2011; IPCC, 2006). Partial life-cycle inventories related to fuel production and pre-combustion developed by CETEA - Packaging Technology Center (Coltro et al., 2003; Garcia et al., 1999) were incorporated into the transport inventory for bananas.

The goal and scope of this study was to evaluate the environmental impact of banana transportation inside and outside the country. The environmental indicators may be incorporated in LCA of bananas produced in Brazil, which could boost ecolabeling of this product and larger volumes of trade.

A broad survey on recent banana production data in Brazil characterizing it geographically, both domestic consumption and exports, was performed in trusted databases and literature. The information considered in this study (distances, fuel consumption, capacity of the transport modals, packaging etc.) were obtained via the collection of data from reliable sources. Extrapolations were justified based on data published in the literature.

The functional unity adopted was 1,000 kg of bananas delivered to retail in the domestic market or at port in case of export.

The system boundaries considered the fuel production and the transportation in the domestic market and exports to MERCOSUR and EUROPE, simulating three scenarios, as follow: 1) the ships and trucks returned empty from their trip, 2) they returned full, and 3) they returned full but with 33% loss due to injuries during the transportation.

Transport distances were estimated using Google Maps inserting the main producing cities in the region considered and the main consumption centers of its production. Exports to Europe considered Germany and the cities of Buenos Aires and Montevideo, when exported to Argentina and Uruguay respectively.

The considered impact categories are: climate change (CO_2 eq), energy use (MJ) and non-renewable resources (kg). GHG emission factors for transport and energy production were obtained from GHG Protocol Brasil (2012). The inventory quantities primary energy demand (PED) and non-renewable resources were analyzed. GWP (100 years) were estimated according to the CML method (GUINÉE, 2002).

3. Results

In Brazil, banana production is almost entirely directed towards the domestic market due to its large population and high per capita consumption, 29.1 kg of bananas per inhabitant per year (FAO, 2009). Accordingly, the country has not developed good postharvest handling and conservation practices for transportation to overseas markets, as have the more traditional banana exporting countries: Ecuador, Philippines, Colombia, Costa Rica, Guatemala etc. (Lichtemberg, Lichtemberg 2011). Small producers scattered over national territory are mostly responsible for Brazilian production.

In 2011, the domestic market consumed 98.5% of the banana production and a mere 1.5% was exported, primarily to Europe and MERCOSUR countries as seen in Figure 1 (IBGE, 2014b). In 2010, exports had been a little higher, reaching 2%. The main destinations for Brazil's exports in 2011 were Germany (31% of total value and 25% of the exported volume), Uruguay (25% of the total value exported), UK (16% of total value) and Argentina (14.5% of total value). In 2011, approx. 52% of the volume of banana exports was destined for MERCOSUR (SECEX, 2014).

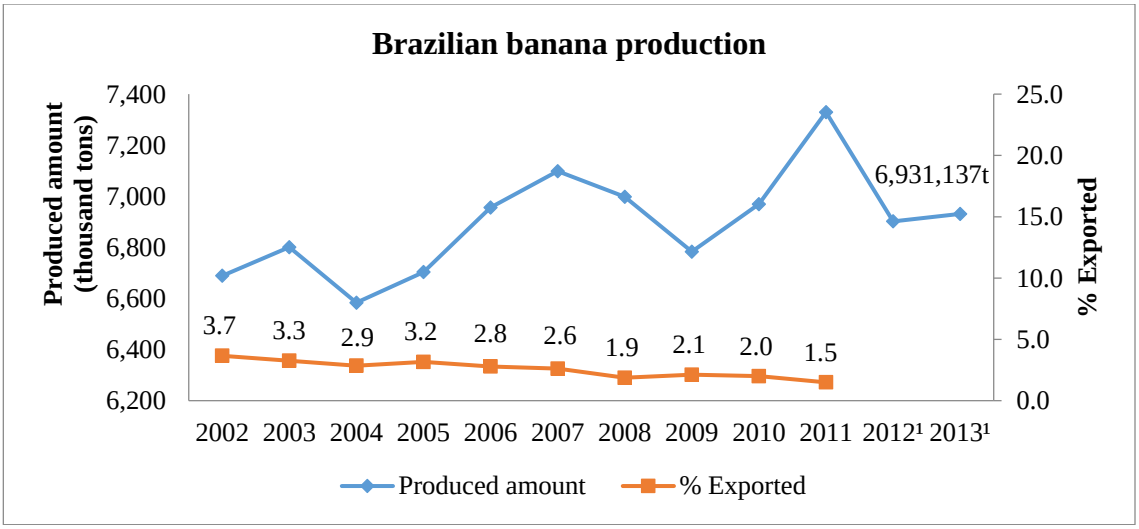

Figure.1. Brazilian banana production historical series (IBGE, 2014a, 2014b) and exports (SECEX, 2014).

Another reason for the low level of postharvest care in Brazil is that the largest part of domestic production comprises bananas of the *Prata* subgroup, which are more resistant to inadequate handling in the postharvest period (Lichtemberg, Lichtemberg, 2011). According to Reinhard et al. (2013), only 2% to 5% of Brazilian banana production is exported, domestic consumption amounts between 65% and 70% of production and postharvest losses are approx. 30%. Banana productivity in Brazil, between 13 and 14.5 t/ha (FAO, 2014), is still low when compared to the global average of approx. 20 t/ha. Europe has a rate of 36 t/ha and Asia 28 t/ha (EMBRAPA, 2009).

The main banana producing regions in Brazil are the Northeast (34.1%) and Southeast (33.5%), as shown in Figure 2. The value of production for these two regions, in 2012, was 3,162,691 thousand Brazilian reais (IBGE, 2014b).

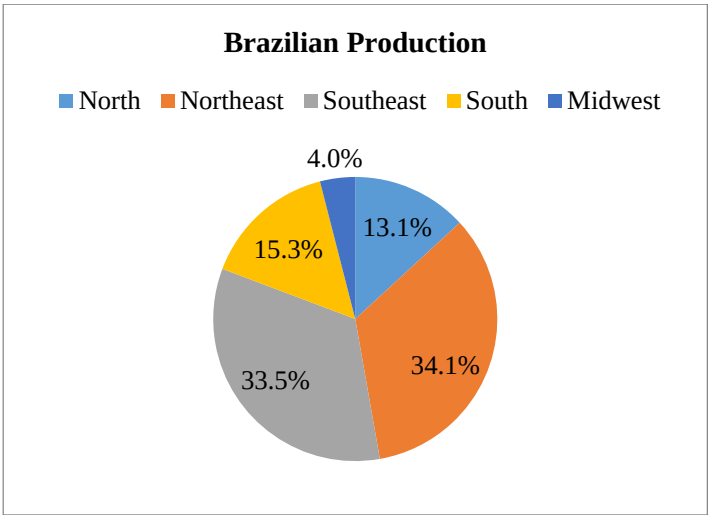

Figure 2. Regional production share for the 2013 banana crop (IBGE, 2014a).

The main banana producing states in Brazil are: São Paulo, Bahia, Santa Catarina, Minas Gerais and Pará, together accounting for 61% of domestic banana production and over 63% of the value of the 2012 crop, as shown in Table 2 (IBGE, 2014b).

Table 2. States with the highest share of domestic banana production in 2012 (IBGE, 2014b).

State	Yield (t)	Share of Domestic Production (%)	Value of Production (000´s Brazilian Reais)	Share of the value of Domestic Production (%)	Productivity (t/ha)
São Paulo (SP)	1,215,435	17.6	851,210	19.36	22.5
Bahia (BA)	1,083,346	15.7	734,725	16.71	15.0
Santa Catarina (SC)	689,815	10.0	275,528	6.27	23.3
Minas Gerais (MG)	687,293	10.0	639,030	14.54	16.4
Pará (PA)	547,098	7.9	275,409	6.26	13.1
Ceará (CE)	415,763	6.0	217,275	4.94	8.8
Pernambuco (PE)	407,574	5.9	168,451	3.83	9.7
Paraná (PR)	276,890	4.0	127,579	2.90	24.0
Espírito Santo (ES)	241,997	3.5	151,224	3.44	11.3
Goiás (GO)	197,990	2.9	155,626	3.54	15.8
Brazil (Total)	6,902,184	100.0	4,396,349	100.00	14.1

In 2012, the municipalities where the main banana producers were located are the following: Corupá/SC (2.4% of domestic production), Miracatu/SP (2.3%), Cajati/SP (2.1%), Bom Jesus da Lapa/BA (1.8%) and Luiz Alves/SC (1.8%). In terms of the value of production, the following are worthy of mention: Cajati/SP, Sete Barras/SP, Eldorado/SP, Wenceslau Guimarães/BA and Jaíba/MG. As can be seen in Table 3, the top ten municipalities for domestic banana production account for less than 20% of the share of domestic production as well as value of production. This demonstrates the wide geographical distribution of banana producers throughout the country (present in the 27 states of Brazil as well as the federal district of Brasilia), with only a few centers that stand out as the largest producers, as shown in Figure 3. In 2012, the vast majority of producing municipalities had a turnover of as much as 3 million Brazilian reais. Only Cajati/SP and Sete Barras/SP earned more than 90 million Brazilian reais from banana production. The strategic banana producing regions are the follow: the Southern coastal region of the state of São Paulo, the North of Minas Gerais, the Southern coastal region of the state of Bahia, the Southwest of Pará and the Northern Santa Catarina.

Table 3. Municipalities with highest values of banana production in 2012 (IBGE, 2014b).

Municipalities	Quantity produced (t)	Share of Domestic Production (%)	Municipalities	Value of production (´000 Reais)	Share of value production (%)
Corupá - SC	165,420	2.4	**Cajati - SP**	130,950	3.0
Miracatu - SP	158,400	2.3	**Sete Barras - SP**	100,000	2.3
Cajati - SP	145,500	2.1	**Eldorado - SP**	87,750	2.0
Bom Jesus da Lapa - BA	127,179	1.8	**Wenceslau Guimarães - BA**	83,680	1.9
Luiz Alves - SC	127,100	1.8	**Jaíba - MG**	82,820	1.9
Wenceslau Guimarães - BA	115,900	1.7	**Jacupiranga - SP**	70,200	1.6
Sete Barras - SP	100,000	1.4	**Registro - SP**	69,750	1.6
Eldorado - SP	97,500	1.4	**Bom Jesus da Lapa - BA**	69,313	1.6
Guaratuba - PR	96,480	1.4	**Luiz Alves - SC**	68,507	1.56
Jaíba - MG	82,000	1.2	**Janaúba - MG**	58,888	1.34
Total	1,215,479	17.6	**Total**	821,858	18.7

This study was concentrated on several centers that stand out as being the largest producers, namely Northern Santa Catarina, Vale do Ribeira, Northern Minas Gerais, Bom Jesus da Lapa - BA, Vale do Submédio do São Francisco, Vale do Açu - RN and Vale do Jaguaribe - CE and the Southern and Central-Southern regions of the state of Bahia. Figure 3 locates these production centers and the arrows indicate the main destination markets. Production in these centers is, for the most part, intended for the large cities in the region, however the states with the highest exports are Rio Grande do Norte, exported 21.8% of its production to Europe in 2011 (31,000 tons, corresponding to 28.3% of exports from Brazil); Santa Catarina, which exported 8.3% of its production (54,300 tons, or 49.3% of Brazilian exports) to MERCOSUR countries (Uruguay and Argentina); and Ceará, which exported 23,000 tons of bananas to Europe (21% of Brazilian exports) (SECEX, 2014, IBGE, 2014b).

The distances considered for the assessment of the environmental impact of bananas transporting in Brazil, as well as the burdens associated with this life cycle stage are shown in Table 4. Figure 4 shows the contribution of the different scenarios to the burdens evaluated.

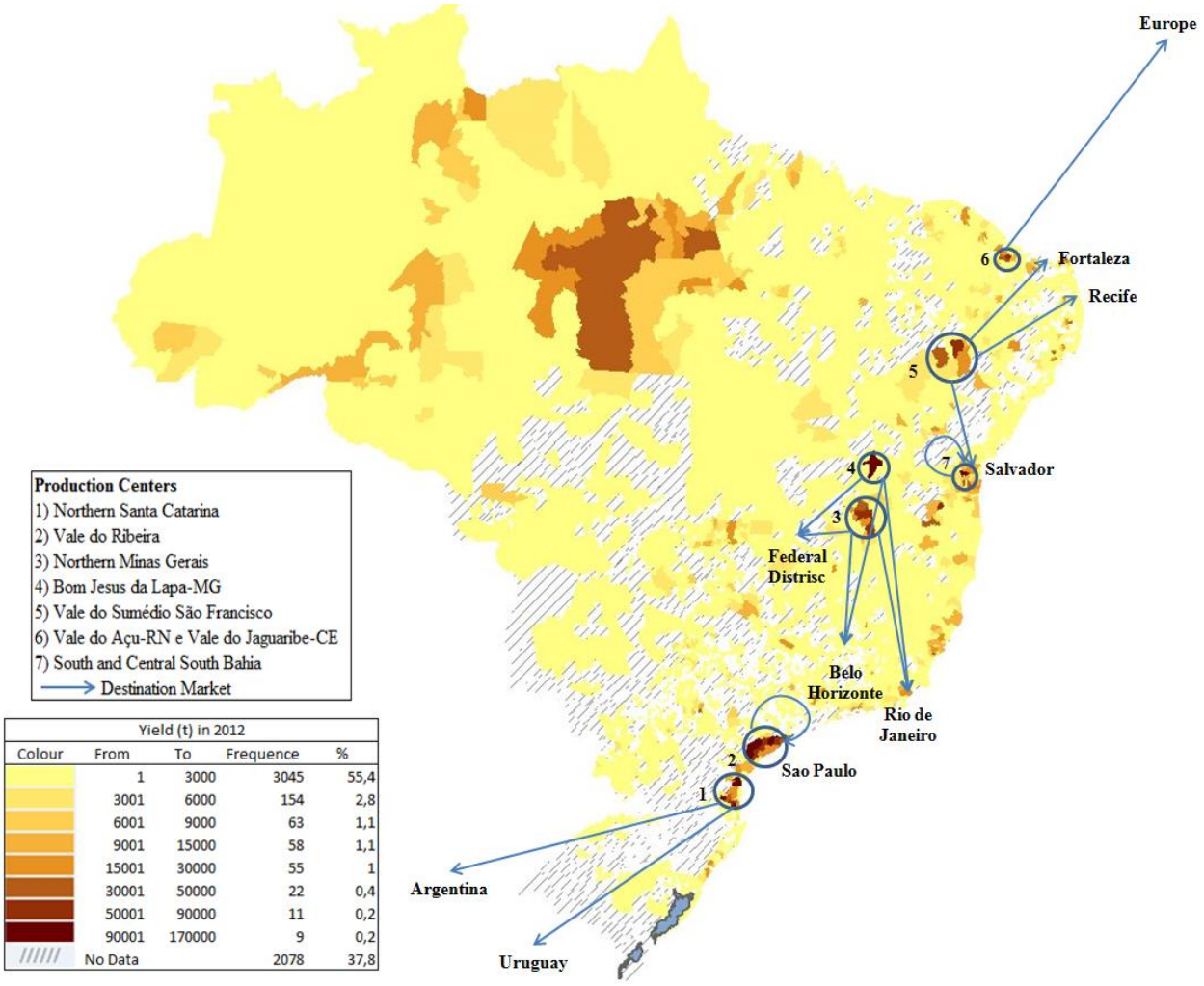

Figure 3. Banana production hotspots in Brazil and main destination market (IBGE, 2014b; Embrapa, 2009).

Table 4. Burdens associated with the transport of bananas in Brazil (Functional unity = 1 ton).[1]

Production center / Distance from domestic markets[2]	Burdens	Scenario 1 Return full	Scenario 2 Return empty	Scenario 3 Return full and 33% losses in T
Northern Santa Catarina State / 378 km	CO2 eq (kg)	22.72	45.44	33.86
	Energy use (MJ)	49.06	98.13	73.11
	Non renewable resources (kg)	8.24	16.48	12.28
Vale do Ribeira / 193 km	CO2 eq (kg)	11.60	23.20	17.29
	Energy use (MJ)	25.05	50.10	37.33
	Non renewable resources (kg)	4.21	8.41	6.27
Northern Minas Gerais State / 909.7 km	CO2 eq (kg)	54.68	109.37	81.48
	Energy use (MJ)	118.08	236.16	175.94
	Non renewable resources (kg)	19.83	39.65	29.54
Bom Jesus da Lapa - BA / 1207.85 km	CO2 eq (kg)	72.61	145.21	108.18
	Energy use (MJ)	156.78	313.55	233.60
	Non renewable resources (kg)	26.32	52.65	39.22
Vale do Submédio São Francisco / 717.5 km	CO2 eq (kg)	43.13	86.26	64.26
	Energy use (MJ)	93.13	186.26	138.76
	Non renewable resources (kg)	15.64	31.27	23.30

Table 4. Burdens associated with the transport of bananas in Brazil (Functional unity = 1 ton).[1] (continuation)

Vale do Açu - RN and Vale do Jaguaribe - CE / 281.5 km	CO2 eq (kg)	16.92	33.84	25.21
	Energy use (MJ)	36.54	73.08	54.44
	Non renewable resources (kg)	6.14	12.27	9.14
South and Central South Bahia State / 277.7 km	CO2 eq (kg)	16.69	33.39	24.87
	Energy use (MJ)	36.04	72.09	53.71
	Non renewable resources (kg)	6.05	12.10	9.02
Exports from Northern Santa Catarina State to Argentina and Uruguay / 3,009.7 km	CO2 eq (kg)	211.55	423.10	315.21
	Energy use (MJ)	456.79	913.58	680.62
	Non renewable resources (kg)	76.70	153.40	114.28
Exports from Vale do Açu - RN and Vale do Jaguaribe - CE to Europe (mainly Germany) / 9,000 km	CO2 eq (kg)	149.11	298.21	222.17
	Energy use (MJ)	276.18	552.36	411.51
	Non renewable resources (kg)	46.37	92.75	69.10

[1] Transport with 80% load in all scenarios
[2] Average Distance Covered (one-way) in the Domestic Market.
[3] Average Distance Covered (one-way) for Exports, to the receiving port.

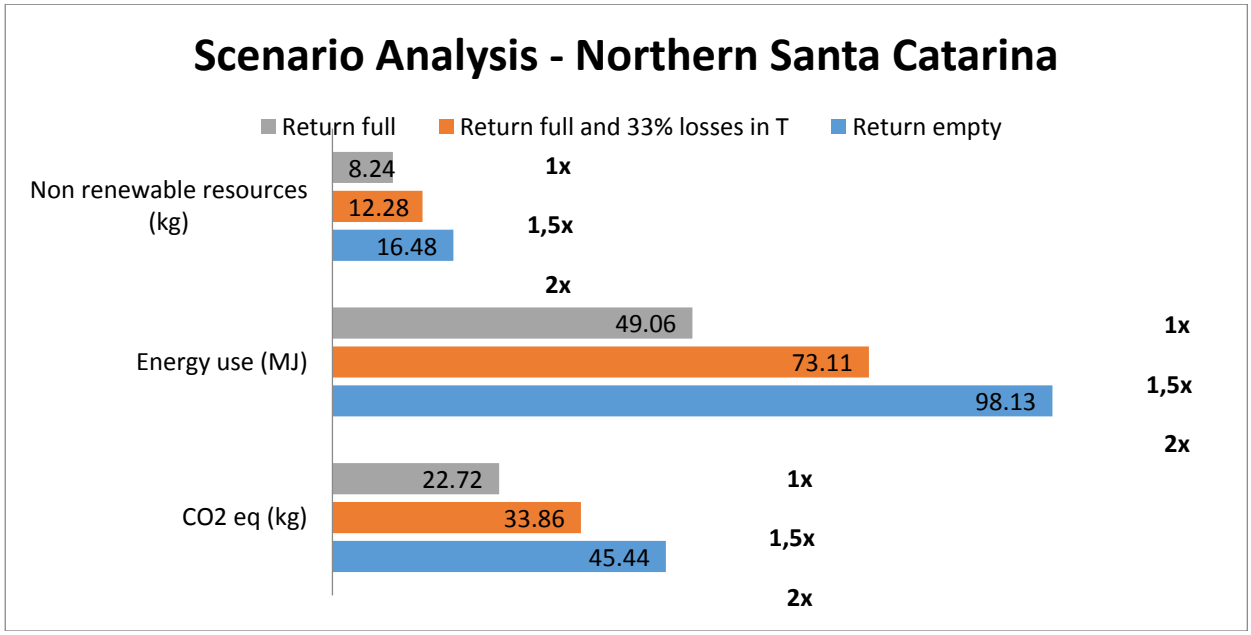

Figure 4. Contribution of the different scenarios to the burdens evaluated.

4. Discussion

Brazil has seven banana producer regions distributed along the country. Most of the banana produced in Brazil are consumed near the production centers, except for Northern Minas Gerais and Bom Jesus da Lapa - BA regions which distances from the consumers are approx. 1,000 km.

The banana consumed in São Paulo has the lowest environmental impact related to the transport stage since it was produced in the Vale do Ribeira region that is the region with the shortest distance between production site and consumers (193 km).

On the other hand, the banana consumed in Rio de Janeiro, Brasília and Belo Horizonte has the highest environmental impact related to the transport stage since it is produced in the Bom Jesus da Lapa - BA region which is the region with the highest distance from the consumers (approx. 1200 km).

There have been various studies on the LCA of bananas, the majority having a "cradle-to-gate" scope (from production to retail in Europe), except for Kilian et al. (2012) who took into account the “cradle-to-grave”

scope which includes up to consumption stage and the study by Svanes & Aronsson (2013), which took both scopes into consideration. Kilian et al. (2012) stated that this tropical fruit emits 1.09 kg of CO_2-eq per kg of exported bananas, with overseas transport being responsible for 78% of emissions, followed by agricultural production with 15% and distribution with 7%. Lescot (2012) calculated that the carbon footprint of bananas exported to Europe is 0.85 kg of CO_2e per kg of bananas, the stages with the greatest impact being overseas transport (43%), agricultural production (29%) and packing (12%). Luske (2010) estimated the carbon footprint at 1.12 kg of CO_2-eq per kg of exported bananas and also showed overseas transport and agricultural production to be the stages with the greatest impact, whose contributions were 62% and 12%, respectively. Svanes and Aronsson (2013) found the carbon footprint (from farm-to-retail) of 1.37 kg of CO_2-eq/kg and concluded that the banana hot spots in their study were overseas transport, which accounted for around 55% of the carbon footprint, followed by agricultural production, which accounted for 16%.

Differently from the other studies on LCA of banana available in the literature, the export stage of Brazilian banana to Europe is the life cycle stage with the lowest environmental impact due to the optimum relation of the load per trip ratio of the ships which minimizes the consumption of fuel per ton of transported banana.

Surprisingly despite a travelling distance 3 times larger from the northeastern Brazil to Europe than Santa Catarina to MERCOSUR the average overseas transport impacts are 4.2 to 4.5 times smaller (436.13%) than export via truck to Argentina and Uruguay. Besides, the exports of banana to Mercosur is the highest environmental impacting stage since it is based on truck transportation while all the transportation to Europe are made by ship.

Apart from the higher consumption of fuel per ton of banana transported by trucks than ships, the distances of the producer regions from domestic market can reach values over 1,000 km due to the continental dimensions of Brazil which contributes to enhance the environmental impact of this stage of the life cycle.

The data shows that in the domestic market the burdens vary in more than 80%, that is, the banana consumed in São Paulo has an estimated transport emission of 23.2 kg of CO_2 eq, 50.1 MJ of energy use and 8.41 kg of non renewable resources, while the largest environmental impact of the banana that is produced in Bom Jesus da Lapa – BA, serving cities in Rio de Janeiro, Brasília and Belo Horizonte has emissions of 145.21 kg of CO_2 eq., 313.55 MJ of energy use and 52.65 kg of non renewable resources. This variation is smaller when analyzing exports to MERCOSUR and Europe: (29.5%) in CO_2 eq, and 39.5% of energy use and non renewable resources.

Taking into account the different scenarios, the impact of the transport of bananas in scenario 3 (truck returns full and 33% banana losses in transport) is 1.5 times higher than scenario 1 (truck returns full). If the cultivation stage is being accounted, the impact of banana loss is even higher. So, efforts must be made to reduce the product loss through the life cycle.

5. Conclusion

The results have shown that the banana consumed in São Paulo has the lowest environmental impact related to the transport stage since it was produced in the region with the shortest distance between production site and consumers.

On the other hand, the banana consumed in Rio de Janeiro, Brasília and Belo Horizonte has the highest environmental impact related to the transport stage since it was produced in the region with the highest distance from the consumers.

Despite three times higher distance, the exports to Europe has 70% lower environmental impact than exports to MERCOSUR since it is based on ship transportation while transportation to Argentina and Uruguay is made by truck.

This study reinforces the importance of the transport modals and reduction of food loss in reducing the product environmental impacts.

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