LCA of soybean supply chain produced in state of Pará, located on Brazilian amazon biome

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Abstract: Recently, Brazil turned the biggest soybean producer and exporter of the world. The state of Pará, located in the Brazilian amazon biome, was turned one of last agricultural frontier of the country, which increased positively the soybean cultivation along it is territory. However, it is necessary to know the associated environmental impacts along the supply chain. Thus, we are applying the life cycle assessment (LCA) methodology using *openLCA* software in two producing regions: northeast pole (Paragominas) and south pole (Redenção). Based on the cradle to grave scope, the Recipe Midpoint (H) and Intergovernmental Panel on Climate Change (IPCC) method of environmental impacts categories were used. To calculate the land use change (LUC), we used the BRLUC regionalized model (v1.3). The obtained results showed that LUC were the main responsible for the global warming potential (GWP) along all soybean supply chain, especially when the land occupied with tropical forest was changed for soybean growth. Despite the largest distance between origin and destiny (road + railway = 1306 km), the soybean produced in south pole (Redenção) is better shipped through the TEGRAM port of São Luis – Maranhão due to the use of multimodal platforms (lorry + train), allowing a more efficient logistical performance (greater loads of grains transported and less environmental impacts). The soybean produced in northeast pole (Paragominas) is better shipped through the ports around Barcarena – Pará due to the shortest distance by road (average 350 km) and hence less environment impacts.

Keywords: environmental impacts; grains; life cycle assessment; soybean production

Material and Methods

- Apply life cycle assessment (LCA) and land use change (LUC);
- Recipe midpoint (H), IPCC 2013 and BRLUC model (v.1.3) methods;
- Cradle to grave scope and Agribalyse database (v.3).

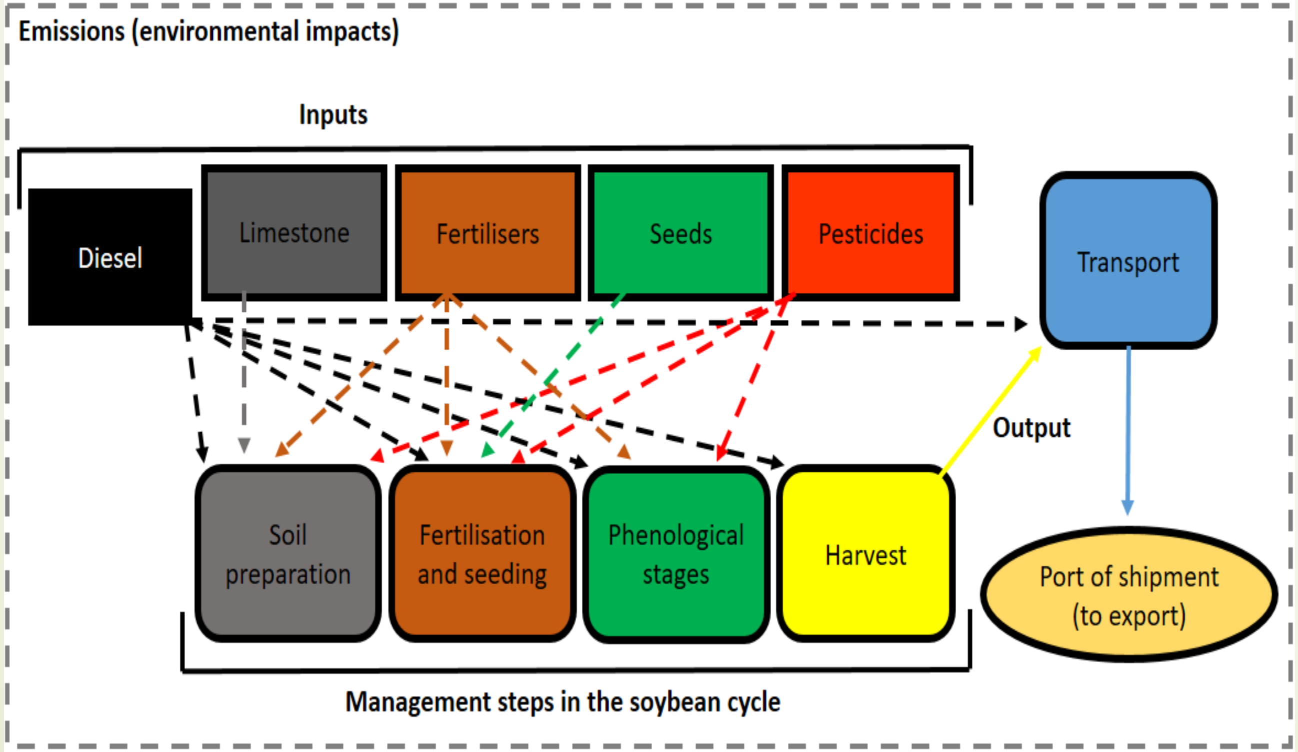

Figure 1. Supply chain flowchart for cycle soybean crop

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Results

Table 1. Traveling distances (in km), transportation modals and port of shipment

Pole Origin	Road distance (km)	Multimodal platform	Railway distance (km)	Total distance traveled (km)	Port of Shipment
Paragominas (PGM)	351			351	BAR - PA[3]
Paragominas (PGM)	406	Porto Franco - MA[1]	783	1189	SLZ– MA[4]
Redenção (RDX)	827			827	BAR - PA[3]
Redenção (RDX)	305	Palmeirante - TO[2]	1001	1306	SLZ– MA[4]

[1] Transshipment in Porto Franco, state of Maranhão; [2] Transshipment in Palmeirante, state of Tocantins; [3] Barcarena, state of Pará; [4] São Luis, state of Maranhão.

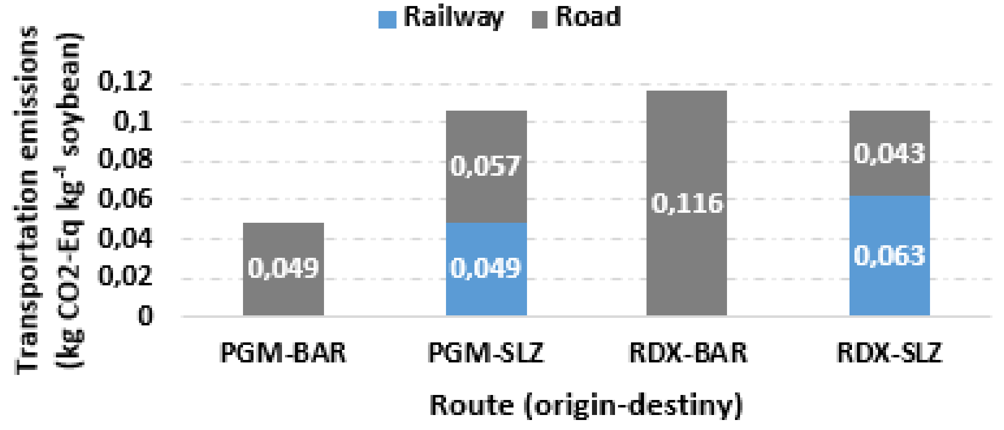

Figure 2. Climate change (GWP 20a) emissions from soybean transportation using IPCC 2013

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Results

Table 2. Inputs and outputs of soybean production system in state of Pará, Brazil (FU 1kg of soybean)

Input	Amount	Output	Amount
Application of plant protection product, by field sprayer	0.00258 ha	Ammonia (NH_3)	0.00028 kg
Combine harvesting	0.00030 ha	Dinitrogen monoxide (N_2O)	0.00063 kg
Fertilizing, by broadcaster	0.00030 ha	Nitrate	0.02804 kg
Sowing	0.00030 ha	Nitrogen oxides	0.00013 kg
Tillage, harrowing, by spring tine harrow	0.00028 ha	Carbon dioxide, fossil	0.02502 kg
Tillage, ploughing	0.00010 ha	2,4-D	0.00045 kg
Transport, tractor and trailer, agricultural	0.01570 t*km	Acetamiprid	2.65000E-5 kg
Soybean seed, for sowing	0.01280 kg	Fenpropathrin	1.70000E-5 kg
Lime	0.04929 kg	Fluazinam	0.00011 kg
Urea, as N	0.00212 kg	Glyphosate	0.00061 kg
Phosphate fertilizer, as P2O5	0.03576 kg	Mancozeb	0.00034 kg
Phosphate Rock, as P2O5, beneficiated, dry	0.00212 kg	Prothioconazol	2.65000E-5 kg
Potassium chloride, as K2O	0.03030 kg	Pyraclostrobin (prop)	2.52300E-5 kg
Occupation, annual crop, non-irrigated, intensive	3.25298 m^2*year	Pyriproxyfen	7.60000E-6 kg
Transformation, from annual crop, non-irrigated	3.03030 m^2	Phosphorus	0.00128 kg
Transformation, to annual crop, non-irrigated, intensive	3.03030 m^2	Thiophanate-methyl	0.00011 kg
Energy, gross calorific value, in biomass	20.5000 MJ	Trifloxystrobin	2.27000E-5 kg
Carbon dioxide, in air	1.37808 kg	Soybean production	1 kg
2,4-dichlorophenol	0.00045 kg		
Pesticide, unspecified	7.44300E-5 kg		
Pyrethroid-compound	1.70000E-5 kg		
Pyridine-compound	0.00012 kg		
Glyphosate	0.00061 kg		
Mancozeb	0.00034 kg		
Triazine-compound	2.65000E-5 kg		
[Sulfonyl] urea-compound	0.00011 kg		

Results

Table 3. Life cycle impact assessment (LCIA) results at recipe midpoint (H) (FU 1kg of soybean)

Impact category	Unit	Total emissions	Main Hotspot
Agricultural land occupation (ALOP)	m^2 year	3.25298E+0	PS = 3.25298E+0 (100%)
Climate change (GWP100)	kg CO2-Eq	0.48312E+0	PS = 0.21154E+0 (43.8%)
Freshwater ecotoxicity (FETPinf)	kg 1,4-DCB-Eq	1.99383E-2	PS = 1.946E-2 (95.4%)
Freshwater eutrophication (FEP)	kg P-Eq	1.89967E-4	PS = 1.011E-4 (53.2%)
Human toxicity (HTPinf)	kg 1,4-DCB-Eq	0.10915E-0	MFPF = 4.81E-2 (44.1%)
Ionising radiation (IRP_HE)	kg U235-Eq	1.97907E-2	MFPF = 8.14E-3 (41.1%)
Marine ecotoxicity (METPinf)	kg 1,4-DCB-Eq	2.42444E-3	PS = 1.429E-3 (58.9%)
Marine eutrophication (MEP)	kg N-Eq	7.10465E-3	PS = 6.413E-3 (90.2%)
Ozone depletion (ODPinf)	kg CFC-11-Eq	2.82500E-8	MFCH = 7.59E-9 (26.9%)
Particulate matter formation (PMFP)	kg PM10-Eq	9.67280E-3	MFPF = 3.24E-4 (29.6%)
Photochemical oxidant formation (POFP)	kg NMVOC-Eq	2.03110E-3	MFCH = 6.67E-3 (32.8%)
Terrestrial acidification (TAP100)	kg SO2-Eq	2.57782E-3	PS = 7.623E-4 (29.6%)
Terrestrial ecotoxicity (TETPinf)	kg 1,4-DCB-Eq	0.01326E-0	PS = 1.243E-2 (93.7%)

PS = production system, MFPF = market for phosphate fertilizer; MFCH = market for combine harvesting.

Table 4. LUC and estimated scenarios of CO2 emissions between 1999 and 2018 in the estate of Pará

Soybean Crop expansion (%)	Scenarios	Emissions (tCO_2 Eq.$ha^{-1}.yr^{-1}$)	T0 soy (ha), Pre existent 1999	T1 soy (ha), 1st season 2018	Arable	Permanent crops	Unspecified, natural
100	Min.	3,8	1 238	545 227	455 187 (84%)	38 523 (7%)	50 279 (9%)
	Pro.	30,35	1 238	545 227	36 811 (7%)	3 115 (1%)	504 063 (92%)
	Max.	32,69	1 238	545 227	-	-	543 989 (100%)

Source: adapted from [13].

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Discussion

- The production system (agricultural phase) had the greatest contribution (hotspot) in eight impact categories: ALOP, GWP100, FETPinf, FEP, METPinf, MEP, TAP100 and TETPinf due to the sum of the inputs used in this stage, besides the operations that took place.

- The soybean transported from the Redenção pole converges better to São Luis due to the lower CO2 release from rail transport. In addition, each wagon can carry 92.5 tonnes, and a company train on this line has up to 80 wagons each, and can ship up to 7 400 tonnes. However, a truck can only transport between 32 and 50 tonnes.

- The soy produced at the Paragominas pole converges better to the Barcarena because it is relatively closer and hence emits less pollutant.

Discussion

- The LUC methodology considers only the deforestation made in the last 20 years, which somewhat penalizes agricultural supply chains located in new agricultural frontiers, such as the case of the Northern region in Brazil (Novaes et al., 2017; Cederberg et al., 2013). According to the same author, several efforts have been made toward a low carbon agriculture.

- Gibbs et al., (2015) highlighted that after soy moratorium, the majority of expansion of soy cultivation in amazon biome were allocated in already cleared areas.

- Only 1.9% of the soybean crop area in the Pará State was allocated to deforested areas after July 22 of 2008. This is due to the soy moratorium, which aims to ensure that the soy produced and sold in the Amazon biome is not associated with deforestation of rainforest (ABIOVE et al., 2020).

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Conclusions

- For the simulations done with the Recipe Midpoint (H), the production system was the main hotspot in the most of categories.

- We suggest that the train modal should be promoted, namely the expansion of the existing infrastructure and creation of a railroad between the producing regions and Barcarena since this modal can transport large loads more efficiently emitting less GHG to air.

- LUC were the main responsible for the global warming potential (GWP) along all soybean supply chain, especially when the land occupied with tropical forest was changed for soybean growth

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