ENVIRONMENTAL IMPACT OF AGRICULTURE OPERATIONS ON THE PRODUCTION OF ETHANOL FUEL

IMPACTO AMBIENTAL DAS OPERAÇÕES AGRÍCOLAS NA PRODUÇÃO DE ETANOL COMBUSTÍVEL

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Abstract

In order to contribute to the reduction of greenhouse gases (GHG) emission targeted in the 2015 Paris Agreement, the RenovaBio was instituted in Brazil aiming to encourage the increase of biofuels production in a more sustainable way, through the emission of decarbonisation credits (CBios) to biofuel producers. The calculation of CBios is done according to the methodology of Life Cycle Assessment, using as tool RenovaCalc, which counts the GHG emissions from the agricultural and industrial phases, generating the index of carbon intensity (in g CO_{2eq} / MJ). Around 80% of the index of carbon intensity for the production of ethanol from sugarcane in Brazil is due to the agricultural operations, especially from nitrogen-based fertilizers and fuel from the agricultural machinery. In this work, RenovaCalc was used to evaluate several scenarios of the replacement of a diesel-based (B10 - mixture of 90% diesel and 10% biodiesel) by cleaner fuels in the agricultural operations in order to measure the increase on CBios emission. The highest index of carbon intensity of 17.4 g CO_2eq / MJ was obtained when B10 was used while the lowest, 14.2 g CO_2eq / MJ was obtained for ethanol. The replacement of B10 by ethanol as a fuel in all the agricultural operations increased the number of CBios by 4.6%, which means that the ethanol industry can increase its profits by selling these credits in the market. The results of this work highlights the importance of developing agricultural machinery that can be fueled by non-fossil based fuels.

Keywords: life cycle analysis; GHG; RenovaCalc; biodiesel; biomethane; ethanol.

Purpose

In this work, RenovaCalc was used to evaluate several scenarios of the replacement of a diesel-based (B10 - mixture of 90% diesel and 10% soybean biodiesel) by cleaner fuels, like hydrated ethanol, biomethane, B50 and B100, in the agricultural operations in order to measure the increase on CBios emission.

Methods

Sugarcane

State of Sao Paulo is the most important sugarcane producer in Brazil with an average of 337,744.93 ton year^{-1} of sugarcane from 2005 to 2018 harvesting seasons with an average yield of 80.67 ton ha^{-1} (CONAB, 2019). In this study, a sugar mill with crushing capacity of 2,607,873.34 ton of sugarcane per year located in Sao Paulo State was considered in an area of 32.3 thousand of hectare (CONAB, 2017). It was used a crop cycle of 6 years: 6 months of soil without crop, the first cycle of 18 months from planting to harvesting (plant cane) and four subsequent cycles of 12 months each (ratoon cane).

RenovaCalc

RenovaCalc is a set of Excel spreadsheets available to download at ANP website (ANP, 2019). For the sugarcane ethanol 1G route, the sheets must be filled with data regarding to sugarcane production, area, fertilizers and correctives amount, fuels and industry yields. In this study, all inputs were obtained from the study of Picoli (2017) except when advised otherwise (Table 1). It was assumed that anhydrous and hydrated ethanol were distributed by road transportation.

Table 1. RenovaCalc data

Total area (1000 ha)	32.3	Sugarcane harvested (million ton)	2.61
Straw recovery (ton db)[a]	182,551.13	Burned area (% of total area)	3
Anhydrous ethanol (L/ton)[b]	17.59	Hydrated ethanol (L/ton)[b]	21.15
Sugar yield (kg/ton)[b]	70.64	Elect. exported to the grid (kWh/ton)[c]	199.34

[a]Calculated based on Hassuani et al. (2005) with recovery of 50%
[b]CONAB (2018)
[c]Calculated based on:

$$Electricityexportedthegrid = \left[(straw \times LHV_{straw} \times cogef) + \left(bagasse \times LHV_{bagasse} \times cogef\right)\right] \times eexported$$

Low heating value: LHV_{straw}=4,14 kWh/kg (MC=14%); $LHV_{bagasse}$=2,08 kWh/kg (MC=50%) (Picoli, 2017)
Cogef (cogeneration efficiency)=40%
Eexported (electricity exported)=60%

A detailed explanation of how RenovaCalc was developed, including how the Energetic-Environmental Efficiency Score is calculated can be found in Matsuura et al. (2018). Once this score is calculated the next step is to calculate the decarbonisation credits (CBios). One unit of the decarbonisation credits (CBios) is equivalent to the reduction in the emission of 1 ton of CO2eq and can be calculated according to Eq. 1. The goal is that CBios can be sold in the market by biofuel producers but the price of this title is not determined yet. In this work, it was assumed that 1 CBio worth US$10.00.

$$CBio = Energetic\ Environmental\ Efficiency\ Score \times LHV_{biofuel} \times density_{biofuel} \times volume_{biofuel} \quad \text{Eq. (1)}$$

Fuel consumption and scenarios

For each of agricultural operations considered in this study, the fuel consumption was determined considering sugarcane cycles (plant and ratoon cane). The data related to the fuel consumption for the operations of pre-planting, soil tillage, planting, cultivation, sugarcane haul-out, sugarcane transportation and straw recovering were obtained in Cabellero et al. (2017) while for the harvesting operation was obtained in Ramos et al. (2016). A weighted average was performed in order to calculate the total of B10 fuel for the 6-year sugarcane cycle obtaining an average consumption of 3 L ton^{-1} for all agricultural operations.

Otto and Diesel cycle engines have different combustion efficiencies. As in the present study the objective is to evaluate scenarios related to the use of fuels not yet used in commercial agricultural machines, it was decided to calculate the volume of these fuels based on the amount of energy demanded by each machine when the B10 is used. An example of calculation can be found in Equations 1 and 2 and fuel properties are according to ANP (2019). Fuel amount for each one of the scenarios can be found in Table 2.

$$Energytractor_{B10} = Vol_{B10} \times LHV_{B10} \times Density_{B10} = 0.89 \times 41.81 \times 0.844 = 31.45 \frac{MJ}{tonsugarcane} \quad \text{(Eq. 2)}$$

$$Tractor_{volume_{ethanol}} = \frac{Energycontenttractor_{B10}}{LHV_{ethanol} \times Density_{ethanol}} = \frac{31.45}{26.38 \times 0.809} = 1.47 \frac{L}{tonsugarcane} \quad \text{(Eq. 3)}$$

Table 2. Fuel scenarios evaluated in this study*.

Scenario	Fuel	Tractor	Sprayer	Harvester	Truck
Baseline	B10 (L ton^{-1})	0.89	0.01	1.51	0.59
	Energy content (MJ ton^{-1})	31.45	0.44	53.28	20.63
1	Biomethane (Nm^3 ton^{-1})	0.86	---	---	0.56
	B10 (L ton^{-1})	---	0.01	1.51	---
2	Ethanol (L ton^{-1})	1.47	---	---	0.97
	Biomethane (Nm^3 ton^{-1})	---	0.01	1.45	---
3	B50 (L ton^{-1})	0.92	0.01	1.56	0.60
4	B100 (L ton^{-1})	0.95	0.01	1.62	0.63
5	Biomethane (Nm^3 ton^{-1})	0.86	0.01	1.45	0.56
6	Ethanol (L ton^{-1})	1.47	0.02	2.50	0.97

** Values are per ton of sugarcane*

Results and discussion

The contribution of each agricultural operation and machinery type in the total fuel used in the sugarcane production is presented in Figure 1. As seen in Figure 1, sugarcane harvest and haul-out are the operations with the higher fuel consumption.

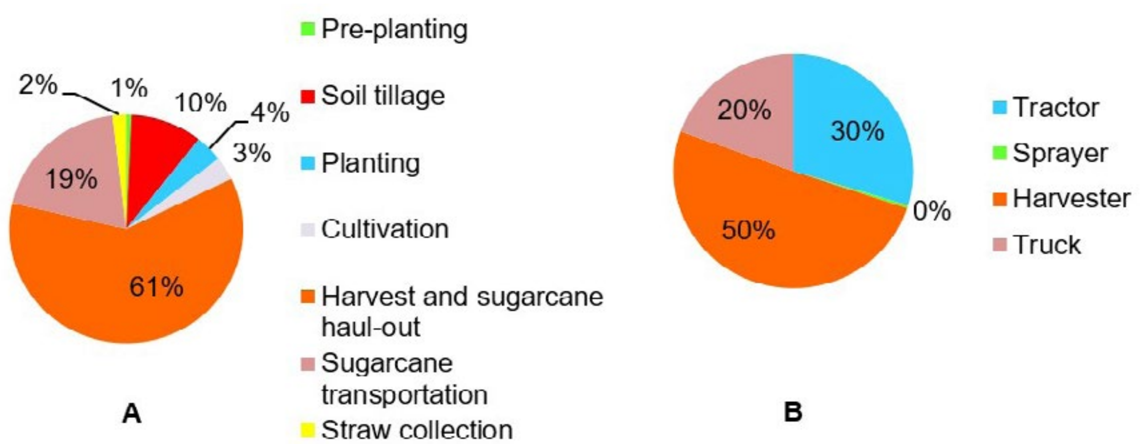

Figure 1. Amount of fuel consumed in agricultural operations (A) and per machinery (B).

Figure 2 presents the contribution of each agricultural operation in the carbon intensity for the base scenario. Nitrogen-based fertilizers represents around 50%, followed by the industrial processing of sugarcane, transportation and use of ethanol as fuel in vehicles (labeled as Production, Transportation and Use), representing 20% and by B10 consumption, accounting for 18% of the carbon intensity. “Sugarcane production” represents the share of emissions generated for the cultivation of sugarcane, including emissions from production and use of agricultural inputs.

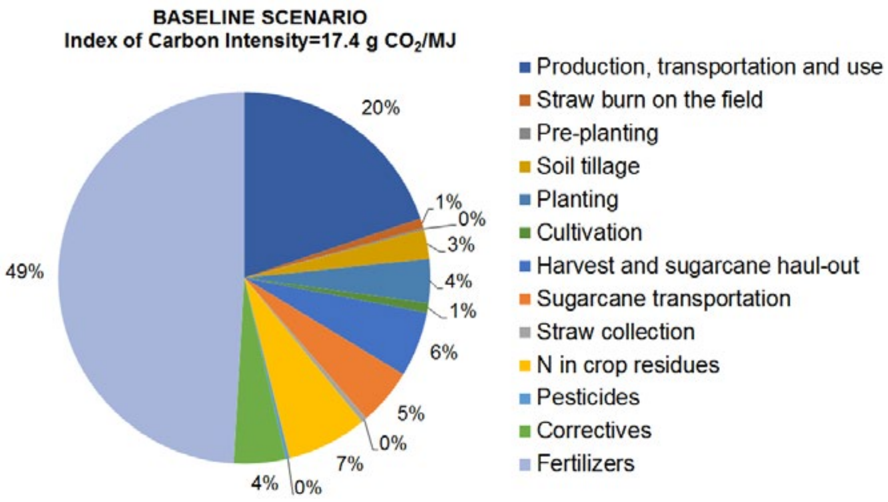

Figure 2. Contribution of each agricultural operation on the Index of Carbon Intensity for baseline scenario

Figure 3 shows how the replacement of B10 fuel by other fuels affects the index of carbon intensity. For a better visualization of the results, some categories not dependent on fuel consumption were hidden since they are the same regardless the fuel type.

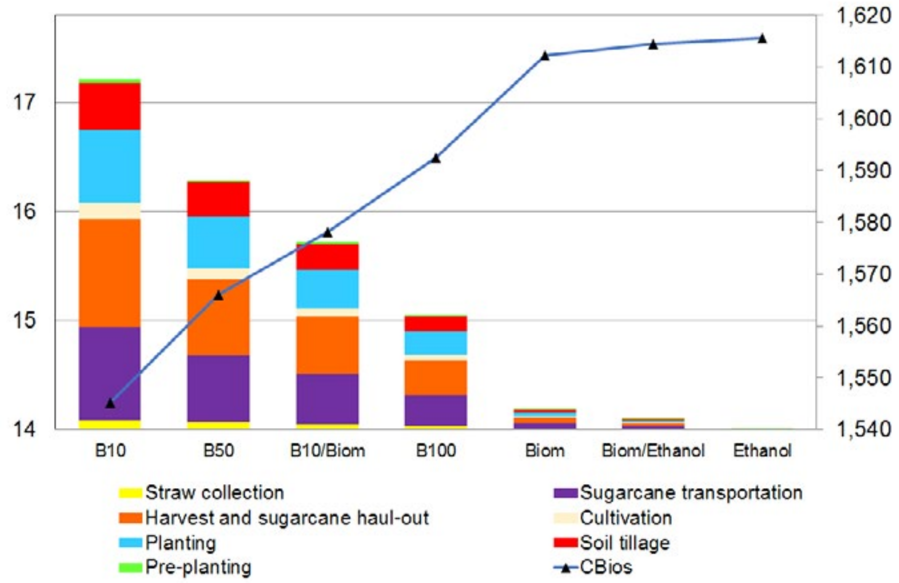

Figure 3. Index of Carbon Intensity and CBios for different scenarios.

The Index of Carbon Intensity is continually decreased by the replacement of B10 by the fuels evaluated in this paper. The addition of biomethane and ethanol presented higher reduction compared with biodiesel scenario and three best scenarios are respectively, biomethane, biomethane with ethanol in tractors and trucks and ethanol, with reduction of 17.2%, 17.8% and 18.4% on when compared to baseline scenario. It is worth saying that the biodiesel evaluated in this study is a soybean-based biodiesel and if a waste like beef-tallow was used as feedstock, we would expected different results.

Assuming that there is an ongoing market for CBios in Brazil, the reduction of the Index of Carbon Intensity means that a typical Brazilian sugarcane mill could increase its revenue by up to 4.6% (from 1.545 to 1.615 millions US$) only by replacing the petroleum-based fuels used in its agricultural machinery by cleaner fuels.

Conclusions

From the results obtained, it was possible to conclude that the fuel used in the agricultural operations has an important impact in the GHG emissions in the sugarcane ethanol 1G production chain. With the adoption of the RenovaBio program in Brazil and the beginning of the commercialization of CBios in the market, it is expected that sugarcane ethanol producers demand the agricultural machinery industries for equipments operating with renewable fuels and with a lower environmental footprint then the ones used nowadays.

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