# ENVIRONMENTAL PROFILE OF THE INTEGRATED PRODUCTION OF ETHANOL AND BEEF CATTLE IN BRAZIL

# PERFIL AMBIENTAL DA PRODUÇÃO INTEGRADA DE ETANOL E PECUÁRIA DE CORTE NO BRASIL

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## Abstract

Sugarcane outstands as an important renewable source of energy with expected steady production growth. However, expansion of sugarcane is critical, since the environmental performance of ethanol may be affected by GHG emissions derived from LUC. On the other hand, livestock farming currently practiced in Brazil is mainly extensive, occupying large areas and showing low productivity levels. Hence, in order to sustain the increase of ethanol production, mitigation of iLUC effects should be a priority on sugarcane expansion strategies. Integration of ethanol and beef cattle production can be part of this strategy by contributing to reduction of GHG emissions and improving land use management. This study made a comparative evaluation of the environmental profile of integrating ethanol and beef cattle production, considering different scenarios. The production chains were connected in such a way that the land used for biofuels would be converted from pre-existing extensive pasture, thereby minimizing iLUC and food vs. fuel competition. Results show that integrated production have better environmental performance for most LCA categories analyzed, but the relative differences between scenarios do not exceed 10%. The potential for mitigating GHG emissions through ethanol production and intensification of cattle husbandry became evident when they replace fossil resources and extensive production. Finally, it is important to remark that such integration can largely contribute to avoid iLUC and to support the achievement of the Brazilian emissions target from the Paris Agreement, especially through the increase of bioenergy participation in the Brazilian energy matrix and the restoration of degraded pasture areas.

Keywords: life cycle assessment (LCA); land use management; biofuel; livestock

## Purpose

Sugarcane outstands as important renewable source of energy with expected steady production growth. Brazilian government forecasts annual sugarcane ethanol production rising from the current 30 billion litters to around 50 billion litters in 2030, which would require, in combination with other bioenergy initiatives, additional 10 million hectares of planted area (MARQUES, 2018).

Environmental benefits of using Brazilian ethanol as a substitute for gasoline have been extensively explored in the literature (CAVALETT et al., 2013; MACEDO et al., 2008). However, expansion of sugarcane crop is a critical issue for the marginal contribution from biofuels, as environmental performance of ethanol can be adversely affected by direct (dLUC) and indirect (iLUC) land use changes (ALKIMIM et al., 2015; LAPOLA et al., 2010). At the same time, most of the 190 million head cattle herd in Brazil is kept under extensive, low yielding grazing systems, spread over large areas. This reflects on high GHG emissions (GOLDEMBERG et al., 2014). In the other hand, restrictions for land clearing combined with land competition from other agricultural commodities gradually leads farmers to intensify their ranching systems (DE OLIVEIRA SILVA et al., 2018), thereby giving the opportunity to accommodate different land use demands.

To prevent ethanol expansion from indirectly causing conversion of native vegetation or unintended competition with food crops, the development of low iLUC risk strategies for sugarcane expansion should be a priority. Integrated systems can be part of this strategy by contributing to the reduction of GHG emissions and improving land use management.

In this context, main goal of this study was to assess whether the integrated production of sugarcane ethanol and beef cattle could lead to net environmental benefits as compared to the traditional production practices. The production chains were connected in such a way that land used for biofuels would be converted from pre-existing extensive pasture, thereby minimizing pressure for iLUC and food versus fuel.

## Methods

A cradle-to-gate life cycle assessment (LCA) was used to estimate the performance of different scenarios for ethanol and beef cattle production. The approach applied is compliant with the ISO 14040-14044 standards and follows the current state of the art of LCA methodology documents (ISO, 2006 a, b).

### Systems descriptions

In this study, we explore sugarcane expansion over pastures through intensification as a key strategy to ensure environmental benefits of sugarcane ethanol in Brazil. Three scenarios were assessed: Reference system ($S_0$); Non-integrated system ($S_1$) and Integrated system ($S_2$). The total area (55,000 ha) was calculated considering two constraints: no indirect land use change and no change in food supply. It is important to remark that the integration proposed here is based on the “circular economy” perspective where resources are passed from one system to the other and not the farming practice of integrating crops themselves. Major characteristics of the given scenarios are described in Table 1.

**Table 1.** Main characteristics of the three scenarios evaluated in this study.

| Systems | Description |
|---|---|
| Reference system ($S_0$) | Extensive production of beef cattle. Function of this system is production of beef in 55,000 ha in one year. The output of the system is 3.48E+06 kg-LW (live weight) of beef. |
| Non-integrated system ($S_1$) | Independent production of anhydrous ethanol and intensive production of beef cattle, i.e., without exchange of by-products or residues. Function of this system is production of beef, ethanol and electricity in 55,000 ha in one year. Output of the system is 3.48E+06 kg-LW beef; 4.88E+09 MJ anhydrous ethanol and 501.7 GWh surplus electricity. |
| Integrated system ($S_2$) | Integrated production of anhydrous ethanol and beef cattle, i.e., with by-products exchange. Bagasse and yeast are used to feed cattle. Cattle manure, in turn, is composted and used as fertilizer for sugarcane. Function of the system is the production of beef, ethanol and electricity in 55,000 ha in one year. Output of the system is 3.48E+06 kg-LW beef; 4.88E+09MJ anhydrous ethanol and 498.0 GWh surplus electricity. |

As shown in Table 1, sugarcane processing generates important amounts of industrial residues that can be used as fertilizer or, as proposed here, as animal feed. For beef production on the integrated systems, bagasse and yeast are used in feedlot diets. The total amount of bagasse and yeast required for cattle feed is approximately 0.8% and 17.1% of the total produced by the mill. Using part of the bagasse for animal feeding causes a small reduction (less than 1%) in production of surplus electricity. The use of manure compost in sugarcane cultivation by the integrated system reduces the N, $P_2O_5$ and $K_2O$ inputs by 6%, 20% and 8%, respectively. The other industrial residues (vinasse and filter cake) return to sugarcane fields as organic fertilizers.

Beef production under intensive systems ($S_1$ and $S_2$) had yields per area three times higher (190.8 vs. 63.7 kg-LW $ha^{-1}$ $yr^{-1}$) and reduced age of slaughter by the half (23 vs. 45 months).

#### Systems boundaries and data quality

The system boundaries include (i) the ethanol and/or beef production processes; (ii) the upstream processes, such as the production of pastures, supplement, feed and sugarcane. Transport of inputs, infrastructure, production and use of pharmaceuticals were not included. Direct LUC was not considered.

In order to better represent the Brazilian condition, inventories of the S0, S1 and S2 product systems as well as of the most important upstream processes were created. The main data source was provided by Picoli (2017). Background processes inventories corresponded to those available in the ecoinvent v3.1 database (WERNET et al., 2016).

#### Allocation procedures

According to LCA methodology, allocation is required for multi-output processes (ISO, 2006 a, b). In this study, a detailed evaluation of environmental impacts was carried out considering two approaches: (i) System-oriented analysis and (ii) Product-oriented analysis (ethanol and beef cattle).

For the system-oriented analysis, expansion of the system through the additive approach was applied. In this way, equivalent products were added to the system in order to equalize the functions performed by systems studied. For this purpose, neat gasoline was assumed to be equivalent (on energy basis) to anhydrous ethanol, and natural gas thermoelectricity equivalent to the bioelectricity exported by the distillery. In addition, the economic allocation factors were applied to the following products: soybean meal (0.68) and soybean oil (0.32) (PICOLI, 2017). For the product-oriented analysis, the environmental impacts generated by the processes were allocated according to the economic criteria. Allocation factors were based on Picoli (2017).

#### Life cycle impact assessment method

Five midpoint impact categories were selected for the study: climate change (CC), terrestrial acidification (TA), freshwater eutrophication (FE), human toxicity (HT) and fossil depletion (FD). The ReCiPE (H) v 1.12 method (GOEDKOOP et al., 2012) with midpoint approach was applied for assessing impacts on TA, FE and HT. Quantification of the impacts in terms of CC and FD used IPCC 2013 100a v1.01 (MYHRE et al., 2013) and CML-IA baseline methods (GUINÉE, 2001), respectively. Calculations were performed using the software SimaPro 8.4.

## Results and discussion

Table 2 presents the environmental profile of producing fuels, beef and surplus electricity for the different scenarios considered in the system-oriented analysis. As mentioned above, the additive expansion approach was used to ensure that all scenarios perform the same function. In the case of anhydrous ethanol and gasoline fuels, the "well-to-wheels" approach was considered and, therefore, the emissions of their use were accounted for.

**Table 2.** Environmental profile of the different systems studied, in 55,000 ha.

| Impact category | Unit | $S_0$ | $S_1$ | $S_2$ |
|---|---|---|---|---|
| Climate change | kg $CO_2$ eq | 8.21E+08 | 1.77E+08 | 1.76E+08 |
| Terrestrial acidification | kg $SO_2$ eq | 2.16E+06 | 4.02E+06 | 3.93E+06 |
| Freshwater eutrophication | kg P eq | 1.50E+04 | 2.24E+04 | 2.02E+04 |
| Human toxicity | kg 1,4-DB eq | 3.25E+07 | 1.95E+07 | 1.79E+07 |
| Fossil depletion | MJ | 1.18E+10 | 7.54E+08 | 7.61E+08 |

S0: Reference system S1: Non-integrated system; S2: Integrated system.

Although the values presented in Table 2 are associated with the assumptions and methodological approaches of this work, it is clear the potential of ethanol as an effective alternative for GHG emissions mitigation when replacing gasoline. As expected, results show that, when compared to reference $S_1$, the integrated scenario presented the best environmental performance, with the most significant reductions in FE (-10%), HT (-8%) and TA (-2%). This is because these systems use less mineral fertilizers in sugarcane cultivation and grains in animal feed.

Compared to the other systems, scenario $S_0$ presented the worst environmental performance in three impact categories: FD (+ 94%), CC (+ 80%), HT (+ 40%). In general, the performance of this scenario was greatly affected by the use of fossil fuels (gasoline and natural gas) and the extensive production of beef cattle. On the other hand, the need to cultivate sugarcane (for the production of ethanol) and grains (for the intensive production of beef) was unfavorable to the $S_1$ and $S_2$ systems in TA and FE categories. Poorer results on these categories are common to products envolving farming when compared to fossil resources such as gasoline and natural gas.

Integrated production had better environmental performance also in the product-oriented analysis (Table 3), however, the comparative differences between $S_1$ and $S_2$ scenarios did not reach 5%. In this approach, the allocation procedure adopted to distribute the environmental loads among the products had influence on results.

**Table 3.** Carbon footprint of the different systems studied.

| Product | Unit | $S_0$ | $S_1$ | $S_2$ |
|---|---|---|---|---|
| Anhydrous ethanol | kg $CO_2$ eq kg$^{-1}$ | --- | 0.48 | 0.47 |
| Beef-cattle | kg $CO_2$ eq kg-lw$^{-1}$ | 23.9 | 17.7 | 18.1 |

S0: Reference system S1: Non-integrated system; S2: Integrated system.

For ethanol production, the integrated system reduced the environmental impacts of this product mainly due to: (1) reduction in the use of fertilizer for the cultivation of sugarcane and (2) commercialization of by-products, bagasse and yeast.

For beef-cattle production, $S_0$ features the worst environmental performance in the CC category, with results about 25% higher than the other systems. In general, lower values for intensive systems are due to reduced time to slaughter and increased productivity. Emissions related to feed production in intensive systems do not reach 5% of total GHG emissions.

## Conclusions

The comparative results show that scenarios $S_1$ and $S_2$ exhibit similar environmental performance. From the land management perspective, integrated production of biofuels and food should be an important tool for low iLUC risk strategies. Results highlight the great GHG mitigation potential associated with ethanol and intensification of cattle production, in face of the options that rely on fossil resources and extensive cattle ranching. Therefore, such integration can contribute significantly to the mitigation of GHG emissions of the sectors involved and, consequently, to the achievement of the Brazilian targets established in international agreements.

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