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The use of biochar to offset the lifecycle greenhouse gas emissions of sugarcane produced in Brazil

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1. INTRODUCTION

The agricultural sector contributes with over 30% of the greenhouse gas (GHG) emissions of the Brazilian economy (MCTI, 2023). To offset part of these emissions, the application of biochar in the field (**Fig. 1**) has been promoted as a promising method, due to suitable cost and logistics. Potential benefits of biochar as a carbon removal technique include the sequestration of carbon in the soil and reduction in N_2O emissions (Grutzmacher et al., 2018).

The sugarcane production chain presents a good fit for biochar use in Brazil. In addition to a planted area of 8.3 million hectares and a volume of 653 million tonnes of sugarcane harvested in the 2023/24 season, sugarcane production generates large amounts of bagasse (10.4 dry tonne/ha.yr) and straw (2.9 dry tonne/ha.yr) (Silva et al., 2019) as residues, which can potentially be used to produce biochar via pyrolysis (**Fig. 1**).

In this study, we assessed the potential use of biochar, produced from sugarcane residues, to offset the lifecycle emissions of the sugarcane production sector in the state of Sao Paulo (largest producer in Brazil).

2. METHODS

We used the Ecoinvent database v3.9.1 to obtain the inventory of sugarcane production in the state of Sao Paulo (valid for 2012-2022) and the SimaPro v9.5.0.1 to assess the lifecycle impacts in terms of GHG emissions, according to the GWP 100-yr method (2022). For land use change (LUC) we used the BRLUC model v2.0 (Garofalo et al., 2022), which provided an impact value of 0.4 tonne CO_2e/ha.yr (2000-2019) for the state of Sao Paulo.

We used the study by Lefebvre et al. (2021) to estimate the credit for the carbon sequestration of biochar (0.39 kg C/kg biochar or 1.42 kg CO_2e/kg biochar). We took a conservative approach in this study by not accounting for other potential benefits as credits, such as reduced field N_2O emissions, reduced fertilizer need and electricity generation from the pyrolysis process.

3. RESULTS AND DISCUSSION

Table 1 presents the amounts of biochar needed to offset the lifecycle emissions of sugarcane production for each of the main categories considered. The combined value of 1.25 tonne biochar/ha needed to offset the emissions of field CO_2 and N_2O and agricultural inputs is comparable to the amount of agricultural correctives for the sugarcane crop typically applied in the field, which would facilitate the biochar application operations.

One tonne of dry sugarcane residue generates roughly 300 kg of biochar; therefore, the total offset value of 1.87 tonne biochar/ha would demand 6.23 dry tonne residues/ha, which seems compatible with the generation of bagasse and straw. These residues, however, are typically reserved for the generation of electricity used in the mills and/or sold to the grid, under contracts with the government. Outsourced residues from other biomass types might be an option to produce biochar for sugarcane crops.

4. CONCLUSIONS

Biochar has good potential to offset part of the emissions of sugarcane produced; however, the availability of biomass needed to produce biochar will be an obstacle.

5. ACKNOWLEDGEMENTS

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Table 1. Biochar needed to offset the lifecycle emissions of sugarcane production in SP, Brazil

Parameter	Lifecycle GHG emission impacts of sugarcane	Biochar needed to offset the impacts of sugarcane	
	kg CO_2e/ tonne cane	kg biochar/ tonne cane[f]	tonne biochar/ ha[g]
Agricultural inputs[a]	6.39	4.50	0.32
Field N_2O emissions[b]	15.9	11.19	0.80
Field CO_2 emissions[c]	2.58	1.82	0.13
Diesel[d]	5.20	3.66	0.26
Land use change[e]	5.56	3.92	0.28
Other inputs and emissions	1.33	0.93	0.07
Total	**36.94**	**26.01**	**1.87**

[a]Emissions from the production and packaging of agricultural inputs (e.g. urea, glyphosate, superphosphate, pesticides).
[b]Direct and indirect N_2O emissions from fertilizers, and emissions from sugarcane straw burning (IPCC, 2019).
[c]CO_2 releases from urea and limestone application, according to IPCC (2006), plus emissions from fuel combustion (diesel 88%, and biodiesel 12%), using emission factors from Nemecek and Kagi (2007).
[d]Emissions from the production of diesel used in agricultural operations (e.g. application of fertilizers, planting).
[e]Obtained from the Brazilian Land Use Change (BRLUC) method v2.0 (Garofalo et al., 2022)
[f]Biochar credit of 1.42 kg CO_2e/kg biochar, calculated from Lefebvre et al. (2021), only considering the benefit of carbon sequestration.
[g]Considering a sugarcane productivity of 71.94 tonne cane/ha in the state of Sao Paulo.

Figure 1. Biochar pyrolysis system, external aspect, porosity, and application in the field