

Greenhouse gas emissions and soil carbon stocks in the agricultural phase of sugarcane-derived ethanol production in Brazil

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Due to its vigorous growth, photosynthetic efficiency, and a production system which often includes the use of crop residues to generate power for the processing mills, sugarcane is one of the most attractive feedstocks for bioethanol production, considering both energy input to output ratios and greenhouse gas emission reductions compared to fossil fuels. In the sugarcane production system, burning the residues has been a common practice in Brazil in order to facilitate more efficient manual harvest and transport operations. In recent years, due to environmental, agronomic and economical reasons, the manual harvest of sugarcane with burning has been gradually replaced by mechanical harvest with maintenance of the dry leaves and tops on the field. The mulch formed impacts the whole production process of sugarcane, influencing cane yields, weed control, fertilizer management, soil erosion, soil water infiltration rates and soil organic matter dynamics, and greenhouse gas balances.

This study is an assessment of the differences in greenhouse gas emissions and soil carbon stocks under these two harvesting systems, in order to provide input for broader life cycle analyses of sugarcane-derived ethanol. Sugarcane farms in three regions with contrasting climate and soil conditions in Brazil were considered in this study. Greenhouse gas emissions from fossil fuel used in agricultural operations such as planting, disking, harrowing, tilling, harvesting, and input application were calculated in both systems. Embedded emissions from the production of fertilizers, pesticides and insecticides were also accounted for. CO₂ emissions from liming and non-CO₂ emissions from organic residues applied at different crop stages were included in the GHG balance. Soil carbon stocks down to 30 cm were evaluated in both burned and unburned harvesting systems. Direct soil N₂O emissions from nitrogen fertilizer application were measured using static field chambers. The N₂O fluxes were used to estimate the actual percentage of N₂O emitted from the soil due to nitrogen fertilizer application. Indirect fertilizer-induced N₂O emissions, related to leaching and volatilization, as well as non-CO₂ emissions from crop residue decomposition and burning were calculated using IPCC default values.

The results for the GHG balance indicate that the mechanically harvest, unburned sugarcane leads to lower GHG emissions and higher soil carbon sequestration than conventionally harvest sugarcane with pre-harvest burning. The conservation of sugarcane residues prevents emissions from the burning process, promotes carbon sequestration in soils and returns nitrogen back to the soil during the decomposition process, thereby replacing the need for, and GHG emissions from, fossil fuel-based nitrogen fertilizer sources. When converted into CO₂ equivalent, soil carbon stocks represented values in the same order of magnitude, and sometimes higher, than the GHG emissions from the agricultural phase sugarcane-derived ethanol in Brazil. Therefore, our results show that soil carbon stock changes from improved agricultural management, often not included in GHG balances for biofuels, can have a significant impact in the sustainability of ethanol production from a global warming perspective.