LAND-USE CHANGE AND CARBON STOCKS: REGIONAL ASSESSMENT OF SUGARCANE AREAS IN BRAZIL

MUDANÇA DE USO DA TERRA E ESTOQUES DE CARBONO: AVALIAÇÕES REGIONAIS EM CANA-DE-AÇÚCAR NO BRASIL

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Abstract

In agricultural product Life Cycle Assessment (LCA), emissions or removals of carbon (C) from land-use change can highly affect the global warming. The aim of this study was to evaluate the impacts of biomass C values and stock change factors on land use change (LUC) emissions in areas of sugarcane expansion in Brazil. In this study, we used stratified random sample in order to estimate changes in land cover through geotechnologies and associated C stocks from literature data. For that, the total area was stratified by three criteria: soil type, % of native vegetation in 1998 and age of sugarcane plantation in 2018. The sample size represented 12.8% of the studied area (172,000 ha). To this end, a matrix of primary combinations was combined with spatial data such as land cover in 1998, soil types, biomes and Köppen climate classification. Estimates of C stock changes in soil and biomass were calculated the Stock-Difference Method, according to IPCC Guidelines and specialized literature. Respecting the uncertainties, this approach allowed to have an estimate of C balance in sugarcane fields at the regional level in Brazil. Three main recommendations: (i) values of $F_{MG} > 1.0$ (F_{MG}, stock change factor for management regime), should be used for sugarcane, but future research ratification is necessary; (ii) biomass C values of sugarcane biomass above 5 tonnes C ha^{-1} should be used, especially when sugarcane is harvested without burning; and (iii) as there is still no relationship between level of pasture degradation and C content in soil, biomass C values and pasture F_{MG} should be carefully chosen in pasture conversion to sugarcane.

Keywords: geoprocessing, biomass, conversion factors, degraded pastures, native vegetation

Purpose

In agricultural product LCA, emissions or removals of carbon from land-use change can highly affect the Climate Change impact category. Many methodologies emerged in the past to estimate direct and indirect greenhouse gas (GHG) emissions caused by land use change in crop production, which fueled the ethanol sustainability debate. However, many of those methodologies were proposed for developed temperate countries, and their applicability to systems like sugarcane production in Brazil requests many adaptations, given its biophysicial and geographical features. The objective of this study was to evaluate the impacts of biomass C values and soil stock change factors on LUC emissions in sugarcane expansion areas in Brazil, using available methods and deriving recommendations for future works. The study was conducted by a multi-institutional team: Atvos, a sugarcane and ethanol supplier, Braskem, its client and bioplastic producer, Embrapa, the Brazilian agricultural research public company and Quantis, an international consultancy in sustainability, allowing an overview of the process.

Methods

For developing this study the general guidelines came from IPCC Guidelines (2006). The "Land use change guidance: accounting for GHG emissions in the supply chain" methodology developed by Quantis in its pilot format (2017) was also used, as well the BRLUC method (Novaes et al., 2017). At regional scale, LUC was analyzed for 20 years (from 1998 to 2018) through visual interpretation of remote sensing imagery, accompanied by literature review and data from sugarcane suppliers. The total area under study was 172,000 ha of sugarcane farms, from where it is harvested for Braskem bioplastics production. The farms are mainly located in the states of São Paulo and Mato Grosso do Sul, Brazil.

Results and discussion

At first, considering the available time and resources, it was not viable to have the spatial analysis of the entire area, which required a sampling procedure. Atvos provided sugarcane areas in 2018, and the following stratification criteria were defined as the first sampling step: (a) age of plantation; (b) forested areas before 1998, source TM/Landsat-5 images, and (c) soil type, source Brazilian soil map IBGE (2018a). Then, these layers were intersected in order to obtain the strata where the samples, which represented 22,085.3 ha (12.8% of the study area), were randomly selected (Adami et al., 2007).

For each sample, TM/Landsat-5 images were used to visual interpretation of land use in 1998. The land use classes and percentages of total area classified were: a) cultivated pasture: 76.1%; b) sugarcane: 11.6%; c) annual crops: 9.4%; d) native vegetation: 2.9%.

Estimates of soil carbon stock (ΔC_{SOC}) and biomass carbon stock change (ΔC_{BIO}) as a function of the land use change were performed according to the Stock-Difference Method of IPCC (2006). Values of different components of ΔC_{SOC} and ΔC_{BIO} are detailed in Tables 1 and 2.

According to the literature review on the carbon stock changes related to native vegetation (NV) conversions to pastures (Braz et al., 2013), there is no clear evidence of the trends of increase or decrease, and, accordingly, F_{LU} and F_I for pasture were considered as 1 (Table 1). Related to F_{MG}, taking into account that it is not possible to affirm that degraded pastures always have lower carbon content in the soil than other uses (e.g. managed pastures, native vegetation, sugarcane), but given that some authors estimate that 75% of the pastures in Brazil present themselves with some level of degradation (Dias-Filho, 2014), we considered a baseline scenario (C1) in which all pastures present a moderate degradation condition, and two scenarios with 23% (C2) and 83% (C3) of severely degraded pastures.

Table 1. Stock change factors for different land use changes and climate classification.

Land use change	Soil types	Climate classification	F_{LU}	F_{MG}	F_{I}	F_{C}
NV to Pasture[1] (C1:Baseline)	All classes	Cfa	1	0,95	1	0,95
		Am/Aw	1	0,97	1	0,97
NV to Pasture[1] (C2: 23% of degraded pasture)	Clay and medium texture soils	Cfa	1	0,95	1	0,95
		Am/Aw	1	0,97	1	0,97
	Sandy soils	all climates	1	0,70	1	0,70
NV to Pasture[1] (C3: 83% of degraded pasture))	Clay soils	Cfa	1	0,95	1	0,95
		Am/Aw	1	0,97	1	0,97
	Medium texture and sandy soils	all climates	1	0,70	1	0,70
NV to Annual crops[1]	All classes	all climates	0,58	1,16	0,91	0,61
NV to Sugarcane	All classes	Cfa	0,79	1,08[1]	1	0,85
		Am/Aw	0,77	1,09[1]	1	0,84
All land uses to Sugarcane	All classes	Cfa	0,79[1/2]	1,08[1]	1,11[1]	0,95
		Am/Aw	0,77[1/2]	1,09[1]	1,04[1]	0,87

[1]IPCC, 2006; [2]Mello et al., 2014; FLU: Land use factor; FMG: Management factor; FI: Input factor; FC: Final change factor; NV: Native vegetation; Cfa: wet temperate; Am/Aw: tropical dry

The reference soil carbon stock values (SOC_{REF}) are based on the national soil profiles presented by Fidalgo et al. (2007).

According to Mello et al. (2014), the LUC factors calculated for Cerrado to sugarcane, after 20 years, were 0.74 (±0.03), indicating C losses following Cerrado conversion. The F_{LU} values for sugarcane were approximated, given the lack of data. The average F_{LU} values of annual crops (0.69 - wet temperate and 0.58 - tropical dry) and perennial crops (1.0 - all climates) were considered to approximate the F_{LU} of sugarcane as a semi-perennial crop. This results in values of 0.84 and 0.79, respectively. Considering Mello's work with sugarcane in national areas, a new adjustment was made to a mean point, resulting in F_{LU} values of 0.79 (wet temperate) and 0.77 (tropical dry) for conversion of NV for sugarcane (Table 1).

For the $F_{MG,}$ reduced tillage was assumed since the soil is only mobilized once every 5 or 6 years. The factors for the wet and tropical dry temperate climates are 1.08 and 1.09, respectively (Table 1). The F_{I} of "high inputs without manure" was used considering information on non-burning of sugarcane and maintenance of straw on the soil only in 2018. The factors for the wet and tropical dry temperate climates are 1.11 and 1.04, respectively (Table 1). In 1998, sugarcane harvesting system was considered to have been carried out with burning and therefore, there was no high input of residual plant material, with F_{I} value of 1 (Table 1).

For estimates, the sugarcane biomass (AGB+BGB+DOM) in 2018 was considered equal to 9.8 tonnes C ha^{-1} (Table 2). This value is consistent with values of national literature that consider sugarcane without burning in the harvest. On the other hand, in 1998, the sugarcane biomass value was 6.1 tonnes C ha^{-1} (Table 2). The same way as with F_{I}, there were losses in biomass when sugarcane is harvested with burning. The European Commission recommended a value of 5 tonnes C ha^{-1} and this value was considered in the sensitivity analyzes.

Table 2. Biomass carbon stocks of annual crops, pasture, sugarcane, and native vegetation.

Land use	IPCC climate zone / Biome	AGB & BGB (tonne C ha^{-1})	DOM (tonne C ha^{-1})
Annual crops[1]	all climate	0	
Pasture (man-made)[2]	moderately degraded pastures	6.3	
	Severely degraded pastures	4.4	
Sugarcane[1]	all climate	5.0	
Sugarcane with burning[3]	all climate	5.5	0.6
Sugarcane without burning[4]	all climate	7,1	2.7
Natural forest[5]	Atlantic forest & Cerrado	39.9	3.6
Natural grassland[5]	Cerrado	24.7	-

[1]European Commission, 2010; [2]Boddey et al., 2004 and Fisher et al., 2007; [3]Macedo, 1997; [4]Yamaguchi et al., 2017; Ramos et al., 2016; Carvalho et al., 2013; [5]Brazil, 2016; AGB: Above-ground biomass; BGB: Bellow-ground biomass; DOM: Dead organic matter.

The baseline scenario is the most reliable based on database and expertise of the team. In this scenario, where pastures were considered moderately degraded in 1998, the option between the highest value of sugarcane biomass (assuming national values of sugarcane biomas, 9.8 tonnes C ha^{-1}) and the lowest value of sugarcane biomass in 2018 (value provided by the EU commission, 5 tonnes C ha^{-1}) resulted in the difference between removals (2.3 tonnes C ha^{-1}) and emissions of carbon (2.3 tonnes C ha^{-1}), respectively.

On the other hand, the results were also very sensitive to the SOC and biomass carbon stock of pasture. Maintaining sugarcane biomass (with burning in the harvest in 1998 and without burning in 2018) through data from the national literature and varying the carbon content in the soil and biomass of pastures in 1998 (scenarios), the carbon stock always resulted in removal, ranging from 2.3 (Baseline), 2.6 (C2) and 10 (C3) tonnes C ha^{-1}.

Conclusions

Assessing land use change emissions at regional levels in Brazil for a large and diverse area of sugarcane has proven not to be a simple task. Many peculiarities of the production system led to the needs of adaptation and development pointed above. Four main recommendations arose from the experience: (i) in the absence of better information, values of FMG> 1.0 should be used for sugarcane, however, future research ratification of this option is necessary, considering the intense mechanical tillage during the reform of the sugarcane plantation; (ii) biomass carbon values of sugarcane biomass higher than that recommended by the EC (2010) (5 tonnes C ha-1) should be used, since this value is inconsistent with national data, especially in the case of sugarcane harvested without burning; (iii) considering the fact that there is no clear relationship between level of pasture degradation and soil carbon content, special attention should be given to the choice of pasture biomass and FMG values, since these values are critical in carbon stock calculations assuming conversions from pastures to sugarcane, and (iv) georeferenced and associated data availability allowed more precision on spatial data intersection, on development of scenarios, thus reducing uncertainty over LUC results.

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